

**ASSESSMENT OF *Jatropha curcas* L. AS ALTERNATIVE
NEMATICIDE IN CONTROLLING ROOT-KNOT NEMATODE
DISEASE OF OKRA FOR IMPROVED YIELD**

BY

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CERTIFICATION

This is to certify that this work entitled “Assessment of *Jatropha curcas* as alternative nematocide in controlling root-knot nematode disease of Okra for improved yield,” was carried out by I, OGWUDIRE EZECHUKWU VINCENT (Reg. No: 20094833918) in Partial fulfillment for the award of the degree of Ph.D in Nematology in the Department of Crop Science and Technology of Federal University of Technology, Owerri.




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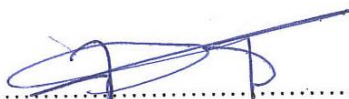
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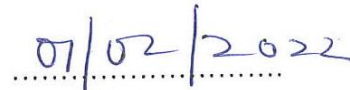
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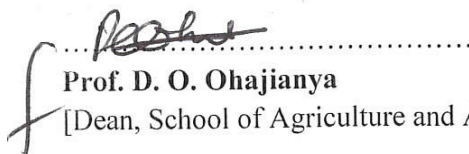
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DEDICATION

This disertation is dedicated to Almighty GOD who makes all things beautiful in his time; especially for his grace that enabled me to complete the race required by this study, sustaining me from the start of this work to the end.

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ABSTRACT

The assessment of *Jatropha curcas* L. as alternative nematicide in controlling root-knot nematode (*Meloidogyne incognita*) disease on Okra for improved yield was conducted in ultisols of Owerri, Nigeria. These were in 2016 and 2017 cropping seasons at the teaching and research farms of Federal University of Technology Owerri. *Jatropha curcas* L. cultivars; Cv 'Illorin', Cv 'Kwara' and Cv 'Ihiagwa' were first screened in a potted experiment for susceptibility to *Meloidogyne incognita* naturally endemic in the area using scoring index. Results on root-knot assessment showed no root-knot infection in either of the cultivars tested. Phytochemical investigations carried out for a Plant Based Nematicide revealed the presence of Alkaloids, Saponins, Flavonoids and Tannins in the Seeds, Roots and Leaves respectively. Laboratory test for nematicidal properties against hatchability and mortality of *M. incognita* was conducted using a 3x4x4 factorial experiment fitted in Completely Randomized Design with three replications. Alkaloids, Saponins, Flavonoids and Tannins applied at 0, 5 and 10 mls per thirty Juveniles (J_2) for mortality and twenty egg masses for hatchability were suspended in 10 mls of distilled water respectively. Petri dishes were kept at ambient temperature after 12, 24, 48, and 72 h incubation. Results show that at 10 mls, Seed Alkaloids recorded highest mortality (99.73 %) after 72 h treatment exposure while at 5 mls, Root Alkaloids recorded highest mortality (94.73 %) after 72 h treatment exposure. Most egg hatchability reduction (0.00 i.e 100%) was achieved with Seed Saponin after 12 h treatment exposure time at 10 mls, while at 5 mls (0.08) egg hatchability reduction was achieved with Seed Saponins after 12 h treatment exposure time. Individual Plant based nematicides were further evaluated for their effects on root-gall nematode susceptible Okra variety "NHAe47-4". Four independent 3x6 *factorial* experiments arranged in Completely Randomized Design with five replications were conducted in the screen house. Each nematicidal extract was applied at 0,1,2,3,4, and 5 mls, and *Jatropha* parts with three levels-seed, root and leaves. Results showed that all plant based nematicides applied at 5 mls/pot significantly ($p<0.05$) reduced root-galls and increased the growth, yield, mucilaginous property, and nutritional composition of okra. This was particularly with Leaf Tannins application which increased pod weight by 67 % and 61 % over control at 4.88 g and 5.11 g in 2016 and 2017 respectively. This was followed by Root and Seed Alkaloids which increased pod weight to 4.02 g & 4.26 g indicating 71 % and 67 % increase over control in 2016 and 2017 respectively. Seed and leaf Saponins increased pod weight to 3.62 g & 3.84 g indicating 58 % & 51 % increase over control in 2016 and 2017 respectively. Seed and Leaf Flavonoids increased pod weight to 3.56 g & 3.80 g indicating 75 % & 71 % increase over control in 2016 and 2017 respectively. Correlation analysis showed that root-knot nematode correlated negatively with growth and yield parameters of Okra. Nematicidal extracts of *Jatropha curcas* and plant parts at the respective rates/levels-controlled root-knot nematode (*Meloidogyne incognita*) infection on okra, enhanced the pod weights, Mucilaginous property and nutritional composition of okra and are therefore recommended for use in Okra production

Keywords: Okra variety, *Meloidogyne incognita*, *Jatropha curcas*, Phytochemical Hatchability, Mortality and Yield

Chapter I: Introduction

1.1 Background Information

The incidence and severity of root-knot nematode disease caused by parasitic nematodes on okra are serious constraints to high okra yields in Nigeria (Adebowale, Tanimola, and Papadopoulos, 2004). Root-knot nematodes (*Meloidogyne* species) have been reported as the major plant-parasitic nematodes on okra (Saufiuddin, Sheila, and Shweta, 2011). *Meloidogyne* species cause about 70-90 % yield losses in okra (Saufiuddin *et al.*, 2011). The three species of root-knot nematodes: *M. arenaria*, *M. javanica* and *M. incognita* very frequently attack Okra (De Waele and Elsen, 2007; Siji, Jayaprakas, Sheila, and Mohandas, 2010). However, *M. incognita* is the most destructive and economically important plant parasitic nematode species (Gebissa, 2021). Bhatti and Jain (2013) reported that in fields infested with *M. incognita* and planted with Okra (*Abelmoschus esculentus*), Tomato (*Lycopersicon esculentus*) and Eggplant (*Solanum melongena*) the nematode population at harvest increased by 69 % under okra, 40 % under Tomato and 32 % under Eggplant. Yield losses in the three crops were estimated to be 91 %, 46 % and 27 percent respectively This implies that okra is a good host, Tomato a moderate host and Eggplant a poor host.

Agwu and Ezigbo, (2005) reported that *M. incognita* elicited leaf browning, suppression in plant growth, fruit yield and photosynthetic pigmentation in okra. They are found to be serious pest of okra, damaging stands and greatly reducing and diminishing pod production. (Bolles and Johnson, 2012).

Main symptoms are irregular swellings (galls) on the roots, resulting from hypertrophy of root cortex and the formation of giant cells in the region of the pericycle. If

heavily infected, the giant cells disrupt vascular bundles and interfere with their function thereby leading to increased susceptibility to water and nutrient deficiencies.

Symptoms such as early senescence, chlorosis, wilting, splitting of fruits, stunting, reduction in quantity and quality of produce are characteristic of host-nematode interactions (Bridge, Plowright, and Peng, 2005). In addition, the conspicuous giant cells (galls) produced on roots and excessive lateral root growth has been shown to be the major symptoms of root-knot nematode infection (Castillo, Di-Vito, Vovlas, and Jiménez-Díaz., 2001)

Root-galling decreases the ability of infected plants to translocate nutrients and water from soil and this cause symptoms of water and nutrient deficiencies on the above ground parts of the plants; the conductive tissues no longer function properly; Absorption and translocation of water and nutrient from the soil to the vegetative organs are impaired and as a result, growth is adversely affected (Alabama and Alabama, 2009)

The root-knot nematodes (*Meloidogyne* spp.) have gained international recognition as one of the most serious constraints to increased crop production especially in the developing nations. In some of the developed countries, estimates of losses due to the nematode have been recorded.

Meloidogyne spp. has been reported to cause an estimated annual loss of \$157 billion globally (Abad, Gouzy, Aury and Castagnone-Sereno, 2008). However, in most cases, the impact of *Meloidogyne* spp. is grossly underestimated. This is more in Africa than anywhere else in the world. Hence, it is likely that the overall annual losses due to these pathogens are much higher than estimated.

However, the protection of crop plants from root-knot nematode disease is achieved in industrialised countries almost entirely through the application of chemical products. This is at the expense of other control methods. A number of control methods and practices have however, been developed. These include: inclusion of non-hosts in rotation sequence

(Adesiyani, Caveness, Adeniji, and Fawole, 2000), introduction of resistant varieties (Aubertot, West, Bousset-Vaslin, Salam, Barbetti, and Diggle, 2006), heat and chemical treatment (Adesiyani *et al.*, 2000), use of organic manure (Agu, 2008 b), use of biological control agents (Kumar and Singh, 2006) and the use of botanicals (Agu *et al.*, 2013).

The basis of using resistant cultivars to control *Meloidogyne spp* relies on knowing exactly which species is being targeted. Several studies have been undertaken to develop crops with resistance genes against various *Meloidogyne spp*. (Norshie, Been, and Schomaker, 2011). There are certain cases of known resistant crops as in the case of tomatoes (due to the Mi-1 gene) and wild potato (*Solanum bulbocastunum*). Initially, the resistance gene (Rmc-1) located on chromosome 11 of wild potatoes was found to confer resistance against *M. chitwoodi* and other *Meloidogyne spp* such as *M. fallax* and *M. hapla* (Gebhardt and Valkonen, 2001; Brown, Mojtahedi, James, Novy, and Love, 2006). But with the entry of resistance breaking *Meloidogyne spp*. some of the crops have been rendered susceptible (Brown, Mojtahedi, Zhang, and Riga, 2009; Kiewnick, Dessimoz, and Franck, 2009). Ultimately the cost and availability of resistant genotypes will be a huge influencing factor on whether these benefits will trickle down to small scale growers in Africa.

Biological methods entail the use of living organisms either in pure cultures or mixtures to control *Meloidogyne spp*. Some biological products such as those developed by Pasteuria Inc., and Koppert Biological Systems against certain *Meloidogyne spp*. have demonstrated significant effect in the control of these plant parasitic nematodes. These products are usually developed from microorganisms such as *Pasteuria penetrans*, *Pasteuria hartismeri*, *Pochonia chlamydosporia*, *Bacillus firmus*, *Paecilomyces lilacinus* and *Trichoderma spp.*, which attach to the nematode cuticle or parasitize the female eggs therefore killing the nematodes eventually (Kariuki and Dickson, 2007; Bishop, Gowen, Pembroke and Trotter, 2007).

In addition, some studies have also shown another biological strategy where endophytes such as *Fusarium oxysporum* (FO162) can induce systemic resistance against *Meloidogyne spp.* in some crops as tomato (Walters, 2009). Colonization of roots by *Fusarium oxysporum* (FO162) leads to the accumulation of root exudates in tomato roots which have a repelling effect on *M. incognita* (Mohammed, 2010).

Cultural practices include the development and use of resistant crop cultivars, planting clean planting materials, intercropping, and crop rotation and cleaning of farm implements (Brown *et al.*, 2006). Many of these practices have been used successfully in various parts of Africa to reduce the spread of *Meloidogyne spp.* in different crop fields for many years. However, the cost and availability of clean planting material can at times be a hindrance to many small-scale growers. Furthermore, the elimination of crop rotation as a control strategy in commercial farms is that it is not economically feasible due to economic losses which may be incurred during the fallow periods and also in trying to establish a new crop in large scale as the previous one.

Growth challenges associated with human population also make crop rotation virtually impractical in certain parts of the continents. Physical methods such as heat treatment and solarization of the soil before planting can be combined with cultural methods for effective control of various *Meloidogyne spp.* (Ioannou, 2000). Solarization of nursery soil up to 40 cm for a period of three weeks has been found effective in reducing egg infectivity (Nico, Jimenez-Diaz, and Castillo, 2003).

In a study to demonstrate the efficacy of organic manure in checking root-knot nematode population, carrots, *Daucas carota* was found to grow well and better in soils with chicken manure (Dawuda, Boateng, Hemeng and Nyarko, 2011).

The use of organic manures to control root-knot nematode attack on crops have been found to work by influencing and causing a modification of structure and changes in

metabolism depending on which nutrients are supplied to the entry and growth of the pathogens (Agu, 2008 a). Changing the Physical environment of the soil by adding organic amendment has been shown to affect the nematode community. Agu (2008 b) reported that rare galls were found on the roots of African yam bean when treated with poultry and farm yard manure. Organic manure added to the soil has also been found to increase the activity of nematode trapping fungi (Marshall, 2002).

Amending soil with organic matter has in some cases been shown to reduce population of *Meloidogyne javanica* and other species of plant-parasitic nematodes (Akhtar and Malik, 2000).

Sun hemp, *Crotalaria juncea L.* is a legume that has received increased attention due to its rapidly produced biomass, increased soil organic matter, and suppresses many plant-parasitic nematodes (Hong, Li, Zhou, Wang, and Zhang, 2007).

Chemical methods of control involve the application of different inorganic formulations to kill or interfere with the reproduction of *Meloidogyne spp.* in infested soils. In *Meloidogyne spp.* control programmes, nematicides are usually the most effective method of controlling high levels of *Meloidogyne spp.* in various farms.

Nematicides containing active ingredients of methyl bromide and other harmful compounds have been banned in various parts of the world. Other nematicides which are known to control various *Meloidogyne spp.* include Fenamiphos, Oxamyl, 1, 3 dichloropropene (1, 3-D), Aldicarb, Dazomet and Metam-sodium. Cooney, (2017) reported that application of Carbofuran (Furadan 10 G) at 50 kg/ha reduced root galls and increased Cowpea yields

1.2 Problem Statement

Following interest generated by Okra as an invaluable tropical crop, efforts have been made to increase its production and yield per unit area. However, the yield potential of this crop has not been achieved in this part of the tropics due to pest and disease problem

The root-gall nematode cause by *Meloidogyne incognita* has been reported as one of the most yield limiting factors to Okra production (Muktar, 2014) leading to 90 % yield loss when grown in fields infested with 3-4 *Meloidogyne incognita* per gram soil (Claudius-Cole, 2018)

Agu, Mbuka, and Ogwudire, (2009) reported that the popular and widely grown Okra variety NH47-4 (Otukwuruomia) used in this study was not only susceptible to root-gall nematode infection amongst four cultivars tested but had significant reduction in their mucilaginous property and nutritional constituents when grown on untreated ultisol. Moreso, sufficient work has not been done in exploring alternative control nematicides of plant origin in view of adverse ecological and environmental effects of synthetic pesticides on the wellbeing of Man.

1.3 Objectives of the Study

Main objective is therefore:

to assess the efficacy of *Jatropha* cultivars as alternative nematicide in controlling root-knot nematode disease of okra (*Abelmoschus esculentus*) for improved yield.

Specific objectives hereby include:

- i. to assess the resistance status of *Jatropha curcas* cultivars; Cv 'Illorin', Cv 'Kwara' and Cv 'Ihiagwa' to *M. incognita* infection,
- ii. to identify the phytochemical constituents of the cultivars
- iii. to assess the nematicidal potency of Identified phytochemicals,
- iv. to ascertain the *M. incognita* growth stage most affected by the phytochemicals, and

- v. to determine *J. curcas* parts (seed, leaf or root) containing most effective phytochemical for control of *Meloidogyne incognita*,

1.4 Justification of Study

The dangers of chemical plant protection to man and the ecosystem have been reported (FAO, 2001). The disadvantages of using chemical methods to control these *Meloidogyne spp.* are that some of them are harmful to human due to residues in the food chain, they contribute to environmental pollution through the pollution of the ozone layer, (such as methyl bromide), they are expensive to small scale farmers and their continued use can lead to some level of resistance to the target nematode species.

The disadvantages associated with the use of synthetic chemicals in agriculture cannot be over emphasized. Pesticides residues have been reported in vegetables such as onions, lettuce, cabbage, spinach, okra and tomato (EL-Nahhal, 2004). This clearly indicates the need for alternative control measures which are environmentally safe and effective against the pests. However, Wahab (2009) reported that the extensive and very often indiscriminate use of these synthetic plant protectants on pest and diseases have often aided development of resistance and caused serious damage to their natural enemies (Cui, Sartin, Pleiss, and Wolfne

It has, become necessary to view pesticides (synthetic nematicide) use as a threat to clean environment and to sustainability in production because of its many negative consequences such as high costs, potential pest resurgence, secondary pest outbreaks as well as human and animal poisoning and environmental pollution (Harsimran and Harsh 2014). Even though, the use of nematicide may have led to increased quantity and quality of yields

of our crops, the drawback caused by its high nematicidal and damage to environment has fueled the need for relatively safer alternative.

Although, some higher plants have been examined as sources of novel compounds with activity against parasitic nematodes (Adesiyan *et al.*, 2000), only 6 % have been studied for biological activity and 15 % among estimated 4 million plant species investigated phytochemically (Uma, 2015). Over the years examination of plants for novel compounds with nematicidal action has not yielded adequate information, especially on nematicidal constituents/ isolates of plants.

While the use of plant extract as alternative nematicides is becoming widespread and gaining prominence, the lack of scientific validation of the active compounds of such plants has hampered the optimization of its use. Little is however, known on the relative efficacy of *Jatropha curcas* variety and its phytochemical constituents in the control of root-knot nematode disease for improved Okra yield.

1.5 Scope of Study

This work is limited to the use of *Jatropha curcas* L. cultivars on root-gall nematode (*Meloidogyne incognita*) disease control in okra production. The experiment will be conducted in the field, laboratory and screen house at the teaching and research farm of the Department of Crop Science and Technology, Federal University of Technology Owerri. The work covered in this study includes: (i) Assessment of resistance status of *Jatropha curcas* cultivars to *M. incognita* infection, (ii) Identification of *Jatropha curcas* phytochemical constituents, (iii) Assessment of nematicidal potency of Identified phytochemicals, (iv) Determination of *M. incognita* growth stage most affected by the phytochemicals, and (v) Determination of *J. curcas* parts containing most effective phytochemical for control of *Meloidogyne incognita*, as stated before.

Chapter II: Literature Review

2.1 Root-Gall Nematodes: Origin and Distribution

Root-knot nematodes were first discovered in England by Berkeley in 1855 when he studied galls on the roots of cucumber plant grown in greenhouse (Adesiyani *et al.*, 2000). Goeldi (1887) first used the generic *Meloidogyne* for the nematodes causing root-galls on coffee roots in Brazil. Root-knot nematodes have however, been given different scientific names since then. Before 1949, the root-knot nematodes were considered as species, *Heterodera marioni*. Chitwood (1949) made a morphological study of the root-knot nematodes and removed them from the genus *Heterodera* and again placed them in the genus *Meloidogyne* with twenty species and one sub species identified. Presently, over thirty- six known species and three subspecies of the genus, *Meloidogyne* have been discovered (Hunt and Handoo, 2009).

There are currently nearly 100 recognised *Meloidogyne spp.*, with 22 of these species reported to be present in Africa. Historically, *Meloidogyne spp.* have been divided into major and emerging species. According to Moens *et al.* (2009), *M. arenaria*, *M. incognita*, *M. javanica* (occurring in tropical regions) and *M. hapla* (occurring in temperate regions) are considered to be the four major *Meloidogyne spp.* However, some researchers have considered a further five species as emerging species. These five emerging species are: *Meloidogyne chitwoodi*, *M. fallax*, *M. enterolobii*, *M. minor* and *M. paranaensis*.

In Africa, *Meloidogyne arenaria*, *M. javanica* and *M. incognita* are regarded as the most dominant species reported in different countries across the continent, respectively (IITA, 1981; De Waele and Elsen, 2007). Collectively, these three species have been reported to cause damage on economically important crop plants such as okra (*Abelmoschus esculentus*), sweet potato, banana, tomato, cabbage, potatoes, pineapple, cassava, maize,

tobacco, cowpea as well as others such as, papaya, buchu (*Agathos mabetulina*) and African spinach. On the other hand, three of the five emerging species, namely *M. chitwoodi*, *M. enterolobii* and *M. fallax*, were reported from Africa. For example, the resistance-breaking apomictic species, *M. enterolobii* has been isolated from Burkina Faso, DRC, Malawi, Mozambique, Senegal, South Africa and Togo causing damage in potatoes and gauva (Marais, 2012; Onkendi and Moleleki, 2013).

Root-knot nematodes are worldwide in distribution, although, some are restricted to certain climatic zones. It is reported that they could attack more than 2000 known species of plants, some of which are field crops such as cotton, yam, groundnuts, tobacco, sugarcane, soybean, potatoes, rice, maize and cassava; vegetable crops like lettuce, pepper, okra, pumpkin, tomato, carrot, cucumber, onion and cabbage. Others attack tree crops and ornamentals (Mujeebur, 2012). Among the plant parasitic nematodes, root-knot nematodes are the most destructive species which cause serious problem to a great number of economically important crops (Tsay *et al.*, 2004). Its approximate distribution in agricultural soils of Nigeria is 75 % (Adegbite and Adesanya, 2005).

A major bio-constraint in the production of okra is the plant-parasitic nematodes (Saffiudin *et al.*, 2011). Plant-parasitic nematodes (PPNs) cause loss of yield and quality of okra which indirectly reduces the economic value of the crop (Saufiuddin *et al.*, 2011). Root-knot nematodes (*Meloidogyne* species) have been reported as the major plant-parasitic nematodes on okra (Saufiuddin *et al.*, 2011). *Meloidogyne incognita* are responsible for about 90% yield losses in okra (Saufiuddin *et al.*, 2011; Claudius-Cole, 2018). *Meloidogyne incognita* is the most widespread and commonly encountered species of root-knot nematodes on okra (Siji *et al.*, 2010). The management of root-knot nematodes with synthetic nematicides is the predominant strategy for many years (Siji *et al.*, 2010), but studies have shown that high cost of synthetic nematicides and their hazardous effects on the environment,

non-target organisms are banes to their use by most peasant farmers in Africa (Adekunle and Fawole, 2003; Fawole, 2009). Many measures are being explored in the management of root-knot nematodes such as crop rotation, planting of resistant varieties, use of botanicals, amongst others (Siji *et al.*, 2010). The use of botanicals in the management *M. incognita* is being promoted due to its reported effectiveness and environment-friendliness (Adegbite and Agbaje, 2007; Fawole, 2009; Claudius-Cole *et al.*,

Okendi, kariuki, Marais, and Moleleki (2014) in a review reported other *Meloidogyne spp* affecting economically important crop plants in Africa which includes those that infect coffee (*M. africana*, *M. decalineata*, *M. decalieata* and *M. oteifai*); cassava (*M. exigua*, *M. chitwoodi*, *M. megadora*, and *M. naasi*); sugarcane (*M. hispanica* and *M. kikuyensis*) and cotton (*M. acronea*); trees and woody shrubs such as *M. ethiopica* infecting black wattle (*Acacia mearnsii*); *M. morocciensis* infecting peach trees: *M. partityla* infecting pecan and walnut trees *M. propora* reported on black night shade (*Solanum nigrum*) as well as *M. vandervegtei* which has been reported on woody plants and coastal forests.

2.2 Root-Gall Nematode Life Cycle

The root-knot nematodes exist as males and females and are identified on the basis of shapes, size and special structures. The adult female nematodes are vemi-form in shape, when examined under a microscope while the juvenile nematodes are wormlike. Reproduction is by means of egg, from which tiny larvae are hatched. The nematode undergoes a molt procedure which is repeated to the third and fourth stage larvae before it finally becomes an adult nematode. The life cycle for most species is completed between 25 to 40 days and is repeated as long as susceptible host plant grows (Adesiyan *et al.*, 2000). The root-knot nematodes, *Meloidogyne spp.* depends on successful formation of feeding sites (Coenocytes) in susceptible plant for its development and reproduction.

The degree of root galling induced by root-gall nematode attack generally depends on three factors: nematode population density, *Meloidogyne* species and "race," and host plant species and even cultivar. (Mitkowski and Abawi, 2003).As the density of nematodes increases in a particular field, the number of galls per plant also will increase. Large numbers of nematodes penetrating roots in close proximity also will result in larger galls.

At lower inoculum levels, the nematodes stimulate plant growth but at higher densities shoot growth is suppressed. However, owing to their developing root systems young plants are more susceptible to serious injury by root knot nematodes than older plants. For example, young corn is usually more susceptible to damage from nematodes than older corn simply because of the developing root system and older corn appears to be more tolerant (Charles, Xavier and Deborah, 2016) and therefore, becomes a predominant factor in infection and pathogenesis. The development and severity of plant disease are often influenced by weather, soil and other environmental factors. In fact, high temperature, high relative humidity and leaf wetness are critical environmental factors that influence disease development (Ruiz, 2003).

Agu and Oguji, (1996) showed that root-knot nematodes removed large quantities of potassium from plant grown in nutrient solutions and addition of potassium increased the rate of reproduction of the nematodes. However, the response of the root to the nematode is a local one and is related to the amount of stimulation provided by each. Total crop failure in soils heavily infested with root-gall nematode (*Meloidogyne spp.*) has also been reported (Agu, 2006).

2.3 Nematodes and Control

Antagonistic plants such as African marigold (*Tagetes spp.*) have been examined for nematicidal compounds and found to suppress populations of soil nematodes (Koon-Hui,

Wang, Cerruti, Hooks and Antoon, 2007). Results of studies by Kimpinski, Arsenault, Gallant, and Sanderson (2000) indicated that populations of *Pratylenchus* species were greatly reduced in soils after growing marigold for one season compared to other cover crops tested. Higher plants have however, been increasingly examined as source for novel compounds with activity against nematodes. Marigold (*Tagetes spp.*) was among the first plant to be examined for nematicidal properties and found to suppress populations of soil nematodes. Results of studies by Kimpinsky *et al.*, (2000) indicated that populations of *Pratylenchus species* were greatly reduced in soils after growing marigold for one season. *Tagetes mutula* has also been proven to be effective against *Meloidogyne hapla*.

Other higher plants with naturally occurring phytochemicals with biological activity against nematodes include; *Mulan helenium* (Mahajan *et al.*, 1992); *Dapheme odora* (Tada *et al.*, 1988); *Eragrostic curvula* (Osman and Viglierchio, 1988), and *Xylopium aethiopicum*. (Agu, 2005)

Over the years, considerable interest has, however been developed in the possibility of using organic manure to reduce nematode populations and increase crop yields (Agu 2008b; Dawuda *et al*; 2011). In a study to demonstrate the efficacy of organic manure in checking root-knot nematode population, Carrots, *Daucas carota* was found to grow better in soils with poultry manure than with stable Cow manure (Ogbuji 1981)

. In a field trial experiment on the effect of five commercial organic materials -Dried poultry faeces (DPF), dried poultry manure (DPM), composted oil cake (COC), composted municipal refuse (CMR) and partially composted poultry manure (CPM) on *Meloidogyne incognita* [(kofoid &white) Chitwood] attacking tomatoes, all the organic materials applied significantly reduced the root-knot indices compared with the untreated control (Errico and Di-Maio, 2010). The application of some types of crop residue has been shown to reduce the

number of plant pathogenic nematodes (Abawi and Windmer, 2000). Olive Pomace has been shown to reduce numbers of root-knot nematodes, *Meloidogyne javanica* in the roots of glass house grown tomato and pepper (Marull, Pinochet, and Rodrigues-Kabana, 1997). Also, Mojtahedi, Santo, Hang, and Wilson (1991) showed that root-knot nematode population was reduced when certain rapeseeds cultivars were used as a green manure.

In a study involving the use of poultry manure and saw dust as control for root-knot nematode on ginger, both amendments provided good control of root-knot nematodes with significantly fewer rhizomes being discarded at late harvest (Stirling, 2009)

There has been considerable progress in the use of compost as soil amendment for the control of plant parasitic nematodes and many studies reported reductions in nematode numbers and activity following compost manure application (Akhtar and Malik, 2002), Green pepper and tomatoes grown in soils amended with municipal compost showed lower number of root-knot nematode (*Meloidogyne javanica*) in the rhizosphere than those grown in unamended soils (Marull *et al.*, 1997). In a related development, yard waste compost applied to field soils in was shown to be associated with reduction in population of several species of parasitic nematodes including *Paratrichodorus minor* (Mcsorely and Gallerher, 1995). Che *etal.*, (2000) found that the application of brewery compost reduced root galling severity and egg production of *Meloidogyne hapla* on lettuce.

The effect of compost manure on parasitic nematodes has been traced to its' direct and indirect influence on soil structure, texture, pH, temperature and micro biota and the various organic and inorganic compounds they release into the soil. Compost manures have increased pH and temperature added to the soil (Miller and Donahue, 1990). Changes in soil pH and temperatures (which may result from organic matter decomposition) have been shown to influence root-knot nematode survival. The reproduction of the nematode (*Pratylenchus penetrans*) has also been shown to be significantly greater at an increased PH

of 5.2 and 6.4 than at PH of 4.4. Sikora (1989) reported that soil texture and structure are directly related to water holding capacity and aeration and influence nematodes survival, emergency and disease severity.

Ononuju and Kpadobi (2008) also studied the efficacy of leaf ash of *Iconia lotefolia*, *Uvaria chamae*, *Cymnopogon citrus*, *Tetrapleura tetraptera* and *Azadirachta indica* in the control of root-knot nematode infesting soybean and found that the population of the nematode in the soil and roots as well as number of galls were significantly reduced by the treatments as compared to the control. Yield parameters from treated plants were also significantly better than the non-treated.

The protection of crop plants from pest and diseases in industrialised nations has been reportedly achieved almost entirely through chemical protection. Certain chemicals such as 1,2-Dibromo-3- chloropropane, better known as DBCP have been used as nematicides while maintaining a low phytoneumaticity, but the folia spray of Phenylalanine are more effective than soil drenches for inhibiting the development of *M. incognita* in tomato. However, indiscriminate use of synthetic pesticides for controlling nematodes has given rise to Phytotoxicity, environmental pollution and nematode resistance (Adegbite and Adesiyun, 2005).

The use of aqueous extracts in disease control is eliciting much interest in developing countries due to high cost of synthetic pesticides and their hazardous residual effects on the environment. Tovignan, Vodoulie, and Dinhan (2001) stated that the use of synthetic chemicals in disease control is giving rise to much concern owing to the undesirable effects emanating from their use.

Dudu and William (1991) reported that considering the high cost of synthetic pesticides, threats to human health as a result of their effects and pollution of the

environment, there is need for further research into the use of plant extracts as alternatives to synthetic pesticides.

Nematicidal activity of extracts from different plants against bacteria, fungi and nematodes has been reported by many researchers. Ogwulumba, Ugwuoke, and Iloba (2008) reported the use of extracts of pawpaw and bitter leaf to control fungal pathogens of groundnut. Yasmin *et al.* (2003) reported that extracts from the seeds of *Neem*, *Azadiracta indica* were effective against root-knot nematodes on Sweet gourd. Many studies have been done to demonstrate the efficacy of *Jatropha curcas* against a wide array of bacteria (Oyi, Onaolapo, Haruna, Morah, 2007; Igbinsola, Igbinsola, and Aiyegoro, 2009) and fungi (Ayambimpe and Fagbemi 2005; Saetae and Suntosuk, 2010). Berger (2002) also reported that leaves of *Jatropha curcas* soaked overnight in water were used in controlling pests of Vegetables in Ghana

2.4 *Jatropha curcas*

The genus *Jatropha* belongs to the tribe Jatropeae in the Euphorbiaceae family and contains approximately 170 known species (Dehgan and Webster, 1979; Carels, 2009;). The botanical name of the genus *Jatropha* was derived from the Greek word “Jatros” meaning a doctor and “trophe” meaning food (Kumar and Sharma, 2008) which incorporates the historical medicinal uses of this plant.



Figure 1: *Jatropha curcas* (Physic nuts) fruits and seeds

Benefits of Jatropha

- Low cost of seeds.
- High oil content.
- Small gestation period.
- Grows on good to poor soils.
- Grows in low to high rainfall.
- Plant size makes seed collection convenient.



Figure 2: Some attributes of *Jatropha curcas* (Physic nuts)



Figure 3: *Jatropha curcas* (Physic nuts) plant

Jatropha curcas commonly called or referred to as Physic nut is a non-edible multiple purpose plant with potential for biodiesel production and medicinal uses. It reaches about 6-8m height and grows widely in many parts of West Africa. Its fast and luxuriant growth makes it commonly used for fencing in rural areas of South Eastern Nigeria.

Jatropha curcas is reported to have originated from the Northeastern part of South America and the dry areas of Mexico (Jongschaap, Corre, Bindraban, & Brandenburg, 2007; Makkar, Francis, and Becker, 2009). The plant is reported to have been distributed by Portuguese ships via the Cape Verde Islands and Guinea Bissau to other countries in Africa and Asia (Heller, 1996).

Presently it is cultivated abundantly in many tropical and sub-tropical regions in Africa and Asia (Schmook and Serralta-Peraza, 1997) as an ornamental tree (Iwu, 1993) or as sturdy hedges (Neuwinger, 1996). *Jatropha curcas* grows under conditions where the temperature ranges between 15 and 40 °C (Kumar and Sharma, 2008). The plant is not sensitive to day

length and may flower any time of the year (Heller, 1996). It grows well under a wide range of rainfall from 250 to over 1200 mm per annum. The plant sheds its leaves as a counter to drought during low rainfall and prolonged dry periods. The plant grows well in well drained soils with good aeration and is well adapted to marginal soils with low nutrient content (Openshaw, 2000).

Some studies on the antimicrobial activity of different parts of the plant were reported by Namuli, Abdullah, Sieo, Zuhainis, and Oskoueian (2011) who noted the antimicrobial activity of the crude aqueous, methanolic and hexane extracts of various parts of *J. curcas*. Also studied were the antimicrobial activity of alcoholic extracts from the leaves of *J. curcas* plant (Akinpelu, Aiyegoro, and Okoh, 2009); Irene and Cariño (2011) for methanol extracts, and Sharma *et al.*, (2010) who used ethanol extracts. The active ingredient in the physic nut is known as curcin.

Antimicrobial activity of crude ethanolic, methanolic and water extracts of the stem bark of *J. curcas* have also been reported (Igbinsosa *et al.*, 2009; Gupta, Haque, Islam, Mondal, and Shibib, 2010 and Obasi, Ejikeme, and Egbuna, 2011).

J. curcas root extracts showed antimicrobial activities especially those responsible for sexually transmitted diseases (Aiyelaagbe, Adeniyi, Fatunsi, and Armish, 2007). The antimicrobial activity of *J. curcas* latex from stems and leaves was reported by Oyi *et al.* (2007).

2.5 Phytochemical Constituents

According to Akinmoladun, Ibukun, Afor, Obuotor and Farombi (2007), the medicinal value of *Jatropha* plants is due to the phytochemical constituents they produce. Phytochemicals are plant derived chemical compounds, which are non-essential nutrients,

some of which show potential health promoting properties. The Phytochemicals are grouped into two main categories namely, primary constituents which includes Amino acids, common sugars, protein and chlorophyll etc., and secondary constituents which consists of Alkaloids, essential oils, Flavonoids, Tannins, Terpenoids, Saponins, Phenolic compounds etc. (Akinmoladun *et al.*, 2007). Majority of Phytochemicals have been known to have valuable therapeutic activities like insecticidal, antifungal, antibacterial anticommutative and spasmolytic activities (Edeogo *et al.*, 2005; Bisset and Wichtl, 1994).

Phytochemical screening of different plants has revealed numerous bioactive compounds including alkaloids, tannins, flavonoids, glycosides and saponins. These plant secondary metabolites serve as defense mechanisms against many microorganisms, insects and herbivores (Vaghasiya *et al.*, 2011).

Many higher plants accumulate extractable organic substances in quantities sufficient to be economically used in management of diseases in agricultural and medicinal fields. Plants have been a rich source of pesticides and medicine drugs because they produce wide array of bioactive molecules, most of which probably evolved as chemical defense against predation or infection. The demand for nature -based biopesticides, predominantly those derived from plants is rising all over the world. This is because of increased public awareness of environment and the pollution potential and health hazards related to many conventional synthetic pesticides.

Biopesticides are cost effective, safer, readily available, biodegradable and therefore more environment-friendly and will offer alternative to those conventional pesticides (Ranasing, 2007).

2.6 Tannins

Tannins are widely distributed in plants and occur in solution in the cell sap, often in distinct vacuoles. Tannins are any phenolic compounds of sufficiently high molecular weight containing sufficient hydroxyls and other suitable groups to form effectively strong complexes with protein and other macromolecules under a particular environment. Tannins are readily soluble in water or alcohol given as astringent solution that is useful in medicine. They are organic substances of diverse composition with pronounced astringent properties that hasten the healing of wounds and inflame mucous membrane (Okwu, 2004).

Tannins are involved in the protection of plants against micro-organisms (Ayres, Clausen, MacLean, Redman, and Reichardt, 1997). The effects of tannins on soil microbes to play a role in succession in plant communities (Schimel *et al.*, 1996).

2.7 Flavonoids

Flavonoids are the largest group of naturally occurring phenols and occur in plants, both in free state and as glycosides. Some flavonoids have fungicidal properties and are found to protect the plant against attack by parasites, etc. More so, flavonoids including phenolic acids have been able to show inhibitory activity towards one or more of the bacteria studied. Krammer *et al.* (1984) reported the fungicidal activity of isoflavones from soybeans and chickpeas on three food-contaminating fungi, *Aspergillus ochraceus*, *Penicillium digitatum* and *Fusarium culmorum*.

2.8 Alkaloids

They are organic nitrogenous compounds, either of plant or animal origin that have complex molecular structures and show significant pharmacological activity. They have bitter taste and most of them are basic in nature (El-Olemy, Farid, and Abdel-Fattah, 1994).

Alkaloids are among the classes of compounds that have earlier been reported with microbial activity (Savoia, 2012).

2.9 Saponins

Saponins are one of the groups of glycosides found in many plant species with known foaming properties when mixed with water, allowing the formation of small stable bubbles. Harbone (1973) reported that Saponins prevent disease invasion of plant by parasitic fungi. Saponins are reported to have antibiotic activities (Soetan, Oyekunle, Aiyelaagbe, and Fafunso, 2006), antifungal activities (Jun, Park and Jo, 1989) and antiviral activity (Okubo *et al.*, 1994). Oleszek *et al.* (1990) and Shimoyamada, Susulki, Sonta, Maruyama, and Okubo (1990) reported that plants often defend themselves against microorganisms through the production and or accumulation of antinutritional factors.

Chapter III:

MATERIALS AND METHODS

3.1 Site Location

The experiments were conducted at the Teaching and Research Farm of Federal University of Technology, Owerri (FUTO) located on Lat 5⁰27' 50.23" North and Longitude 07⁰02' 49.33" East at 55 msl (Hand held global positioning system). Owerri has a rain forest agro ecology characterized with more than 2500 mm annual rainfall, 27-29°C annual temperature and 89-93 % humidity. The Soil was loamy sand and naturally infested with root-gall nematode, *Meloidogyne* Specie (*M. incognita*) (Agu, 2008b).

3.2 Identification of The Root-Knot Nematode Attacking Okra Cultivar

A stock pot culture of the *Meloidogyne spp.* that previously attacked the Okra cultivar in the field was maintained in the greenhouse. It was necessary to re-examine the identity of the *Meloidogyne spp* that attacked the Okra on which the culture was maintained. The infected Okra plants root carefully up-rooted from the soil, washed in clean tap water and chopped in pieces were placed in a 500 ml beaker into which lactophenol and fushin acid stain were added and root heated using a spirit lamp to near boiling point and later cleared in fresh lactophenol. Mature females were picked from the teased galls using electronic stereomicroscope. Tail regions of these females was cut, cleaned and mounted on the slides with a drop of lactophenol. Examination of theperineal pattern was made using a research microscope. The perineal patterns were exposed and the type observed conformed to those of *Meloidogyne incognita* (Eisenbacket *al.*, 1981)

3.3 Population Build Up of The Nematode

Four- weeks old nursery seedlings of Okra (*Abelmoschus esculentus*) raised in sterilized soil were transplanted into separate pot cultures of the nematode. Compound fertilizer (NPK 15:15:15) was applied to the Okra plants at the rate of 20g per 30cm diameter pot in split doses. These pot cultures were kept in a well-ventilated greenhouse. The plants were watered as and when necessary. Galling of roots was noticed in about seven days. Plants were kept for three months to allow for nematode reproduction. More Okra seedlings were added to replace dying ones. By this way the population of *M. incognita* was built up considerably.

3.3.1 Inoculum Preparation

The inoculum source was the *M. incognita* population which has been maintained and built up on Okra (*Abelmoschus esculentum*) in pot cultures. The infected roots of the Okra plants were recovered intact by inverting the pots to free the root system. Galled roots were also chopped into smaller pieces and put into warren blender containing about 1 litre of water. In order to avoid inactivating nematode larvae, the warren blending was allowed to run for three seconds only intervals. The slurry was made up to 1200 ml by adding more water. Thirty millilitres (30mls) of this mixture were taken and poured into a Petri-dish and the number of larvae counted using a stereomicroscope. The mean number of larvae in three counts was 430.

3.4 Preliminary Experiment

3.4.1 Screening of *Jatropha curcas* Cultivars for Root-Knot Nematode Infection

Three *Jatropha curcas* cultivars, viz: cv 'Ihiagwa', cv. 'Ilorin' and cv. 'India' raised in steam sterilized ultisol, at seedling stage were transplanted differently into polybags and

allowed to attain 1 month of age. The potted plants were laid out in the green house in Completely Randomized Design (CRD) replicated six times. The test *Jatropha* seedlings were then subsequently inoculated with 5,000 infective larvae (J₂) of *Meloidogyne incognita*. The uninoculated potted plants served as the control. Both inoculated and controls were watered as and when necessary. Three months after inoculation, the plants were then assessed for infection. This was done by carefully recovering the plants roots intact by rinsing with tap water and scoring for root-knot nematode infection according to Agu and Ogbuji (1996) in which

- O = No infection (no galls present)
- 1 = Rare infection (1-3galls present)
- 2 = light infection (4-10) galls present)
- 3 = Moderate infection (11-30 galls present)
- 4 = Severe infection (>30 galls present)

Plant Materials and Preparation of Crude Extracts

Fresh plant materials of *Jatropha curcas* L. were collected from three different agroecological zones namely; Owerri Rain forest zone, Ilorin in Kwara, South and Lafiagi.

Plant materials (leaves, roots and seeds) were dried under shade and later pulverized into coarse powder using clean mortar and pestle and sieved into fine particles and then stored in a cool dry place until required.

3.4.2 Extraction and Isolation of Alkaloids

The extraction of the alkaloids was done using the continuous extraction methods using soxhlet apparatus. Four hundred grams (400g) of 100 µm size powder samples were weighed and packed in a cheese cloth bag which served as extraction thimble.

The thimble was then placed into a conical flask with cover and the sample was moistened with 650 ml amount of 95% Ethanol. This was made alkaline by adjusting to pH of 8 with ammonia and mixed thoroughly. The sample in the thimble was submerged over-night in ethanol and then placed in the soxhlet extractor on the next day and the sample was extracted for 4 hours. The ethanol extract was filtered and was evaporated in soxhlet distillate apparatus at 60 °C. The crude alkaloid extract was further treated with 40 ml of 0.1 N Hydrochloric acid. This was filtered and the filtrate was collected in conical flask. The filtrate was alkalified with 2 ml of ammonia and placed in a separatory funnel. Three hundred millilitres were added into the separatory funnel, mixed and shaken for about ten minutes and allowed to separate into two layers. The lower layer of the chloroform contained the alkaloids and the upper layer the aqueous portion the remaining alkaloids was extracted from the upper layer until the last chloroform extract tested negative to Dragendoff's reagent. The combined alkaloids extract was evaporated in soxhlet distilling apparatus at 60°C and also evaporated in water bath maintained at the same temperature until semi-dry. The residue was weighed and percentage yield of alkaloids was calculated using the formula reported by Dimaandal (2003).

$$\% \text{ Yield} = \frac{\text{Weight of the alkaloid residue} \times .100}{\text{Weight of sample}}$$

Test for Alkaloids

Five millilitres of the extract were added to 2ml of HCl. To this acidic medium 1ml of Dragendroff's reagent was added. An orange or red precipitate produced immediately indicated the presence of alkaloids.

3.4.3 Flavonoids Extraction and Isolation

Each of the air-dried powdered sample was weighed and treated with 80% methanol for 24hrs using soxhlet extractor.

The extract obtained from each sample was subsequently extracted in petroleum ether, diethyl ether, and ethyl acetate following the method of Subramanian and Nagarajan (1969). Petroleum ether was discarded due to it being rich in fatty substance. The ether fraction was used for free substance. The ether fraction was used for free flavonoids, whereas ethyl acetate fraction for bond flavonoids. Ethyl acetate fraction of each sample was hydrolyzed further with 7% H₂SO₄ for 24hrs and was then re-extracted with ethyl acetate. The fraction obtained was repeatedly washed with distilled water to neutrality dried and weighed before the yield was calculated.

Test for Flavonoids

To 1 ml of extract, 3 drops of dilute sodium hydroxide was added. An intense yellow colour was produced in the plant extract, which become colourless on addition of 3 drops of dilute hydrochloric acid indicating the presence of flavonoids.

3.4.4 Extraction and Isolation of Saponins

Five hundred grammes (500 gm) of seeds sample was taken and ground to obtain 2 mm mesh size. It was subjected to successive soxhlet extraction first with petroleum ether and subsequently with methanol. The extract was vacuum dried using Rotary Vacuum Flask Evaporator to yield solid residue. Weight of the solid obtained after drying was 60gm. Solid residue was refluxed with 5=80% w/v ethyl acetate for half an hour. Solvent was decanted off and discarded. The residue was then dissolved in 90% w/v methanol. It was further filtered,

concentrated and was precipitated in acetone to yield saponin glycosides. The solvent was decanted off precipitate was filtered, dried and was weighed to estimate total saponin content of the plant drug (Aminet *al.*, 2016).

Test for Saponins

The extract was diluted with 20ml of distilled water and it was agitated in a graduated cylinder for 15 minutes. The formation of 1cm layer of foam showed the presence of saponins.

3.4.5 Extraction and Isolation of Tannins

The purification procedure was essentially according to that of Strumeyer and Malin (1975). Extracts of the dried ground plant parts (seed, root and leaves) was prepared (20g) in 400 ml of 70% aqueous acetone containing 0.1% ascorbic acid using an ultra-sonicator. The supernatant obtained on centrifugation for 15 minutes at 2500 rpm was evaporated under vacuum at about 30°C to remove acetone. The aqueous sample was lyophilized. The dried sample was dissolved in 80% aqueous methanol containing 0.1% ascorbic acid.

After the filtration of the lyophilized sample, Sephadex-20 slurry was prepared in a chromatography column (by addition of 300 ml of 80 % aqueous methanol to 25g Sephadex LH-20 in the column and 0.1 % ascorbic acid). The filtrate was poured into the column and the eluted sample without tannins were collected using conical flask. The tannins remained on the sephadex LH-20 and gave it a brown colour. The tannins were eluted by adding 100 ml of 5 % aqueous acetone containing 1 mg/ml ascorbic acid into the column.

The volume of the eluted tannins was recorded in mls. And the amount of ascorbic acid added during the isolation process was calculated as xmg of ascorbic acid. The acetone

was removed under vacuum at 30°C using rotary vacuum evaporator, then the aqueous solution containing the pure tannins was lyophilized in a pre-weighed beaker (W_1) to get weight of beaker plus tannins solution (W_2). The difference in W_2 and W_1 gives the weight of the tannins containing ascorbic acid (Y, mg)

Hence, the weight of the tannins was obtained by subtraction (Y, mg-X, mg.).

3.4.6 Removal of Ascorbic Acid

The Tannins preparation containing ascorbic acid was dissolved in 80 % aqueous methanol and added to sephadex LH -20 prepared in 80 % aqueous methanol without ascorbic acid. The sephadex LH-20 was washed to remove ascorbic acid using 80 % aqueous methanol (about 300ml for 25g of the gel). Tannins were adsorbed on the gel and the ascorbic acid was removed with washing. The adsorbed tannins were eluted with 50 % aqueous acetone. The rest of the procedure was the same as described in the last paragraph. This preparation was free of ascorbic acid.

Test for Tannins

Three drops of 1 % lead acetate were added to Five millilitres of the extract. A yellow precipitate was formed, indicating the presence of tannin.

3.4.7 Preparation of The Solvent System

Thirty millilitres of (30 ml) chloroform was measured into a beaker and 70ml of methanol added and they were mixed thoroughly. The chloroform methanol solvent system was transferred into a clean chromatographic developing tank and covered for 1 hour. The solvent system was allowed to saturate the developing tank with its vapour to ensure equilibration.

3.4.8 Preparation of Thin Layer Chromatographic (TLC) Plates for Development

Two centimeters (2cm) were measured from one end of the thin layer chromatographic plate. This was taken as the point of origin. Each fraction of the extract was spotted along the 2cm mark, 2cm apart from one another using a narrow capillary tube. The procedure was repeated to increase the concentration of the fractionated extract. The spots were allowed to dry before they were placed into developing tank containing saturated vapour of the solvent system. The TLC plates were developed until the solvent front got to the predetermined mark (10.4cm) on the TLC plates. The plates were then viewed using ultra-violet lamp and various R_f values of the spots were calculated using the formula stated below as described by Trease and Evans (2009).

$$R_f = \frac{\text{Distance moved by the spot}}{\text{Distance moved by the solvent front}}$$

3.5 Nematicidal Assay of *Jatropha curcas* L. Extracts

Nematicidal assay was carried out in six separate Experiments on the;

- i) Effect of *J. curcas* Seed Extracts, Rates and Hours of exposure on *Meloidogyne incognita* Egg hatchability
- ii) Effect of *J. curcas* Seed Extracts, Rates and Hours of exposure on *Meloidogyne incognita* juvenile mortality
- iii) Effect of *J. curcas* Leaf Extracts, Rates and Hours of exposure on *Meloidogyne incognita* Egg hatchability
- iv) Effect of *J. curcas* Leaf Extracts, Rates and Hours of exposure on *Meloidogyne*
- v) *Incognita* juvenile mortality
- vi) Effect of *J. curcas* Root Extracts, Rates and Hours of exposure on *Meloidogyne incognita* Egg hatchability
- vii) Effect of *J. curcas* Root Extracts, Rates and Hours of exposure on *Meloidogyne incognita* juvenile mortality

3.5.1 *Meloidogyne incognita* Juveniles (J₂) and Eggs Extractions

Extraction of Juveniles:

Roots of Indian spinach severely galled by *M. incognita* were harvested from the pot culture, washed and cut in pieces (1-2cm). The cut roots were shaken vigorously in a flask bottle containing 3 litres of water and 0.5 % NaOCl for 5mins. The eggs were passed through a 75 μ pore and 25 μ pore sieve mesh. Then the water containing eggs through the 25 μ pore sieve mesh was collected. The eggs obtained were viewed under microscope to ascertain the population of the overall eggs and this was later kept under cool temperature for one week to hatch. Thirty milliliters (30 mls.) of larvae suspension was taken and poured into a counting dish placed under an electronic stereomicroscope and the number of larvae counted. Mean number of three counts was 30 active larvae per 30 mls suspension. Therefore, 30 mls containing 30 larvae (J₂) was introduced in each Petri dish.

3.5.2 Extraction of Eggs

Infected roots of Indian spinach maintained in pots were harvested, washed well and chopped into smaller pieces. The chopped roots were soaked in a solution containing 5.2 % of sodium hypochlorite, (NaOCl) then shaken vigorously for 2mins according to Adegbita and Adesiyun (2005). Eggs contained in the suspension were sieved by placing it on a 75 μ . and 25 μ sieve mesh. The eggs were then viewed under compound microscope and the number of eggs counted.

3.5.3 Experimental Design and Layout in The Laboratory

The effects of Alkaloids, Saponins, Flavonoids and Tannins extracted from *J. curcas* Seeds, Leaves and Roots were separately applied at 0, 5 and 10 mls to 30 juveniles (J₂) of *M. incognita* in distilled water suspension in sterilized Petri-dishes. Completely Randomized Design (CRD) experiment was adopted and each treatment was replicated 3 times. This gave a

total of 432 Petri-dishes(Treatment units).All the Petri-dishes were kept on laboratory/ incubation table at ambient temperature (± 30).With the aid of electronic stereomicroscope at magnification 100x, dead and living juveniles (J_2) were counted after 12, 24, 48 and 72 hrs of exposure to each treatment. The juvenile (J_2) was considered dead when it did not move on physical stimulus with a fine needle (Hong *et al.*, 2007). Percentage mortality was calculated as ratio of number of dead juveniles to original number of juveniles and expressed in percentage.

$$\text{i.e. \% Mortality} = \frac{X}{N} \times \frac{100}{1}$$

where X= Number of dead juveniles (J_2)

N= Original number of juveniles (J_2)

To determine the effect of *J.curcas* parts extracts, 20 eggs were placed in each Petri dishes containing 0, 5 & 10 ml of different extracts. Each treatment was replicated 3 times. After 12, 24, 48 and 72h of exposure, the number of juveniles hatched was counted with the aid of inverted microscope at magnification 40X.

The data were analysed as factorial experiment in Completely Randomized Design by using ANOVA (Genstat Edition 4). Least significant differences were calculated at $P < 0.05$.



Figure 4: Picture depicting phytochemical extraction and nematocidal assay in the laboratory

3.6 Screen House Experiments

Identified phytochemicals in *Jatropha curcas* plant parts were individually tested for nematocidal effect on the root-knot nematode on Okra plants. Each trial was carried out in a factorial (Completely Randomized Design) experiment.

These tests included:

- i. Effect of Tannins from *Jatropha curca* parts (Seed, leaves and roots) on root-knot nematode disease on Okra

- ii. Effect of Saponins from *Jatropha curcas* parts (Seed, leaves and root) on root-knot nematode disease on Okra
- iii. Effect of Flavonoids from *Jatropha curcas* parts (Seed, leaves and root) on root-knot nematode disease on Okra
- iv. Effect of Alkaloids from *Jatropha curcas* parts (Seed, leaves and root) on root-knot nematode disease on Okra.

3.6.1 Experimental Design and Layout in The Screen House

The experiments were carried out as factorial in completely randomized Design (CRD) with six treatment applications in five replications. Each phytochemical (Factor A) under study had six treatment levels of applications and Factor B, (*Jatropha* parts: root, seed & leaves). Thus a 3x6 factorial arranged in Completely Randomized Design with 5 replications was conducted in each experiment thereby giving a total of 90 pots for each experiment. Therefore, for each phytochemical under study four separate experiments comprising 90 pots containing 4 kg of steam sterilized soil each was used. Hence, a total of 360 pots for the four phytochemicals under study were laid out on the green house benches. The treatments were randomly assigned to the experimental units/pots. The treatments were applied at various rates or levels: 0.00 ml (control), 1.00 ml, 2.00 ml, 3.00 ml, 4.00 ml and 5.00ml on okra plant cultivar (NHA_c47- 4). All the test plants were inoculated with 1200 (J₂) infective larvae of the nematode and treated with various levels of the phytochemical under study. Inoculated plants without treatment or zero level of treatment applications served as the control.

3.6.2 Soil Medium

The soil used in this experiment was collected from the Research Farm of the School of Agriculture and Agricultural Technology located on a Lat 5⁰27N and Long 07⁰2E. The soil

was described by Federal Department of Agriculture Land. Resources(FDALR, 1985) and classified as Ultisols, according to USDA soil order. Soil samples at 0-15cm depth were collected from fifteen sites per hectare according to Okonet *et al.*, (2014). These samples were bulked together and thoroughly mixed to represent soils in the area. The bulked soil sample was steam sterilized by wood-fire for three hours. After cooling, a representative sample of the sterilized soil was analysed for physical and chemical properties.

Physical Properties of Soil Analysed included:

Particle Size Distribution: Analysed using the pipette method with 5% calgon (sodium hexametaphosphate) solution as dispersing agent and silt-clay ratio obtained by calculation.

- 1 **Chemical Properties Determined Included:** Soil pH, determined in water at 1:1 ratio of soil – water suspension using Bechman Model pH meter. (Hendershot *et al.*, 1993).
- 2 **Organic Carbon Content of the Soil:** Determined using wet oxidation method (Nelson and Sommers, 1982) after the soil must have been further passed through 0.5mm sieve. The percentage organic matter was computed by multiplying the value of organic carbon by 1.724 (correction factor) (Bremner, 1996).
- 3 Total nitrogen content of the soil was obtained by modified micro Kjeldhal distillation procedure (Bremner, 1996).
- 4 Available phosphorus was determined by Bray 1 method using spectrophotometer (Olson and Sommers, 1990).
- 5 **Exchangeable cations (bases):** Calcium and Magnesium were determined by compleximetric method EDTA while sodium and potassium were determined using the flame photometer (Olson and Sommer, 1990).

- 6 **Exchangeable Acidity:** Hydrogen ion and Aluminum ion were determined by titration method (Mclean, 1982).
- 7 Effective cation exchange capacity (CEC) (Meq/100g soil) was determined by summation of the exchangeable acidity and bases. (Olson and Sommer, 1990).

3.6.3 Planting

Before planting, one hundred seeds of the test okra cultivar (NHA_e47-4) were surface sterilized. This was done by soaking in 10 % concentration of commercial sodium hypochlorite solution (NaOCl) and later rinsed several times in tap water. The seeds were then plated on moistened filter paper contained in sterilized Petri-dishes to sprout. The Petri-dishes were appropriately labeled. Two sprouted seeds were planted in each potted sterilized soil but later thinned down to one plant per pot before inoculation. The test okra cultivar used was obtained from National Horticultural Research Institute, Okigwe in Imo State (NIHORT).

Inoculum Application

Ten days after planting, some plants of the test okra cultivars were inoculated by measuring out and pouring 30 ml of blended slurry of infected galled roots of African spinach at the root base of each plant and then covered up with thin layer of the sterilized soil. The inoculated plants were kept on benches in well ventilated green house. The uninoculated served as controls. The average soil temperature ranged from 30 – 32 °C. In order to forestall any fungal problem 0.1 % benlate (Benomyl) was incorporated to the potted soil.

Phytochemical Application

Alkaloids, Flavonoids, Saponins and Tannins were applied at the base of the potted plants at the same time the inoculation was done (i.e. Ten days after planting) at the following rates: 0.00, 1.00, 2.00, 3.00, 4.00, and 5.00 mls per plant.

3.6.4 Growth and Yield Parameters Measurement

Plant Height (cm): This was measured with a metre rule placed at the base of the plant to the shoot apex (last nodal branch).

Leaf Area (cm²): leaf area was obtained by measuring the length of the midrib (in the central base) and the widest width and the leaf area calculated by the formula proposed by Bello (2015) in which: for the lobed, okra leaf area = 0.56 x length of the midrib of the central lobe (cm) x widest width (cm); for unlobed okra leaf area = 0.89 x length x width.

Number of leaves at six and eight weeks after planting: This was obtained by counting the number of fully opened leaves per plant at 6 and 8 weeks after planting

Days to First Flowering: This was obtained by noting the number of days from planting to the first flower produced in each treatment.

Days to 50 % flowering: This was obtained by counting the days from planting until 50% of the plants exposed to each treatment have flowered

Fresh Pod Weight (gm): This was obtained by using an electronic Metler balance to weigh okra pods per treatment.

One hundred (100) dry seed weights of okra (gm): This was taken by using the electronic Metler balance to weigh 100 dry okra seeds harvested per treatment.

Fresh shoot weight (gm): obtained by using an electronic Metler balance to weigh fresh shoots severed from the base of the plant per treatment.

Fresh root weights (gm): This was obtained 12 weeks after inoculation and before infection assessment by freeing the root systems of soil particles and weighing using an electronic metler balance per treatment.

3.6.5 Mucilaginous Property Measurement

The mucilaginous property of okra fruits was measured using a Brookfield RVT viscometer (Brookfield Engineering Laboratories mass, USA) and the procedure as described by Sopade *et al.*, (1992). Fifty grammes (50 g) of freshly harvested immature (i. e. 6 days after anthesis) okra fruits from each treatment were sliced into pieces and 150 ml. of water added to it and blended with an electric Warren blender. The solution was poured into a 250 ml beaker. The mucilaginous property was read using a Brookfield viscometer with No. 1 spindle at 15 r.p.m. (15 revolutions per minute). This procedure was repeated three times and the mean taken for each treatment.

3.6.6 Nutrient Composition Analysis

Nutrient composition was determined on all immature fresh fruit samples harvested 6 days after anthesis using the standard methods of Association of Official Analytical chemists (AOAC, 1990);

i. Determination of Crude protein content of fresh Okra fruit:

Half a gram (0.5 gm) of each fresh sample was weighed and put in a 250 ml Kjeldahl digestion flask. 0.6 g of a catalyst (mixture of copper sulphate + Potassium sulphate crystals) and 20 ml of concentrated sulphuric acid were added. The mixture was heated until a clear solution was obtained. It was then cooled to room temperature (± 30) and made up to 100 ml in a volumetric flask with de-ionized water. A blank experiment was also setup involving the digestion of all the materials except any of the test okra samples and made up to 100 ml in a volumetric flask. 10 ml of the fresh

okra sample digest was transferred to the distillation flask and 10 ml of 2 % boric acid solution and 2 drops of methyl red indicator placed in the receiving flask, under the condenser. The tip of the delivery tube extended below the surface of the boric acid solution. To the distillation flask 10ml of 40 % sodium hydroxide solution was added and the plug was quickly replaced. The mixture was distilled till 30ml of the distillate was collected.

The above distillation procedure was also carried out on the blank. The distillate collected from the samples and blank experiment were then titrated against 0.1.N hydrochloric acid.

The digestion, distillation and titration procedures were carried out for each sample and from their titre values their nitrogen contents were calculated thus:

$$\text{Percentage Nitrogen} = \frac{(T - B) \times \text{NHCL} \times 0.0014 \times \text{Vol made} \times 100}{\text{Aliquot} \times \text{Weight of sample use}}$$

Percentage crude protein=Percentage Nitrogen X 6.25

T = Titre values of sample

B = Blank titre

NHCL = Normality of HCL used (i.e. 0.1 N)

Aliquot = Sample aliquot taken = 10 ml

- ii Determination of fat content:** The oil content was determined using the standard method of the Association of official Analytical Chemists (AOAC, 1990), Two grammes (2 g) of ground dry sample of the okra fruits of each treatment was wrapped in filter paper and placed in a Soxhlet extractor fixed to round bottomed flask containing 150 ml of petroleum spirit. The flask was then heated on heating mantle at 60 °C for five hours. The apparatus was disconnected and the oil-free sample wrapped in filter paper removed from the extractor. The filter paper and its content were

reweighed after expelling the solvent. Each determination was done in duplicate and percentage fat content calculated as:

$$\text{Percentage Oil} = \frac{\text{Loss in Weight of sample}}{\text{Weight of sample}} \times \frac{100}{1}$$

- iii Determination of moisture content:** The oven drying method was used to determine the moisture content. Fresh Okra fruits were weighed and later oven-dried at 150 °C to a constant weight. The percentage moisture content was calculated thus

$$\text{Percentage Moisture} = \frac{\text{Loss in Weight after oven drying}}{\text{Weight of original sample}} \times \frac{100}{1}$$

- iv Determination of Ash Content:** The method adopted by Association of official Analytical Chemists (AOAC, 1990) was used. Twenty grams (20 gm) of each sample was weighed into a Porcelain crucible. The crucibles were previously ignited and cooled in desiccators. The crucibles and their contents were then placed in the muffle furnace at 200 °C and the temperature gradually increased to 600 °C. They were incinerated for about five hours to get a light grey ash. The crucibles and their contents were cooled in desiccators and allowed to cool and then weighed. Incineration was resumed and the samples reweighed at 30minutes intervals until two consecutive readings agreed.

The percentage ash content was thus calculated as:

$$\text{Percentage Ash} = \frac{\text{Weight of Ash obtained}}{\text{Weight of sample}} \times \frac{100}{1}$$

- v Determination of potassium and sodium by flame photometry:** Half gram(0.5 gm) of each okra sample of each treatment was weighed into a clean crucible and incinerated in a furnace at 25 °C for 8 hours and later allowed to cool. 5ml of 1MHN₃ (nitric acid) was afterward added and subsequently evaporated to dryness

using hot plate. The crucibles and their content were returned to the furnace, incinerated again for 10-15 minutes and then allowed to cool. 3ml of 1MHCl (hydrochloric acid) was added and filtered through filter paper and funnel into 50ml volumetric flask. The residue on the filter paper was then rinsed with 0.1 MHCl and made up to 50ml mark with 0.1 MHCl and then labeled.

Standard solution for Na^+ and K^+ were prepared using 2.5 g NaCl (A.R) and 1.91 g KCl (A.R) respectively and dissolved in 1 dm³ volumetric flask with distilled water. For sodium, it was equivalent to 1 g Na per 1 dm³ (or 1 mg Na/ml or 1000 ppm Na) For potassium (K^+) it was equivalent to 1 g K per dm³ (or 1 mg per ml or 1000 ppm K).

For sodium, aliquot for the stock solution: 0.40, 0.80, 1.20, 1.60, and 2.00 ml were taken in different 100 ml volumetric flask and made up to 100 ml mark with distilled water. These gave 4, 8, 12, 16, 20 ppm Na respectively.

With sodium filter in position, the flame photometer was adjusted to zero. It was calibrated with standard sodium solution and the reading taken. A calibration graph was plotted for which the concentration of the unknown sample was determined.

For potassium, aliquot of the stock: 0.40, 0.80, 1.20, 1.60 and 2.00 ml were taken and made up to 100 ml mark with distilled water which corresponded to 4, 8, 12, 16, 20 ppm K respectively.

With potassium filter in position, the flame photometer was calibrated as above and the instrument reading for each of the standard solution was recorded as well as unknown sample. A calibration graph of emission intensity against concentration (ppm) was plotted from which the concentration of unknown sample was determined.

vi Determination of Phosphorus: The procedure for preparation of the sample for phosphorus determination was the same as that of sodium and potassium. A standard

solution for P^{3+} using 0.4379 g KH_2PO_4 (A.R) 27 was prepared and dissolved in 1 dm³ volumetric flask with distilled water.

For phosphorus, this was equivalent to 0.10g P per 50 ml (or 2 mg P per ml. or 2000 ppm P)

Aliquots of stock solution, 0.20, 0.40, 0.80, 1.20, 1.60 ml were taken and made up to 100 ml mark using volumetric flasks with distilled water. These gave 4, 8, 16, 24 and 32 ppm P respectively. Their colours were developed with Ammonium molybdate and stannous chloride. The Absorbance of each standard solution and that of the unknown sample were measured at 660 nm and the readings were recorded. A graph of Absorbance against Concentration of the unknown sample was determined.

vii Determination of Calcium and Magnesium by Compleximetric method using EDTA

- i. 0.931 g of Ethylene diamine tetra acetic acid (EDTA) was dissolved in 1 litre of distilled water.
- ii. Twenty milligram of calgon was dissolved in 50ml methanol
- iii. Forty milligram of NaOH was weighed out and dissolved in 1 litre of distilled water.

viii Determination of Calcium by EDTA

- i. A reference end point was obtained by mixing 5 mls of 1MNaOH with 5 drops of Calgon and diluted with 100ml of water, then titrated with EDTA solution.
- ii. 5 ml aliquot of the sample extract was pipetted into a conical flask and 100ml of water, 5 ml of 1MNaOH, 5 drops of indicator and 15 ml of buffer solution added.
- iii. Titration with EDTA solution was done to obtain the end point which was indicated by matching the colour of the solution to the reference end point. Blank titration was done in the same manner and subtracted from the sample reading.

Calculation:

$$\text{Ca (g/kg)} = \frac{\text{Vol.of EDTA required for titration} \times \text{vol.of solution}}{10 \times \text{aliquot} \times \text{sample mass (g)}} \times \frac{100}{1}$$

ix Determination of (calcium + Magnesium) by EDTA

- i. 0.931 g of EDTA was dissolved in litre of distilled water
- ii. Indicator (Eriochrome black T) 0.25 g Eriochrome Blank T was dissolved in 50 ml methylated spirit.
- iii. Buffer solution: 65.70 g NH₄CL was dissolved in water, 570 ml of 0.88N NH₄OH solution was added and diluted with water to 1 litre.
 - i. Five millilitres of the sample or extract was pipetted into a conical flask and diluted with 1 ml of water.
 - ii. Fifteen millilitres of buffer solution, 10 drops of the indicators and 2ml of triethanol amine were added
 - iii. Titration was done with EDT A to get a colour change from red to a clear blue colour
 - iv. Blank titration was done in the same manner and subtracted from the sample reading.
 - v. Magnesium was then obtained by difference between calcium determined above and (ca + mg) determination.

Calculation:

$$\text{Ca(g+mg)g/kg} = \frac{\text{Vol.of EDTA solution used in titration} \times \text{vol. of solution}}{10 \times \text{aliquot} \times \text{sample mass (g)}} \times \frac{100}{1}$$

3.6.7 Infection Assessment

The experiment was terminated 12 weeks after inoculation. By this time all the plants have produced fruits. In assessing the extent of root infection by *M. incognita* in each treatment level, the root systems were recovered intact. This was done by inverting the pots to free the root system. Adhering soils were gently removed from the roots by rinsing in water. Root systems were individually scored according to Agu and Ogbuji (1996) in which

- 0 = No infection (no galls present)
- 1 = Rare infection (1-3 galls present)
- 2 = Light infection (4-10 galls present)
- 3 = Moderate infection (11-30 galls present)
- 4 = Severe infection (30 and above galls present)

3.7 Data Analysis

Data obtained were subjected to analysis of variance using GENSTAT Edition 4. Differences between means were separated using Fisher's least significant Difference (F - LSD) at 5 % level of probability. Correlation analysis showing the relationship between root-gall index and growth/yield attributes under the various treatments were computed using SPSS version 22.0

CHAPTER IV:

RESULTS AND DISCUSSION

4.1 Results

The 2016 and 2017 results of used soil physico-chemical analysis showed that it is an acidic sandy loam soil, low in organic matter and total nitrogen contents (Table 4.1).

Results of Preliminary screening of three *Jatropha curcas* cultivars for susceptibility/resistance to root-gall nematode infection revealed no root-galls on all the root systems assessed. (Table 4.2). This confirmed the report of Devappa, Makkar, and Becker (2010) which stated that all parts of *J. curcas* are nematicidal to lower animals.

Phytochemical screening of *Jatropha curcas* parts showed that it contained high amounts of Tannins, Alkaloids, Saponins and Flavonoids however, the seed contained highest percentage of phytochemicals (Table 4.3). Percentage availability of these phytochemicals however differs amongst the *J. curcas* parts (Table 4.4). El Diwani (2009); Makkar *et al.*, (2009); Manpong *et al.*, (2009); Igbinosa *et al.* (2011); Namuli *et al.* (2011); Oskoueian *et al.* (2011) all reported the presence of these phytochemicals as secondary metabolites in different parts of *Jatropha curcas*.

Table 4.1:Physico-chemical Properties of the soil used at the study site in 2016 and 2017

| Physico-chemical Properties | 2016 | 2017 |
|------------------------------------|--------------------|---------------------|
| Sand | 91.90 % | 92.10 % |
| Silt | 4.48 % | 4.40 % |
| Clay | 3.56% | 3.73 % |
| pH in H2O | 5.57 % | 5.49 % |
| Calcium | 1.00 meq/100g Soil | 0.95 meq/100g Soil |
| Magnesium | 0.84 meq/100g Soil | 0.83 meq/100g Soil |
| Sodium | 0.032meq/100g Soil | 0.062 meq/100g Soil |
| Potassium | 0.053meq/100g Soil | 0.050 meq/100g Soil |
| Organic carbon | 0.76 % | 0.80 % |
| Organic matter | 1.31 % | 1.29 % |
| Total Nitrogen | 0.09 % | 0.08 % |
| Available Phosphorus | 10.43ppm | 9.61ppm |

Table 4.2: Varietal response of *Jatropha curcas* cultivars to root-knot nematode (*M.incognita*) in a Nigerian ultisol

| Varieties | Root-knot index (0-4) | |
|-------------|-----------------------|------------|
| | Uninoculated | Inoculated |
| Ihiagwa“cv” | 0 | 0 |
| Ilorin “cv” | 0 | 0 |
| India“cv” | 0 | 0 |

Table 4.3:Phytochemical Screening (Qualitative Analysis) of *Jatropha curcas* plant parts

| Phytochemical | Seed | Leaf | Root |
|----------------------|-------------|-------------|-------------|
| Tannins | +++ | +++ | +++ |
| Alkaloids | +++ | +++ | +++ |
| Flavonoids | +++ | +++ | +++ |
| Saponins | +++ | +++ | +++ |

Key: +++ = High

Table 4.4: Phytochemical constituents (Quantitative analysis) of *Jatropha curcas* plant parts

| <i>Jatropha curcas</i> Parts | Phytochemical constituents (%) | | | |
|---------------------------------|--------------------------------|-----------|------------|----------|
| | Tannins | Alkaloids | Flavonoids | Saponins |
| Seed (g/l) | 49.05 | 1.32 | 5.51 | 10.68 |
| Leaf (g/l) | 11.04 | 1.02 | 5.51 | 9.34 |
| Root (g/l) | 12.65 | 3.32 | 3.59 | 4.2 |

4.2 Laboratory Experimental Results

Result of Laboratory assay conducted on the nematicidal activities of *Jatropha curcas* parts revealed that the phytochemical extracts varied in their effects on egg hatchability and Juvenile (J₂) performance.

4.2.1 Egg Hatchability: Effect of *Jatropha curcas* extracts, Rates and Hours of Exposure on Hatchability of *Meloidogyne incognita* eggs

Inhibition of egg hatch was observed in the egg masses treated with various phytochemicals extracted from *J. curcas* seeds, leaves and roots. This was not so with eggs in distilled water (control).

Highest mean egg hatch inhibition (1.50) was achieved with Seed Saponin when compared to the control (5.50) (Table 4.5). This was followed by those caused by Seed Flavonoid (1.92) and then Seed Alkaloids (2.97). Seed Tannins (3.08) caused the least mean egg hatch inhibition. There was however, no significant difference ($P < 0.05$) between Seed Saponins and Seed Flavonoids on mean egg hatch inhibition.

Egg hatchability decreased with increased rates of each phytochemical applied. Egg hatch inhibition was significant both at 5 mls and 10 mls rates application when compared to the control.

Results of these study showed that Seed Saponins achieved complete egg hatch inhibition at 5 ml and 10mls application rates. This was unlike Seed Tannins where egg hatch inhibition was 3.08 and 1.75 at 5 and 10 mls respectively. For the purpose of cost effectiveness, 5 mls of Seed Saponins should be preferred to its 10 mls since egg hatch inhibitions caused by both rates are statistically equal.

Egg hatch inhibition decreased with increased numbers of hours of exposure to test phytochemical of *J. curcas*. Highest hatch inhibition (1.39) occurred at 12 hours of egg

exposure to the phytochemical at 5 and 10 mls (Table 4.5). This was followed by 24, 48 and 72 hrs of exposure at 5 mls and 10 mls of treatment applied.

Phytochemical leaf extracts also significantly reduced nematode mean egg hatchability as shown in Table 4.5. However, Egg hatch inhibition was not significant both at 5 mls and 10mls of treatment application when compared to the control. Egg hatch inhibition was highest at 12 hrs and decreased with increased exposure time.

Phytochemical root extracts significantly reduced nematode egg hatchability (Table 4.5). Root Alkaloids was most effective in inhibiting egg hatch. This was followed by Root Saponins. The effects of RootAlkaloids and Root Saponins differed significantly ($P<0.05$.) from those of Root Flavonoids and Root Tannins. Egg hatch inhibition increased with increased rate. Root Alkaloids at 5 mls (0.16.) achieved the same mean egg hatch inhibition as Root Saponins at 10 mls (0.16).

Egg hatch inhibition decrease with increased hours of exposure to phytochemicals. Mean egg hatch inhibition was greatest after 12 hours (1.27) of exposure time and differed significantly from that of 24 hrs of exposure. Root Alkaloids at 5 or 10 mls application rate and 12 hours exposure gave the highest egg hatch inhibition.

Table 4.5:Effect of *Jatropha curcas* extracts, Rates and Hours of Exposure on Hatchability of *Meloidogyne incognita* eggs

| Plant Based Nematicides (Phytochemicals) | Seed | | | | Leaf | | | | Root | | | |
|---|-----------|-------|------|------|------------|------|------|------|------------|------|------|------|
| | Rate (ml) | | | Mean | Rates (ml) | | | Mean | Rates (ml) | | | Mean |
| | 0 | 5 | 10 | | 0 | 5 | 10 | | 0 | 5 | 10 | |
| Alkaloids | 4.42 | 2.58 | 1.92 | 2.97 | 5.5 | 1 | 0.58 | 2.36 | 5.58 | 0.16 | 0.16 | 1.97 |
| Flavonoids | 4.42 | 1.00 | 0.33 | 1.92 | 5.5 | 1.42 | 0.58 | 2.50 | 5.58 | 1.58 | 0.25 | 2.47 |
| Saponins | 4.42 | 0.08 | 0.00 | 1.50 | 5.5 | 1.25 | 0.42 | 2.39 | 5.58 | 0.66 | 0.16 | 2.13 |
| Tannin | 4.42 | 3.08 | 1.75 | 3.08 | 5.5 | 3.25 | 1.33 | 3.36 | 5.58 | 2.16 | 1.66 | 3.13 |
| Mean | 4.42 | 1.69 | 1.00 | | 5.5 | 1.73 | 0.73 | | 5.58 | 1.14 | 0.56 | |
| LSD _{0.05} (Rate) | | 0.52 | | | | 0.51 | | | | 0.33 | | |
| LSD _{0.05} (Phytochemical) | | 0.60 | | | | 0.59 | | | | 0.38 | | |
| LSD _{0.05} (Phytochemical X Rate) | | 1.04 | | | | ns | | | | 0.67 | | |
| Hours of Treatment Exposure | | | | | | | | | | | | |
| 12 | 2.67 | 0.92 | 0.58 | 1.39 | 2.33 | 0.83 | 0.5 | 1.22 | 2.66 | 0.83 | 0.33 | 1.27 |
| 24 | 4.00 | 2.08 | 1.33 | 2.47 | 4.33 | 2.25 | 1.17 | 2.58 | 4.66 | 1.5 | 0.91 | 2.36 |
| 48 | 4.67 | 2.00 | 1.25 | 2.64 | 6.67 | 2.17 | 0.67 | 3.17 | 7.00 | 1.25 | 0.58 | 2.94 |
| 72 | 6.33 | 1.75 | 0.83 | 2.97 | 8.67 | 1.67 | 0.58 | 3.67 | 8.00 | 1.00 | 0.41 | 3.13 |
| Mean | 4.42 | 1.69 | 1.00 | | 5.50 | 1.73 | 0.73 | | 5.58 | 1.14 | 0.56 | |
| LSD _{0.05} (Rate) | | 0.52 | | | | 0.51 | | | | 0.33 | | |
| LSD _{0.05} (Treatment Exposure) | | 0.6.0 | | | | 0.59 | | | | 0.38 | | |
| LSD _{0.05} (Treatment Exposure X Rate) | | 1.04 | | | | 1.03 | | | | 0.67 | | |

*=Significant; ns = not significant

Juvenile Mortality: Effect of *Jatropha curcas* extracts, Rates and Hours of Exposure on Mortality of *Meloidogyne incognita* Juveniles

Table 4.6 shows how second stage larva (juvenile) of the nematode reacted to phytochemicals extracted from *J. curcas* seeds, leaves and roots. Over 18 out of 30 juveniles died when Seed Alkaloids was applied. The same was true for Seed Saponins. Seed Tannins and Seed Flavonoids caused 14 and 12.8 mean deaths respectively.

Juvenile mortality increased with increased rate of phytochemical treatment applied. Mortality of nematode juveniles was significant both at 5 mls and 10 mls of treatment application when compared to the control.

In the interactions of phytochemical X Rate, the highest mean and percent of nematode mortality was achieved by the application of Seed Alkaloids both at 5mls. (26.50) (88.3%) and 10mls (29.92) (99.7 %) as shown in Table 4.6 and figure 1. This was closely followed by Seed Saponins at 5 mls (26.17) (87.2 %) and 10mls (29.67) (98.9 %). Although, there was no statistical difference ($P < 0.05$) between them, they however, differed significantly from Seed Tannins and Seed Flavonoids both at 5 mls and 10 mls of treatment applications respectively.

Within the hours of exposure intervals, mortality increased with increased hours of exposure, the most nematode juvenile mortality was obtained after 72 hrs (19.11) of exposure time, with significant differences ($P < 0.05$) from others in the following order: 48 hrs (17.61), 24hrs (15.47) and 12hrs (12.25).

Interactions involving Hours of exposure X Rate maintained the same order, with highest juvenile mortality occurring after 72 hrs at 5 mls (28.33) and 10 mls (29.00) respectively. However, at 10mls of treatment application, there were no significant differences observed in juvenile mortality after 48 hrs and 72 hrs of exposure time.

Table 4.6 also showed that phytochemical leaf extracts of *J. curcas* caused juveniles (J₂) mortality. Highest mortality was recorded on application of Leaf Alkaloids This was followed by those caused by Leaf Saponins. Mortalities caused by Leaf Flavonoids and Leaf Tannins were significantly ($P < 0.05$) lower than those of Leaf Alkaloids and Leaf Saponins.

Increased rate of phytochemical application caused increased juvenile mortality. Highest percent mortality recorded for each phytochemical was when 10 mls was (Figure 2). The same was true for the period of exposure (i.e. number of hours) to the phytochemical. Juvenile mortality was highest at 72 hrs.

Phytochemical root extracts tested for their nematicidal effects significantly ($P < 0.05$) affected juvenile mortality (Table 4.6). The highest mean juvenile mortality was recorded with Root Alkaloids and Root Saponins applications. Both differed significantly ($P < 0.05$) from Root Flavonoids and Root Tannins. Nematode juvenile percent mortality significantly ($P < 0.05$) increased with increased rates of the phytochemicals (Table 4.6 and Figure 3). Highest Juvenile mortality caused by Root Alkaloids at 10 mls application rate did not however differ significantly from that caused by 5 mls of Root Alkaloids and 10 mls of Root Saponins, Root Flavonoids and Root Tannins.

Most mean juvenile mortality occurred after 48 and 72 hours of exposure to the phytochemicals and differed from those of 12 and 24 hours of exposure.

The interactions between phytochemical seed extract X hours of exposure are shown in Table 4.7. While the greatest juvenile mortality occurred after 72 hrs of exposure with Alkaloids (20.00) and Saponins (20.00). Least juvenile mortality was obtained with Flavonoids treatment across hours of exposure intervals after Tannins at $P < 0.05$.

Table 4.6:Effect of *Jatropha curcas* extracts, Rates and Hours of Exposure on Mortality of *Meloidogyne incognita* Juveniles

| Plant Based Nematicides (Phytochemical) | Seed | | | | Leaf | | | | Root | | | |
|---|-----------|-------|-------|-------|------------|-------|-------|-------|------------|-------|-------|-------|
| | Rate (ml) | | | Mean | Rates (ml) | | | Mean | Rates (ml) | | | Mean |
| | 0 | 5 | 10 | | 0 | 5 | 10 | | 0 | 5 | 10 | |
| Alkaloids | 0 | 26.5 | 29.92 | 18.81 | 0 | 24.42 | 26.83 | 17.08 | 0 | 28.42 | 29.67 | 19.36 |
| Flavonoids | 0 | 16.83 | 21.75 | 12.86 | 0 | 12.92 | 20.92 | 11.28 | 0 | 20.83 | 28.42 | 16.42 |
| Saponins | 0 | 26.17 | 29.67 | 18.61 | 0 | 19.33 | 25.92 | 15.08 | 0 | 25.67 | 28.83 | 18.17 |
| Tannins | 0 | 17.92 | 24.58 | 14.17 | 0 | 9.58 | 20.83 | 10.14 | 0 | 17.33 | 28.25 | 15.19 |
| Mean | 0 | 21.85 | 26.48 | | 0 | 16.56 | 23.62 | | 0 | 23.06 | 28.79 | |
| LSD _{0.05} (Rate) | | 1.18 | | | | 1.31 | | | | 1.17 | | |
| LSD _{0.05} (Phytochemical) | | 1.36 | | | | 1.51 | | | | 1.35 | | |
| LSD _{0.05} (Phytochemical X Rate) | | 2.36 | | | | 2.62 | | | | 2.34 | | |
| Hours of Treatment Exposure | | | | | | | | | | | | |
| 12 | 0 | 14.67 | 22.08 | 12.25 | 0 | 9.92 | 16.08 | 8.67 | 0 | 18 | 26.42 | 14.81 |
| 24 | 0 | 20.08 | 26.33 | 15.47 | 0 | 14.83 | 23.33 | 12.72 | 0 | 21.67 | 28.75 | 16.81 |
| 48 | 0 | 24.33 | 28.50 | 17.61 | 0 | 19.50 | 26.92 | 15.47 | 0 | 25.08 | 30.00 | 18.36 |
| 72 | 0 | 28.33 | 29.00 | 19.11 | 0 | 22.00 | 28.17 | 16.72 | 0 | 27.5 | 30.00 | 19.17 |
| Mean | 0 | 21.85 | 26.48 | | 0 | 16.56 | 23.62 | | 0 | 23.06 | 28.79 | |
| LSD _{0.05} (Rate) | | 1.83 | | | | 1.31 | | | | 1.17 | | |
| LSD _{0.05} (Treatment Exposure) | | 1.36 | | | | 1.51 | | | | 1.35 | | |
| LSD _{0.05} (Treatment Exposure X Rate) | | 2.36 | | | | 2.62 | | | | 2.34 | | |

*=significant, ns= not significant

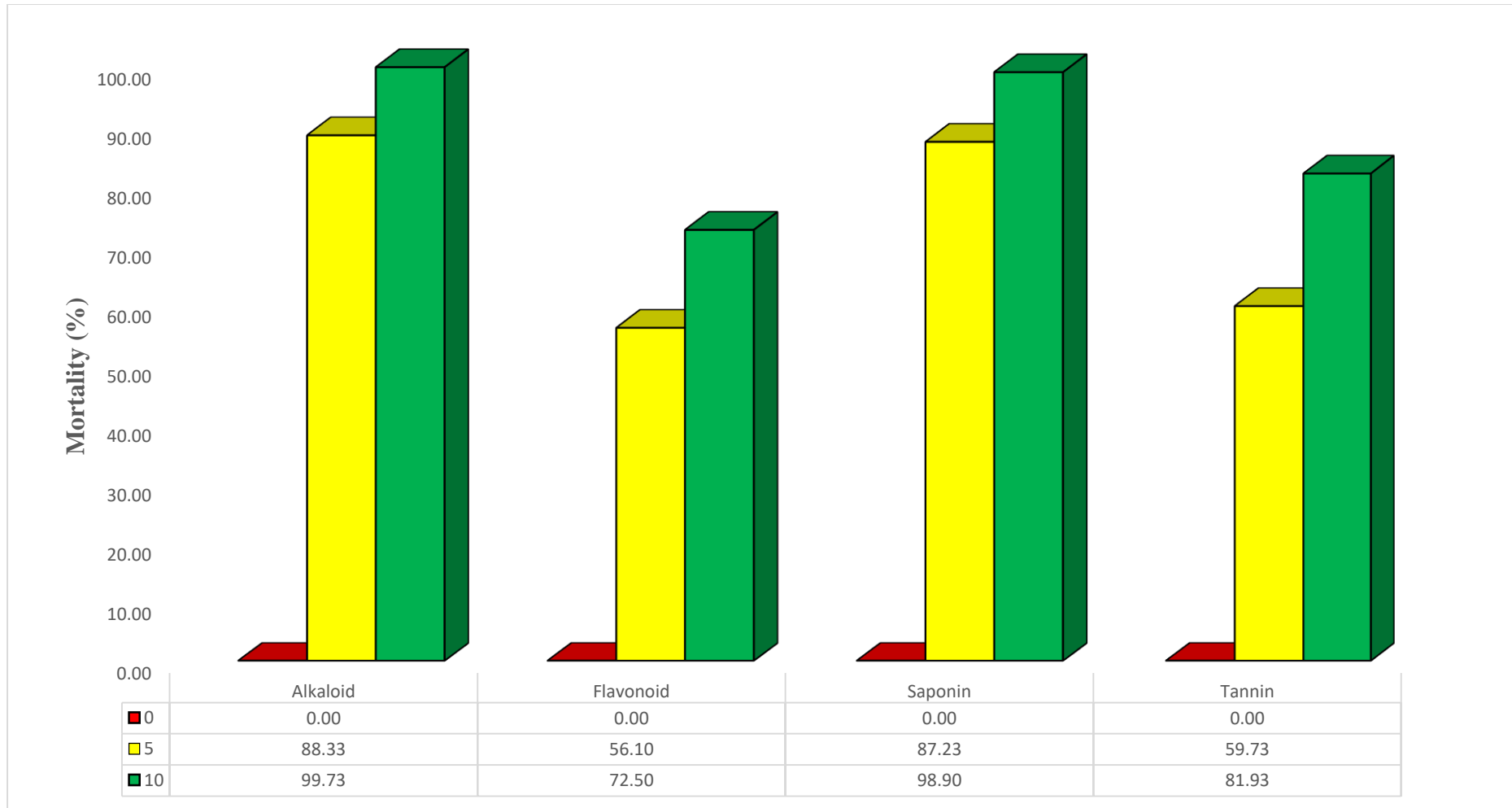


Figure 4.1: Relationship between Phytochemical Seed Extract and Juvenile Mortality of root-knot nematode *Meloidogyne incognita*

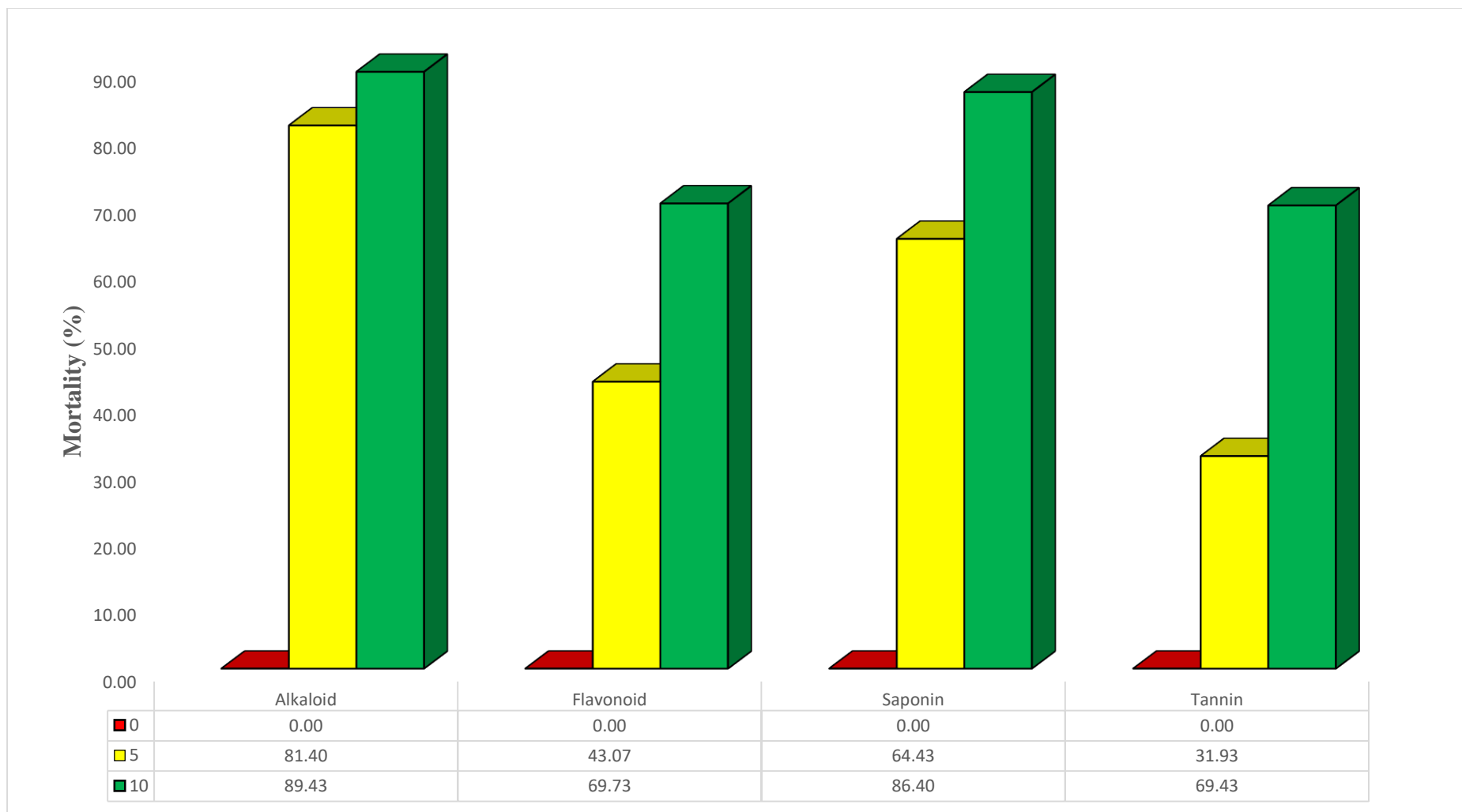


Figure 4.2: Relationship between Phytochemical Leaf Extract and Juvenile Mortality of root-knot nematode *Meloidogyne incognita*

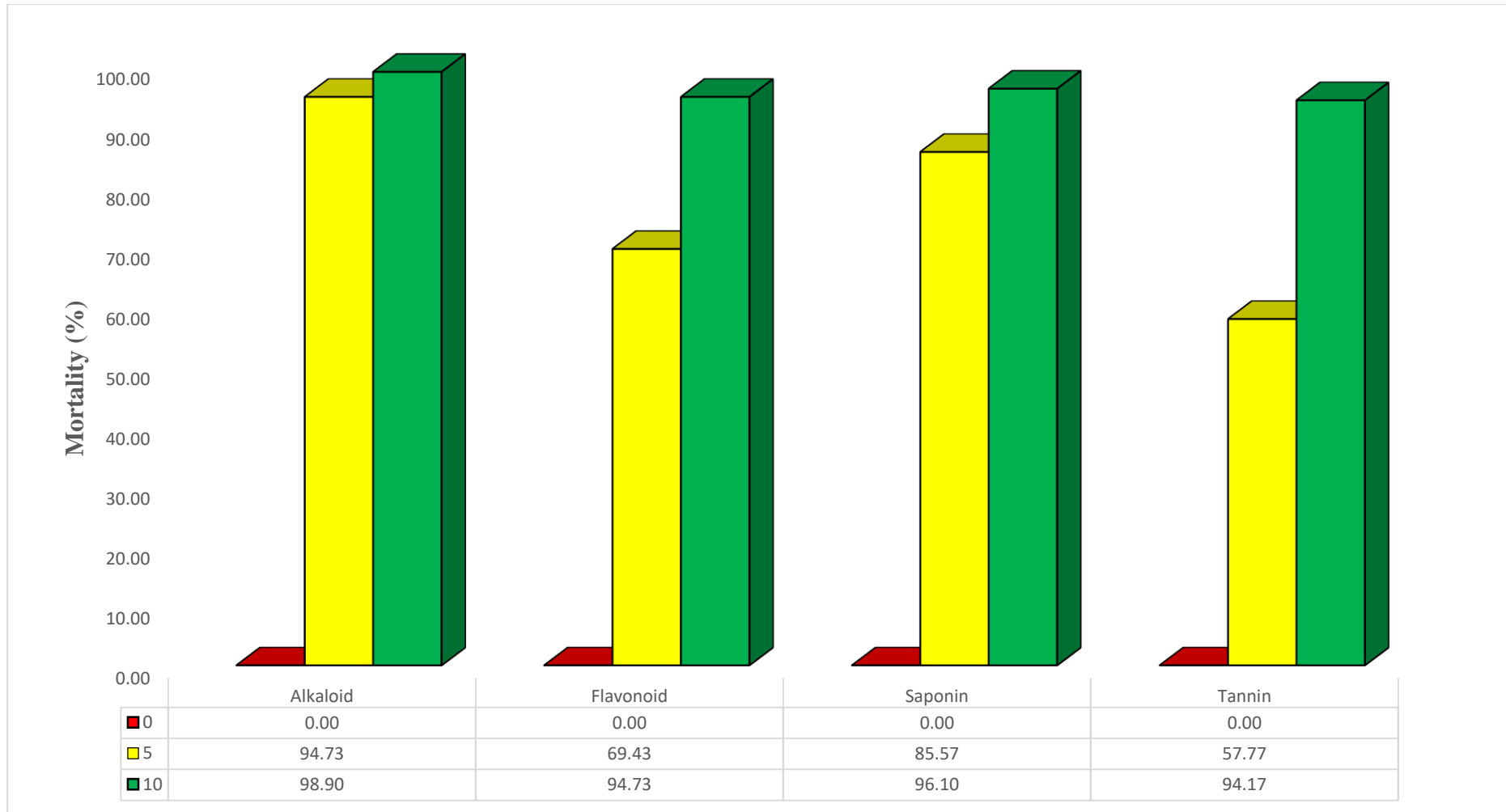


Figure 4.3: Relationship between Phytochemical Root Extract and Juvenile Mortality of root-knot nematode *Meloidogyne incognita*

Table 4.7:Effect of *Jatropha curcas* Seed Extracts and Hours of Exposure on mortality of *Meloidogyne incognita* juveniles

| (Phytochemicals) | Hours of Exposure (hr) | | | | Mean |
|--|-------------------------------|-----------|-----------|-----------|-------------|
| | 12 | 24 | 48 | 72 | |
| Alkaloids | 16.44 | 18.78 | 20.00 | 20.00 | 18.81 |
| Flavonoids | 7.00 | 11.67 | 15.00 | 17.78 | 12.86 |
| Saponins | 16.44 | 18.78 | 19.22 | 20.00 | 18.61 |
| Tannins | 9.11 | 12.67 | 16.22 | 18.67 | 14.17 |
| Mean | 12.25 | 15.47 | 17.61 | 19.11 | |
| LSD _{0.05} (Treatment Exposure) | | | 1.36 | | |
| LSD _{0.05} (Phytochemical) | | | 1.36 | | |
| LSD _{0.05} (Phytochemical X Treatment Exposure) | | | 2.73 | | |

4.3 Effect of phytochemicals and source of extraction on growth and yield parameters of okra

4.3.1 Alkaloids

Alkaloids from *J. curcas* seeds and roots demonstrated higher efficacy in controlling root-gall nematode infection and improving okra plant height than those from the leaves. This was so for both 2016 and 2017 (Table 4.8). Plant heights from leaf alkaloid were the least in both years. There was steady increase in plant heights as alkaloids application rate increased. Hence, highest plant height occurred at highest (5 mls) alkaloids application rate.

The effects of Alkaloids and *Jatropha* parts on Okra leaf area as influenced by root-gall nematode is recorded in Tables 4.9. Results showed that okra plants in pots treated with various rates of alkaloids had reduced root-galls and produced significantly ($p < 0.05$) higher leaf area than the severely galled untreated okra plants in both years (2016 and 2017). This was more so at 5 mls application rate which produced highest leaf area highest in both years. This contrasted with the least leaf area produced on severely galled okra plants grown on untreated pots.

The effects of Alkaloids from different *Jatropha* parts on Okra number of leaves and root-gall incidences are shown in Table 4.10. The treated plants had reduced root-galls and produced significantly ($p < 0.05$) higher number of leaves than the severely galled untreated plants in both years (2016 and 2017). Plants treated with 5 mls of Alkaloids produced least galling responses and highest number of leaves compared to other rates and the untreated plants. Also, okra plants treated with seed and root alkaloids produced lower root-galling responses and higher number of leaves than those treated with leaf alkaloids.

The effects of Alkaloids from different *Jatropha* parts on Okra fresh shoot weight and root-gall incidences are recorded in Table 4.11 The plants treated with various rates of alkaloid

had reduced root-galls and produced significantly ($p < 0.05$) higher shoot weights than the severely galled untreated plants in both years (2016 and 2017).

Okra plants treated with root and seed alkaloids produced significantly ($p < 0.05$) lower root galls and higher fresh shoot weights than leaf alkaloids in both years. This was more so on plants treated with root alkaloids which produced the highest shoot weight at 5 mls compared to plants treated with seed and leaf alkaloid. This contrasted the least shoot weights produced on severely galled plants grown on untreated pots.

Least fresh root weight and root-galls were obtained on pots treated with Alkaloids than on the untreated plants with higher fresh root weights and root-galls (Table 4.12). Mean fresh root weights of Okra decreased with decreases in root-galls at increased application rates of alkaloid treatment in both years (2016 and 2017). Least root weight and root galls irrespective of the *Jatropha* plant part occurred at 5 mls of alkaloids treatment application.

Table 4.8: Effect of Alkaloids and *Jatropha curcas* parts on Okra plant height as influenced by root-gall nematode

| Alkaloids (ml) | 2016 | | | | | | | | 2017 | | | | | | | |
|--|-------------------|-------|-------|-------|-----------------------|------|-----|------|-------------------|-------|-------|-------|-----------------------|------|------|------|
| | Plant height (cm) | | | | Root-gall Index (0-4) | | | | Plant height (cm) | | | | Root-gall index (0-4) | | | |
| | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | |
| | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean |
| Untreated (control) | 7.68 | 11.55 | 12.06 | 10.43 | 4 | 4 | 4 | 4 | 8.58 | 12.45 | 12.96 | 11.33 | 4 | 4 | 4 | 4 |
| 1 | 10.11 | 11.23 | 12.27 | 11.21 | 3.8 | 3.4 | 3.6 | 3.6 | 11.01 | 12.13 | 13.17 | 12.11 | 3.6 | 3.2 | 3.4 | 3.4 |
| 2 | 11.13 | 13.33 | 13.03 | 12.5 | 3.8 | 3 | 3.2 | 3.33 | 12.03 | 14.23 | 13.93 | 13.4 | 3.8 | 3 | S | 3.33 |
| 3 | 12.4 | 15.27 | 13.86 | 13.84 | 3 | 2 | 2.2 | 2.4 | 13.3 | 16.17 | 14.76 | 14.74 | 3 | 2 | 2 | 2.33 |
| 4 | 13 | 16.7 | 14.21 | 14.64 | 2.6 | 1.2 | 1.4 | 1.73 | 13.9 | 17.59 | 15.12 | 15.54 | 2.4 | 1.2 | 1.4 | 1.66 |
| 5 | 14.7 | 23.34 | 15.63 | 17.89 | 2.2 | 1 | 1.2 | 1.46 | 15.6 | 24.24 | 16.53 | 18.79 | 2 | 1 | 1.2 | 1.4 |
| Mean | 11.5 | 15.24 | 13.51 | | 3.23 | 2.43 | 2.6 | | 12.4 | 16.14 | 14.41 | | 3.13 | 2.4 | 2.53 | |
| LSD 0.05(Jatropha parts) | | 0.87 | | | | 0.28 | | | | 0.87 | | | | 0.31 | | |
| LSD 0.05 (Alkaloids) | | 1.23 | | | | 0.4 | | | | 1.23 | | | | 0.44 | | |
| LSD 0.05(Jatropha parts X Alkaloids mls) | | 2.14 | | | | ns | | | | 2.13 | | | | ns | | |

ns = not significant, L = leaf, R= root, S = seed

Table 4.9: Effect of Alkaloids and *Jatropha curcas* parts on Okra Leaf Area (cm²) as influenced by root-gall nematode

| Alkaloids (ml) | 2016 | | | | | | | | 2017 | | | | | | | |
|--|------------------------------|-------|-------|-------|-----------------------|------|-----|------|------------------------------|-------|-------|-------|-----------------------|------|------|------|
| | Leaf Area (cm ²) | | | | Root-gall Index (0-4) | | | | Leaf Area (cm ²) | | | | Root-gall index (0-4) | | | |
| | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | |
| | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean |
| Untreated (control) | 6.79 | 10.21 | 9.38 | 8.79 | 4 | 4 | 4 | 4 | 7.75 | 11.17 | 10.33 | 9.75 | 4 | 4 | 4 | 4 |
| 1 | 10.1 | 13.82 | 15.74 | 13.22 | 3.8 | 3.4 | 3.6 | 3.6 | 11.06 | 14.78 | 16.7 | 14.18 | 3.6 | 3.2 | 3.4 | 3.4 |
| 2 | 12.48 | 20.91 | 14.81 | 16.07 | 3.8 | 3 | 3.2 | 3.33 | 13.44 | 21.87 | 15.77 | 17.03 | 3.8 | 3 | 3.2 | 3.33 |
| 3 | 15.74 | 23.93 | 16.82 | 18.83 | 3 | 2 | 2.2 | 2.4 | 16.7 | 24.89 | 17.79 | 19.79 | 3 | 2 | 2 | 2.33 |
| 4 | 17.47 | 29.22 | 19.38 | 22.02 | 2.6 | 1.2 | 1.4 | 1.73 | 18.43 | 30.18 | 20.34 | 22.98 | 2.4 | 1.2 | 1.4 | 1.66 |
| 5 | 20.52 | 33.93 | 25.82 | 26.76 | 2.2 | 1 | 1.2 | 1.46 | 21.48 | 34.89 | 26.78 | 27.71 | 2 | 1 | 1.2 | 1.4 |
| Mean | 13.85 | 22 | 16.99 | | 3.23 | 2.43 | 2.6 | | 14.81 | 22.96 | 17.95 | | 3.13 | 2.4 | 2.53 | |
| LSD _{0.05} (Jatropha parts) | | 2.22 | | | | 0.28 | | | | 2.21 | | | | 0.31 | | |
| LSD _{0.05} (Alkaloids) | | 3.14 | | | | 0.4 | | | | 3.13 | | | | 0.44 | | |
| LSD _{0.05} (Jatropha parts X Alkaloids mls) | | ns | | | | ns | | | | ns | | | | ns | | |

ns = not significant, L = leaf, R= root, S = seed

Table 4.10: Effect of Alkaloids and *Jatropha curcas* parts on Okra Number of leaves as influenced by root-gall nematode

| Alkaloids (ml) | 2016 | | | | | | | | 2017 | | | | | | | |
|--|------------------|------|------|------|-----------------------|------|-----|------|------------------|------|------|------|-----------------------|-----|------|------|
| | Number of leaves | | | | Root-gall Index (0-4) | | | | Number of leaves | | | | Root-gall index (0-4) | | | |
| | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | |
| | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean |
| Untreated (control) | 3.2 | 3.57 | 3.45 | 3.41 | 4 | 4 | 4 | 4 | 3.8 | 3.82 | 3.9 | 3.84 | 4 | 4 | 4 | 4 |
| 1 | 3.55 | 3.72 | 3.97 | 3.75 | 3.8 | 3.4 | 3.6 | 3.6 | 4 | 4.12 | 4.27 | 4.13 | 3.6 | 3.2 | 3.4 | 3.4 |
| 2 | 3.88 | 3.88 | 4.05 | 3.94 | 3.8 | 3 | 3.2 | 3.33 | 4.18 | 4.33 | 4.61 | 4.37 | 3.8 | 3 | 3.2 | 3.33 |
| 3 | 3.89 | 3.88 | 4.62 | 4.13 | 3 | 2 | 2.2 | 2.4 | 4.39 | 4.43 | 4.96 | 4.6 | 3 | 2 | 2 | 2.33 |
| 4 | 4.12 | 4.66 | 4.58 | 4.45 | 2.6 | 1.2 | 1.4 | 1.73 | 4.67 | 4.96 | 4.88 | 4.83 | 2.4 | 1.2 | 1.4 | 1.66 |
| 5 | 5.2 | 5.14 | 5.01 | 5.12 | 2.2 | 1 | 1.2 | 1.46 | 5.65 | 5.84 | 5.61 | 5.7 | 2 | 1 | 1.2 | 1.4 |
| Mean | 3.97 | 4.14 | 4.28 | | 3.23 | 2.43 | 2.6 | | 4.45 | 4.58 | 4.7 | | 3.13 | 2.4 | 2.53 | |
| LSD _{0.05} (Jatropha parts) | Ns | | | | 0.28 | | | | ns | | | | 0.31 | | | |
| LSD _{0.05} (Alkaloids) | 0.37 | | | | 0.4 | | | | 0.49 | | | | 0.44 | | | |
| LSD _{0.05} (Alkaloids mls X Jatropha parts) | ns | | | | ns | | | | ns | | | | ns | | | |

ns = not significant, L = leaf, R= root, S = seed

Table 4.11: Effect of Alkaloid and Jatropha parts on Okra Shoot weight (g) as influenced by root-gall nematode

| Alkaloid (ml) | 2016 | | | | | | | | 2017 | | | | | | | |
|----------------------------------|------------------|------|------|------|-----------------------|------|-----|------|------------------|------|------|------|-----------------------|------|------|------|
| | Shoot weight (g) | | | | Root-gall Index (0-4) | | | | Shoot weight (g) | | | | Root-gall index (0-4) | | | |
| | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | |
| | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean |
| Untreated (control) | 1.27 | 1.27 | 2.21 | 1.59 | 4 | 4 | 4 | 4 | 1.99 | 1.99 | 2.93 | 2.31 | 4 | 4 | 4 | 4 |
| 1 | 1.28 | 2 | 2.57 | 1.95 | 3.8 | 3.4 | 3.6 | 3.6 | 2 | 2.72 | 3.29 | 2.67 | 3.6 | 3.2 | 3.4 | 3.4 |
| 2 | 1.49 | 2.08 | 2.74 | 2.1 | 3.8 | 3 | 3.2 | 3.33 | 2.21 | 2.8 | 3.46 | 2.82 | 3.8 | 3 | 3.2 | 3.33 |
| 3 | 2.29 | 3.2 | 3.2 | 2.89 | 3 | 2 | 2.2 | 2.4 | 3.01 | 3.92 | 3.92 | 3.61 | 3 | 2 | 2 | 2.33 |
| 4 | 2.6 | 3.47 | 3.39 | 3.15 | 2.6 | 1.2 | 1.4 | 1.73 | 3.32 | 4.19 | 4.11 | 3.87 | 2.4 | 1.2 | 1.4 | 1.66 |
| 5 | 2.8 | 6.38 | 3.72 | 4.3 | 2.2 | 1 | 1.2 | 1.46 | 3.52 | 7.1 | 4.44 | 5.02 | 2 | 1 | 1.2 | 1.4 |
| Mean | 1.96 | 3.07 | 2.97 | | 3.23 | 2.43 | 2.6 | | 2.68 | 3.79 | 3.69 | | 3.13 | 2.4 | 2.53 | |
| LSD 0.05(J.part) | | 0.55 | | | | 0.28 | | | | 0.65 | | | | 0.31 | | |
| LSD 0.05 (Alkaloids) | | 0.77 | | | | 0.4 | | | | 0.92 | | | | 0.44 | | |
| LSD 0.05(J.part X Alkaloids mls) | | 1.34 | | | | ns | | | | ns | | | | ns | | |

ns = not significant, L = leaf, R= root, S = seed

Table 4.12: Effect of Alkaloid and Jatropha parts on Okra Root weight as influenced by root-gall nematode

| Alkaloid (ml) | 2016 | | | | | | | | 2017 | | | | | | | |
|---------------------------------|-----------------|------|------|------|-----------------------|------|-----|------|-----------------|------|------|------|-----------------------|------|------|------|
| | Root weight (g) | | | | Root-gall Index (0-4) | | | | Root weight (g) | | | | Root-gall index (0-4) | | | |
| | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | |
| | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean |
| Untreated (control) | 2.22 | 2.8 | 2.8 | 2.6 | 4 | 4 | 4 | 4 | 2.46 | 3.04 | 3.04 | 2.84 | 4 | 4 | 4 | 4 |
| 1 | 1.2 | 0.6 | 0.72 | 0.84 | 3.8 | 3.4 | 3.6 | 3.6 | 1.44 | 0.84 | 0.96 | 1.08 | 3.6 | 3.2 | 3.4 | 3.4 |
| 2 | 0.61 | 0.4 | 0.6 | 0.54 | 3.8 | 3 | 3.2 | 3.33 | 0.85 | 0.64 | 0.84 | 0.78 | 3.8 | 3 | 3.2 | 3.33 |
| 3 | 0.59 | 0.4 | 0.5 | 0.5 | 3 | 2 | 2.2 | 2.4 | 0.83 | 0.64 | 0.74 | 0.74 | 3 | 2 | 2 | 2.33 |
| 4 | 0.5 | 0.29 | 0.31 | 0.37 | 2.6 | 1.2 | 1.4 | 1.73 | 0.74 | 0.53 | 0.55 | 0.61 | 2.4 | 1.2 | 1.4 | 1.66 |
| 5 | 0.2 | 0.29 | 0.31 | 0.27 | 2.2 | 1 | 1.2 | 1.46 | 0.44 | 0.53 | 0.55 | 0.51 | 2 | 1 | 1.2 | 1.4 |
| Mean | 0.89 | 0.79 | 0.87 | | 3.23 | 2.43 | 2.6 | | 1.13 | 1.03 | 1.11 | | 3.13 | 2.4 | 2.53 | |
| LSD 0.05(J.part) | | ns | | | | 0.28 | | | | ns | | | | 0.31 | | |
| LSD 0.05 (Alkaloid) | | 0.22 | | | | 0.4 | | | | 0.29 | | | | 0.44 | | |
| LSD 0.05(J.part X Alkaloid mls) | | 0.38 | | | | ns | | | | ns | | | | ns | | |

ns = not significant, L = leaf, R= root, S=seed

seed

Table 4.13 shows the effects of alkaloids from different *Jatropha* parts on Okra number of days to flowering and root gall incidences. Number of days to flowering was significantly ($p < 0.05$) lower with reduced galls on plants grown on treated plants than those of untreated plants. Mean number of days to flowering decreased with decreased root-galls at increased alkaloids treatment application in both years (2016 and 2017). However, in both years, lowest number of days to flowering obtained at 5 mls of alkaloids treatment application significantly differed from other rates and the untreated pots. Okra plants treated with root alkaloids flowered significantly much earlier than those treated with seed and leaf alkaloids.

Effects of Alkaloids from different *Jatropha* parts on Okra days to 50 % flowering and root-gall incidence shown in Table 4.14 followed the same trend as “days to flowering” earlier presented. Number of days to 50% flowering was significantly ($p < 0.05$) lower with reduced galls on plants grown on treated plants than those of untreated plants. Mean number of days to 50% flowering also decrease with increased alkaloids treatment application in both years (2016 and 2017). *Jatropha* root alkaloid however topped the list in lowering the number of days to 50 % flowering than the seed and leaf alkaloids. Earliest number of days to 50% flowering was obtained in the Interactions of *Jatropha* parts and Root Alkaloids at 5 mls which significantly ($p < 0.05$) reduced days to 50% flowering in both years (2016 and 2017). This was followed by plants treated with seed and leaf alkaloids at 5 mls of Alkaloids treatment application.

Effects of Alkaloids from different *Jatropha* parts on Okra pod weight and root-gall incidence are shown in Table 4.15. Plants treated with alkaloids had reduced root-galls and produced significantly ($p < 0.05$) higher pods weights than the severely galled untreated plants in both years (2016 and 2017). Mean pod weights of Okra increased with decreased root-galls at increased application rates of Alkaloids treatments. However, Okra plants treated with root and seed alkaloids produced significantly ($p < 0.05$) lower root-galls and higher fresh pod

weights than those of leaf alkaloids in both years. Fresh pod weights of okra produced by plants treated with root and seed alkaloids are statistically the same.

Table 4.13: Effect of Alkaloids and Jatropha parts on Okra days to flowering as influenced by root-gall nematode

| Alkaloids (ml) | 2016 | | | | | | | | 2017 | | | | | | | |
|--|------------------------|------|------|-------|-----------------------|------|-----|------|------------------------|------|-------|-------|-----------------------|------|------|------|
| | days to Okra flowering | | | | Root-gall Index (0-4) | | | | days to Okra flowering | | | | Root-gall index (0-4) | | | |
| | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | |
| | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean |
| Untreated (control) | 54 | 54.6 | 54 | 54.2 | 4 | 4 | 4 | 4 | 54.6 | 55.2 | 54.4 | 54.73 | 4 | 4 | 4 | 4 |
| 1 | 50 | 49 | 52 | 50.47 | 3.8 | 3.4 | 3.6 | 3.6 | 50.6 | 50 | 52.6 | 51.07 | 3.6 | 3.2 | 3.4 | 3.4 |
| 2 | 50.8 | 46 | 50.8 | 49.2 | 3.8 | 3 | 3.2 | 3.33 | 51.4 | 46.6 | 51.4 | 49.8 | 3.8 | 3 | 3.2 | 3.33 |
| 3 | 50 | 44 | 47.8 | 47.27 | 3 | 2 | 2.2 | 2.4 | 50.6 | 44.6 | 48.4 | 47.87 | 3 | 2 | 2 | 2.33 |
| 4 | 47 | 43 | 47 | 45.67 | 2.6 | 1.2 | 1.4 | 1.73 | 47.6 | 43.6 | 47.6 | 46.27 | 2.4 | 1.2 | 1.4 | 1.66 |
| 5 | 45.8 | 42 | 43 | 43.6 | 2.2 | 1 | 1.2 | 1.46 | 46.4 | 42.6 | 43.6 | 44.2 | 2 | 1 | 1.2 | 1.4 |
| Mean | 49.6 | 46.5 | 49.1 | | 3.23 | 2.43 | 2.6 | | 50.2 | 47.1 | 49.67 | | 3.13 | 2.4 | 2.53 | |
| LSD _{0.05} (Jatropha parts) | | 1.4 | | | | 0.28 | | | | 1.36 | | | | 0.31 | | |
| LSD _{0.05} (Alkaloid) | | 1.98 | | | | 0.4 | | | | 1.93 | | | | 0.44 | | |
| LSD _{0.05} (Jatropha parts X Alkaloids mls) | | ns | | | | ns | | | | ns | | | | ns | | |

ns = not significant, L = leaf, R= root, S = seed

Table 4.14: Effect of Alkaloid and Jatropha parts on Okra days to 50% flowering as influenced by root-gall nematode

| Alkaloid(ml) | 2016 | | | | | | | | 2017 | | | | | | | |
|-----------------------------------|-----------------------|-------|------|-------|-----------------------|------|-----|------|-----------------------|-------|------|-------|-----------------------|------|------|------|
| | Days to 50% flowering | | | | Root-gall Index (0-4) | | | | Days to 50% flowering | | | | Root-gall index (0-4) | | | |
| | Jatropha Parts | | | Mean | Jatropha Parts | | | Mean | Jatropha Parts | | | Mean | Jatropha Parts | | | Mean |
| | L | R | S | | L | R | S | | L | R | S | | L | R | S | |
| Untreated (control) | 56.1 | 54.1 | 54.1 | 54.76 | 4 | 4 | 4 | 4 | 56.7 | 54.7 | 54.7 | 55.36 | 4 | 4 | 4 | 4 |
| 1 | 52.1 | 49.1 | 52.1 | 51.1 | 3.8 | 3.4 | 3.6 | 3.6 | 52.7 | 49.7 | 52.7 | 51.7 | 3.6 | 3.2 | 3.4 | 3.4 |
| 2 | 51.1 | 46.1 | 51.1 | 49.43 | 3.8 | 3 | 3.2 | 3.33 | 51.7 | 46.7 | 51.7 | 50.03 | 3.8 | 3 | 3.2 | 3.33 |
| 3 | 50.1 | 44.1 | 48.1 | 47.43 | 3 | 2 | 2.2 | 2.4 | 50.7 | 44.7 | 48.7 | 48.03 | 3 | 2 | 2 | 2.33 |
| 4 | 47.1 | 43.1 | 46.1 | 45.43 | 2.6 | 1.2 | 1.4 | 1.73 | 47.7 | 43.7 | 46.7 | 46.03 | 2.4 | 1.2 | 1.4 | 1.66 |
| 5 | 45.9 | 42.1 | 43.1 | 43.7 | 2.2 | 1 | 1.2 | 1.46 | 46.5 | 42.7 | 43.7 | 44.3 | 2 | 1 | 1.2 | 1.4 |
| Mean | 54.4 | 46.43 | 49.1 | | 3.23 | 2.43 | 2.6 | | 51 | 47.03 | 49.7 | | 3.13 | 2.4 | 2.53 | |
| LSD 0.05(J.part) | | 0.29 | | | | 0.28 | | | | 0.43 | | | | 0.31 | | |
| LSD 0.05 (Alkaloids) | | 0.41 | | | | 0.4 | | | | 0.61 | | | | 0.44 | | |
| LSD 0.05(J.part X Alkaloids mls) | | 0.72 | | | | ns | | | | 1.06 | | | | ns | | |

ns = not significant, L = leaf, R= root, S = seed

Table 4.15: Effect of Alkaloid and Jatropha parts on Okra pod weight as influenced by root-gall nematode

| Alkaloid (ml) | 2016 | | | | | | | | 2017 | | | | | | | |
|----------------------------------|----------------|------|------|------|-----------------------|------|-----|------|----------------|------|------|------|-----------------------|------|------|------|
| | Pod weight (g) | | | | Root-gall Index (0-4) | | | | Pod weight (g) | | | | Root-gall index (0-4) | | | |
| | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | |
| | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean |
| Untreated (control) | 0.92 | 1.11 | 1.22 | 1.08 | 4 | 4 | 4 | 4 | 1.16 | 1.34 | 1.46 | 1.32 | 4 | 4 | 4 | 4 |
| 1 | 1.18 | 1.52 | 1.82 | 1.5 | 3.8 | 3.4 | 3.6 | 3.6 | 1.42 | 1.76 | 2.06 | 1.74 | 3.6 | 3.2 | 3.4 | 3.4 |
| 2 | 1.07 | 1.62 | 2.82 | 1.83 | 3.8 | 3 | 3.2 | 3.33 | 1.31 | 1.86 | 3.06 | 2.07 | 3.8 | 3 | 3.2 | 3.33 |
| 3 | 2.02 | 3.28 | 3.1 | 2.8 | 3 | 2 | 2.2 | 2.4 | 2.26 | 3.52 | 3.34 | 3.04 | 3 | 2 | 2 | 2.33 |
| 4 | 2.06 | 3.65 | 3.51 | 3.07 | 2.6 | 1.2 | 1.4 | 1.73 | 2.3 | 3.89 | 3.75 | 3.31 | 2.4 | 1.2 | 1.4 | 1.66 |
| 5 | 2.68 | 4.02 | 4.02 | 3.57 | 2.2 | 1 | 1.2 | 1.46 | 2.92 | 4.26 | 4.26 | 3.81 | 2 | 1 | 1.2 | 1.4 |
| Mean | 1.65 | 2.53 | 2.74 | | 3.23 | 2.43 | 2.6 | | 1.89+ | 2.77 | 2.98 | | 3.13 | 2.4 | 2.53 | |
| LSD 0.05(J.part) | | 0.05 | | | | 0.28 | | | | 0.13 | | | | 0.31 | | |
| LSD 0.05 (Alkaloids) | | 0.08 | | | | 0.4 | | | | 0.19 | | | | 0.44 | | |
| LSD 0.05(J.part X Alkaloids mls) | | 0.14 | | | | ns | | | | 0.33 | | | | ns | | |

* = Significant, ns = not significant, L = leaf, R= root, S=seed

Effect of Alkaloids from different *Jatropha* parts on Okra dry seed weight and root-gall incidence are recorded in Table 4.16. Plants treated with Alkaloids had reduced root-galls and produced significantly ($p < 0.05$) higher 100 dry seed weight than the severely galled untreated plants in both years (2016 and 2017). Mean 100 dry seed weights of Okra increased with decreased root-gall at increased application of alkaloid treatments. Okra plants treated with root alkaloids recorded significantly ($p < 0.05$) higher 100 dry seed weights than those from plants treated seed and leaf alkaloids in both years (2016 and 2017). Root Alkaloids at 5 mls produced highest 100 dry seed weights compared to other rates and the untreated (control). This was followed by plants treated with Seed Alkaloids. Plants treated with leaf alkaloids had the least 100 dry seed weights in both years.

The effect of Alkaloids from different *Jatropha* parts on Okra Mucilaginity and root-gall incidence are shown in Table 4.17. Plants treated with alkaloids had reduced root-galls and produced okra with significantly ($p < 0.05$) higher mucilaginous property than the severely galled untreated plants in both years (2016 and 2017). Mucilaginous property significantly ($p < 0.05$) increased with decreased root galls at increased rates of alkaloids treatment. Mucilaginous property of plants treated with root alkaloids was significantly ($p < 0.05$) higher than those treated with seed and leaf alkaloids in both years (2016 and 2017). Root Alkaloids at 5 mls produced pods with higher mucilaginous property compared to other rates and the untreated (control). This was followed by plants treated with 5 mls of Seed Alkaloids. Plants treated with leaf alkaloids had the least mucilaginous property in the pods.

Table 4.16: Effect of Alkaloids and Jatropha parts on Okra 100 dry seed weight (g) as influenced by root-gall nematode

| Alkaloids (ml) | 2016 | | | | | | | | 2017 | | | | | | | |
|--|-------------------------|------|------|------|-----------------------|------|-----|------|-------------------------|------|------|------|-----------------------|------|------|------|
| | 100 dry seed weight (g) | | | | Root-gall Index (0-4) | | | | 100 dry seed weight (g) | | | | Root-gall index (0-4) | | | |
| | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | |
| | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean |
| Untreated (control) | 1.8 | 2.1 | 1.1 | 1.66 | 4 | 4 | 4 | 4 | 2.04 | 2.34 | 1.34 | 1.9 | 4 | 4 | 4 | 4 |
| 1 | 2.2 | 2.5 | 2.7 | 2.46 | 3.8 | 3.4 | 3.6 | 3.6 | 2.44 | 2.74 | 2.94 | 2.7 | 3.6 | 3.2 | 3.4 | 3.4 |
| 2 | 2.05 | 2.62 | 3.7 | 2.79 | 3.8 | 3 | 3.2 | 3.33 | 2.29 | 2.86 | 3.94 | 3.03 | 3.8 | 3 | 3.2 | 3.33 |
| 3 | 3 | 4.26 | 4 | 3.75 | 3 | 2 | 2.2 | 2.4 | 3.24 | 4.5 | 4.24 | 3.99 | 3 | 2 | 2 | 2.33 |
| 4 | 3.03 | 4.63 | 4.48 | 4.04 | 2.6 | 1.2 | 1.4 | 1.73 | 3.27 | 4.87 | 4.72 | 4.28 | 2.4 | 1.2 | 1.4 | 1.66 |
| 5 | 3.5 | 6.2 | 5 | 4.9 | 2.2 | 1 | 1.2 | 1.46 | 3.74 | 6.44 | 5.24 | 5.14 | 2 | 1 | 1.2 | 1.4 |
| Mean | 2.59 | 3.71 | 3.49 | | 3.23 | 2.43 | 2.6 | | 2.83 | 3.95 | 3.73 | | 3.13 | 2.4 | 2.53 | |
| LSD _{0.05} (Jatropha parts) | | 0.07 | | | | 0.28 | | | | 0.13 | | | | 0.31 | | |
| LSD _{0.05} (Alkaloids mls) | | 0.1 | | | | 0.4 | | | | 0.19 | | | | 0.44 | | |
| LSD _{0.05} (Jatropha parts X Alkaloids mls) | | 0.18 | | | | ns | | | | 0.33 | | | | ns | | |

ns = not significant, L = leaf, R = root, S = seed

Table 4.17: Effect of Alkaloids and Jatropha parts on Okra Mucilaginous as influenced by root-gall nematode

| Alkaloids (ml) | 2016 | | | | | | | | 2017 | | | | | | | |
|--|-------------------------------|--------|--------|--------|-----------------------|------|-----|------|-------------------------------|-------|------|------|-----------------------|------|------|------|
| | Mucilaginous property (mpa*s) | | | | Root-gall Index (0-4) | | | | Mucilaginous property (mpa*s) | | | | Root-gall index (0-4) | | | |
| | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | |
| | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean |
| Untreated (control) | 1021 | 1000 | 1010 | 1010.3 | 4 | 4 | 4 | 4 | 1024 | 1003 | 1013 | 1013 | 4 | 4 | 4 | 4 |
| 1 | 1099 | 1111 | 1101 | 1103.7 | 3.8 | 3.4 | 3.6 | 3.6 | 1102 | 1114 | 1104 | 1106 | 3.6 | 3.2 | 3.4 | 3.4 |
| 2 | 1120 | 1201 | 1190 | 1170.3 | 3.8 | 3 | 3.2 | 3.33 | 1123 | 1204 | 1193 | 1173 | 3.8 | 3 | 3.2 | 3.33 |
| 3 | 1231 | 1389 | 1301 | 1307 | 3 | 2 | 2.2 | 2.4 | 1234 | 1392 | 1304 | 1310 | 3 | 2 | 2 | 2.33 |
| 4 | 1306 | 1701 | 1664 | 1557 | 2.6 | 1.2 | 1.4 | 1.73 | 1309 | 1704 | 1667 | 1560 | 2.4 | 1.2 | 1.4 | 1.66 |
| 5 | 1601 | 2180 | 2101 | 1960.7 | 2.2 | 1 | 1.2 | 1.46 | 1604 | 2183 | 2104 | 1963 | 2 | 1 | 1.2 | 1.4 |
| Mean | 1229.7 | 1430.3 | 1394.5 | | 3.23 | 2.43 | 2.6 | | 1232 | 1433 | 1397 | | 3.13 | 2.4 | 2.53 | |
| LSD _{0.05} (Jatropha parts) | | 6.64 | | | | 0.28 | | | | 6.64 | | | | 0.31 | | |
| LSD _{0.05} (Alkaloids) | | 9.4 | | | | 0.4 | | | | 9.4 | | | | 0.44 | | |
| LSD _{0.05} (Jatropha parts X Alkaloids mls) | | 16.28 | | | | ns | | | | 16.28 | | | | ns | | |

ns = not significant, L = leaf, R= root, S=seed

The effects of Alkaloids from different *Jatropha* parts on percentage nutrient composition of Okra and root-gall incidence are recorded in Tables 4.18-4.20. The results showed that neither root-gall disease nor *Jatropha* parts from which alkaloids was taken affected Magnesium (Mg), Ash and Potassium (K) contents of Okra fruits (Table 4.18).

Table 4.18 showed that Phosphorus (P) and Nitrogen (N) contents were significant ($P < 0.05$) enhanced by root-gall nematode infection at no alkaloids when compared with the treated plants. This was more so with plants on pots treated with 5mls of leaf alkaloids whose phosphorus (P) and Potassium (K) contents were significantly ($p < 0.05$) enhanced than seed and root alkaloids treated plants.

Fat, Sodium (Na), Calcium (Ca) and Moisture were significantly reduced by root-gall nematode infection in the untreated control plants (Tables 4.19-4.20). Plants treated with root alkaloid produced okra pods with significantly ($P < 0.05$) higher percentage of Fat, Sodium (Na), Calcium (Ca) and Moisture contents. This was followed by seed alkaloid which significantly ($P < 0.05$) differed from leaf alkaloids.

Table 4.18: Effect of Alkaloid and Jatropha parts on percentage nutrient composition of Magnesium, Ash and Potassium as influenced by root-gall nematode

| 2017 | | | | | | | | | | | | | | | | |
|----------------------------------|----------------|--------|--------|--------|----------------|-------|-------|-------|----------------|--------|--------|---------|-----------------------|------|------|------|
| Alkaloid (ml) | % Magnesium | | | | % Ash | | | | % Potassium | | | | Root-gall index (0-4) | | | |
| | Jatropha Parts | | | Mean | Jatropha Parts | | | Mean | Jatropha Parts | | | Mean | Jatropha Parts | | | Mean |
| | L | R | S | | L | R | S | | L | R | S | | L | R | S | |
| Untreated (control) | 0.105 | 0.1042 | 0.1058 | 0.1046 | 3.265 | 3.243 | 3.24 | 3.25 | 0.1142 | 0.1144 | 0.1136 | 0.11407 | 4 | 4 | 4 | 4 |
| 1 | 0.1048 | 0.1042 | 0.1046 | 0.1042 | 3.302 | 3.324 | 3.369 | 3.331 | 0.1142 | 0.1148 | 0.1138 | 0.11427 | 3.6 | 3.2 | 3.4 | 3.4 |
| 2 | 0.1042 | 0.1032 | 0.1044 | 0.1041 | 3.374 | 3.441 | 3.441 | 3.419 | 0.1142 | 0.1148 | 0.1142 | 0.1144 | 3.8 | 3 | 3.2 | 3.33 |
| 3 | 0.1032 | 0.1038 | 0.1044 | 0.1036 | 3.411 | 3.565 | 3.57 | 3.515 | 0.1146 | 0.115 | 0.1138 | 0.11447 | 3 | 2 | 2 | 2.33 |
| 4 | 0.1042 | 0.1036 | 0.1022 | 0.1032 | 3.488 | 3.614 | 3.618 | 3.573 | 0.1148 | 0.1154 | 0.1144 | 0.11487 | 2.4 | 1.2 | 1.4 | 1.66 |
| 5 | 0.1042 | 0.1034 | 0.1032 | 0.1036 | 3.584 | 3.92 | 3.859 | 3.788 | 0.1152 | 0.1154 | 0.1146 | 0.11507 | 2 | 1 | 1.2 | 1.4 |
| Mean | 0.104 | 0.1032 | 0.1048 | | 3.404 | 3.518 | 3.516 | | 0.115 | 0.115 | 0.1141 | | 3.13 | 2.4 | 2.53 | |
| LSD 0.05(J.part) | | ns | | | | ns | | | | ns | | | | 0.31 | | |
| LSD 0.05 (Alkaloids) | | ns | | | | ns | | | | ns | | | | 0.44 | | |
| LSD 0.05(J.Part X Alkaloids mls) | | ns | | | | ns | | | | ns | | | | 0.76 | | |

ns = not significant, L = leaf, R = root, S = seed

Table 4.19: Effect of Alkaloid and Jatropha parts on percentage nutrient composition of Nitrogen, Phosphorus and Fat as influenced by root-gall nematode

| 2017 | | | | | | | | | | | | | | | | |
|----------------------------------|----------------|--------|--------|--------|----------------|--------|--------|--------|----------------|--------|--------|--------|-----------------------|------|------|------|
| Alkaloid (ml) | % Nitrogen | | | | % Phosphorus | | | | % Fat | | | | Root-gall index (0-4) | | | |
| | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | |
| | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean |
| Untreated (control) | 2.45 | 2.44 | 2.45 | 2.4467 | 0.0058 | 0.0036 | 0.0059 | 0.0051 | 0.0681 | 0.0778 | 0.078 | 0.0746 | 4 | 4 | 4 | 4 |
| 1 | 1.96 | 1.71 | 1.88 | 1.85 | 0.0049 | 0.0037 | 0.0049 | 0.0045 | 0.8002 | 0.1 | 0.089 | 0.3297 | 3.6 | 3.2 | 3.4 | 3.4 |
| 2 | 1.88 | 1.61 | 1.7 | 1.73 | 0.0004 | 0.0038 | 0.0004 | 0.0039 | 0.09 | 0.106 | 0.1 | 0.0986 | 3.8 | 3 | 3.2 | 3.33 |
| 3 | 1.69 | 1.5 | 1.66 | 1.617 | 0.0039 | 0.0039 | 0.0025 | 0.0034 | 0.1 | 0.13 | 0.14 | 0.1233 | 3 | 2 | 2 | 2.33 |
| 4 | 1.53 | 1.466 | 1.5 | 1.4987 | 0.0038 | 0.001 | 0.0038 | 0.003 | 0.15 | 0.1945 | 0.1845 | 0.1763 | 2.4 | 1.2 | 1.4 | 1.66 |
| 5 | 1.43 | 1.372 | 1.42 | 1.407 | 0.0037 | 0.0016 | 0.0036 | 0.003 | 0.196 | 0.2056 | 0.205 | 0.2022 | 2 | 1 | 1.2 | 1.4 |
| Mean | 1.8233 | 1.683 | 1.7683 | | 0.0044 | 0.0029 | 0.0039 | | 0.234 | 0.1356 | 0.1327 | | 3.13 | 2.4 | 2.53 | |
| LSD 0.05(J.part) | | 0.0185 | | | | 0.0001 | | | | 0.0001 | | | | 0.31 | | |
| LSD 0.05 (Alkaloids) | | 0.0262 | | | | 0.0001 | | | | 0.0001 | | | | 0.44 | | |
| LSD 0.05(J.part X Alkaloids mls) | | 0.0454 | | | | 0.0002 | | | | 0.0001 | | | | 0.76 | | |

ns = not significant, L = leaf, R= root, S = seed

Table 4.20: Effect of Alkaloid and Jatropha parts on percentage nutrient composition of Sodium, Calcium and Moisture as influenced by root-gall nematode

| 2017 | | | | | | | | | | | | | | | | |
|----------------------------------|----------------|--------|--------|--------|----------------|--------|--------|--------|----------------|--------|-------|--------|-----------------------|------|------|------|
| Alkaloid (ml) | % Sodium | | | | % Calcium | | | | % Moisture | | | | Root-gall index (0-4) | | | |
| | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | |
| | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean |
| Untreated (control) | 0.0375 | 0.0386 | 0.0376 | 0.0379 | 0.2026 | 0.205 | 0.204 | 0.2038 | 62.9 | 63.8 | 61.1 | 62.6 | 4 | 4 | 4 | 4 |
| 1 | 0.0377 | 0.04 | 0.0379 | 0.0385 | 0.3 | 0.303 | 0.3 | 0.301 | 63.9 | 65.2 | 64.2 | 64.433 | 3.6 | 3.2 | 3.4 | 3.4 |
| 2 | 0.038 | 0.0409 | 0.038 | 0.0389 | 0.389 | 0.399 | 0.39 | 0.3926 | 64.6 | 66.3 | 66.1 | 65.667 | 3.8 | 3 | 3.2 | 3.33 |
| 3 | 0.04 | 0.0432 | 0.04 | 0.041 | 0.42 | 0.42 | 0.401 | 0.4126 | 68.2 | 70.03 | 69.3 | 69.177 | 3 | 2 | 2 | 2.33 |
| 4 | 0.0444 | 0.046 | 0.044 | 0.0448 | 0.45 | 0.501 | 0.4956 | 0.4822 | 70.2 | 76.1 | 75.1 | 73.8 | 2.4 | 1.2 | 1.4 | 1.66 |
| 5 | 0.0488 | 0.0589 | 0.0489 | 0.0522 | 0.461 | 0.562 | 0.5606 | 0.5278 | 75.3 | 91.32 | 85.1 | 83.907 | 2 | 1 | 1.2 | 1.4 |
| Mean | 0.041 | 0.0446 | 0.041 | | 0.3704 | 0.3983 | 0.3918 | | 67.517 | 72.125 | 70.15 | | 3.13 | 2.4 | 2.53 | |
| LSD 0.05(J.part) | | 0.0016 | | | | 0.0003 | | | | 0.0532 | | | | 0.31 | | |
| LSD 0.05 (Alkaloids) | | 0.0023 | | | | 0.0004 | | | | 0.0752 | | | | 0.44 | | |
| LSD 0.05(J.part X Alkaloids mls) | | 0.004 | | | | 0.0008 | | | | 0.1302 | | | | 0.76 | | |

ns = not significant, L = leaf, R= root, S=seed

Correlation Analysis

Correlation analysis of the root gall index and other attributes of the okra plants as influenced by the Alkaloids extracts in the pot experiments in 2016 and 2017 are presented in Table 4.21. The results showed that the root gall index had significant negative correlation with Plant height, Leaf area, Number of leaves, Pod weight, Hundred seed weight and Mucilaginous property in both study years.

The Mucilaginous property correlated positively and significantly with Plant height, Leaf area, Number of leaves, Pod weight and Hundred seed weight in both years respectively.

Hundred seed weights correlated positively and significantly with Plant height, Leaf area, Number of leaves and Pod weights.

Pod weights correlated positively and significantly with Plant heights, Leaf area and Number of leaves in both years.

Table 4.21: Linear correlation matrix between root-gall index and six plant attributes as influenced by alkaloids treatment application for 2016/2017 pot experiments

| 2016 | PLHT | LFA | NOLVS | PODWT | HUNSEDWT | MUCIL | RGI |
|-------------|-------------|------------|--------------|--------------|-----------------|--------------|------------|
| PLHT | 1 | .752** | .574** | .738** | .784** | .768** | -.699** |
| LFA | | 1 | .556** | .743** | .788** | .775** | -.685** |
| NOLVS | | | 1 | .655** | .651** | .692** | -.636** |
| PODWT | | | | 1 | .946** | .880** | -.855** |
| HUNSEDWT | | | | | 1 | .902** | -.839** |
| MUCIL | | | | | | 1 | -.833** |
| RGI | | | | | | | 1 |
| 2017 | | | | | | | |
| PLHT | 1 | | | | | | |
| LFA | .751** | 1 | | | | | |
| NOLVS | .571** | .524** | 1 | | | | |
| PODWT | .745** | .737** | .671** | 1 | | | |
| HUNSEDWT | .791** | .786** | .662** | .947** | 1 | | |
| MUCIL | .768** | .775** | .647** | .861** | .891** | 1 | |
| RGI | -.663** | -.691** | -.540** | -.803** | -.800** | -.808** | 1 |

PLHT = Plant Height

LFA = Leaf Area

NOLVS = Number of Leaves

HUNSEDWT = 100 Seed Weight

MUCIL = Mucilaginous property -mpa*s

RGI = Root-Gall Index

4.3.2 Tannins

Table 4.22 shows the effect of Tannins and *Jatropha* parts on Okra plant heights as influenced by root-knot nematode. The plants on pots treated with various rates of Tannins extracts had reduced root galls and produced significantly ($p < 0.05$) higher plant heights than the severely galled untreated plants in both years (2016 and 2017). This was particularly with the interactions of *Jatropha* parts and Tannins where 5 mls of leaf Tannins produced highest plant heights in 2017 compared to 2016. This was followed by plants treated with 5 mls of Seed Tannins which significantly differed from Root Tannins in both years.

The effects of Tannins and *Jatropha* parts on Okra leaf area as influenced by root-gall nematode are recorded in Table 4.23. Results showed that both Tannins and *Jatropha* parts had significant ($p < 0.05$) effect on Okra leaf area in 2016 and 2017 cropping season. Although, interactions were not significant, highest leaf area was produced on plants treated with 5 mls Leaf Tannins which significantly differed from seed and root Tannins in both years.

Number of leaves also increased as the rate of Tannins treatment increased Table (4.24). Results showed that plants on pots treated with tannins extracts had reduced root galls and produced significantly ($p < 0.05$) higher number of leaves than the severely galled untreated plants in both years (2016 and 2017). Highest number of leaves were obtained in plants on pots treated with 5 mls of leaf Tannins which significantly ($p < 0.05$) differed from Seed and Root Tannins in 2016.

The effects of Tannins from different *Jatropha* parts on Okra shoot weight and root-gall incidence are recorded in Table 4.25. The plants treated with various rates of tannin had reduced root-galls and produced significantly ($p < 0.05$) higher shoot weight than the severely galled untreated plants in both years (2016 and 2017). However, okra plants treated with

Jatropha root and seed tannins produced significantly ($p < 0.05$) higher shoot weights than those treated with leaf tannin. Highest shoot weight was produced when root tannins was applied at 5 mls and this differed significantly ($p < 0.05$) from those of seed and leaf tannins treatment at the same time.

Least fresh root weight and root-galls were obtained on plants treated with tannins than on the untreated plants with higher fresh root weights and root-galls (Table 4.26). Mean root weights of okra decreased with decreased galling response at increased application of tannin treatment in both years (2016 and 2017).

Table 4.22: Effect of Tannins and *Jatropha curcas* parts on Okra plant height (cm) as influenced by root-gall nematode

| Tannins (ml) | 2016 | | | | | | | | 2017 | | | | | | | |
|--|-------------------|-------|-------|-------|-----------------------|------|------|------|-------------------|-------|-------|-------|-----------------------|------|-----|------|
| | Plant Height (cm) | | | | Root-gall Index (0-4) | | | | Plant height (cm) | | | | Root-gall index (0-4) | | | |
| | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | |
| | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean |
| Untreated (control) | 9.92 | 9.59 | 9.51 | 9.67 | 4 | 4 | 4 | 4 | 10.82 | 10.48 | 10.41 | 10.57 | 4 | 4 | 4 | 4 |
| 1 | 10.12 | 10.04 | 11.28 | 10.48 | 3.4 | 3.8 | 3.2 | 3.46 | 11.02 | 10.94 | 12.18 | 11.38 | 3 | 3.6 | 3 | 3.2 |
| 2 | 10.77 | 11.39 | 12.67 | 11.61 | 3 | 3.8 | 2.8 | 3.2 | 11.67 | 12.29 | 13.57 | 12.51 | 2.8 | 3.8 | 2.8 | 3.13 |
| 3 | 14.81 | 11.99 | 13.77 | 13.52 | 2 | 3 | 2 | 2.33 | 15.71 | 12.89 | 14.67 | 14.42 | 1.8 | 2.8 | 1.8 | 2.13 |
| 4 | 15.87 | 13.21 | 15.36 | 14.81 | 1 | 2.4 | 1.2 | 1.5 | 16.77 | 14.11 | 16.26 | 15.71 | 1 | 2 | 1.2 | 1.4 |
| 5 | 20.79 | 14.62 | 17.59 | 17.67 | 1 | 2 | 1 | 1.33 | 21.69 | 15.52 | 18.49 | 18.57 | 1 | 1.8 | 1 | 1.26 |
| Mean | 13.71 | 11.8 | 13.36 | | 2.4 | 3.16 | 2.36 | | 14.61 | 12.7 | 14.26 | | 2.26 | 3 | 2.3 | |
| LSD _{0.05} (Jatropha parts) | | 0.93 | | | | 0.29 | | | | 1.08 | | | | 0.33 | | |
| LSD _{0.05} (Tannins) | | 1.31 | | | | 0.42 | | | | 1.52 | | | | 0.46 | | |
| LSD _{0.05} (Jatropha.parts X Tannins mls) | | ns | | | | ns | | | | 2.64 | | | | ns | | |

ns = not significant, L = leaf, R= root, S = seed

Table 4.23: Effect of Tannins and *Jatropha curcas* parts on Okra Leaf (cm²) Area as influenced by root-gall nematode

| Tannins (ml) | 2016 | | | | | | | | 2017 | | | | | | | |
|--|------------------------------|-------|-------|-------|-----------------------|------|------|------|------------------------------|-------|-------|-------|-----------------------|------|-----|------|
| | Leaf Area (cm ²) | | | | Root-gall Index (0-4) | | | | Leaf Area (cm ²) | | | | Root-gall index (0-4) | | | |
| | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | |
| | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean |
| Untreated (control) | 10.46 | 9.79 | 11.17 | 10.47 | 4 | 4 | 4 | 4 | 11.42 | 10.75 | 12.13 | 11.43 | 4 | 4 | 4 | 4 |
| 1 | 11.09 | 11.46 | 12.93 | 11.83 | 3.4 | 3.8 | 3.2 | 3.46 | 12.05 | 12.42 | 13.89 | 12.79 | 3 | 3.6 | 3 | 3.2 |
| 2 | 12.38 | 12.74 | 14.06 | 13.06 | 3 | 3.8 | 2.8 | 3.2 | 13.34 | 13.7 | 15.02 | 14.02 | 2.8 | 3.8 | 2.8 | 3.13 |
| 3 | 21.45 | 15.29 | 15.54 | 17.43 | 2 | 3 | 2 | 2.33 | 22.41 | 16.81 | 16.5 | 18.57 | 1.8 | 2.8 | 1.8 | 2.13 |
| 4 | 25.15 | 18.03 | 18.88 | 20.69 | 1 | 2.4 | 1.2 | 1.5 | 26.11 | 18.99 | 19.84 | 21.65 | 1 | 2 | 1.2 | 1.4 |
| 5 | 34.04 | 24.12 | 27.48 | 28.55 | 1 | 2 | 1 | 1.33 | 35.03 | 25.08 | 28.44 | 29.51 | 1 | 1.8 | 1 | 1.26 |
| Mean | 19.1 | 15.24 | 16.68 | | 2.4 | 3.16 | 2.36 | | 20.06 | 16.29 | 17.64 | | 2.26 | 3 | 2.3 | |
| LSD _{0.05} (Jatropha Parts) | | 2.78 | | | | 0.29 | | | | 2.91 | | | | 0.33 | | |
| LSD _{0.05} (Tannins) | | 3.93 | | | | 0.42 | | | | 4.12 | | | | 0.46 | | |
| LSD _{0.05} (Jatropha Parts X Tannins mls) | | ns | | | | ns | | | | ns | | | | ns | | |

ns = not significant, L = leaf, R= root, S = seed

Table 4.24: Effect of Tannins and *Jatropha curcas* parts on Okra Number of leaves as influenced by root-gall nematode

| Tannins (ml) | 2016 | | | | | | | | 2017 | | | | | | | |
|---|------------------|------|------|------|-----------------------|------|------|------|------------------|------|------|------|-----------------------|------|-----|------|
| | Number of leaves | | | | Root-gall Index (0-4) | | | | Number of leaves | | | | Root-gall index (0-4) | | | |
| | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | |
| | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean |
| Untreated (control) | 3.09 | 3.2 | 3.24 | 3.18 | 4 | 4 | 4 | 4 | 4 | 4.11 | 4.14 | 4.08 | 4 | 4 | 4 | 4 |
| 1 | 3.51 | 3.43 | 3.84 | 3.59 | 3.4 | 3.8 | 3.2 | 3.46 | 4.41 | 4.33 | 4.74 | 4.49 | 3 | 3.6 | 3 | 3.2 |
| 2 | 3.81 | 3.68 | 3.89 | 3.79 | 3 | 3.8 | 2.8 | 3.2 | 4.71 | 4.58 | 4.79 | 4.69 | 2.8 | 3.8 | 2.8 | 3.13 |
| 3 | 4.3 | 3.94 | 4.05 | 4.1 | 2 | 3 | 2 | 2.33 | 5.2 | 4.84 | 4.95 | 5 | 1.8 | 2.8 | 1.8 | 2.13 |
| 4 | 4.99 | 4.36 | 4.19 | 4.51 | 1 | 2.4 | 1.2 | 1.5 | 5.89 | 5.26 | 5.09 | 5.41 | 1 | 2 | 1.2 | 1.4 |
| 5 | 5.81 | 4.85 | 4.18 | 4.95 | 1 | 2 | 1 | 1.33 | 6.71 | 5.75 | 5.08 | 5.85 | 1 | 1.8 | 1 | 1.26 |
| Mean | 4.25 | 3.91 | 3.9 | | 2.4 | 3.16 | 2.36 | | 5.15 | 4.81 | 4.8 | | 2.26 | 3 | 2.3 | |
| LSD _{0.05} (Jatropha Parts) | | 0.26 | | | | 0.29 | | | | ns | | | | 0.33 | | |
| LSD _{0.05} (Tannin) | | 0.38 | | | | 0.42 | | | | 0.66 | | | | 0.46 | | |
| LSD _{0.05} (Jatropha PartsXTannin mls) | | 0.65 | | | | ns | | | | ns | | | | ns | | |

ns = not significant, L = leaf, R= root, S = seed

Table 4.25: Effect of Tannins and Jatropha parts on Okra Shoot weight(g) as influenced by root-gall nematode

| Tannins (ml) | 2016 | | | | | | | | 2017 | | | | | | | |
|---|-----------------|------|------|------|-----------------------|------|------|------|-----------------|------|------|------|-----------------------|------|-----|------|
| | Shoot weight(g) | | | | Root-gall Index (0-4) | | | | Shoot weight(g) | | | | Root-gall index (0-4) | | | |
| | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | |
| | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean |
| Untreated (control) | 2.28 | 2.28 | 2.72 | 2.43 | 4 | 4 | 4 | 4 | 3 | 3 | 3.44 | 3.15 | 4 | 4 | 4 | 4 |
| 1 | 2.29 | 3.07 | 3.58 | 2.98 | 3.4 | 3.8 | 3.2 | 3.46 | 3.01 | 3.79 | 4.3 | 3.7 | 3 | 3.6 | 3 | 3.2 |
| 2 | 2.5 | 2.89 | 3.75 | 3.05 | 3 | 3.8 | 2.8 | 3.2 | 3.22 | 3.61 | 4.47 | 3.77 | 2.8 | 3.8 | 2.8 | 3.13 |
| 3 | 3.1 | 4.01 | 4.01 | 3.7 | 2 | 3 | 2 | 2.33 | 3.82 | 4.73 | 4.73 | 4.42 | 1.8 | 2.8 | 1.8 | 2.13 |
| 4 | 3.61 | 4.56 | 4.4 | 4.19 | 1 | 2.4 | 1.2 | 1.5 | 4.33 | 5.28 | 5.12 | 4.91 | 1 | 2 | 1.2 | 1.4 |
| 5 | 3.81 | 7.39 | 4.73 | 5.31 | 1 | 2 | 1 | 1.33 | 4.53 | 8.11 | 5.45 | 6.03 | 1 | 1.8 | 1 | 1.26 |
| Mean | 2.93 | 4.03 | 3.86 | | 2.4 | 3.16 | 2.36 | | 3.65 | 4.75 | 4.58 | | 2.26 | 3 | 2.3 | |
| LSD _{0.05} (Jatropha parts) | | 0.55 | | | | 0.29 | | | | 0.66 | | | | 0.33 | | |
| LSD _{0.05} (Tannins) | | 0.78 | | | | 0.42 | | | | 0.93 | | | | 0.46 | | |
| LSD _{0.05} (Jatropha partXTannins mls) | | 1.35 | | | | ns | | | | ns | | | | ns | | |

ns = not significant, L = leaf, R= root, S = seed

Table 4.26: Effect of Tannins and Jatropha parts on Okra Root weight (g) as influenced by root-gall nematode

| Tannins (ml) | 2016 | | | | | | | | 2017 | | | | | | | |
|---|----------------|------|------|------|-----------------------|------|------|------|----------------|------|------|------|-----------------------|-----|-----|------|
| | Root weight(g) | | | | Root-gall Index (0-4) | | | | Root weight(g) | | | | Root-gall index (0-4) | | | |
| | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | |
| | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean |
| Untreated (control) | 2.23 | 2.84 | 2.85 | 2.64 | 4 | 4 | 4 | 4 | 2.47 | 3.08 | 3.09 | 2.88 | 4 | 4 | 4 | 4 |
| 1 | 1.18 | 0.58 | 0.7 | 0.82 | 3.4 | 3.8 | 3.2 | 3.46 | 1.42 | 0.82 | 0.94 | 1.06 | 3 | 3.6 | 3 | 3.2 |
| 2 | 0.59 | 0.38 | 0.56 | 0.51 | 3 | 3.8 | 2.8 | 3.2 | 0.83 | 0.62 | 0.8 | 0.75 | 2.8 | 3.8 | 2.8 | 3.13 |
| 3 | 0.57 | 0.38 | 0.48 | 0.48 | 2 | 3 | 2 | 2.33 | 0.81 | 0.62 | 0.72 | 0.72 | 1.8 | 2.8 | 1.8 | 2.13 |
| 4 | 0.48 | 0.27 | 0.29 | 0.35 | 1 | 2.4 | 1.2 | 1.5 | 0.72 | 0.51 | 0.53 | 0.59 | 1 | 2 | 1.2 | 1.4 |
| 5 | 0.18 | 0.27 | 0.29 | 0.25 | 1 | 2 | 1 | 1.33 | 0.42 | 0.51 | 0.53 | 0.49 | 1 | 1.8 | 1 | 1.26 |
| Mean | 0.87 | 0.79 | 0.86 | | 2.4 | 3.16 | 2.36 | | 1.11 | 1.03 | 1.1 | | 2.26 | 3 | 2.3 | |
| LSD _{0.05} (Jatropha Parts) | ns | | | | 0.29 | | | | ns | | | | 0.33 | | | |
| LSD _{0.05} (Tannins) | 0.22 | | | | 0.42 | | | | 0.29 | | | | 0.46 | | | |
| LSD _{0.05} (Jatropha Parts XTannins mls) | 0.38 | | | | ns | | | | ns | | | | ns | | | |

ns = not significant, L = leaf, R= root, S=seed

Table 4.27 shows the effects of Tannins from different *Jatropha* parts on okra days to flowering and root-gall incidence. Number of days to flowering significantly ($p < 0.05$) lower with reduced galls on treated plants than those of untreated plants. Mean number of days to flowering decreased with decreases in galling responses at increased tannin treatment application in both years (2016 and 2017). Lowest number of days to flowering obtained at 5 mls of Tannins treatment application significantly differed from those of other rates and the untreated pots. Okra plants treated with *Jatropha* leaf and seed tannins significantly ($p < 0.05$) flowered earlier than the treated with *Jatropha* root tannins in both years.

Effect of Tannins from different *Jatropha* parts on Okra days to 50% flowering and root-gall incidence is shown in Table 4.28. Number of days to 50% flowering was significantly ($p < 0.05$) lower with reduced galls on Tannins plants treated than those of untreated plants. Mean number of days to 50% flowering also decreased with decreases in galling responses at increased tannins treatment application in both years (2016 and 2017). Plants treated with *Jatropha* leaf and seed tannins flowered earlier than those treated with *Jatropha* the root tannins in both years. Earliest flowering was obtained in plants treated with 5 mls leaf tannin in both years (2016 and 2017). This was followed by plants treated with 5mls of seed tannins.

Effects of Tannins from different *Jatropha* parts on Okra pod weight and root-gall incidence is shown in Table 4.29. Plants treated with tannins had reduced root-galls and produced significantly ($p < 0.05$) higher pod weights than the severely galled untreated plants in both years (2016 and 2017). Mean pod weights of Okra increased with decreased root-galls at increased application of tannins treatments. Okra plants treated with *Jatropha* leaf and seed tannins significantly ($p < 0.05$) produced higher pod weights than those treated with root tannins in both years.

Table 4.27: Effect of Tannins and Jatropha parts on Okra days to flowering as influenced by root-gall nematode

| Tannins (ml) | 2016 | | | | | | | | 2017 | | | | | | | |
|---|-------------------|-------|-------|-------|-----------------------|------|------|------|-------------------|-------|-------|-------|-----------------------|-----|-----|------|
| | Days to flowering | | | | Root-gall Index (0-4) | | | | Days to Flowering | | | | Root-gall index (0-4) | | | |
| | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | |
| | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean |
| Untreated (control) | 51 | 55 | 58 | 54.67 | 4 | 4 | 4 | 4 | 50.4 | 54.4 | 57.4 | 54.04 | 4 | 4 | 4 | 4 |
| 1 | 49.2 | 51 | 52 | 50.73 | 3.4 | 3.8 | 3.2 | 3.46 | 48.6 | 50.4 | 51.4 | 50.13 | 3 | 3.6 | 3 | 3.2 |
| 2 | 48.6 | 50.5 | 51 | 50.03 | 3 | 3.8 | 2.8 | 3.2 | 48 | 49.9 | 50.4 | 49.43 | 2.8 | 3.8 | 2.8 | 3.13 |
| 3 | 46.8 | 50 | 50 | 48.93 | 2 | 3 | 2 | 2.33 | 46.2 | 49.4 | 49.4 | 48.33 | 1.8 | 2.8 | 1.8 | 2.13 |
| 4 | 48 | 50 | 49.4 | 49.13 | 1 | 2.4 | 1.2 | 1.5 | 47.4 | 49.4 | 48.8 | 48.53 | 1 | 2 | 1.2 | 1.4 |
| 5 | 42 | 49.6 | 43 | 44.87 | 1 | 2 | 1 | 1.33 | 41.4 | 49 | 42.4 | 44.27 | 1 | 1.8 | 1 | 1.26 |
| Mean | 47.6 | 51.02 | 50.57 | | 2.4 | 3.16 | 2.36 | | 47 | 50.42 | 49.97 | | 2.26 | 3 | 2.3 | |
| LSD _{0.05} (Jatropha parts) | 1.68 | | | | 0.29 | | | | 1.68 | | | | 0.33 | | | |
| LSD _{0.05} (Tannins) | 2.38 | | | | 0.42 | | | | 2.38 | | | | 0.46 | | | |
| LSD _{0.05} (J. part X Tannins mls) | ns | | | | ns | | | | Ns | | | | ns | | | |

ns = not significant, L = leaf, R= root, S = seed

Table 4.28: Effect of Tannins and Jatropha parts on Okra days to 50% flowering as influenced by root-gall nematode

| Tannin (ml) | 2016 | | | | | | | | 2017 | | | | | | | |
|---|-----------------------|-------|-------|-------|-----------------------|------|------|------|-----------------------|-------|-------|-------|-----------------------|------|-----|------|
| | Days to 50% flowering | | | | Root-gall Index (0-4) | | | | Days to 50% Flowering | | | | Root-gall index (0-4) | | | |
| | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | |
| | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean |
| Untreated (control) | 51 | 55 | 58 | 54.66 | 4 | 4 | 4 | 4 | 50.4 | 54.4 | 57.4 | 54.06 | 4 | 4 | 4 | 4 |
| 1 | 51 | 51 | 52 | 51.33 | 3.4 | 3.8 | 3.2 | 3.46 | 50.4 | 50.4 | 51.4 | 50.73 | 3 | 3.6 | 3 | 3.2 |
| 2 | 49 | 50.5 | 51 | 50.17 | 3 | 3.8 | 2.8 | 3.2 | 48.4 | 49.9 | 50.4 | 49.56 | 2.8 | 3.8 | 2.8 | 3.13 |
| 3 | 48 | 50 | 50 | 49.33 | 2 | 3 | 2 | 2.33 | 47.4 | 49.4 | 49.4 | 48.73 | 1.8 | 2.8 | 1.8 | 2.13 |
| 4 | 48 | 50 | 49 | 49 | 1 | 2.4 | 1.2 | 1.5 | 47.4 | 49.4 | 48.4 | 48.4 | 1 | 2 | 1.2 | 1.4 |
| 5 | 42 | 49 | 42 | 44.33 | 1 | 2 | 1 | 1.33 | 41.4 | 48.4 | 41.4 | 43.7 | 1 | 1.8 | 1 | 1.26 |
| Mean | 48.16 | 50.91 | 50.33 | | 2.4 | 3.16 | 2.36 | | 47.56 | 50.31 | 49.73 | | 2.26 | 3 | 2.3 | |
| LSD _{0.05} (Jatrophaparts) | | 0.36 | | | | 0.29 | | | | 0.46 | | | | 0.33 | | |
| LSD _{0.05} (Tannins) | | 0.51 | | | | 0.42 | | | | 0.65 | | | | 0.46 | | |
| LSD _{0.05} (Jatropha.partXTannins mls) | | 0.89 | | | | ns | | | | 1.12 | | | | ns | | |

ns = not significant, L = leaf, R = root, S = seed

Table 4.29: Effect of Tannins and Jatropha parts on Okra Pod weight (g) as influenced by root-gall nematode

| Tannins (ml) | 2016 | | | | | | | | 2017 | | | | | | | |
|---|----------------|------|------|------|-----------------------|------|------|------|----------------|------|------|------|-----------------------|------|-----|------|
| | Pod weight (g) | | | | Root-gall Index (0-4) | | | | Pod weight (g) | | | | Root-gall index (0-4) | | | |
| | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | |
| | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean |
| Untreated (control) | 1.9 | 1.7 | 1.3 | 1.63 | 4 | 4 | 4 | 4 | 2.14 | 1.94 | 1.54 | 1.87 | 4 | 4 | 4 | 4 |
| 1 | 2.3 | 2 | 2.4 | 2.23 | 3.4 | 3.8 | 3.2 | 3.46 | 2.54 | 2.24 | 2.64 | 2.47 | 3 | 3.6 | 3 | 3.2 |
| 2 | 2.4 | 1.85 | 3.6 | 2.61 | 3 | 3.8 | 2.8 | 3.2 | 2.64 | 2.09 | 3.84 | 2.85 | 2.8 | 3.8 | 2.8 | 3.13 |
| 3 | 4.06 | 2.8 | 3.9 | 3.58 | 2 | 3 | 2 | 2.33 | 4.3 | 3.04 | 4.14 | 3.82 | 1.8 | 2.8 | 1.8 | 2.13 |
| 4 | 4.43 | 2.84 | 4.29 | 3.85 | 1 | 2.4 | 1.2 | 1.5 | 4.67 | 3.08 | 4.53 | 4.09 | 1 | 2 | 1.2 | 1.4 |
| 5 | 4.95 | 3.46 | 4.8 | 4.4 | 1 | 2 | 1 | 1.33 | 5.19 | 3.7 | 5.04 | 4.64 | 1 | 1.8 | 1 | 1.26 |
| Mean | 3.34 | 2.44 | 3.38 | | 2.4 | 3.16 | 2.36 | | 3.58 | 2.68 | 3.62 | | 2.26 | 3 | 2.3 | |
| LSD _{0.05} (Jatropha parts) | | 0.07 | | | | 0.29 | | | | 0.13 | | | | 0.33 | | |
| LSD _{0.05} (Tannins | | 0.1 | | | | 0.42 | | | | 0.18 | | | | 0.46 | | |
| LSD _{0.05} (Jatropha parts XTannins mls) | | 0.17 | | | | ns | | | | 0.32 | | | | ns | | |

ns = not significant, L = leaf, R= root, S=seed

The effects of Tannins from different *Jatropha* parts and root-gall incidence on Okra dry seed weight is recorded in Table 4.30. Plants on treated with tannins had reduced root-galls and produced significantly ($p<0.05$) higher 100 dry seed weights than the severely galled untreated plants in both years (2016 and 2017). Mean 100 dry seed weights of Okra increased with decreases in galling responses at increased application of tannins treatments.

Okra plants from pots treated with *Jatropha* root tannin significantly ($p<0.05$) recorded higher 100 dry seed weight than than those from seed and leaf tannin in both years (2016 and 2017). *Jatropha* root tannins at 5 mls significantly($p<0.05$) produced highest 100 dry seed weights compared to other rates. This was followed by plants treated with seed tannins. Plants treated with leaf tannins had the least 100 dry seed weights in both years.

The effect of Tannins from different *Jatropha* parts on Okra Mucilaginous property and root-gall incidence is shown in Table 4.31. Plants treated with tannins had reduced root-galls and produced okra with significantly ($p<0.05$) higher mucilaginous property than the severely galled untreated plants in both years (2016 and 2017). Mucilaginous property significantly ($p<0.05$) increased with increased rates of Tannin treatment applied.

Mucilaginous property of plants treated with root tannin was significantly ($p<0.05$) higher than those treated with seed and leaf tannin in both years. Root tannins at 5 mls significantly ($p<0.05$) produced plants with higher mucilaginous property compared to other rates. This was followed by plants treated with 5 mls of seed tannins. Plants treated with leaf tannin had the least mucilaginous property in both years.

Table 4.30: Effect of Tannins Jatropha parts on Okra 100 dry seed weight (g) as influenced by root-gall nematode

| Tannins (ml) | 2016 | | | | | | | | 2017 | | | | | | | |
|---|-------------------------|------|------|------|-----------------------|------|------|------|-------------------------|------|------|------|-----------------------|------|-----|------|
| | 100 dry seed weight (g) | | | | Root-gall Index (0-4) | | | | 100 dry seed weight (g) | | | | Root-gall index (0-4) | | | |
| | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | |
| | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean |
| Untreated (control) | 2.7 | 2.9 | 1.9 | 2.5 | 4 | 4 | 4 | 4 | 2.94 | 3.14 | 2.14 | 2.74 | 4 | 4 | 4 | 4 |
| 1 | 3 | 3.3 | 3.5 | 3.26 | 3.4 | 3.8 | 3.2 | 3.46 | 3.24 | 3.54 | 3.74 | 3.5 | 3 | 3.6 | 3 | 3.2 |
| 2 | 2.85 | 3.4 | 4.5 | 3.58 | 3 | 3.8 | 2.8 | 3.2 | 3.09 | 3.64 | 4.74 | 3.82 | 2.8 | 3.8 | 2.8 | 3.13 |
| 3 | 3.8 | 5.06 | 4.8 | 4.55 | 2 | 3 | 2 | 2.33 | 4.04 | 5.3 | 5.04 | 4.79 | 1.8 | 2.8 | 1.8 | 2.13 |
| 4 | 3.83 | 5.42 | 5.28 | 4.84 | 1 | 2.4 | 1.2 | 1.5 | 4.07 | 5.66 | 5.52 | 5.08 | 1 | 2 | 1.2 | 1.4 |
| 5 | 4.3 | 6.91 | 5.8 | 5.67 | 1 | 2 | 1 | 1.33 | 4.54 | 7.15 | 6.04 | 5.91 | 1 | 1.8 | 1 | 1.26 |
| Mean | 3.41 | 4.49 | 4.29 | | 2.4 | 3.16 | 2.36 | | 3.65 | 4.73 | 4.53 | | 2.26 | 3 | 2.3 | |
| LSD _{0.05} (Jatropha parts) | | 0.07 | | | | 0.29 | | | | 0.13 | | | | 0.33 | | |
| LSD _{0.05} (Tannins) | | 0.1 | | | | 0.42 | | | | 0.18 | | | | 0.46 | | |
| LSD _{0.05} (Jatropha parts XTannins mls) | | 0.17 | | | | ns | | | | 0.32 | | | | ns | | |

ns = not significant, L = leaf, R= root, S = seed

Table 4.31: Effect of Tannins and Jatropha parts on Okra mucilaginous property as influenced by root-gall nematode

| Tannins (ml) | 2016 | | | | | | | | 2017 | | | | | | | |
|---|-------------------------------|------|------|------|-----------------------|------|------|------|-------------------------------|---------|---------|---------|-----------------------|------|-----|------|
| | Mucilaginous property (mpa*s) | | | | Root-gall Index (0-4) | | | | Mucilaginous property (mpa*s) | | | | Root-gall index (0-4) | | | |
| | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | |
| | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean |
| Untreated(control) | 1025 | 1004 | 1011 | 1013 | 4 | 4 | 4 | 4 | 1025.6 | 1005 | 1012 | 1014 | 4 | 4 | 4 | 4 |
| 1 | 1103 | 1115 | 1104 | 1107 | 3.4 | 3.8 | 3.2 | 3.46 | 1104 | 1116 | 1105 | 1108 | 3 | 3.6 | 3 | 3.2 |
| 2 | 1124 | 1205 | 1194 | 1174 | 3 | 3.8 | 2.8 | 3.2 | 1124.6 | 1205.6 | 1195 | 1174.93 | 2.8 | 3.8 | 2.8 | 3.13 |
| 3 | 1235 | 1393 | 1105 | 1244 | 2 | 3 | 2 | 2.33 | 1235 | 1394 | 1106 | 1245 | 1.8 | 2.8 | 1.8 | 2.13 |
| 4 | 1310 | 1705 | 1669 | 1561 | 1 | 2.4 | 1.2 | 1.5 | 1311 | 1706 | 1669.6 | 1561.93 | 1 | 2 | 1.2 | 1.4 |
| 5 | 1605 | 2124 | 2105 | 1944 | 1 | 2 | 1 | 1.33 | 1606 | 2125 | 2106 | 1945 | 1 | 1.8 | 1 | 1.26 |
| Mean | 1233 | 1424 | 1364 | | 2.4 | 3.16 | 2.36 | | 1234.28 | 1424.93 | 1365.26 | | 2.26 | 3 | 2.3 | |
| LSD _{0.05} (Jatropha parts) | | 0.36 | | | | 0.29 | | | | 0.46 | | | | 0.33 | | |
| LSD _{0.05} (Tannins) | | 0.51 | | | | 0.42 | | | | 0.65 | | | | 0.46 | | |
| LSD _{0.05} (J.partsXTannins mls) | | 0.89 | | | | ns | | | | 1.12 | | | | ns | | |

ns = not significant, L = leaf, R= root, S = seed

Effects of Tannins from different *Jatropha* parts on percentage nutrient composition of Okra are shown in Tables 4.32-4.34. The results showed that neither root-gall disease nor *Jatropha* parts affected Magnesium (Mg). Although, root-gall disease did not have any effect on Potassium (K) contents of Okra fruits, plants treated with 5 mls of leaf tannins produced okra fruits with significantly ($P<0.05$) higher in Potassium content than seed and root tannins (Table4.32).

Phosphorus (P) and Nitrogen (N) contents were significantly ($P<0.05$) enhanced by root-gall nematode infection when compared with the treated control (Table 4.33). This was more so with plants treated with 5mls of Root tannins whose phosphorus (P) and Nitrogen (N) contents were significantly ($p<0.05$) enhanced than those treated with seed and leaf tannins respectively.

Fat, Sodium (Na), Calcium (Ca) and Moisture were significantly reduced by root-gall nematode infection in the untreated control plants (Tables 4.33-4.34). Plants treated with 5 mls of leaf tannins produced okra pods with significantly ($P<0.05$) higher percentage of Fat, Sodium (Na), Calcium (Ca) and Moisture contents. This was followed by seed and root tannins.

Table 4.32: Effect of Tannins and Jatropha parts on percentage nutrient composition of Magnesium, Ash and Potassium as influenced by root-gall nematode

| 2017 | | | | | | | | | | | | | | | | |
|--|----------------|------|------|-------|----------------|------|------|------|----------------|--------|--------|--------|-----------------------|------|-----|------|
| Tannins (ml) | % Magnesium | | | | % Ash | | | | % Potassium | | | | Root-gall index (0-4) | | | |
| | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | |
| | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean |
| Untreated (control) | 0.32 | 0.31 | 0.3 | 0.311 | 4.1 | 4.11 | 4.11 | 4.12 | 0.34 | 0.32 | 0.322 | 0.3273 | 4 | 4 | 4 | 4 |
| 1 | 0.33 | 0.31 | 0.32 | 0.32 | 4.1 | 4.11 | 4.11 | 4.12 | 0.34 | 0.322 | 0.318 | 0.3273 | 3.6 | 3.2 | 3.4 | 3.4 |
| 2 | 0.33 | 0.32 | 0.32 | 0.325 | 4.2 | 4.11 | 4.12 | 4.13 | 0.344 | 0.318 | 0.32 | 0.3273 | 3.8 | 3 | 3.2 | 3.33 |
| 3 | 0.34 | 0.32 | 0.33 | 0.329 | 4.2 | 4.12 | 4.12 | 4.13 | 0.346 | 0.32 | 0.322 | 0.3293 | 3 | 2 | 2 | 2.33 |
| 4 | 0.34 | 0.33 | 0.33 | 0.334 | 4.2 | 4.13 | 4.13 | 4.14 | 0.348 | 0.322 | 0.328 | 0.3327 | 2.4 | 1.2 | 1.4 | 1.66 |
| 5 | 0.34 | 0.33 | 0.34 | 0.337 | 4.2 | 4.13 | 4.14 | 4.14 | 0.35 | 0.328 | 0.33 | 0.336 | 2 | 1 | 1.2 | 1.4 |
| Mean | 0.33 | 0.32 | 0.32 | | 4.2 | 4.12 | 4.12 | | 0.345 | 0.3217 | 0.3233 | | 3.13 | 2.4 | 2.5 | |
| LSD _{0.05} (Jatropha parts) | | ns | | | | 0.02 | | | | 0.0087 | | | | 0.31 | | |
| LSD _{0.05} (Tannins) | | ns | | | | ns | | | | ns | | | | 0.44 | | |
| LSD _{0.05} (Jatropha parts X Tannins) | | ns | | | | ns | | | | ns | | | | 0.76 | | |

ns = not significant, L = leaf, R= root, S = seed

Table 4.33: Effect of Tannins and Jatropha parts on percentage nutrient composition of Nitrogen, Phosphorus and Fat as influenced by root-gall nematode

| 2017 | | | | | | | | | | | | | | | | |
|---|----------------|------|------|-------|----------------|------|------|-------|----------------|--------|--------|--------|-----------------------|------|-----|------|
| Tannins (ml) | % Nitrogen | | | | % Phosphorus | | | | % Fat | | | | Root-gall index (0-4) | | | |
| | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | |
| | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean |
| Untreated (control) | 2.46 | 2.47 | 2.44 | 2.457 | 0 | 0.01 | 0.01 | 0.006 | 0.078 | 0.0777 | 0.0776 | 0.0778 | 4 | 4 | 4 | 4 |
| 1 | 1.98 | 2 | 2.02 | 2.001 | 0 | 0.01 | 0.01 | 0.005 | 0.12 | 0.0777 | 0.0891 | 0.0956 | 3 | 3.6 | 3 | 3.2 |
| 2 | 1.53 | 1.97 | 1.83 | 1.774 | 0 | 0.01 | 0 | 0.004 | 0.123 | 0.081 | 0.11 | 0.1047 | 2.8 | 3.8 | 2.8 | 3.13 |
| 3 | 1.42 | 1.53 | 1.44 | 1.462 | 0 | 0 | 0 | 0.004 | 0.131 | 0.088 | 0.152 | 0.1237 | 1.8 | 2.8 | 1.8 | 2.13 |
| 4 | 1.35 | 1.51 | 1.42 | 1.427 | 0 | 0 | 0 | 0.003 | 0.21 | 0.097 | 0.2 | 0.169 | 1 | 2 | 1.2 | 1.4 |
| 5 | 1.33 | 1.47 | 1.37 | 1.389 | 0 | 0 | 0 | 0.003 | 0.213 | 0.15 | 0.201 | 0.188 | 1 | 1.8 | 1 | 1.26 |
| Mean | 1.68 | 1.82 | 1.75 | | 0 | 0 | 0 | | 0.1458 | 0.0952 | 0.1383 | | 2.26 | 3 | 2.3 | |
| LSD _{0.05} (Jatropha parts) | | 0.03 | | | | 0 | | | | 0.0001 | | | | 0.33 | | |
| LSD _{0.05} (Tannins) | | 0.04 | | | | 0 | | | | 0.0001 | | | | 0.46 | | |
| LSD _{0.05} (Jatropha parts XTannins mls) | | 0.06 | | | | 0 | | | | 0.0002 | | | | ns | | |

* = Significant, ns = not significant, L = leaf, R= root, S = seed

Table 4.34: Effect of Tannins and Jatropha parts on percentage nutrient composition of Sodium, Calcium and Moisture as influenced by root-gall nematode

| 2017 | | | | | | | | | | | | | | | | |
|--|----------------|--------|--------|--------|----------------|--------|-------|-------|----------------|--------|--------|--------|-----------------------|------|-----|------|
| Tannins (ml) | % Sodium | | | | % Calcium | | | | % Moisture | | | | Root-gall index (0-4) | | | |
| | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | |
| | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean |
| Untreated (control) | 0.0384 | 0.0377 | 0.0376 | 0.0379 | 0.204 | 0.202 | 0.202 | 0.203 | 64.5 | 63.3 | 62.5 | 63.433 | 4 | 4 | 4 | 4 |
| 1 | 0.0403 | 0.038 | 0.0381 | 0.0388 | 0.307 | 0.297 | 0.302 | 0.302 | 65.8 | 64.82 | 65.5 | 65.373 | 3 | 3.6 | 3 | 3.2 |
| 2 | 0.0413 | 0.0381 | 0.0382 | 0.0392 | 0.402 | 0.304 | 0.4 | 0.369 | 65.9 | 65.5 | 66.5 | 65.967 | 2.8 | 3.8 | 2.8 | 3.13 |
| 3 | 0.047 | 0.0382 | 0.0401 | 0.0418 | 0.431 | 0.356 | 0.406 | 0.397 | 70.54 | 69.5 | 70.5 | 70.18 | 1.8 | 2.8 | 1.8 | 2.13 |
| 4 | 0.0502 | 0.0397 | 0.0442 | 0.0447 | 0.504 | 0.46 | 0.497 | 0.487 | 76.7 | 72.5 | 76.5 | 75.233 | 1 | 2 | 1.2 | 1.4 |
| 5 | 0.0591 | 0.0432 | 0.05 | 0.0507 | 0.563 | 0.494 | 0.561 | 0.539 | 89.55 | 76.5 | 85.5 | 83.85 | 1 | 1.8 | 1 | 1.26 |
| Mean | 0.0461 | 0.0391 | 0.0419 | | 0.402 | 0.352 | 0.395 | | 72.165 | 68.687 | 71.167 | | 2.26 | 3 | 2.3 | |
| LSD _{0.05} (Jatropha parts) | | 0.0001 | | | | 0.0012 | | | | 0.3525 | | | | 0.33 | | |
| LSD _{0.05} (Tannins) | | 0.0001 | | | | 0.0017 | | | | 0.4986 | | | | 0.46 | | |
| LSD _{0.05} (JatrophapartXTannins mls) | | 0.0002 | | | | 0.0029 | | | | 0.8636 | | | | ns | | |

* = Significant, ns = not significant, L = leaf, R= root, S = seed

Correlation Analysis

Correlation analysis of the root gall index and other attributes of the okra plants as influenced by the Tannins extracts in the experiments in 2016 and 2017 are presented in Table 4.35. The results showed that the root gall index had negative and highly significant correlation with Plant height. The Mucilaginous property correlated positively and significantly with Plant height. The same was true for Hundredseedweight, Pod weights, leaf area and number of leaves.

Table 4.35: Linear correlation matrix between root-gall index and six plant attributes as influenced by tannins treatment application for 2016/2017 pot experiments

| | 2016 | PLHT | LFA | NOLVS | PODWT | HUNSEDWT | MUCIL | RGI |
|-------------|-------------|-------------|------------|--------------|--------------|-----------------|--------------|------------|
| PLHT | | 1 | .771** | .616** | .814** | .533** | .608** | -.738** |
| LFA | | | 1 | .553** | .710** | .490** | .597** | -.676** |
| NOLVS | | | | 1 | .664** | .479** | .510** | -.626** |
| PODWT | | | | | 1 | .653** | .615** | -.847** |
| HUNSEDWT | | | | | | 1 | .870** | -.583** |
| MUCIL | | | | | | | 1 | -.623** |
| RGI | | | | | | | | 1 |
| 2017 | | | | | | | | |
| PLHT | | 1 | | | | | | |
| LFA | | .785** | 1 | | | | | |
| NOLVS | | .639** | .584** | 1 | | | | |
| PODWT | | .820** | .728** | .616** | 1 | | | |
| HUNSEDWT | | .550** | .515** | .465** | .662** | 1 | | |
| MUCIL | | .586** | .588** | .397** | .606** | .860** | 1 | |
| RGI | | -.682** | -.638** | -.488** | -.808** | -.588** | -.616** | 1 |

PLHT = Plant Height

LFA = Leaf Area

NOLVS = Number of Leaves

HUNSEDWT = 100 Seed Weight

MUCIL = Mucilaginous property -mpa*s

RGI = Root-Gall Index

4.3.3 Saponins

The effects of Saponins from different *Jatropha* parts on Okra plant heights and root-gall incidence is shown in table 4.36. The plants treated with various rates of Saponin extracts had reduced root galls and produced significantly ($p < 0.05$) higher plant heights than the severely galled untreated plants in both years (2016 and 2017). Saponins extract at 5mls application gave the highest mean plant height of 14.54 cm and 15.44 cm in 2016 and 2017 respectively which differed significantly ($p > 0.05$) from those of other rates.

Plants treated with *Jatropha* leaf and seed saponins gave plant heights that differed significantly ($p < 0.05$) from that treated with *Jatropha* root saponin in both years. Plant heights increased, with increased rates of saponin treatment application. However, highest plant height produced at 5mls after planting was not statistically ($p < 0.05$) different from plant heights produced at 4 mls of saponins in both years.

The effects of Saponins from different *Jatropha* parts on Okra leaf area and root-gall incidence is recorded in Tables 4.37. Results showed that okra plants in treated with various rates of saponin had reduced root-galls and produced significantly ($p < 0.05$) higher leaf area than the severely galled untreated plant in both years.

This was more so on 5 mls application of saponins which produced highest mean leaf area in both years (2016 and 2017). This contrasted with the least leaf area produced on severely galled okra plants grown on untreated plants. Highest leaf area produced by plants treated with 5 and 4 mls of saponins significantly ($p < 0.05$) differed from the other rates and control in 2016 and 2017. Application of Saponins from *Jatropha* parts significantly ($p < 0.05$) affected leaf areas of plants. Leaf areas from plants treated with *Jatropha* leaf and seed saponins were significantly ($p < 0.05$) higher than leaf areas from plants treated with *Jatropha*

root saponin in both years (2016 and 2017). However, there was no significant ($p < 0.05$) difference in leaf areas between leaf and seed saponin treatments respectively.

The effects of Saponins from different and *Jatropha* parts on Okra Number of leaves and root-gall incidence is recorded in Tables 4.38. Saponins treated plants had reduced root-galls and produced significantly ($p < 0.05$) higher number of leaves than the severely galled untreated plants in both years.

This was more so on plants treated with 5 mls of saponins which produced the highest number of leaves in both years. This contrasted the least number of leaves produced on severely galled untreated plants. Plants treated with *Jatropha* leaf and seed saponins significantly ($p < 0.05$) produced higher number of leaves than those treated with *Jatropha* root saponins.

Table 4.36: Effect of Saponins and *Jatropha curcas* parts on Okra plant height as influenced by root-gall nematode

| Saponins (ml) | 2016 | | | | | | | | 2017 | | | | | | | |
|--|-------------------|-------|-------|-------|-----------------------|------|-----|------|-------------------|-------|-------|-------|-----------------------|------|------|------|
| | Plant height (cm) | | | | Root-gall Index (0-4) | | | | Plant height (cm) | | | | Root-gall index (0-4) | | | |
| | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | |
| | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean |
| Untreated (control) | 8.49 | 8.79 | 8.95 | 8.74 | 4 | 4 | 4 | 4 | 9.39 | 9.69 | 9.85 | 9.67 | 4 | 4 | 4 | 4 |
| 1 | 9.82 | 9.96 | 10.02 | 9.93 | 3.8 | 3.4 | 3.6 | 3.6 | 10.73 | 10.86 | 10.92 | 10.83 | 3.6 | 3.2 | 3.4 | 3.4 |
| 2 | 11.31 | 11.13 | 10.32 | 10.92 | 3.8 | 3 | 3.2 | 3.33 | 12.21 | 12.03 | 11.22 | 11.82 | 3.8 | 3 | 3.2 | 3.33 |
| 3 | 11.91 | 11.63 | 10.91 | 11.48 | 3 | 2 | 2.2 | 2.4 | 12.81 | 12.53 | 11.81 | 12.38 | 3 | 2 | 2 | 2.33 |
| 4 | 13.62 | 12.33 | 12.38 | 12.78 | 1.6 | 2.6 | 1.6 | 1.93 | 14.52 | 13.23 | 13.28 | 13.68 | 1.6 | 2.4 | 1.6 | 1.86 |
| 5 | 15.99 | 13.24 | 14.39 | 14.54 | 1.4 | 2.2 | 1.6 | 1.73 | 16.89 | 14.14 | 15.29 | 15.44 | 1.4 | 2 | 1.6 | 1.66 |
| Mean | 11.86 | 11.18 | 11.16 | | 2.93 | 2.86 | 2.7 | | 12.76 | 12.08 | 12.06 | | 2.9 | 2.76 | 2.63 | |
| LSD _{0.05} (Jatropha parts) | ns | | | | ns | | | | ns | | | | ns | | | |
| LSD _{0.05} (Saponins) | 1.26 | | | | 0.42 | | | | 1.41 | | | | 0.46 | | | |
| LSD _{0.05} (Jatropha part X Saponins mls) | ns | | | | 0.73 | | | | ns | | | | ns | | | |

ns = not significant, L = leaf, R= root, S = seed

Table 4.37: Effect of Saponins and *Jatropha curcas* parts on Okra Leaf area (cm²) as influenced by root-gall nematode

| Saponins (ml) | 2016 | | | | | | | | 2017 | | | | | | | |
|---|------------------------------|-------|-------|-------|-----------------------|------|-----|------|------------------------------|-------|-------|-------|-----------------------|------|------|------|
| | Leaf area (cm ²) | | | | Root-gall Index (0-4) | | | | Leaf area (cm ²) | | | | Root-gall index (0-4) | | | |
| | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | |
| | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean |
| Untreated (control) | 6.81 | 5.92 | 6.97 | 6.56 | 4 | 4 | 4 | 4 | 7.77 | 6.88 | 7.93 | 7.52 | 4 | 4 | 4 | 4 |
| 1 | 13 | 8.55 | 8.85 | 10.13 | 3.8 | 3.4 | 3.6 | 3.6 | 13.96 | 9.51 | 9.81 | 11.09 | 3.6 | 3.2 | 3.4 | 3.4 |
| 2 | 11.9 | 10.06 | 20.56 | 14.17 | 3.8 | 3 | 3.2 | 3.33 | 12.86 | 11.02 | 21.52 | 15.13 | 3.8 | 3 | 3.2 | 3.33 |
| 3 | 14.81 | 11.73 | 13.89 | 13.48 | 3 | 2 | 2.2 | 2.4 | 15.77 | 12.69 | 14.85 | 14.44 | 3 | 2 | 2 | 2.33 |
| 4 | 17.44 | 14.13 | 17.27 | 16.28 | 1.6 | 2.6 | 1.6 | 1.93 | 18.39 | 15.09 | 18.23 | 17.24 | 1.6 | 2.4 | 1.6 | 1.86 |
| 5 | 28.56 | 18.8 | 25.4 | 24.25 | 1.4 | 2.2 | 1.6 | 1.73 | 29.52 | 19.76 | 26.36 | 25.21 | 1.4 | 2 | 1.6 | 1.66 |
| Mean | 15.42 | 11.53 | 15.49 | | 2.93 | 2.86 | 2.7 | | 16.38 | 12.49 | 16.45 | | 2.9 | 2.76 | 2.63 | |
| LSD _{0.05} (Jatropha parts) | | 3.65 | | | | ns | | | | 3.61 | | | | ns | | |
| LSD _{0.05} (Saponins) | | 5.14 | | | | 0.42 | | | | 5.11 | | | | 0.46 | | |
| LSD _{0.05} (Jatropha parts X Saponins mls) | | ns | | | | 0.73 | | | | ns | | | | ns | | |

ns = not significant, L = leaf, R= root, S = seed

Table 4.38: Effect of Saponins and *Jatropha curcas* parts on Okra Number of leaves as influenced by root-gall nematode

| Saponins (ml) | 2016 | | | | | | | | 2017 | | | | | | | |
|---|------------------|------|------|------|-----------------------|------|-----|------|--------------------------|------|------|------|-----------------------|------|------|------|
| | Number of leaves | | | | Root-gall Index (0-4) | | | | Number of leaves @ 8 WAP | | | | Root-gall index (0-4) | | | |
| | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | |
| | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean |
| Untreated (control) | 2.77 | 2.52 | 3.12 | 2.81 | 4 | 4 | 4 | 4 | 3.67 | 3.43 | 4.03 | 3.71 | 4 | 4 | 4 | 4 |
| 1 | 3.06 | 2.82 | 3.25 | 3.04 | 3.8 | 3.4 | 3.6 | 3.6 | 3.96 | 3.72 | 4.15 | 3.94 | 3.6 | 3.2 | 3.4 | 3.4 |
| 2 | 3.75 | 3.35 | 3.6 | 3.57 | 3.8 | 3 | 3.2 | 3.33 | 4.65 | 4.25 | 4.5 | 4.47 | 3.8 | 3 | 3.2 | 3.33 |
| 3 | 3.95 | 3.75 | 3.9 | 3.86 | 3 | 2 | 2.2 | 2.4 | 4.85 | 4.63 | 4.8 | 4.76 | 3 | 2 | 2 | 2.33 |
| 4 | 4.42 | 4.02 | 4.14 | 4.19 | 1.6 | 2.6 | 1.6 | 1.93 | 5.32 | 4.92 | 5.04 | 5.09 | 1.6 | 2.4 | 1.6 | 1.86 |
| 5 | 4.85 | 4.58 | 4.65 | 4.69 | 1.4 | 2.2 | 1.6 | 1.73 | 5.75 | 5.48 | 5.55 | 5.59 | 1.4 | 2 | 1.6 | 1.66 |
| Mean | 3.8 | 3.5 | 3.78 | | 2.93 | 2.86 | 2.7 | | 4.7 | 4.4 | 4.68 | | 2.9 | 2.76 | 2.63 | |
| LSD _{0.05} (Jatropha parts) | ns | | | | ns | | | | ns | | | | ns | | | |
| LSD _{0.05} (Saponins) | 0.42 | | | | 0.42 | | | | 0.74 | | | | 0.46 | | | |
| LSD _{0.05} (Jatropha parts X Saponins mls) | ns | | | | 0.73 | | | | ns | | | | ns | | | |

ns = not significant, L = leaf, R= root, S = seed

The effects of Saponins from different *Jatropha* parts on Okra shoot weight and root-gall incidence is recorded in Table 4.39. The plants treated with various rates of saponin had reduced root-galls and produced significantly ($p < 0.05$) higher shoot weights than the severely galled untreated plants in both years (2016 and 2017). Saponins treatments applied at 5 mls significantly ($p < 0.05$) increased mean shoot weights which differed significantly from those treated with 2, 1 and 0 mls.

The effects of Saponin from different *Jatropha* parts on root weight and root-gall incidence is shown in Table 4.40. Least fresh root weight and root-galls were obtained on plants treated with Saponins than on the untreated plants. Mean root weights of saponins treated plants decreased with increased application of saponins treatment in both years (2016 and 2017). Least mean root weights and highest reduced galls were obtained at 5 mls of saponins treatment.

Table 4.41 shows the effects of saponins from different *Jatropha* parts on Okra days to flowering and root-gall incidence. Number of days to flowering was significantly ($p < 0.05$) lower with reduced galls on saponins treated plants than those of untreated plants. Mean number of days to flowering decreased with increased saponin treatment application in both years (2016 and 2017). However, in both years, lowest number of days to flowering obtained at 5 mls of saponins treatment application significantly differed from those of other rates and the untreated plants. Plants treated with *Jatropha* leaf and seed saponins significantly ($p < 0.05$) flowered earlier than those treated with *Jatropha* root saponins in both years.

Effects of Saponins from different *Jatropha* parts on Okra days to 50% flowering and root-gall incidence shown in Table 4.42 followed the same trend as “days to flowering” earlier stated. Number of days to 50 % flowering was significantly ($p < 0.05$) lower with reduced galls on plants treated pots saponins than those of untreated plants. Mean number of days to

50 % flowering also decreased with increased saponin treatment application in both years (2016 and 2017).

Plants treated with Jatropha leaf and seed saponins also flowered significantly ($p < 0.05$) earlier than those with Jatropha root saponin in both years. Earliest flowering was obtained in plants treated with 5 mls of leaf and seed saponin in both years (2016 and 2017).

Effects of Saponins from different Jatropha parts on Okra pod weight and root-gall incidence are shown in Table 4.43. Plants treated with saponins had reduced root-galls and produced significantly ($p < 0.05$) higher number of pod weights than the severely galled untreated plants in both years (2016 and 2017). Mean pod weights of Okra increased with increased application of saponin treatments. Okra plants treated with Jatropha leaf and seed saponins produced pod weights significantly ($p < 0.05$) higher than those treated with Jatropha root saponins in both years. This was more so on application of 5 mls of the saponins.

Table 4.39: Effect of Saponins and Jatropha parts on Okra days to flowering as influenced by root-gall nematode

| Saponins (ml) | 2016 | | | | | | | | 2017 | | | | | | | |
|---|-------------------|------|------|-------|-----------------------|------|-----|------|-------------------|------|------|-------|-----------------------|------|------|------|
| | Days to flowering | | | | Root-gall Index (0-4) | | | | Days to flowering | | | | Root-gall index (0-4) | | | |
| | Jatropha Parts | | | Mean | Jatropha Parts | | | Mean | Jatropha Parts | | | Mean | Jatropha Parts | | | Mean |
| | L | R | S | | L | R | S | | L | R | S | | L | R | S | |
| Untreated (control) | 56 | 62 | 60.3 | 59.44 | 4 | 4 | 4 | 4 | 55.4 | 61.4 | 59.7 | 58.84 | 4 | 4 | 4 | 4 |
| 1 | 50 | 54.5 | 56.5 | 53.67 | 3.8 | 3.4 | 3.6 | 3.6 | 49.4 | 53.9 | 55.9 | 53.07 | 3.6 | 3.2 | 3.4 | 3.4 |
| 2 | 50 | 53.3 | 50.5 | 51.27 | 3.8 | 3 | 3.2 | 3.33 | 49.4 | 52.7 | 49.9 | 50.67 | 3.8 | 3 | 3.2 | 3.33 |
| 3 | 48.5 | 52.5 | 50 | 50.33 | 3 | 2 | 2.2 | 2.4 | 47.9 | 51.9 | 49.4 | 49.73 | 3 | 2 | 2 | 2.33 |
| 4 | 48.2 | 49 | 49.3 | 48.84 | 1.6 | 2.6 | 1.6 | 1.93 | 47.6 | 48.4 | 48.7 | 48.24 | 1.6 | 2.4 | 1.6 | 1.86 |
| 5 | 44.5 | 48.2 | 48.2 | 46.97 | 1.4 | 2.2 | 1.6 | 1.73 | 43.9 | 47.6 | 47.6 | 46.37 | 1.4 | 2 | 1.6 | 1.66 |
| Mean | 49.5 | 53.3 | 52.5 | | 2.93 | 2.86 | 2.7 | | 48.9 | 52.7 | 51.9 | | 2.9 | 2.76 | 2.63 | |
| LSD _{0.05} (Jatropha parts) | | 2.51 | | | | ns | | | | | 2.6 | | | ns | | |
| LSD _{0.05} (Saponins) | | 3.55 | | | | 0.42 | | | | | 3.68 | | | 0.46 | | |
| LSD _{0.05} (Jatropha parts X Saponins) | | Ns | | | | 0.73 | | | | | Ns | | | ns | | |

ns = not significant, L = leaf, R= root, S = seed

Table 4.40: Effect of Saponins and Jatropha parts on Okra Shoot weight (g) as influenced by root-gall nematode

| Saponins (ml) | 2016 | | | | | | | | 2017 | | | | | | | |
|---|------------------|------|------|------|-----------------------|------|-----|------|------------------|------|------|------|-----------------------|------|------|------|
| | Shoot weight (g) | | | | Root-gall Index (0-4) | | | | Shoot weight (g) | | | | Root-gall index (0-4) | | | |
| | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | |
| | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean |
| Untreated (control) | 1.85 | 1.06 | 0.55 | 1.15 | 4 | 4 | 4 | 4 | 2.57 | 1.78 | 1.27 | 1.87 | 4 | 4 | 4 | 4 |
| 1 | 1.99 | 1.78 | 1.37 | 1.72 | 3.8 | 3.4 | 3.6 | 3.6 | 2.71 | 2.5 | 2.09 | 2.44 | 3.6 | 3.2 | 3.4 | 3.4 |
| 2 | 2.16 | 1.78 | 1.56 | 1.83 | 3.8 | 3 | 3.2 | 3.33 | 2.88 | 2.5 | 2.28 | 2.55 | 3.8 | 3 | 3.2 | 3.33 |
| 3 | 2.32 | 2.07 | 2.26 | 2.22 | 3 | 2 | 2.2 | 2.4 | 3.04 | 2.79 | 2.98 | 2.94 | 3 | 2 | 2 | 2.33 |
| 4 | 2.88 | 2.12 | 2.6 | 2.53 | 1.6 | 2.6 | 1.6 | 1.93 | 3.6 | 2.84 | 3.32 | 3.25 | 1.6 | 2.4 | 1.6 | 1.86 |
| 5 | 5.03 | 2.3 | 3.38 | 3.57 | 1.4 | 2.2 | 1.6 | 1.73 | 5.75 | 3.02 | 4.1 | 4.29 | 1.4 | 2 | 1.6 | 1.66 |
| Mean | 2.7 | 1.85 | 1.95 | | 2.93 | 2.86 | 2.7 | | 3.42 | 2.57 | 2.67 | | 2.9 | 2.76 | 2.63 | |
| LSD _{0.05} (Jatropha parts) | ns | | | | ns | | | | ns | | | | ns | | | |
| LSD _{0.05} (Saponins) | 1.28 | | | | 0.42 | | | | 1.42 | | | | 0.46 | | | |
| LSD _{0.05} (Jatropha parts X Saponins mls) | ns | | | | 0.73 | | | | ns | | | | ns | | | |

ns = not significant, L = leaf, R= root, S = seed

Table 4.41: Effect of Saponins and Jatropha parts on Okra Root weight as influenced by root-gall nematode

| Saponins (ml) | 2016 | | | | | | | | 2017 | | | | | | | |
|---|----------------|------|------|------|-----------------------|------|-----|------|----------------|------|------|------|-----------------------|------|------|------|
| | Pod weight (g) | | | | Root-gall Index (0-4) | | | | Pod weight (g) | | | | Root-gall index (0-4) | | | |
| | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | |
| | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean |
| Untreated (control) | 1.19 | 0.45 | 0.65 | 0.76 | 4 | 4 | 4 | 4 | 1.43 | 0.69 | 0.89 | 1 | 4 | 4 | 4 | 4 |
| 1 | 1.35 | 0.55 | 1.05 | 0.98 | 3.8 | 3.4 | 3.6 | 3.6 | 1.59 | 0.79 | 1.29 | 1.22 | 3.6 | 3.2 | 3.4 | 3.4 |
| 2 | 2.35 | 0.6 | 1.15 | 1.36 | 3.8 | 3 | 3.2 | 3.33 | 2.59 | 0.84 | 1.39 | 1.6 | 3.8 | 3 | 3.2 | 3.33 |
| 3 | 2.65 | 1.55 | 2.81 | 2.33 | 3 | 2 | 2.2 | 2.4 | 2.89 | 1.79 | 3.05 | 2.57 | 3 | 2 | 2 | 2.33 |
| 4 | 3.18 | 1.59 | 3.04 | 2.6 | 1.6 | 2.6 | 1.6 | 1.93 | 3.42 | 1.83 | 3.28 | 2.84 | 1.6 | 2.4 | 1.6 | 1.86 |
| 5 | 3.7 | 2.21 | 3.54 | 3.15 | 1.4 | 2.2 | 1.6 | 1.73 | 3.94 | 2.45 | 3.78 | 3.39 | 1.4 | 2 | 1.6 | 1.66 |
| Mean | 2.4 | 1.15 | 2.04 | | 2.93 | 2.86 | 2.7 | | 2.64 | 1.39 | 2.28 | | 2.9 | 2.76 | 2.63 | |
| LSD _{0.05} (Jatropha parts) | | 0.01 | | | | ns | | | | 0.11 | | | | Ns | | |
| LSD _{0.05} (Saponins) | | 0.02 | | | | 0.42 | | | | 0.16 | | | | 0.46 | | |
| LSD _{0.05} (Jatropha parts X Saponins mls) | | 0.04 | | | | 0.73 | | | | 0.27 | | | | Ns | | |

ns = not significant, L = leaf, R= root, S = seed

Table 4.42: Effect of Saponins and *Jatropha curcas* parts on Okra days to 50% flowering as influenced by root-gall nematode

| Saponins (ml) | 2016 | | | | | | | | 2017 | | | | | | | |
|---|-----------------------|------|------|-------|-----------------------|------|-----|------|-----------------------|------|------|-------|-----------------------|------|------|------|
| | Days to 50% flowering | | | | Root-gall Index (0-4) | | | | Days to 50% flowering | | | | Root-gall index (0-4) | | | |
| | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | |
| | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean |
| Untreated (control) | 56 | 62 | 60.4 | 59.46 | 4 | 4 | 4 | 4 | 55.4 | 61.4 | 59.8 | 58.86 | 4 | 4 | 4 | 4 |
| 1 | 50 | 54.5 | 56.5 | 53.66 | 3.8 | 3.4 | 3.6 | 3.6 | 49.4 | 53.9 | 55.9 | 53.06 | 3.6 | 3.2 | 3.4 | 3.4 |
| 2 | 50 | 53 | 50.5 | 51.16 | 3.8 | 3 | 3.2 | 3.33 | 49.4 | 52.4 | 49.9 | 50.56 | 3.8 | 3 | 3.2 | 3.33 |
| 3 | 48.5 | 52.5 | 50 | 50.33 | 3 | 2 | 2.2 | 2.4 | 47.9 | 51.9 | 49.4 | 49.73 | 3 | 2 | 2 | 2.33 |
| 4 | 47 | 49 | 49 | 48.33 | 1.6 | 2.6 | 1.6 | 1.93 | 46.4 | 48.4 | 48.4 | 47.73 | 1.6 | 2.4 | 1.6 | 1.86 |
| 5 | 44.5 | 47 | 47 | 46.16 | 1.4 | 2.2 | 1.6 | 1.73 | 43.9 | 46.4 | 46.4 | 45.56 | 1.4 | 2 | 1.6 | 1.66 |
| Mean | 49.3 | 53 | 52.2 | | 2.93 | 2.86 | 2.7 | | 48.7 | 52.4 | 51.6 | | 2.9 | 2.76 | 2.63 | |
| LSD _{0.05} (Jatropha parts) | | 0.35 | | | | ns | | | | 0.45 | | | | ns | | |
| LSD _{0.05} (Saponins) | | 0.5 | | | | 0.42 | | | | 0.63 | | | | 0.46 | | |
| LSD _{0.05} (Jatropha partsXSaponins mls) | | 0.88 | | | | 0.73 | | | | 1.1 | | | | ns | | |

ns = not significant, L = leaf, R= root, S = seed

Table 4.43: Effect of Saponins and Jatropha parts on Okra Pod weight (g) as influenced by root-gall nematode

| Saponins (ml) | 2016 | | | | | | | | 2017 | | | | | | | |
|---|----------------|------|------|------|-----------------------|------|-----|------|----------------|------|------|------|-----------------------|------|------|------|
| | Pod weight (g) | | | | Root-gall Index (0-4) | | | | Pod weight (g) | | | | Root-gall index (0-4) | | | |
| | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | |
| | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean |
| Untreated (control) | 1.19 | 0.45 | 0.65 | 0.76 | 4 | 4 | 4 | 4 | 1.43 | 0.69 | 0.89 | 1 | 4 | 4 | 4 | 4 |
| 1 | 1.35 | 0.55 | 1.05 | 0.98 | 3.8 | 3.4 | 3.6 | 3.6 | 1.59 | 0.79 | 1.29 | 1.22 | 3.6 | 3.2 | 3.4 | 3.4 |
| 2 | 2.35 | 0.6 | 1.15 | 1.36 | 3.8 | 3 | 3.2 | 3.33 | 2.59 | 0.84 | 1.39 | 1.6 | 3.8 | 3 | 3.2 | 3.33 |
| 3 | 2.65 | 1.55 | 2.81 | 2.33 | 3 | 2 | 2.2 | 2.4 | 2.89 | 1.79 | 3.05 | 2.57 | 3 | 2 | 2 | 2.33 |
| 4 | 3.18 | 1.59 | 3.04 | 2.6 | 1.6 | 2.6 | 1.6 | 1.93 | 3.42 | 1.83 | 3.28 | 2.84 | 1.6 | 2.4 | 1.6 | 1.86 |
| 5 | 3.7 | 2.21 | 3.54 | 3.15 | 1.4 | 2.2 | 1.6 | 1.73 | 3.94 | 2.45 | 3.78 | 3.39 | 1.4 | 2 | 1.6 | 1.66 |
| Mean | 2.4 | 1.15 | 2.04 | | 2.93 | 2.86 | 2.7 | | 2.64 | 1.39 | 2.28 | | 2.9 | 2.76 | 2.63 | |
| LSD _{0.05} (Jatropha parts) | | 0.01 | | | | ns | | | | 0.11 | | | | ns | | |
| LSD _{0.05} (Saponins) | | 0.02 | | | | 0.42 | | | | 0.16 | | | | 0.46 | | |
| LSD _{0.05} (Jatropha parts X Saponins mls) | | 0.04 | | | | 0.73 | | | | 0.27 | | | | ns | | |

ns = not significant, L = leaf, R= root, S = seed

Table 4.44 shows the effect of Saponins from different *Jatropha* parts on Okra dry seed weight and root-gall incidence. Plants treated with Saponins had reduced root-galls and produced significantly ($p < 0.05$) higher 100 dry seed weight than the severely galled untreated pots in both years (2016 and 2017). Mean 100 dry seed weights of Okra also increased with increased application of Saponins treatments. Interactions of *Jatropha* parts and Seed/Root Saponins at 5 mls significantly ($p < 0.05$) produced highest 100 dry seed weights compared to other rates and the untreated (control). This was followed by plants treated with leaf Saponins.

The effects of Saponins from different *Jatropha* parts on Okra Mucilaginous property and root-gall incidence are shown in Table 4.45. Plants on pots treated with Saponins had reduced root-galls and produced okra with significantly ($p < 0.05$) higher mucilaginous property than the severely galled untreated pots in both years (2016 and 2017). Mucilaginous property of plants treated with Seed and Root Saponins were significantly ($p < 0.05$) higher than those treated with leaf Saponins. This was more so in the Interactions of *Jatropha* Parts and Saponins which significantly ($p < 0.05$) produced plants with higher mucilaginous property compared to other rates and the untreated (control). This was followed by plants treated with 5mls of leaf Saponins. Plants treated with leaf saponins had the least mucilaginous property in both years.

Table 4.44: Effect of Saponins and Jatropha parts on Okra 100 dry seed weight as influenced by root-gall nematode

| Saponins (ml) | 2016 | | | | | | | | 2017 | | | | | | | |
|---|-------------------------|-----|-----|------|-----------------------|-----|-----|------|-------------------------|-----|-----|------|-----------------------|-----|-----|------|
| | 100 dry seed weight (g) | | | | Root-gall Index (0-4) | | | | 100 dry seed weight (g) | | | | Root-gall index (0-4) | | | |
| | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | |
| | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean |
| Untreated (control) | 1.50 | 2.6 | 1.2 | 1.75 | 4 | 4 | 4 | 4 | 1.7 | 2.8 | 1.4 | 1.99 | 4 | 4 | 4 | 4 |
| 1 | 2.15 | 3.6 | 2.5 | 2.73 | 3.8 | 3.4 | 4 | 3.6 | 2.4 | 3.8 | 2.7 | 2.97 | 4 | 3.2 | 3.4 | 3.4 |
| 2 | 2.4 | 3.7 | 3.5 | 3.2 | 3.8 | 3 | 3 | 3.33 | 2.6 | 3.9 | 3.7 | 3.44 | 4 | 3 | 3.2 | 3.33 |
| 3 | 2.9 | 4.3 | 4 | 3.7 | 3 | 2 | 2 | 2.4 | 3.1 | 4.5 | 4.2 | 3.94 | 3 | 2 | 2 | 2.33 |
| 4 | 3 | 4.9 | 4.3 | 4.05 | 1.6 | 2.6 | 2 | 1.93 | 3.2 | 5.1 | 4.5 | 4.29 | 2 | 2.4 | 1.6 | 1.86 |
| 5 | 3.4 | 5.8 | 5 | 4.74 | 1.4 | 2.2 | 2 | 1.73 | 3.6 | 6 | 5.3 | 4.98 | 1 | 2 | 1.6 | 1.66 |
| Mean | 2.55 | 4.1 | 3.4 | | 2.9 | 2.9 | 3 | | 2.8 | 4.4 | 3.7 | | 3 | 2.8 | 2.6 | |
| LSD _{0.05} (Jatropha parts) | | 0.1 | | | | | ns | | | 0.1 | | | | ns | | |
| LSD _{0.05} (Saponins) | | 0.1 | | | | | 0.4 | | | 0.2 | | | | 0.5 | | |
| LSD _{0.05} (Jatropha parts X Saponins mls) | | 0.2 | | | | | 0.7 | | | 0.3 | | | | ns | | |

ns = not significant L = leaf, R= root, S = seed

Table 4.45: Effect of Saponins and Jatropha parts on Okra mucilaginous(mpa*s) property as influenced by root-gall nematode

| Saponins (ml) | 2016 | | | | | | | | 2017 | | | | | | | |
|---|------------------------------|--------|------|--------|-----------------------|-----|---|------|-------------------------------|--------|------|--------|-----------------------|-----|-----|------|
| | Mucilaginous propert (mpa*s) | | | | Root-gall Index (0-4) | | | | Mucilaginous property (mpa*s) | | | | Root-gall index (0-4) | | | |
| | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | |
| | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean |
| Untreated(control) | 1019 | 998 | 1008 | 1008.3 | 4 | 4 | 4 | 4 | 1021 | 1000 | 1010 | 1010.3 | 4 | 4 | 4 | 4 |
| 1 | 1097 | 1109 | 1099 | 1101.7 | 3.8 | 3.4 | 4 | 3.6 | 1099 | 1111 | 1101 | 1103.7 | 4 | 3.2 | 3.4 | 3.4 |
| 2 | 1118 | 1199 | 1188 | 1168.3 | 3.8 | 3 | 3 | 3.33 | 1120 | 1201 | 1190 | 1170.3 | 4 | 3 | 3.2 | 3.33 |
| 3 | 1229 | 1387 | 1299 | 1305 | 3 | 2 | 2 | 2.4 | 1231 | 1389 | 1301 | 1307 | 3 | 2 | 2 | 2.33 |
| 4 | 1304 | 1699 | 1662 | 1555 | 1.6 | 2.6 | 2 | 1.93 | 1306 | 1701 | 1664 | 1557 | 2 | 2.4 | 1.6 | 1.86 |
| 5 | 1599 | 2118 | 2099 | 1938.7 | 1.4 | 2.2 | 2 | 1.73 | 1601 | 2120 | 2101 | 1940.7 | 1 | 2 | 1.6 | 1.66 |
| Mean | 1227.7 | 1418.3 | 1393 | | 2.9 | 2.9 | 3 | | 1229.7 | 1420.3 | 1395 | | 3 | 2.8 | 2.6 | |
| LSD _{0.05} (Jatrphapart) | | 0.36 | | | | | | | | | | | | | | |
| LSD _{0.05} (Saponins) | | 0.51 | | | | | | | | | | | | | | |
| LSD _{0.05} (J.part X Saponins mls) | | 0.89 | | | | | | | | | | | | | | |

ns = not significant, L = leaf, R= root, S = seed

Effects of Saponins from different *Jatropha* parts on percentage nutrient composition of Okra are shown in Tables 4.46-4.48. The result showed that neither root-gall disease nor *Jatropha* parts affected Magnesium (Mg) and Ash. Although, root-gall disease did not have any effect on Potassium (K) contents of Okra fruits. However, plants treated with 5 mls leaf Saponins produced okra fruits significantly ($P < 0.05$) higher in Potassium than seed and root Saponins (Table 4.46).

In Table 4.47 Phosphorus (P) and Nitrogen (N) contents were significantly ($P < 0.05$) enhanced by root-gall nematode infection when compared with the treated pots. This was more so with plants on pots treated with 5mls of Root Saponins whose Nitrogen contents were significantly ($p < 0.05$) enhanced than seed and leaf Tannin respectively. However, percentage phosphorus recorded same value when 5 mls of leaf, seed and root Saponin were applied.

Fat, Sodium (Na), Calcium (Ca) and Moisture were significantly reduced by root-gall nematode infection in the untreated control pots Tables 4.47-4.48. Plants on pots treated with 5 mls of leaf Saponin produced okra pods with significantly ($P < 0.05$) higher percentage of Fat, Sodium (Na), Calcium (Ca) and Moisture contents. This was followed by seed and root Saponins.

Table 4.46: Effect of Saponins and Jatropha parts on percentage nutrient composition of Magnesium, Ash and Potassium as influenced by root-gall nematode

| 2017 | | | | | | | | | | | | | | | | |
|---|----------------|--------|--------|--------|----------------|--------|--------|--------|----------------|--------|--------|--------|-----------------------|------|------|------|
| Saponins (ml) | % Magnesium | | | | % Ash | | | | % Potassium | | | | Root-gall index (0-4) | | | |
| | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | |
| | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean |
| Untreated (control) | 0.104 | 0.104 | 0.1036 | 0.1038 | 2.7032 | 2.7024 | 2.702 | 2.7025 | 0.11 | 0.1074 | 0.1076 | 0.1083 | 4 | 4 | 4 | 4 |
| 1 | 0.1042 | 0.1042 | 0.1038 | 0.1041 | 2.7028 | 2.702 | 2.7016 | 2.7021 | 0.1102 | 0.1076 | 0.1078 | 0.1085 | 3.6 | 3.2 | 3.4 | 3.4 |
| 2 | 0.1044 | 0.1048 | 0.104 | 0.1044 | 2.7024 | 2.7016 | 2.7012 | 2.7017 | 0.1104 | 0.1078 | 0.108 | 0.1087 | 3.8 | 3 | 3.2 | 3.33 |
| 3 | 0.1046 | 0.105 | 0.1042 | 0.1046 | 2.702 | 2.7012 | 2.7008 | 2.7013 | 0.1106 | 0.108 | 0.1082 | 0.1089 | 3 | 2 | 2 | 2.33 |
| 4 | 0.1048 | 0.1052 | 0.1038 | 0.1046 | 2.7016 | 2.7008 | 2.7004 | 2.7009 | 0.1108 | 0.1082 | 0.1084 | 0.1091 | 2.4 | 1.2 | 1.4 | 1.66 |
| 5 | 0.105 | 0.1054 | 0.104 | 0.1048 | 2.7012 | 2.7004 | 2.7 | 2.7005 | 0.111 | 0.1084 | 0.1086 | 0.1093 | 2 | 1 | 1.2 | 1.4 |
| Mean | 0.1045 | 0.1048 | 0.1039 | | 2.7022 | 2.7014 | 2.701 | | 0.1105 | 0.1079 | 0.1081 | | 3.13 | 2.4 | 2.53 | |
| LSD _{0.05} (Jatropha parts) | | ns | | | | ns | | | | 0.0009 | | | | 0.31 | | |
| LSD _{0.05} (Saponins) | | ns | | | | ns | | | | ns | | | | 0.44 | | |
| LSD _{0.05} (Jatropha parts X Saponins mls) | | ns | | | | ns | | | | ns | | | | 0.76 | | |

ns = not significant, L = leaf, R= root, S = seed

Table 4.47: Effect of Saponins and Jatropha parts on percentage nutrient composition of Nitrogrn, Phosphorus and Fat as influenced by root-gall nematode

| 2017 | | | | | | | | | | | | | | | | |
|---------------------------------|----------------|-------|-------|-------|----------------|-------|-------|--------|----------------|-------|-------|--------|-----------------------|-----|-----|------|
| Saponins (ml) | % Nitrogen | | | | % Phosphorus | | | | % Fat | | | | Root-gall index (0-4) | | | |
| | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | |
| | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean |
| Untreated(control) | 2.446 | 2.456 | 2.452 | 2.451 | 0.006 | 0.006 | 0.006 | 0.0058 | 0.0777 | 0.078 | 0.078 | 0.0776 | 4 | 4 | 4 | 4 |
| 1 | 2.002 | 2.342 | 2.103 | 2.149 | 0.005 | 0.005 | 0.005 | 0.0048 | 0.1 | 0.085 | 0.098 | 0.0942 | 3.6 | 3.2 | 3.4 | 3.4 |
| 2 | 1.9 | 2.12 | 2 | 2.007 | 0.004 | 0.003 | 0.004 | 0.0037 | 0.1048 | 0.098 | 0.101 | 0.1012 | 3.8 | 3 | 3.2 | 3.33 |
| 3 | 1.932 | 1.904 | 1.82 | 1.852 | 0.004 | 0.003 | 0.004 | 0.0034 | 0.1297 | 0.1 | 0.119 | 0.1161 | 3 | 2 | 2 | 2.33 |
| 4 | 1.622 | 1.805 | 1.703 | 1.71 | 0.003 | 0.003 | 0.003 | 0.0029 | 0.1838 | 0.148 | 0.171 | 0.1674 | 1.6 | 2.4 | 1.6 | 1.86 |
| 5 | 1.503 | 1.76 | 1.692 | 1.651 | 0.003 | 0.003 | 0.003 | 0.0028 | 0.201 | 0.161 | 0.18 | 0.1804 | 1.4 | 2 | 1.6 | 1.66 |
| Mean | 1.884 | 2.064 | 1.961 | | 0.004 | 0.004 | 0.004 | | 0.1328 | 0.111 | 0.124 | | 2.9 | 2.8 | 2.6 | |
| LSD 0.05(J,part) | | 0.013 | | | | | | | | 0.001 | | | | 0.3 | | |
| LSD 0.05 (Saponins) | | 0.019 | | | | | | | | 0.002 | | | | 0.5 | | |
| LSD 0.05(J,part X Saponins mls) | | 0.033 | | | | | | | | 0.003 | | | | 0.8 | | |

ns = not significant, L = leaf, R= root, S = seed

Table 4.48: Effect of Saponin and Jatropha parts on percentage nutrient composition of Sodium, Calcium and Moisture as influenced by root-gall nematode

| 2017 | | | | | | | | | | | | | | | | |
|---------------------------------|----------------|-------|-------|-------|----------------|-------|-------|------|----------------|-------|-------|-------|-----------------------|-----|-----|------|
| Saponin (ml) | % Sodium | | | | % Calcium | | | | % Moisture | | | | Root-gall index (0-4) | | | |
| | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | |
| | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean |
| Untreated (control) | 0.037 | 0.037 | 0.038 | 0.038 | 0.203 | 0.202 | 0.204 | 0.2 | 63.9 | 61 | 61.2 | 62.03 | 4 | 4 | 4 | 4 |
| 1 | 0.039 | 0.039 | 0.039 | 0.039 | 0.288 | 0.256 | 0.271 | 0.27 | 65.3 | 62 | 64.3 | 63.87 | 3.6 | 3.2 | 3.4 | 3.4 |
| 2 | 0.034 | 0.038 | 0.039 | 0.037 | 0.318 | 0.298 | 0.32 | 0.31 | 66.4 | 64.7 | 66.2 | 65.77 | 3.8 | 3 | 3.2 | 3.33 |
| 3 | 0.04 | 0.039 | 0.041 | 0.04 | 0.398 | 0.312 | 0.333 | 0.35 | 70.13 | 68.3 | 69.4 | 69.28 | 3 | 2 | 2 | 2.33 |
| 4 | 0.043 | 0.04 | 0.042 | 0.042 | 0.448 | 0.326 | 0.378 | 0.38 | 76.2 | 70.3 | 75.2 | 73.9 | 2.4 | 1.2 | 1.4 | 1.66 |
| 5 | 0.049 | 0.042 | 0.047 | 0.046 | 0.491 | 0.361 | 0.403 | 0.42 | 89.54 | 75.4 | 85.2 | 83.38 | 2 | 1 | 1.2 | 1.4 |
| Mean | 0.041 | 0.039 | 0.041 | | 0.358 | 0.292 | 0.318 | | 71.91 | 66.95 | 70.25 | | 3.1 | 2.4 | 2.5 | |
| LSD 0.05(J.part) | | 0.001 | | | | 0.006 | | | | 0.547 | | | | 0.3 | | |
| LSD 0.05 (Saponins) | | 0.002 | | | | 0.009 | | | | 0.773 | | | | 0.4 | | |
| LSD 0.05(J.part X Saponins mls) | | 0.003 | | | | 0.155 | | | | 1.339 | | | | 0.8 | | |

ns = not significant, L = leaf, R= root, S = seed

Correlation Analysis

Correlation analysis of the root gall index and other attributes of the okra plants as influenced by the Saponins extracts in the pot experiments in 2016 and 2017 are presented in Table 4.49. The results showed that the root gall index had negative and highly significant correlation with Plantheight. The Mucilaginous property correlated positively and significantly with Plant height in both years respectively. The same was true for Pod weights, Hundsedwt, number of leaves and leaf area in both years.

Table 4.49: Linear correlation matrix between root-gall index and six plant attributes as influenced by saponins treatment application for 2016/2017 pot experiments

| | 2016 | PLHT | LFA | NOLVS | PODWT | HUNSEDWT | MUCIL | RGI |
|----------|-------------|-------------|------------|--------------|--------------|-----------------|--------------|------------|
| PLHT | | 1 | .560** | .630** | .656** | .487** | .607** | -.658** |
| LFA | | | 1 | .419** | .555** | .384** | .500** | -.439** |
| NOLVS | | | | 1 | .694** | .489** | .636** | -.614** |
| PODWT | | | | | 1 | .391** | .620** | -.692** |
| HUNSEDWT | | | | | | 1 | .857** | -.614** |
| MUCIL | | | | | | | 1 | -.659** |
| RGI | | | | | | | | 1 |
| | 2017 | | | | | | | |
| PLHT | | 1 | | | | | | |
| LFA | | .537** | 1 | | | | | |
| NOLVS | | .647** | .311** | 1 | | | | |
| PODWT | | .670** | .547** | .632** | 1 | | | |
| HUNSEDWT | | .506** | .379** | .467** | .408** | 1 | | |
| MUCIL | | .580** | .502** | .476** | .610** | .846** | 1 | |
| RGI | | -.588** | -.409** | -.387** | -.635** | -.603** | -.658** | 1 |

PLHT = Plant Height

LFA = Leaf Area

NOLVS = Number of Leaves

HUNSEDWT = 100 Seed Weight

MUCIL = Mucilaginous property -mpa*s

RGI = Root-Gall Index

4.3.4 Flavonoids

The effects of Flavonoids from different *Jatropha* parts on Okra plant heights and root-knot incidence are shown in Table 4.50. Pots treated with Flavonoids had reduced root galls and produced significantly ($p < 0.05$) higher plant heights than the severely galled untreated plants in both years. Plant heights from leaf Flavonoids produced plant heights which were significantly ($p < 0.05$) higher than those from Seed and Root Flavonoids in both years. However, there was no significant difference in plant heights between seed and root Flavonoids application in 2016 and 2017. Interaction of *Jatropha* parts and Flavonoids were not significant ($p < 0.05$).

Table 4.51 shows the effects of Flavonoids from different *Jatropha* parts on Okra leaf area and root-gall incidence. Results showed that okra plants in pots treated with various rates of Flavonoids had reduced root-galls and produced significantly ($p < 0.05$) higher leaf area than the severely galled untreated pots in both years (2016 and 2017). This was more so in the interaction of *Jatropha* parts and Leaf Flavonoids which produced highest leaf areas at 5 mls of treatment application in both years. This was followed by plant heights produced by Seed and Root Flavonoids respectively.

Effects of Flavonoids from different *Jatropha* parts on Okra number of leaves and root-gall incidence are shown in Table 4.52. Number of leaves increased as the rate of Flavonoids treatment increased. Interactions of *Jatropha* parts and 5 mls leaf Flavonoids produced Highest number of leaves which significantly ($p < 0.05$) differed from Seed and Root Flavonoids in 2016.

The same trend followed in Table 4.53. Plants grown on Pots treated with Leaf Flavonoids significantly ($p < 0.05$) flowered earlier than plants treated with Seed and Root Flavonoids

which were statistically the same in both years. Interactions of Jatropha parts and Flavonoids was not significant ($p < 0.05$).

Table 4.50: Effect of Flavonoids and *Jatropha curcas* parts on Okra plant height (cm) as influenced by root-gall nematode

| Flavonoids (ml) | 2016 | | | | | | | | 2017 | | | | | | | |
|---|-------------------|------|------|------|-----------------------|------|------|------|-------------------|-------|-------|-------|-----------------------|-----|-----|------|
| | Plant height (cm) | | | | Root-gall Index (0-4) | | | | Plant height (cm) | | | | Root-gall index (0-4) | | | |
| | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | |
| | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean |
| Untreated (control) | 6.34 | 5.49 | 5.16 | 5.67 | 4 | 4 | 4 | 4 | 7.24 | 6.39 | 6.06 | 6.57 | 4 | 4 | 4 | 4 |
| 1 | 7.54 | 6.51 | 6.72 | 6.92 | 3.8 | 3.4 | 3.6 | 3.6 | 8.43 | 7.41 | 7.62 | 7.82 | 3.6 | 3.2 | 3.4 | 3.4 |
| 2 | 8.09 | 7.01 | 7.3 | 7.47 | 3.8 | 3 | 3.2 | 3.33 | 8.99 | 7.91 | 8.2 | 8.37 | 3.8 | 3 | 3.2 | 3.33 |
| 3 | 8.71 | 7.82 | 7.56 | 8.03 | 3 | 2 | 2.2 | 2.4 | 9.61 | 8.72 | 8.46 | 8.93 | 3 | 2 | 2 | 2.33 |
| 4 | 9.88 | 8.66 | 8.7 | 9.08 | 2 | 2.6 | 2.2 | 2.26 | 10.78 | 9.56 | 9.6 | 9.98 | 2 | 2.4 | 2 | 2.13 |
| 5 | 10.36 | 9.42 | 9.72 | 9.83 | 1.4 | 2.2 | 2 | 1.86 | 11.26 | 10.32 | 10.62 | 10.73 | 1.4 | 2 | 2 | 1.8 |
| Mean | 8.49 | 7.49 | 7.53 | | 3 | 2.86 | 2.86 | | 9.39 | 8.39 | 8.43 | | 3 | 2.8 | 2.8 | |
| LSD _{0.05} (Jatropha parts) | | 0.38 | | | | ns | | | | 0.58 | | | | ns | | |
| LSD _{0.05} (Flavonoids) | | 0.54 | | | | 0.2 | | | | 0.82 | | | | 0.4 | | |
| LSD _{0.05} (Jatropha parts X Flavonoids mls) | | ns | | | | 0.34 | | | | ns | | | | ns | | |

ns = not significant, L = leaf, R= root, S = seed

Table 4.51: Effect of Flavonoids and *Jatropha curcas* parts on Okra (cm²) Leaf area as influenced by root-gall nematode

| Flavonoids (ml) | 2016 | | | | | | | | 2017 | | | | | | | |
|---|------------------------------|------|------|-------|-----------------------|------|------|------|------------------------------|------|------|-------|-----------------------|-----|-----|------|
| | Leaf area (cm ²) | | | | Root-gall Index (0-4) | | | | Leaf area (cm ²) | | | | Root-gall index (0-4) | | | |
| | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | |
| | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean |
| Untreated (control) | 3.24 | 3.15 | 3 | 3.13 | 4 | 4 | 4 | 4 | 4.2 | 4.1 | 3.96 | 4.09 | 4 | 4 | 4 | 4 |
| 1 | 5.04 | 4.2 | 4.21 | 4.48 | 3.8 | 3.4 | 3.6 | 3.6 | 6 | 5.16 | 5.17 | 5.44 | 3.6 | 3.2 | 3.4 | 3.4 |
| 2 | 5.74 | 4.85 | 4.93 | 5.17 | 3.8 | 3 | 3.2 | 3.33 | 6.7 | 5.81 | 5.89 | 6.13 | 3.8 | 3 | 3.2 | 3.33 |
| 3 | 8.54 | 5.94 | 5.71 | 6.73 | 3 | 2 | 2.2 | 2.4 | 9.5 | 6.9 | 6.67 | 7.69 | 3 | 2 | 2 | 2.33 |
| 4 | 9.61 | 6.88 | 7.86 | 8.11 | 2 | 2.6 | 2.2 | 2.26 | 10.57 | 7.84 | 8.82 | 9.07 | 2 | 2.4 | 2 | 2.13 |
| 5 | 13.79 | 7.56 | 8.7 | 10.02 | 1.4 | 2.2 | 2 | 1.86 | 14.75 | 8.52 | 9.66 | 10.98 | 1.4 | 2 | 2 | 1.8 |
| Mean | 7.66 | 5.43 | 5.74 | | 3 | 2.86 | 2.86 | | 8.62 | 6.39 | 6.7 | | 3 | 2.8 | 2.8 | |
| LSD _{0.05} (Jatropha parts) | | 0.47 | | | | ns | | | | 0.64 | | | | ns | | |
| LSD _{0.05} (Flavonoids) | | 0.67 | | | | 0.2 | | | | 0.91 | | | | 0.4 | | |
| LSD _{0.05} (Jatropha.parts X Flavonoids mls) | | 1.17 | | | | 0.34 | | | | 1.58 | | | | ns | | |

ns = not significant, L = leaf, R= root, S = seed

Table 4.52: Effect of Flavonoids and *Jatropha curcas* parts on Okra Number of leaves as influenced by root-gall nematode

| Flavonoids (ml) | 2016 | | | | | | | | 2017 | | | | | | | |
|---|------------------|------|------|------|-----------------------|------|------|------|------------------|------|------|------|-----------------------|-----|-----|------|
| | Number of leaves | | | | Root-gall Index (0-4) | | | | Number of leaves | | | | Root-gall index (0-4) | | | |
| | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | |
| | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean |
| Untreated (control) | 2.5 | 2.27 | 2.47 | 2.41 | 4 | 4 | 4 | 4 | 3.4 | 3.17 | 3.37 | 3.31 | 4 | 4 | 4 | 4 |
| 1 | 2.85 | 2.78 | 2.67 | 2.77 | 3.8 | 3.4 | 3.6 | 3.6 | 3.75 | 3.68 | 3.57 | 3.67 | 3.6 | 3.2 | 3.4 | 3.4 |
| 2 | 3.06 | 2.99 | 2.77 | 2.94 | 3.8 | 3 | 3.2 | 3.33 | 3.96 | 3.88 | 3.67 | 3.84 | 3.8 | 3 | 3.2 | 3.33 |
| 3 | 3.5 | 3.23 | 2.95 | 3.23 | 3 | 2 | 2.2 | 2.4 | 4.4 | 4.13 | 3.85 | 4.13 | 3 | 2 | 2 | 2.33 |
| 4 | 4.03 | 3.19 | 3.05 | 3.42 | 2 | 2.6 | 2.2 | 2.26 | 4.92 | 4.09 | 3.95 | 4.32 | 2 | 2.4 | 2 | 2.13 |
| 5 | 4.71 | 3.46 | 3.88 | 4.01 | 1.4 | 2.2 | 2 | 1.86 | 5.61 | 4.36 | 4.78 | 4.91 | 1.4 | 2 | 2 | 1.8 |
| Mean | 3.44 | 2.99 | 2.96 | | 3 | 2.86 | 2.86 | | 4.34 | 3.89 | 3.86 | | 3 | 2.8 | 2.8 | |
| LSD _{0.05} (Jatropha.parts) | | 0.13 | | | | ns | | | | ns | | | | ns | | |
| LSD _{0.05} (Flavonoids) | | 0.19 | | | | 0.2 | | | | 0.63 | | | | 0.4 | | |
| LSD _{0.05} (Jatropha parts X Flavonoids) | | 0.33 | | | | 0.34 | | | | ns | | | | ns | | |

ns = not significant, L = leaf, R = root, S = seed

Table 4.53: Effect of Flavonoids and Jatropha parts on Okra days to flowering as influenced by root-gall nematode

| Flavonoids (ml) | 2016 | | | | | | | | 2017 | | | | | | | |
|---|-------------------|-------|-------|-------|-----------------------|------|------|------|-------------------|-------|-------|-------|-----------------------|------|------|------|
| | Days to flowering | | | | Root-gall Index (0-4) | | | | Days to flowering | | | | Root-gall index (0-4) | | | |
| | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | |
| | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean |
| Untreated (control) | 58 | 64 | 62.31 | 61.44 | 4 | 4 | 4 | 4 | 57.4 | 63.4 | 61.72 | 60.84 | 4 | 4 | 4 | 4 |
| 1 | 52 | 56.4 | 58.3 | 55.57 | 3.8 | 3.4 | 3.6 | 3.6 | 51.4 | 55.8 | 57.7 | 54.97 | 3.6 | 3.2 | 3.4 | 3.4 |
| 2 | 52 | 55.3 | 52.4 | 53.23 | 3.8 | 3 | 3.2 | 3.33 | 51.4 | 54.7 | 51.8 | 52.63 | 3.8 | 3 | 3.2 | 3.33 |
| 3 | 50.5 | 54.5 | 52 | 52.33 | 3 | 2 | 2.2 | 2.4 | 49.9 | 53.9 | 51.4 | 51.73 | 3 | 2 | 2 | 2.33 |
| 4 | 50.2 | 51 | 51.27 | 50.82 | 2 | 2.6 | 2.2 | 2.26 | 49.6 | 50.4 | 50.67 | 50.22 | 2 | 2.4 | 2 | 2.13 |
| 5 | 46.5 | 50.2 | 50.2 | 48.97 | 1.4 | 2.2 | 2 | 1.86 | 45.9 | 49.6 | 49.6 | 48.37 | 1.4 | 2 | 2 | 1.8 |
| Mean | 51.53 | 55.23 | 54.41 | | 3 | 2.86 | 2.86 | | 50.93 | 54.63 | 53.81 | | 2.96 | 2.76 | 2.76 | |
| LSD _{0.05} (Jatropha parts) | | 2.49 | | | | ns | | | | 2.58 | | | | ns | | |
| LSD _{0.05} (Flavonoids) | | 3.52 | | | | 0.2 | | | | 3.65 | | | | 0.43 | | |
| LSD _{0.05} (Jatropha parts X Flavonoids mls) | | ns | | | | 0.34 | | | | ns | | | | ns | | |

ns = not significant, L = leaf, R= root, S = seed

The effects of Flavonoids from different *Jatropha* parts on root weight and root gall incidence are recorded in Table 4.54. Mean root weights of okra decreased with increased application of flavonoid treatment in both years (2016 and 2017). Effect of Flavonoids from *Jatropha* parts was not significant ($p < 0.05$). However, in the interactions of *Jatropha* and Flavonoids, least root weight and root galls were obtained at the application of 5 mls of Leaf, Seed and Root Flavonoids in both years.

Effect of Flavonoids from different *Jatropha* parts on Okra days to 50% flowering and root-gall incidence are shown in Table 4.55. Number of days to 50% flowering was significantly ($p < 0.05$) lower with reduced galls on plants grown on treated pots than those of untreated pots. Mean number of days to 50% flowering also decreased with increased flavonoid treatment application in both years (2016 and 2017). Earliest flowering was obtained in the Interactions of *Jatropha* parts and 5 mls of Flavonoids in both years (2016 and 2017). This was followed by plants treated with Seed and Root Flavonoids whose number of days to 50% flowering were also statistically the same at 5 mls of Flavonoids treatment application.

Table 4.56 shows the Effects of Flavonoids from different *Jatropha* parts on Okra pod weight as root-gall incidence. Plants on pots treated with Flavonoids had reduced root-galls and produced significantly ($p < 0.05$) higher number of pods than the severely galled untreated pots in both years (2016 and 2017). Mean pod weights of Okra also increased with increased application of Flavonoids.

Interactions of *Jatropha* parts and Flavonoids significantly affected okra pod weights. This was more so on pots treated with 5 mls of leaf Flavonoids which produced the highest pod weights at 5 mls compared to pots treated with seed and root Flavonoids in both years. This contrasted the least pod weight recorded on severely galled plants grown on untreated pots.

Although, 2017 cropping season recorded higher pod weights from Leaf Flavonoids. Pods from Root and Seed Flavonoids were similar statistically ($p < 0.05$).

Table 4.54: Effect of Flavonoids and Jatropha parts on Root weight (g) as influenced by root-gall nematode

| Flavonoids (ml) | 2016 | | | | | | | | 2017 | | | | | | | |
|---|-----------------|------|------|------|-----------------------|------|------|------|-----------------|------|------|------|-----------------------|------|------|------|
| | Root weight (g) | | | | Root-gall Index (0-4) | | | | Root weight (g) | | | | Root-gall index (0-4) | | | |
| | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | |
| | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean |
| Untreated (control) | 2.27 | 2.84 | 2.84 | 2.65 | 4 | 4 | 4 | 4 | 2.51 | 3.08 | 3.08 | 2.89 | 4 | 4 | 4 | 4 |
| 1 | 1.24 | 0.64 | 0.76 | 0.88 | 3.8 | 3.4 | 3.6 | 3.6 | 1.48 | 0.88 | 1 | 1.12 | 3.6 | 3.2 | 3.4 | 3.4 |
| 2 | 0.65 | 0.44 | 0.64 | 0.58 | 3.8 | 3 | 3.2 | 3.33 | 0.89 | 0.68 | 0.88 | 0.82 | 3.8 | 3 | 3.2 | 3.33 |
| 3 | 0.63 | 0.44 | 0.54 | 0.54 | 3 | 2 | 2.2 | 2.4 | 0.87 | 0.68 | 0.78 | 0.78 | 3 | 2 | 2 | 2.33 |
| 4 | 0.54 | 0.33 | 0.35 | 0.41 | 2 | 2.6 | 2.2 | 2.26 | 0.78 | 0.57 | 0.59 | 0.65 | 2 | 2.4 | 2 | 2.13 |
| 5 | 0.24 | 0.33 | 0.35 | 0.31 | 1.4 | 2.2 | 2 | 1.86 | 0.48 | 0.57 | 0.59 | 0.55 | 1.4 | 2 | 2 | 1.8 |
| Mean | 0.93 | 0.83 | 0.91 | | 3 | 2.86 | 2.86 | | 1.17 | 1.07 | 1.15 | | 2.96 | 2.76 | 2.76 | |
| LSD _{0.05} (Jatropha parts) | | Ns | | | | ns | | | | ns | | | | ns | | |
| LSD _{0.05} (Flavonoids) | | 0.22 | | | | 0.2 | | | | 0.29 | | | | 0.43 | | |
| LSD _{0.05} (Jatropha parts X Flavonoids mls) | | 0.38 | | | | 0.34 | | | | 0.5 | | | | ns | | |

ns = not significant, L = leaf, R= root, S = seed

Table 4.55: Effect of Flavonoids and Jatropha parts on Okra days to 50% flowering as influenced by root-gall nematode

| Flavonoids (ml) | 2016 | | | | | | | | 2017 | | | | | | | |
|---|-----------------------|-------|------|-------|-----------------------|------|------|------|-----------------------|-------|------|-------|-----------------------|------|------|------|
| | Days to 50% flowering | | | | Root-gall Index (0-4) | | | | Days to 50% flowering | | | | Root-gall index (0-4) | | | |
| | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | |
| | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean |
| Untreated (control) | 57 | 64 | 62 | 61 | 4 | 4 | 4 | 4 | 56.4 | 63.4 | 61.4 | 60.4 | 4 | 4 | 4 | 4 |
| 1 | 52 | 57 | 59 | 56 | 3.8 | 3.4 | 3.6 | 3.6 | 51.4 | 56.4 | 58.4 | 55.4 | 3.6 | 3.2 | 3.4 | 3.4 |
| 2 | 52 | 56 | 52.8 | 53.6 | 3.8 | 3 | 3.2 | 3.33 | 51.4 | 55.4 | 52.2 | 53 | 3.8 | 3 | 3.2 | 3.33 |
| 3 | 51 | 52 | 52 | 51.66 | 3 | 2 | 2.2 | 2.4 | 50.4 | 51.4 | 51.4 | 51.06 | 3 | 2 | 2 | 2.33 |
| 4 | 49 | 51 | 51 | 50.33 | 2 | 2.6 | 2.2 | 2.26 | 48.4 | 50.4 | 50.4 | 49.73 | 2 | 2.4 | 2 | 2.13 |
| 5 | 47 | 49 | 49 | 48.33 | 1.4 | 2.2 | 2 | 1.86 | 46.4 | 48.4 | 48.4 | 47.73 | 1.4 | 2 | 2 | 1.8 |
| Mean | 51.33 | 54.83 | 54.3 | | 3 | 2.86 | 2.86 | | 50.7 3 | 54.23 | 53.7 | | 2.96 | 2.76 | 2.76 | |
| LSD _{0.05} (Jatropha parts) | | 0.37 | | | | Ns | | | | 0.47 | | | | ns | | |
| LSD _{0.05} (Flavonoids) | | 0.53 | | | | 0.2 | | | | 0.67 | | | | 0.43 | | |
| LSD _{0.05} (Jatropha parts X Flavonoids mls) | | 0.92 | | | | 0.34 | | | | 1.16 | | | | ns | | |

ns = not significant, L = leaf, R= root, S = seed

Table 4.56: Effect of Flavonoids and Jatropha parts on Okra Pod weight (g) as influenced by root-gall nematode

| Flavonoids (ml) | 2016 | | | | | | | | 2017 | | | | | | | |
|---|----------------|------|------|------|-----------------------|------|------|------|----------------|------|------|------|-----------------------|------|------|------|
| | Pod weight (g) | | | | Root-gall Index (0-4) | | | | Pod weight (g) | | | | Root-gall index (0-4) | | | |
| | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | |
| | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean |
| Untreated (control) | 1.16 | 0.44 | 0.62 | 0.74 | 4 | 4 | 4 | 4 | 1.4 | 0.68 | 0.86 | 0.98 | 4 | 4 | 4 | 4 |
| 1 | 1.21 | 0.52 | 1.04 | 0.92 | 3.8 | 3.4 | 3.6 | 3.6 | 1.45 | 0.76 | 1.28 | 1.16 | 3.6 | 3.2 | 3.4 | 3.4 |
| 2 | 2.25 | 0.53 | 1.13 | 1.3 | 3.8 | 3 | 3.2 | 3.33 | 2.49 | 0.77 | 1.37 | 1.54 | 3.8 | 3 | 3.2 | 3.33 |
| 3 | 2.45 | 1.51 | 2.61 | 2.19 | 3 | 2 | 2.2 | 2.4 | 2.69 | 1.75 | 2.85 | 2.43 | 3 | 2 | 2 | 2.33 |
| 4 | 3.16 | 1.56 | 3.02 | 2.58 | 2 | 2.6 | 2.2 | 2.26 | 3.4 | 1.8 | 3.26 | 2.82 | 2 | 2.4 | 2 | 2.13 |
| 5 | 3.6 | 2 | 3.52 | 3.04 | 1.4 | 2.2 | 2 | 1.86 | 3.84 | 2.24 | 3.76 | 3.28 | 1.4 | 2 | 2 | 1.8 |
| Mean | 2.3 | 1.09 | 1.99 | | 3 | 2.86 | 2.86 | | 2.54 | 1.33 | 2.23 | | 2.96 | 2.76 | 2.76 | |
| LSD _{0.05} (Jatropha parts) | | 0.03 | | | | ns | | | | 0.11 | | | | ns | | |
| LSD _{0.05} (Flavonoids) | | 0.05 | | | | 0.2 | | | | 0.16 | | | | 0.43 | | |
| LSD _{0.05} (Jatropha parts X Flavonoids mls) | | 0.08 | | | | 0.34 | | | | 0.29 | | | | ns | | |

ns = not significant, L = leaf, R= root, S = seed

In Table 4.57, the effects of Flavonoids from different *Jatropha* parts on Okra dry seed weight and root-gall incidence are recorded. Plants on pots treated with Flavonoids had reduced root-galls and produced significantly ($p < 0.05$) higher 100 dry seed weight than the severely galled untreated pots in both years (2016 and 2017). Mean 100 dry seed weights of Okra increased with increased application of Flavonoids treatments. Plants from pots treated with Root Flavonoids recorded significantly ($p < 0.05$) higher 100 dry seed weight than those from Seed and Leaf Flavonoids in both years.

Interactions of *Jatropha* parts and Flavonoids significantly ($p < 0.05$) affected 100 dry Seed weights of okra plants. Root flavonoid at 5 mls produced highest 100 dry seed weights significantly higher when compared to other rates and the untreated (control) pots. This was followed by plants treated with Seed Flavonoids. Plants treated with Leaf Flavonoids had the least 100 dry seed weights in both years.

The effect of Flavonoids and *Jatropha* parts on Okra Mucilaginous property and root-gall incidence are shown in Table 4.58. Plants on pots treated with flavonoid had reduced root-galls and produced okra with significantly ($p < 0.05$) higher mucilaginous property than the severely galled untreated pots in both years (2016 and 2017). Mucilaginous property significantly ($p < 0.05$) increased with increased rates of flavonoid treatment applied.

Interactions of *Jatropha* Parts and Flavonoids significantly ($p < 0.05$) affected the mucilaginous property of okra treated with Flavonoids from *Jatropha* plant parts. However, Root Flavonoids at 5 mls significantly ($p < 0.05$) produced plants with higher mucilaginous property compared to other rates and the untreated (control). This was followed by plants treated with 5 mls of seed Flavonoids. Plants treated with Leaf Flavonoids had the least mucilaginous property in both years.

Table 4.57: Effect of Flavonoids and Jatropha parts on Okra 100 dry seed weight (g) as influenced by root-gall nematode

| Flavonoids (ml) | 2016 | | | | | | | | 2017 | | | | | | | |
|---|-------------------------|------|------|------|-----------------------|------|------|------|-------------------------|------|------|------|-----------------------|------|------|------|
| | 100 dry seed weight (g) | | | | Root-gall Index (0-4) | | | | 100 dry seed weight (g) | | | | Root-gall index (0-4) | | | |
| | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | |
| | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean |
| Untreated (control) | 1.4 | 2.45 | 1.17 | 1.67 | 4 | 4 | 4 | 4 | 1.64 | 2.69 | 1.41 | 1.91 | 4 | 4 | 4 | 4 |
| 1 | 2.05 | 3.55 | 2.4 | 2.66 | 3.8 | 3.4 | 3.6 | 3.6 | 2.29 | 3.79 | 2.64 | 2.9 | 3.6 | 3.2 | 3.4 | 3.4 |
| 2 | 2.3 | 3.6 | 3.38 | 3.09 | 3.8 | 3 | 3.2 | 3.33 | 2.54 | 3.84 | 3.62 | 3.33 | 3.8 | 3 | 3.2 | 3.33 |
| 3 | 2.8 | 4.15 | 3.8 | 3.58 | 3 | 2 | 2.2 | 2.4 | 3.04 | 4.39 | 4.04 | 3.82 | 3 | 2 | 2 | 2.33 |
| 4 | 2.9 | 4.75 | 4.2 | 3.95 | 2 | 2.6 | 2.2 | 2.26 | 3.14 | 4.99 | 4.44 | 4.19 | 2 | 2.4 | 2 | 2.13 |
| 5 | 3.3 | 5.65 | 4.95 | 4.63 | 1.4 | 2.2 | 2 | 1.86 | 3.54 | 5.89 | 5.19 | 4.87 | 1.4 | 2 | 2 | 1.8 |
| Mean | 2.45 | 4.02 | 3.31 | | 3 | 2.86 | 2.86 | | 2.69 | 4.26 | 3.55 | | 2.96 | 2.76 | 2.76 | |
| LSD _{0.05} (Jatropha parts) | | 0.03 | | | | ns | | | | 0.11 | | | | ns | | |
| LSD _{0.05} (Flavonoids) | | 0.05 | | | | 0.2 | | | | 0.16 | | | | 0.43 | | |
| LSD _{0.05} (Jatropha parts X Flavonoids mls) | | 0.09 | | | | 0.34 | | | | 0.29 | | | | ns | | |

ns = not significant, L = leaf, R= root, S = seed

Table 4.58: Effect of Flavonoids and Jatropha parts on Mucilaginous(mpa*s) property as influenced by root-gall nematode

| Flavonoids (ml) | 2016 | | | | | | | | 2017 | | | | | | | |
|---|-------------------------------|------|------|-------|-----------------------|------|------|------|-------------------------------|------|------|------|-----------------------|------|------|------|
| | Mucilaginous property (mpa*s) | | | | Root-gall Index (0-4) | | | | Mucilaginous property (mpa*s) | | | | Root-gall index (0-4) | | | |
| | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | |
| | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean |
| Untreated(control) | 1015 | 994 | 1004 | 100.4 | 4 | 4 | 4 | 4 | 1016 | 995 | 1005 | 1006 | 4 | 4 | 4 | 4 |
| 1 | 1093 | 1105 | 1095 | 1098 | 3.8 | 3.4 | 3.6 | 3.6 | 1094 | 1106 | 1096 | 1099 | 3.6 | 3.2 | 3.4 | 3.4 |
| 2 | 1114 | 1195 | 1184 | 1164 | 3.8 | 3 | 3.2 | 3.33 | 1115 | 1196 | 1185 | 1166 | 3.8 | 3 | 3.2 | 3.33 |
| 3 | 1225 | 1383 | 1295 | 1301 | 3 | 2 | 2.2 | 2.4 | 1226 | 1384 | 1296 | 1302 | 3 | 2 | 2 | 2.33 |
| 4 | 1300 | 1695 | 1658 | 1551 | 2 | 2.6 | 2.2 | 2.26 | 1301 | 1696 | 1659 | 1552 | 2 | 2.4 | 2 | 2.13 |
| 5 | 1595 | 2114 | 2095 | 1935 | 1.4 | 2.2 | 2 | 1.86 | 1596 | 2115 | 2096 | 1936 | 1.4 | 2 | 2 | 1.8 |
| Mean | 1224 | 1414 | 1389 | | 3 | 2.86 | 2.86 | | 1225 | 1416 | 1390 | | 2.96 | 2.76 | 2.76 | |
| LSD _{0.05} (Jatropha parts) | | 0.36 | | | | ns | | | | 0.69 | | | | ns | | |
| LSD _{0.05} (Flavonoids) | | 0.51 | | | | 0.2 | | | | 0.94 | | | | 0.43 | | |
| LSD _{0.05} (J.part X Flavonoids) | | 0.89 | | | | 0.34 | | | | 1.64 | | | | ns | | |

ns = not significant, L = leaf, R= root, S = seed

The effect of different Flavonoids and Jatropha parts on percentage nutrient composition of Okra are recorded in Tables 4.59-4.61. Jatropha parts affected Magnesium (Mg), Ash and Potassium (K) contents of Okra fruits (Table4.59). Phosphorus (P) and Nitrogen (N) contents were significantly ($P<0.05$) enhanced by root-gall nematode infection when compared with the treated pots (Table 4.60). This was more so with plants on pots treated with 5mls of root flavonoid for Nitrogen and 5 mls of leaf flavonoid for phosphorus (P) respectively.

Fat, Sodium (Na), Calcium (Ca) and Moisture were significantly reduced by root-gall nematode infection in the untreated control pots. Tables 4.60-4.61. Plants on pots treated with Leaf Flavonoids produced okra pods with significantly ($P<0.05$) higher percentage of Fat, Sodium (Na), Calcium (Ca) and Moisture contents. This was followed by Seed Flavonoids which significantly ($P<0.05$) differed from Root Flavonoids.

Table 4.59: Effect of Flavonoids and Jatropha parts on percentage nutrient composition of Magnesium, Ash and Potassium as influenced by root-gall nematode

| 2017 | | | | | | | | | | | | | | | | |
|---|----------------|-------|-------|-------|----------------|------|------|-------|----------------|-------|-------|-------|-----------------------|------|------|------|
| Flavonoids (ml) | % Magnesium | | | | % Ash | | | | % Potassium | | | | Root-gall index (0-4) | | | |
| | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | |
| | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean |
| Untreated(control) | 0.122 | 0.111 | 0.117 | 0.117 | 2.3 | 2.26 | 2.25 | 2.26 | 0.117 | 0.111 | 0.111 | 0.113 | 4 | 4 | 4 | 4 |
| 1 | 0.125 | 0.114 | 0.12 | 0.12 | 2.3 | 2.27 | 2.27 | 2.269 | 0.12 | 0.114 | 0.114 | 0.116 | 3.6 | 3.2 | 3.4 | 3.4 |
| 2 | 0.128 | 0.117 | 0.122 | 0.122 | 2.3 | 2.27 | 2.27 | 2.273 | 0.122 | 0.117 | 0.117 | 0.119 | 3.8 | 3 | 3.2 | 3.33 |
| 3 | 0.131 | 0.12 | 0.125 | 0.125 | 2.3 | 2.27 | 2.28 | 2.276 | 0.125 | 0.12 | 0.12 | 0.122 | 3 | 2 | 2 | 2.33 |
| 4 | 0.134 | 0.122 | 0.13 | 0.129 | 2.3 | 2.27 | 2.28 | 2.278 | 0.11 | 0.122 | 0.122 | 0.118 | 2.4 | 1.2 | 1.4 | 1.66 |
| 5 | 0.138 | 0.125 | 0.135 | 0.133 | 2.3 | 2.28 | 2.28 | 2.281 | 0.108 | 0.125 | 0.125 | 0.12 | 2 | 1 | 1.2 | 1.4 |
| Mean | 0.13 | 0.118 | 0.125 | | 2.3 | 2.27 | 2.27 | | 0.117 | 0.118 | 0.118 | | 3.13 | 2.4 | 2.53 | |
| LSD _{0.05} (Jatropha parts) | | ns | | | | ns | | | | ns | | | | 0.31 | | |
| LSD _{0.05} (Flavonoids) | | ns | | | | ns | | | | ns | | | | 0.44 | | |
| LSD _{0.05} (J.partsX Flavonoids mls) | | ns | | | | ns | | | | ns | | | | 0.76 | | |

ns = not significant, L = leaf, R= root, S = seed

Table 4.60: Effect of Flavonoids and Jatropha parts on percentage nutrient composition of Nitrogen, Phosphorus and Fat as influenced by root-gall nematode

| 2017 | | | | | | | | | | | | | | | | |
|---|----------------|--------|--------|--------|----------------|--------|--------|--------|----------------|--------|--------|--------|-----------------------|------|------|------|
| Flavonoids (ml) | % Nitrogen | | | | % Phosphorus | | | | % Fat | | | | Root-gall index (0-4) | | | |
| | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | |
| | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean |
| Untreated(control) | 2.45 | 2.45 | 2.4512 | 2.4504 | 0.0585 | 0.058 | 0.0591 | 0.0585 | 0.0776 | 0.0775 | 0.0775 | 0.0775 | 4 | 4 | 4 | 4 |
| 1 | 2.4392 | 2.45 | 2.1012 | 2.3301 | 0.0481 | 0.0481 | 0.0471 | 0.0477 | 0.1 | 0.0728 | 0.0952 | 0.0893 | 3.6 | 3.2 | 3.4 | 3.4 |
| 2 | 2 | 2.342 | 2.102 | 2.1477 | 0.0372 | 0.0386 | 0.0451 | 0.0403 | 0.102 | 0.09 | 0.0986 | 0.0968 | 3.8 | 3 | 3.2 | 3.33 |
| 3 | 1.8882 | 2.1 | 2 | 1.996 | 0.0372 | 0.0207 | 0.0296 | 0.0292 | 0.1208 | 0.1 | 0.1 | 0.1069 | 3 | 2 | 2 | 2.33 |
| 4 | 1.721 | 1.915 | 1.8032 | 1.813 | 0.035 | 0.004 | 0.003 | 0.014 | 0.17 | 0.1008 | 0.134 | 0.1349 | 2 | 2.4 | 2 | 2.13 |
| 5 | 1.5322 | 1.8042 | 1.8 | 1.7121 | 0.0297 | 0.0032 | 0.003 | 0.0216 | 0.2 | 0.14 | 0.16 | 0.1666 | 1.4 | 2 | 2 | 1.8 |
| Mean | 2.0051 | 2.1768 | 2.0428 | | 0.041 | 0.0335 | 0.0311 | | 0.1284 | 0.0968 | 0.1108 | | 2.96 | 2.76 | 2.76 | |
| LSD _{0.05} (J.Parts) | | 0.0004 | | | | 0.0039 | | | | 0.0002 | | | | 0.3 | | |
| LSD _{0.05} (Flavonoids) | | 0.0006 | | | | 0.0055 | | | | 0.0003 | | | | 0.43 | | |
| LSD _{0.05} (J.Part X Flavonoids mls) | | 0.0011 | | | | 0.0096 | | | | 0.0006 | | | | 0.74 | | |

ns = not significant, L = leaf, R= root, S = seed

Table 4.61: Effect of Flavonoids and Jatropha parts on percentage nutrient composition of Sodium, Calcium and Moisture as influenced by root-gall nematode

| 2017 | | | | | | | | | | | | | | | | |
|---|----------------|--------|--------|--------|----------------|--------|--------|--------|----------------|--------|-------|--------|-----------------------|------|------|------|
| Flavonoids (ml) | % Sodium | | | | % Calcium | | | | % Moisture | | | | Root-gall index (0-4) | | | |
| | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | | Jatropha Parts | | | |
| | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean | L | R | S | Mean |
| Untreated(control) | 0.0382 | 0.038 | 0.0381 | 0.0381 | 0.2026 | 0.2016 | 0.2046 | 0.2029 | 55.1 | 52.2 | 52.4 | 53.233 | 4 | 4 | 4 | 4 |
| 1 | 0.0388 | 0.0386 | 0.0386 | 0.0387 | 0.2866 | 0.25 | 0.2616 | 0.266 | 56.5 | 53.3 | 55.5 | 55.1 | 3.6 | 3.2 | 3.4 | 3.4 |
| 2 | 0 | 0.0388 | 0.0389 | 0.039 | 0.3146 | 0.2566 | 0.2984 | 0.2898 | 57.6 | 55.9 | 57.4 | 56.967 | 3.8 | 3 | 3.2 | 3.33 |
| 3 | 0.0392 | 0.0388 | 0.04 | 0.0396 | 0.3846 | 0.3 | 0.33 | 0.3382 | 61.33 | 59.58 | 60.6 | 60.503 | 3 | 2 | 2 | 2.33 |
| 4 | 0.04 | 0.0388 | 0.0415 | 0.041 | 0.424 | 0.3046 | 0.3726 | 0.367 | 67.38 | 61.5 | 66.4 | 65.093 | 2 | 2.4 | 2 | 2.13 |
| 5 | 0.0476 | 0.0407 | 0.0448 | 0.0443 | 0.464 | 0.3256 | 0.4 | 0.3965 | 88.5 | 66.6 | 76.4 | 77.167 | 1.4 | 2 | 2 | 1.8 |
| Mean | 0.0411 | 0.0389 | 0.0403 | | 0.346 | 0.273 | 0.3112 | | 64.402 | 58.18 | 61.45 | | 2.96 | 2.76 | 2.76 | |
| LSD _{0.05} (Jatropha parts) | | 0.0004 | | | | 0.0019 | | | | 0.0712 | | | | 0.3 | | |
| LSD _{0.05} (Flavonoids) | | 0.0005 | | | | 0.0025 | | | | 0.1006 | | | | 0.43 | | |
| LSD _{0.05} (Jatropha parts X Flavonoids mls) | | 0.0009 | | | | 0.0043 | | | | 0.1743 | | | | 0.74 | | |

ns = not significant, L = leaf, R = root, S = seed

Correlation Analysis

Correlation analysis of the root gall index and other attributes of the okra plants as influenced by the Flavonoids extracts in the pot experiments in 2016 and 2017 are presented in Table 4.62. The results showed that the root gall index had negative and highly significant correlation with Plant height in 2016 and 2017 respectively. The Mucilaginous property correlated positively and significantly with Plant height. The same was true for Pod weight, Hundred seed weight, Number of leaves and Leaf area in both years.

Table 4.62: Linear correlation matrix between root-gall index and six plant attributes as influenced by flavonoids treatment application for 2016/2017 pot experiments

| | 2016 | PLHT | LFA | NOLVS | PODWT | HUNSEDWT | MUCIL | RGI |
|----------|-------------|---------|---------|---------|---------|----------|---------|---------|
| PLHT | | 1 | .807** | .779** | .794** | .544** | .683** | -.684** |
| LFA | | | 1 | .870** | .828** | .411** | .590** | -.684** |
| NOLVS | | | | 1 | .767** | .400** | .570** | -.667** |
| PODWT | | | | | 1 | .381** | .618** | -.659** |
| HUNSEDWT | | | | | | 1 | .861** | -.626** |
| MUCIL | | | | | | | 1 | -.644** |
| RGI | | | | | | | | 1 |
| | 2017 | | | | | | | |
| PLHT | | 1 | | | | | | |
| LFA | | .816** | 1 | | | | | |
| NOLVS | | .784** | .749** | 1 | | | | |
| PODWT | | .785** | .834** | .634** | 1 | | | |
| HUNSEDWT | | .555** | .435** | .382** | .399** | 1 | | |
| MUCIL | | .619** | .570** | .376** | .608** | .849** | 1 | |
| RGI | | -.558** | -.617** | -.344** | -.605** | -.617** | -.646** | 1 |

PLHT = Plant Height

LFA = Leaf Area

NOLVS = Number of Leaves

HUNSEDWT = 100 Seed Weight

MUCIL = Mucilaginous property -mpa*s

RGI = Root-Gall Index

4.4 Discussion

4.4.1 Screening of *Jatropha curcas* cultivars: (For Root-gall nematode Resistance)

Results obtained in the screening of three *Jatropha curcas* cultivars for susceptibility/resistance to root-gall nematode infection revealed no cultivar differences in their root-gall infection status (0= no infection) amongst the three cultivars using the scoring index and when compared to the uninoculated (control). Ojiako (2011) reported no cultivar differences in the seed performance and growth habit of *Jatropha curcas* cultivars.

The noted resistance observed among the cultivars to root-gall nematode infection may be due to the nematicidal substance present in them irrespective of the cultivar. This confirms the work of Devappa *et al.* (2010) who reported that all parts of *Jatropha curcas* are nematicidal and the degree of nematicidity varies with the extract types, nature of test substances, dose, mode of administration, and sensitivity of animals.

Phytochemical screening of *Jatropha curcas* plant parts and constituents showed that it contained Tannins, Alkaloids, Saponins and Flavonoids. Several workers (El Diwani *et al.*, 2009; Makkar *et al.*, 2009; Manpong *et al.*, 2009; Igbinsosa *et al.*, 2011; Namuli *et al.*, 2011; Oskoueian *et al.*, 2011) have reported the presence of these phytochemicals as secondary metabolites in different parts of *Jatropha curcas*. Quantitative analysis showed that though present in the plant parts studied but are at different concentrations. Nwokocha, Blessing, Agbawa and Okoli (2011) reported that Tannins are the most abundant in plant parts, followed by Saponins, Alkaloids, Flavonoids and Phenols

4.4.2 Laboratory Experimental Result

Hatchability

The application of phytochemical extracts contained in the seed, leaf and root of *Jatropha curcas* reduced egg hatchability when compared to the control. Adegbite and Adesiyon (2005) reported that

the inhibitory effect of root extracts might be due to the presence of phytochemicals that possess ovicidal and larvicidal properties.

Hundred percent egg hatchability inhibition was obtained with the application 10 mls of Seed Saponins compared to the other phytochemical extract. The highest egg hatch inhibition obtained with seed Saponin may be due to its nematicidal activity. Ibrahim and Srour, (2013) reported that Saponins from *Medicago sativa* inhibited cholesterol accumulation in egg and/or larva. Lasisi, Soetan, Fafunso, and Aiyelaagbe (2003) also reported that high concentration of saponins extract reduced egg hatching percentage of bovine gastro intestinal nematodes *in vitro*.

The 100 %egg hatchability reduction recorded at 10 mls of Saponins application might be due to the rate/dosage of application. It has been reported that nematicidal effect of an extract is directly related to its concentration (Khan *et al.*, 2017).Hatchability was found to have decreased with increased rates of phytochemicals applied. Sharma and Prasad (1995) made related observations. They reported that there was inhibition in the further development of egg masses with increase in the dose of extracts of de-oiled cakes of cotton, sunflower and leaves of *datura* and *encalyptus*. Although, it took 10 mls of Seed Saponin to achieve complete egg hatchability reduction, application of Seed Saponin at 5 mls recorded the nearest egg hatchability reduction.

The application of Alkaloids both at 5 and 10 mls achieved the same egg hatchability reduction effects (0.16). This is consistent with the report of Matsushashi *et al.* (2002) who stated that Alkaloids have cytonematicidal effect on nematodes.

Egg hatchability reduction was strongest at 12 h treatment exposure period for all phytochemical extracts irrespective of the plant parts. Hatchability decreased with increased hour of exposure.This is in confirmation of the work of Patil *et al.* (2017) who reported that the rate of hatching was directly proportional to treatment exposure period in his work with reniform nematodes.

Mortality

All Phytochemical extracts from *Jatropha curcas* plant parts had nematicidal effect on nematode juveniles. Differences observed in the nematicidal activity of extracts may be due to their solubility in extracting solvents, and or the presence of inhibitors to the nematicidal principles (Oka *et al.*, 2001). Khan *et al.*, (2017) further reported that nematicidal property of some phytochemicals extracted from plants are characterized by their lipophilic properties that enable them dissolve the cytoplasmic membrane of the nematode cells and their functional groups interfering with enzyme protein structure of nematodes.

Highest mortality of second stage juveniles (J₂) was achieved with Alkaloids from all plant parts tested. Kui *et al.* (2012) also reported that Alkaloids from *M. cordata* exhibited nematicidal activity against nematodes. Corroboratively, Kuljanabhagavad and Wink, (2009) further stated that the mechanism of action of these Alkaloids might be related to their cytonematicidal,

Juvenile mortality increased with increased rate of phytochemical treatment applied. This agrees with similar findings by Salim *et al.* (2016) who reported that concentrations of 5 and 10 percent of aqueous extract significantly increased mortality of nematode juveniles compared to control. Highest nematode mortality was recorded at 72 h treatment exposure time in all phytochemical extracts. Nematode juvenile mortality increased with increased hours of treatment exposure. Okeniyi *et al.* (2010) reported that juvenile mortality increased with corresponding increase in time of exposure

4.4.3 Effects of *Jatropha curcas* plant part on phytochemical efficacy and okra yield parameters

Alkaloids

Okra plants on pots treated with various Alkaloids extracts had reduced galls and performed better in their growth and yield parameter compared to the severely galled untreated control plants in both years (2016 and 2017). This might be as a result of the nematicidal effect of the Alkaloids thereby interfering with the metabolism of the nematodes. Ibrahim *et al.* (2014) reported that Alkaloids interfere with processes such as DNA replication and RNA transcription which are vital to micro-organisms. The mortality level achieved with Alkaloids may be attributed to other mechanisms such as disruption of protein synthesis, stability of biomembranes and metabolically important enzymes (Oyedeji *et al.*, 2011).

The observed increases in plant heights in the treated than untreated in both years of study could be attributed to the adverse effect of the Alkaloids extracts on the activities of the nematodes thereby creating conditions for optimal plant growth. The Alkaloids extracts inhibited the activities of the

nematodes thereby allowing the plants to make optimal use of the soil nutrients for growth and development. This agrees with the works of Ihejirika *et al.* (2006) which stated that the creation of favourable conditions for absorption of available soil nutrient provides ideal crop interaction for efficient use of available soil nutrient for optimal growth and development of the plant. Nematode activities in the roots of the untreated plants affected adversely the plant heights of the control crops.

The least leaf area produced on severely galled okra plants grown on untreated pots in both study years was as a result of the activities of the root-knot nematodes. Root-knot nematodes have been reported to cause measurable changes in the morphology and physiology of the host (Williamson and Gleason, 2003). However, higher increases in the leaf areas and number of treated than the untreated plants were as a result of the nematicidal effect of the Alkaloids on the nematodes. Emeasor *et al.* (2002) stated that plant extracts exert nematicidal effects by disrupting the normal metabolic activities of organisms. This led to enhanced physiological activities in the treated plants.

The production of leaves increased with increased rate of the extracts. However, beyond certain levels of concentration for the root extracts the number of leaves produced by the plant decreased. This was attributed to the interference of the root extract with the physiological functions of the plant due to their nematicidity at higher concentrations. This is in line with the report of Ogwulumba, (2011) who made a similar observation that application of aqueous plant extracts rather interferes with the physiological properties of tomato plant due to toxicity at higher concentrations

The higher root weight of galls recorded in the untreated pots was different from the lower root weights of galls recorded in the treated pots. The application of Alkaloids as biopesticide treatment proved to be the most effective by recording less root weight of galls in the root, since the presence of galls in the roots not only increases root weights but prevents adequate water and nutrient uptake resulting in stunted growth and reduced yield. This report is similar to the findings of Ononuju,

Ekeoma, Orikara and Ikwunagu (2015) which stated that number of galls, eggs in the root, nematode larva in soil were drastically reduced as a result of termidust treatment application.

Okra pod weights obtained in 2017 was higher than 2016, on application of Root and Seed Alkaloids. The efficacy of the seeds and root parts of *J. curcas* have been variously reported (Ohazurikeet *al.*, 2003; Agu *et al.*, 2013 and Ahuchaogu *et al.*, 2014) to have cytonematicidal insecticidal and nematicidal activities on stored seeds and field crops).Therefore, the increased pod weights obtained as a result of increase in the dosage of application of Alkaloids in the treated than the untreated plants could be attributed to the nematicidal effect of the Alkaloid on the nematodes thereby creating favourable environment for the performance of the plants in the treated than the untreated. This is in line with the works of Ihejirika *et al.* (2006) which stated that the creation of favourable conditions for absorption of available soil nutrient provides ideal crop interaction for efficient use of available soil nutrient for optimal growth and development of the plant

Plants treated with leaf alkaloids had the least 100 dry seed weights in both years. 100 dry seed weights produced by the plants were better in the treated than the untreated. The controls had the lowest 100 dry seed weights. This shows some percentage increase in the Alkaloids treated plants than the untreated. This agrees with the works of Mbah *et al.* (2005) who found the yield of tomato plants treated with plant extracts higher than those of the untreated (control) plants. The treatments depressed nematode activities thereby allowing the plants to absorb nutrients for proper seed development.

The delayed flowering obtained in the untreated (control) pots than the treated pots could be attributed to decrease in metabolic activities among plants grown on the untreated control pots. Idorenyin, Udo, Michael, Uguru, Rufus, Ogbuji and Donald, (2008) reported that root-knot nematode *Meloidogyne javanica* prolonged flowering in all tested tomato cultivars by decreasing the metabolic

activities of the plant. Earliest flowering obtained in the treated pots as dosage of Root and Seed Alkaloid treatment increased could therefore be attributed to the nematicidal effect of the alkaloid on the nematode thereby creating the right environment for nutrient uptake and translocation.

Plants treated with leaf alkaloids had the least 100 dry seed weights in both years. 100 dry seed weights produced by the plants were better in the treated than the untreated. The controls had the lowest 100 dry seed weights. This shows some percentage increase in the Alkaloids treated plants than the untreated. This agrees with the works of Mbah *et al.* (2005) who found the yield of tomato plants treated with plant extracts higher than those of the untreated (control) plants. The treatments depressed nematode activities thereby allowing the plants to absorb nutrients for proper seed development.

However, the increased mucilaginous property obtained in the Alkaloids treated pots than the untreated control could be attributed to the cytonematicidal effect of the Alkaloids on the nematode which provided the enabled effective nutrient uptake and transport in the plant. Agu *et al.* (2009) reported that root-knot nematode infection reduced the mucilaginous property of okra fruits.

The result of the effect of Alkaloids and *Jatropha* parts on percentage nutrient composition of Okra showed that neither root-gall disease nor *Jatropha* parts affected Magnesium (Mg), Ash and Potassium (K) contents of Okra fruits. The enhanced Phosphorus and Nitrogen content observed in the root-gall nematode infected plants could be due to uninterrupted translocation of phosphorus. Agu *et al.*, 2009 reported that phosphorus translocation was not interrupted in okra plants infected with *M. incognita* and that the use of Phosphorus by the parasite was not greater than 10 % of the nutrient uptake by the plant. The increases observed in this study may be because Phosphorus enhances nitrogen uptake, efficiency and utilization during such important growth process as seed and fruit development in plants (Huber, 1980).

The significant reduction of Fat, Calcium (Ca), Sodium (Na) and Moisture were observed in okra fruits harvested from root-gall nematode infected plants. Yang *et al.* (1976) reported increased degradation of fat into fatty acids in nematode infected *Arachys hypogea*. Reduced Sodium (Na) and Calcium (Ca) had also been reported in the leaves of Vetch infected with *M. hapla* (Jenkins and Malek, 1966). Percentage Moisture of okra fruits was affected by root-gall nematode infection and Alkaloids from *Jatropha* parts. There was moisture reduction in fruits of infected plants. This agreed with the earlier report of Kirkpatrick, Oosterhuis and Wullschleger (1991) who stated that xylem vessels disruption in infected roots causes interruption of nutrient translocation to the shoot and consequent interference with carbohydrate synthesis (Kirkpatrick *et al.*, 1991).

The observed negative correlation between root-gall index and okra yields showed that as the number of galls increased, the growth and yield attributes of okra decreased. This may be due to abnormal cells (galls) disruption of nutrient and moisture transport within the plants (Udo, 2004).

The positive correlation between the leaf area, number of leaves produced and pod weights, 100 seed weights and mucilaginous property showed that increased number of leaves, leaf area at reduced galling responses gave rise to greater photosynthesis and increased growth and yield attributes of the okra. Agu *et al.* (2013) reported that more leaf production on root-gall nematode controlled okra plants added to the photosynthetic rate of the plants and characteristically resulted in increased pod weight yield.

Tannins

Application of Tannins extracts led to reduced galls and better yield performance on treated plants of Okra when compared to the severely galled untreated control plants in both years (2016 and 2017). This could be attributed to the nematostatic effect of Tannins. Among the natural products extracted from plants, Tannins have been reported to possess antihelmintic properties especially for gastrointestinal nematodes in ruminants. Also, they are nematicidal to a wide range of fungi, bacteria

and yeasts. Maistrello *et al.* (2010) further asserted that Tannins are compounds that could be involved in the passive defense of the plant as chemical barriers to the invasion of the parasite in the roots and they might increase host resistance to nematode infection.

Therefore, the increases recorded in the plant heights and shoot weight on application of 5 mls of Leaf and Root Tannins in the treated than the untreated control in both years could be attributed to the nematicidal effect of the Tannins. This is in line with the works of Maistrello *et al.* (2010) who reported that highest doses of Tannins applied at transplant and again 2 weeks later, significantly reduced root gall index in comparison to inoculated and untreated control.

The reduction in plant heights and fresh shoot weight in the severely galled untreated control plants in both years (2016 and 2017) is as a result of the incidence and severity of the nematodes on the inoculated control plants. Mukhtar *et al.* 2013 reported that all inoculum levels of *M. incognita* caused significant reductions in plant heights and fresh shoot weight at all plant ages of okra.

There were increases recorded in the Leaf area and leaf number on application of 5 mls of Leaf Tannins in the treated than the untreated plants in both years. The enhanced growth parameters in the treated plants were as a result of the nematicidal effects of the Leaf Tannins extracts. Khan *et al.* (2017) reported that extracts from plant leaf are characterized by their lipophytic properties that enable them dissolve the cytoplasmic membrane nematodes. This led to improved physiological activities of the plant. The production of leaves thus increased with increased rates/dosage of tannin treatments. However, beyond certain levels of concentration of extract as shown in the tables the number of leaves started decreasing. This was attributed to the interference of the Tannins extract with the physiological functions of the plant due to their nematicidity at higher concentrations. Jesse *et al.*, 2006 attributed this to the high phytate levels present in the Leaf extracts of *Jatropha curcas*.

Reduction in leaf areas of plants in the infected but untreated control pots may have been caused by reduction in the chlorophyll content of the infected plants as reported by Parveen, Haseeb and Shukla, (2006). Jonathan and Rajendan (2002) stated that infection caused by *M. incognita* also leads to reduction in leaf area.

Mukhtar *et al.* (2013) reported increases in fresh root weights of okra inoculated with nematode as observed in the untreated control. He further stated that increases in fresh root weight is directly proportional to the level of inoculation. However, the least root weights and root galls obtained in the okra plants could be attributed to the nematicidal effect of the tannin treatment on the nematodes which resulted in enhanced physiological activities in the treated plants. This is in line with the works of Ihejirika *et al.* (2006).

Okra plants on pots treated with 5 mls of Leaf and Seed Tannins produced the highest pod weights compared to plants on pots treated with root Tannins in both years (2016 and 2017). Ojiako *et al.* (2015) reported that the seed extract, irrespective of the solvent used had better repellency action than the root extracts. The efficacy of plant leaf extract has also been reported by Khan *et al.* (2017). The weight of fruits produced by the okra plants was better in the treated than the untreated. The untreated (controls) had the lowest weight of fruits. This reveals some percentage increase in weight of fruits in the treated plants than the untreated. This agrees with the works of Mbah *et al.* (2005) who found the yield of tomato plants treated with plant leaf extracts higher than those of untreated (control) plants. The Tannins treatments depressed nematode activities thereby allowing the plants to absorb nutrients for proper development. Sasser (1989) reported that low yield and poor-quality results from nematode damage to crops. The increased okra pod weights recorded could therefore, be attributed to improved physiological activities of the Tannins treated plants. Agu *et al.* (2013) reported that more leaf production on root-gall nematode controlled tomato plants added to the photosynthetic rate of the plants and characteristically resulted in increased fruit yields. Fruit weights are important because it is one of the major determinant parameters in market prices.

Earliest flowering obtained in the treated pots as dosage of Leaf Tannins treatment increased could be attributed to the nematicidal effect of the Tannins on the nematode which created a favourable environment for the plants to flower. The delayed flowering obtained in the untreated (control) pots than the treated pots could be attributed to decrease in metabolic activities among plants grown on the untreated control pots.

The recorded improvement on growth and yield characteristics such as 100 dry seed weights was associated with decreases in root-gall damage which is attributed to improved nutrient absorption and translocation to vegetative organs due to nematicidal effect of Tannins treatment. Aguet *et al.* (2013) stated that plants with fewer root-galls would translocate more nutrients to vegetative organs for proper seed and pod development than heavily galled roots.

Mucilaginous property increased with increased rate of Tannins treatment. Agu *et al.*, (2013) stated that root gall nematode decreased as application rate of *J. curcas* increased. Agu *et al.*, (2009) also noted a steady increase in mucilaginous property in okra pods as okra galling response to *M. incognita* decreased at increased carbofuran rate.

Enhanced Phosphorus and Nitrogen content observed in the root-gall nematode infected plants could be due to uninterrupted translocation of phosphorus. Agu *et al.*, 2009 reported that phosphorus translocation was not interrupted in okra plants infected with *M. incognita* and that the use of Phosphorus by the parasite was not greater than 10 % of the nutrient uptake by the plant. The significant increases observed in this study may be because Phosphorus enhances nitrogen uptake, efficiency and utilization during such important growth process as seed and fruit development in plants (Huber 1980).

Reduction of Fat, Calcium (Ca), Sodium (Na) and Moisture were observed in okra fruits harvested from root-gall nematode infected plants. Yang *et al.* (1976) reported increased degradation of fat into fatty acids in nematode infected *Arachyshypogeal*. Reduced Sodium (Na) and Calcium (Ca) had also

been reported in the leaves of Vetch infected with *M. hapla* (Jenkins and Malek, 1966). Percentage Moisture of okra fruits was also affected by root-gall nematode infection and Tannins from *Jatropha* parts. Moisture reduction was also observed to have occurred in fruits of infected plants.

The observed negative correlation between root-gall index and okra yields showed that as the number of galls increased, the growth and yield attributes of okra decreased. This may be due to abnormal cells (galls) disruption of nutrient and moisture transport within the plants (Anwar and Mckenry, 2010). The positive correlation between the leaf area, number of leaves produced and pod weights, 100 seed weights and Mucilaginous property showed that increased number of leaves and leaf area at reduced galling responses led to higher photosynthesis and increased growth and yield attributes of the okra.

Saponins

Okra plants on pots treated with various Saponins extracts had reduced galls and performed significantly better in their growth and yield compared to the severely galled untreated control plants in both years (2016 and 2017). Saponins are part of active immune system of plants and function as natural antibiotics for plants. Saponins have been reported (Omar *et al.*, 1994) to have reduced total population, number of egg masses and viable juveniles of root-knot nematode *Meloidogyne javanica*. This may be because of their cytonematicidal effect on nematodes (Kuljanabhadgavad and Wink, 2009).

The results reported in this study showed that application of Saponins increased plant heights, leaf areas, number of leaves and shoot weight in the treated than untreated in both years of study. The effect of Saponins was most pronounced by the application of Leaf Saponins and Seed Saponins. This may be because Saponins content in the Leaf and Seed was more than Root Saponins as reported earlier. The saponins extract inhibited the activities of the nematodes thereby allowing the plants to make optimal use of the soil nutrients for growth and development. The least leaf area

produced on severely galled okra plants grown on untreated pots in both study years was as a result of the activities of the root-knot nematodes. Root-knot nematodes cause measurable changes in the morphology and physiology of the host (Williamson and Gleason, 2003).

The observed increases in Plant heights, Leaf area, leaf number and shoot weight in the treated than the untreated plants in both cropping seasons were also as a result of the enhanced growth parameters in the treated plants due to the nematicidal effect of the saponin treatment on the nematodes. Emeasor *et al.* (2002) stated that plant extracts exert nematicidal effects by disrupting the normal metabolic activities of organisms. This led to enhanced physiological activities in the treated plants. The results also confirm the findings of Maleita *et al.*, (2012); they reported that plants heavily infested with root knot nematodes exhibited stunted growth and poor yield and in some cases plants die even before reaching maturity (Singh and Khurma, 2007). However, plants treated with saponin had the nematode activity suppressed with enhanced physiological activity of the plant.

The higher root weight of galls recorded in the inoculated but untreated pots was significantly different from the less root weights of galls recorded in the inoculated but treated pots. The application of saponin treatment as proved to be the most effective by recording less root weight of galls in the root, since the presence of galls in the roots prevents adequate water and nutrient uptake resulting in stunted growth and reduced yield. This report is similar to the findings of Ononjuet *al.* (2015) which stated that number of galls, eggs in the root, nematode larva in soil were drastically reduced as a result of termidust treatment application.

Saponins application also reduced days to flowering, increased pod weights and increased mucilaginous property of Okra. This was most prominent on plants grown on pots treated with 5 mls of Leaf and Seed which performed better than Root Saponins. Ojiako *et al.* (2015) also reported that the effect of *Jatropha* extract concentration was dose related as higher rates produced better performance. This contrasted the least pod weight recorded on severely galled plants grown on

untreated pots. Pod weights obtained in 2017 were higher than pod weights obtained in 2016. The delayed flowering obtained in the untreated (control) pots than the treated pots could be attributed to decrease in metabolic activities among plants grown on the untreated control pots. Earliest flowering and increased mucilaginous property obtained in the treated pots as dosage of saponins treatment increased could therefore be attributed to the nematicidal effect of the Saponins which created a favourable environment for the plants' development and quality of pods. Aguet *et al.* (2009) reported that root-knot nematode infection reduced the mucilaginous property of okra fruits.

Seed and Root saponin at 5 mls produced highest 100 dry seed weights compared to the untreated (control). This was followed by plants treated with leaf saponin. The efficacy of the seed and root parts of *J. curcas* have been variously reported (Agu *et al.*, 2013; Ahuchaoguet *et al.*; 2014) and Ohazuike *et al.*; 2003) to have cytonematicidal nematicidal and insecticidal activities on stored seeds and field crops.

The enhanced Phosphorus and Nitrogen content observed in the root-gall nematode infected plants could be due to uninterrupted translocation of phosphorus. Agu *et al.* (2009) reported that phosphorus translocation was not interrupted in okra plants infected with *M. incognita* and that the use of Phosphorus by the parasite was no greater than 10% of the nutrient uptake by the plant. The significant increases observed in this study may be because Phosphorus enhances nitrogen uptake, efficiency and utilization during such vital growth process as seed and fruit development in plants (Huber 1980).

Significant reduction of Fat, Calcium (Ca), Sodium (Na) and Moisture were also observed in okra fruits harvested from root-gall nematode infected plants. Yang *et al.* (1976) reported increased degradation of fat into fatty acids in nematode infected *Arachyshypogeal*. Reduced Sodium (Na) and Calcium (Ca) had also been reported in the leaves of Vetch infected with *M. hapla* (Jenkins and Malek, 1966). Percentage Moisture of okra fruits was affected by root-gall nematode infection, and

Saponin from *Jatropha* parts. Significant moisture reduction occurred in fruits of infected plants. This agreed with the earlier report of Kirkpatrick *et al.* (1991).

The observed negative correlation between root-gall index and okra yields showed that as the number of galls increased, the growth and yield attributes of okra decreased. This may be due to abnormal cells (galls) disruption of nutrient and moisture transport within the plants (Abubakar *et al.*, 2004).

The positive correlation between the Leaf area, number of leaves produced and pod weights, 100 seed weights and mucilaginous property showed that increased number of leaves, leaf area at reduced galling responses led to higher photosynthesis and increased growth and yield attributes of the okra.

Flavonoids

The Application of Flavonoids extracts also resulted to reduced galls and better yield performance on treated plants of Okra when compared to the severely galled untreated control plants in both years (2016 and 2017). This might be due to the nematicidal activities of Flavonoids. Flavonoids are secondary metabolites with many pharmacological activities such as anticancer, antinematicidal and hepatoprotective activities.

Therefore, the increases in plant heights in the treated than the untreated in both years could be attributed to the nematicidal effect of the Flavonoids extract on the activities of the nematodes thereby creating conditions for optimal plant growth. This agrees with the works of Ihejirika (2006). The reduction in plant heights in the severely galled untreated control plants in both years (2016 and 2017) is as a result of the incidence and severity of the nematodes on the inoculated control plants. Mukhtar *et al.* (2013) reported that all inoculum levels of *M.incognita* caused significant reductions in plant heights and fresh shoot weight at all plant ages of okra.

There were observed increase in leaf area and leaf number in the treated than the untreated plants. The enhanced growth parameters in the treated plants were as a result of the nematicidal effects of the flavonoid extract on the nematodes. Emeasoret *et al.* (2002) stated that plant extract exerts nematicidal effect by disrupting the normal metabolic activities of organisms. This led to enhanced physiological activities in the treated plants. The production of leaves and leaf are thus increased with increased rates/dosage of Flavonoids treatments applied. Reduction in leaf areas and production in the infected but untreated control pots may have been caused by reduction in the chlorophyll content of the infected plants as reported by Parveental *et al.* (2006). Jonathan and Rajendan (2002) stated that infection caused by *M. incognita* also leads to reduction in leaf area.

Mukhtar *et al.* (2013) reported increases in fresh root weights of okra inoculated with nematode as observed in the untreated control. He further stated that increases in fresh root weight is directly proportional to the level of inoculation. However, the least root weights and root galls obtained in the okra plants could be attributed to the nematicidal effect of the flavonoid treatment on the nematodes which resulted in enhanced physiological activities in the treated plants. This is in line with the works of Ihejirika *et al.* (2006).

The increased okra pod weights recorded could be attributed to improved physiological activities of the Flavonoids treated plants. Aguet *et al.* (2013) reported that more leaf production on root-gall nematode controlled tomato plants added to the photosynthetic rate of the plants and characteristically resulted in increased fruit. This was most pronounced on the Leaf Flavonoid treated plants.

The delayed flowering obtained in the untreated (control) pots than the treated pots could be attributed to decrease in metabolic activities among plants grown on the untreated control pots. Idorenyiet *et al.* (2008) reported that *Meloidogyne javanica* delayed flowering in all tested tomato cultivars by decreasing the metabolic activities of the plant. Earliest flowering obtained in the treated

pots as dosage of Leaf Flavonoids treatment increased could therefore be attributed to the nematicidal effect of the Flavonoids on the nematode which created a favourable environment for the plants to flower.

The recorded improvement on growth and yield characteristics such as 100 dry seed weights associated with decreases in root-gall damage can be attributed to improved nutrient absorption and translocation to vegetative organs due to nematicidal effect of Leaf Flavonoids treatment. Aguet *al.* (2013) stated that plants with fewer root-galls would translocate more nutrients to vegetative organs for proper seed and pod development than heavily galled roots.

Mucilaginous property increased with increased rate of Leaf Flavonoid treatment. Agu *et al.* (2013) stated that root gall nematode decreased as application rate of *J. curcas* increased. Aguet *al.* (2009) also noted a steady increase in mucilaginous property in okra pods as okra galling response to *M. incognita* decreased at increased carbofuran rate.

The enhanced Phosphorus and Nitrogen content observed in the root-gall nematode infected plants could be due to uninterrupted translocation of phosphorus. Aguet *al.*, 2009 reported that phosphorus translocation was not interrupted in okra plants infected with *M. incognita* and that the use of Phosphorus by the parasite was no greater than 10% of the nutrient uptake by the plant. The significant increases observed in this study may be because Phosphorus enhances nitrogen uptake, efficiency and utilization during such important growth process as seed and fruit development in plants (Huber 1980).

The significant reduction of Fat, Calcium (Ca), Sodium (Na) and Moisture were observed in okra fruits harvested from root-gall nematode infected plants. Yang *et al.* (1976) reported increased degradation of fat into fatty acids in nematode infected *Arachyshypogeal*. Reduced Sodium (Na) and Calcium (Ca) had also been reported in the leaves of Vetch infected with *M. hapla* (Jenkins and Malek, 1966). Percentage Moisture of okra fruits was affected by both root-gall nematode infection

and Flavonoid from *Jatropha* parts. Significant moisture reduction occurred in fruits of infected plants. This also agreed with the earlier report of Kirkpatrick *et al.* (1991).

The observed negative correlation between root-gall index and okra yields showed that as the number of galls increased, the growth and yield attributes of okra decreased. This may be due to abnormal cells (galls) disruption of nutrient and moisture transport within the plants (Anwar and Mckenry, 2010).

The positive correlation between the leaf area, number of leaves produced and pod weights, 100 seed weights and mucilaginous property showed that increased number of leaves, leaf area at reduced galling responses led to higher photosynthesis and increased growth and yield attributes of the okra. Aguet *al.* (2013) also reported that more leaf production on root-gall nematode controlled okra plants added to the photosynthetic rate of the plants and characteristically resulted in increased pod weight yield.

CHAPTER V

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

All three *Jatropha curcas* L. cultivars; Cv. 'Illorin', Cv. 'Kwara' and Cv. 'Ihiagwa' screened for susceptibility to *Meloidogyne incognita* naturally endemic in the area can be exploited phytochemically and their bio active constituents (with nematicidal properties) harnessed for the innovation of an ecologically friendly non-synthetic alternative nematicide.

Correlation analysis showed that root-knot nematode infection correlated negatively with growth and yield parameters of okra. Phytochemical extracts of *Jatropha curcas* and plant parts at the respective rates/levels-controlled root-knot nematode (*Meloidogyne incognita*) infection on okra and enhanced the pod weights and Mucilaginous property.

5.1.1 Mortality

The comparative efficacy of all phytochemicals tested in vitro for nematicidal properties showed that at 5mls, nematode mortality was highest with Alkaloids (Leaf: 81.40 %, Seed: 88.33 %, Root :94.73 %). This was followed by Saponins (Leaf: 64.43 %, Seed: 87.23 %, Root: 85.7 %), Flavonoids (Leaf: 43.07 %, Seed: 56.10 %, Root 69.43 %) and Tannins (Leaf: 31.93 %, Seed: 59.73 %, Root: 57.77 %).

Comparative efficacy of all phytochemicals tested in vitro at 10 mls also showed that nematode mortality was highest with Alkaloids (Leaf: 89.43 %, Seed: 99.73 %, Root: 98.90 %), This was followed by Saponins (Leaf: 86.40 % : Seed: 98.90 %, Root: 96.10 %), Flavonoid (Leaf: 69.73 %, Seed: 72.50 %, Root : 94.73 %) and Tannin(Leaf: 69.43 %, Seed: 81.93 %, Root: 94.17 %).

Comparative effects of *Jatropha curcas* plant parts tested in vitro showed that for nematode mortality; Root Alkaloids at 5 mls achieved greatest mortality (94.73 %) when compared to other

plant parts while at 10 mls Seed Alkaloids recorded the highest mortality amongst other plant parts (99.73 %).

5.1.2 Hatchability

The comparative efficacy of all phytochemicals tested *in vitro* for nematicidal properties showed that at 5 mls nematode hatchability reduction was highest with Saponins (Leaf: 1.25, Seed: 0.08, Root: 0.66), This was followed by Alkaloid (Leaf :1.00, Seed:2.58, Root:0.16), Flavonoids (Leaf:1.42, Seed:1.00, Root :1.58) and Tannins (Leaf:3.25, Seed: 3.08, Root:2.16).

Comparative efficacy of all phytochemicals tested *in vitro* at 10 mls also showed that nematode hatchability reduction was again highest with Saponins (Leaf: 0.42, Seed: 0.00, Root: 0.42). This was followed by Alkaloids (Leaf: 1.00 Seed: 1.92, Root: 0.16), Flavonoids (Leaf: 1.33, Seed: 0.33, Root :0.25) and Tannins (Leaf: 0.58, Seed: 1.75, Root: 1.66).

Comparative effects of *Jatropha curcas* plant parts tested *in vitro* showed that for nematode hatchability, Seed Saponin at 5 mls achieved greatest reduction (0.08) when compared to other plant parts while at 10 mls Seed Saponin also recorded the highest or complete hatchability reduction (0.00).

The demand for nature-based pesticide (Biopesticides), predominantly those derived from plants is rising all over the world. This is because chemically synthesized nematicides are not only very expensive but has generated global concern and increased public awareness of environment together with the pollution potential and health hazards related to many conventional (synthetic) nematicides.

Conclusively, it appears that the egg shells of *M. incognita* are permeable to the nematicidal phytochemicals used in these studies, consequently killing the developing juveniles. Crude Saponin, Alkaloids, Flavonoids and Tannins extracts found to be active in this study could be useful in the

development of new nematicidal agents. This finding is therefore, very important from the view of controlling plant parasitic nematodes without the use of synthetic chemical nematicides.

Thus, it has been concluded from present research studies that certain biological principles present in *Jatropha curcas* plant parts play key roles as natural nematicides in controlling root knot nematode *M. incognita*.

However, it was observed (as has been reported in previous studies) that beyond certain levels of concentration the nematicidity of phytochemicals may interfere with the physiological functions of the plant. Certain plants found to be effective in suppressing the root-knot nematodes *in vitro* have also been reported to have a negative impact on the plant growth

5.2 Recommendations

The following strategies employed (*in vitro* and *in vivo*) in these experiments could be used to control root-knot nematode infections on Okra plants at various levels and also enhance its pod weights and mucilaginous property.

- 1 For complete (0.00) root-knot nematode egg hatchability reduction/inhibition, 10 mls of seed saponin is recommended. However, for cost benefit effectiveness and in other to avoid economic waste 5 mls of seed saponin (0.08) is therefore recommended since they are statistically the same in terms of efficacy.
- 2 Ten millilitres of Seed Flavonoid is recommended to achieve the same level of egg hatchability reduction efficacy obtained with 5 mls of Seed Saponin.
- 3 For optimum root-knot nematode hatchability reduction/inhibition, 12 h exposure interval is recommended compared to 24 h, 48 h and 72 h exposure intervals tested.
- 4 To achieve highest percentage mortality and control of root-knot nematode juveniles, 10 mls of Seed Alkaloids (99.73 %), Seed Saponins (98.9 %), Root Flavonoids (94.73 %) and Root Tannins (94.17 %) is recommended. However, for cost benefit effectiveness and in other to

avoid economic waste especially where the seed is unavailable, 5 mls of root Alkaloids is recommended in other to achieve (94.73 %) mortality of nematode juveniles.

- 5 For optimum root-knot nematode mortality 72 h exposure interval is recommended compared to 12h, 24 h and 48 h exposure intervals tested.
- 6 For increased okra yield, mucilaginous property, and nutritional composition of okra, 5mls of the following phytochemicals and *Jatropha* parts are recommended for maximum productivity in the following order; Leaf Tannins, Root and Seed Alkaloids, Seed and Leaf Saponins, Seed and leaf Flavonoid respectively.
- 7 Correlation analysis showed that root-knot nematode infection correlated negatively with growth and yield parameters of okra. Phytochemical extracts of *Jatropha curcas* and plant parts at the respective rates/levels-controlled root-knot nematode (*Meloidogyne incognita*) infection on okra and enhanced the pod weights and Mucilaginous property and are therefore recommended.

5.3 Contribution to Knowledge

Scientific validation of bioactive principles in *Jatropha curcas* cultivars and parts studied now makes it possible for crude extracts with known active bio active principles to be harnessed for the development of new environmentally friendly and sustainable nematicidal agents.

Secondly, the three *Jatropha curcas* cultivars; Cv. 'Illorin', Cv. 'Kwara' and Cv. 'Ihiagwa' evaluated in this work has been found to be resistant to *M. incognita* infection and as such could be utilized and further exploited in nematode control or management programme

5.4 Future Research Work

Since crude phytochemical extracts found to be active in this study could be useful in the development of new nematicidal agents, the future therefore, looks bright for identifying new classes

of pesticides from natural plants to replace the synthetic dangerous and expensive chemicals used at present. Further work can be carried out to:

- a. To characterize phytochemical types found to be active in this study
- b. To assess the effect of these phytochemical on other pathogenic organisms
- c. To evaluate the effect of these phytochemicals at different dilution levels to avoid waste and optimize benefits.

Finally, since the egg shells of *M. incognita* are permeable to the nematicidal phytochemicals used in this investigation, consequently killing the developing juveniles. Further research should be undertaken on the utilization and concentration of Crude Saponins and Alkaloids extracts found to be most active in this study for the development of new nematicidal agents.

References

- Abad, P., Gouzy, J., Aury, M.J. and Castagnone-Sereno, P. (2008). Genome sequence of the metazoan plant-parasitic nematode *Meloidogyne incognita*. *Nature Biotechnology*, **26**, 909-915.
- Abawi, H.S. and Windmer T.L. (2000). Impact of Soil Health Management Practices on Soil Borne Pathogens, Nematodes and Root-knot Disease of vegetable crops. *Applied Soil Ecology*, **15**, 37-47.
- Abubakar, U., Adamu, T. and Manja, S.B. (2004). Control of *Meloidogyne incognita* (Kofoid and White) Chitwood (root-gall nematode) of *Lycopersicon esculentus* using cow dung and urine. *African Journal of Biotechnology*, **3**(8), 379-381.
- Adebowale, A., Tanimola, and Papadopoulos, S. (2014.). Management of *Meloidogyne incognita* on Okra Using Three Weeds in Nigeria. *Journal of Applied. Science. & Agriculture.*, **9**(9), 137-144,
- Adegbite, A. A. and Adesiyani, S.O. (2005). Root extracts of plants to control Root-knot Nematode on edible Soybean. *World Journal of Agricultural Sciences*, **1**(1), 18-21.
- Adesiyani, S.O. (1985). Comparative studies on possible Nematicidal Effects of Spores of *Aspergillus Niger*, *Penicillium solerotigenum* and *Fusarium oxysporum* on yam Nematode. *Nigerian Journal for Plant Protection*, **9**.
- Adesiyani, S.O., Caveness, F.E., Adeniji, M.O. and Fawole, B. (2000). Nematode Pests of Tropical crops Heinemann Educational books (Nig.) PLC, 1-24.
- Agu C.M. (2005). Control of Root-Knot Nematode Disease on Tomato by *Xylopium aethiopicum* (Stapf & Hubb), *Ocimum viride* (Lin) and *Hypthis nigrum* (Pegs), *Journal of Sustainable Agriculture*, **26**(2), 149-153.
- Agu, C.M. (2006). Susceptibility of Soybean Cultivars to Root Nematodes in South Western Ethiopia. *Tropical Science*. **46**(3), 143-146.
- Agu, C.M. (2008a). Effects of Intercropping on Root-gall Nematode Disease on Soybean. *Plant Sciences Research*, **1**(1), 20-28.
- Agu, C.M. (2008b). Effect of Organic Manure Types on Root-Gall Nematode Disease and African Yam Bean Yield. *Plant Science Research*, **1**(1):17-19.
- Agu, C.M. and Ogbuji. R.O. (1996). Soybean resistance to the root-gall nematode, as influenced by Potassium nutrition. *East African Agricultural Journal* **66**(3), 273-276.
- Agu, C.M., Mbuka, C.O. and Ogwudire, V.E. (2009). Influence of root-gall nematode on mucilaginous property and nutrient composition of Okra (*Abelmoschus esculentus* L. Moench). *Bionature*, **29**(2), 73-77.
- Agu, C.M., Nwagbaga, A.C., Uwandu, C.G., Onoh, P., Mbuka, C.A., Ojiako, P.O., Ndulue, N.K., and Ogwudire, V.I. (2013). Effect of *Jatropha Curcas* on Root-gall Nematode Disease and the Consequent Proximate Composition of Okra. *Bionature Journal of India*, **33** (2), 59-62.

- Agwu, J.E. and Ezigbo, J.C. (2005). Effects of *Meloidogyne incognita* (Root-knot nematode) on the development of *Abelmoschus esculentus*(okra).A Thesis in the Department of Zoology, University of Nigeria,Nsukka, Enugu State, Nigeria.
- Ahuchaogu, C.E., Ojiako, F.O. and Kabeh, J.D. (2014). Evaluation of *Jatropha curcas* L. an Extracts in the control of some field insect pests of cowpea. *International Journal of Scientific and Technology Research*, **3** (3): 136-141.
- Aiyelaagbe, O.O., Adeniyi, B.A., Fatunsi, O.F. and Armish, B.D. (2007). In vitro antimicrobial activity and phytochemical analysis of *Jatropha curcas* roots. *International Journal of Pharmacology*, **3**, 106-110.
- Akhtar, M. and Malik A. (2002). Roles of Organic Soil Amendment and Soil Organisms in the Biological Control of Plant-Parasitic Nematodes. *A Review of Bioresources Technology*, **24**: 35-47.
- Akhtar, M. and Malik, A., (2000). Roles of organic soil amendments and soil organisms in the biological control of plant-parasitic nematodes: a review. *Bioresour. Technol.* **74**, 35-47.
- Akinmoladun, A.C., Ibukun, E.O., Afor, E., Obuotor, E.M. and Farombi, E.O. (2007). Phytochemical Constituents and Antioxidant Activity of Extract from the Leaves of the *Ocimum gratissimum*. *Sci. Res. Essay*, **2**, 163-166.
- Akinpelu, D.A., Aiyegoro, O.A., and Okoh, A.I. (2009). The Bioactive Potentials of Two Medicinal Plants Commonly used as Folklore remedies among tribes in West Africa. *African Journal of Biotechnology*, **8** (9), 1660-1664.
- Alabama, A. and Alabama, M. (2009). Nematode Control in The Home Vegetable Garden. Alabama Cooperative Extension System.
- Amin, M.M, Kajal, P. Uzma, T. and Ekata, K. (2016). Estimation of Alkaloids, Saponins and Flavonoids, Content in Various Extracts of *Crocus sativa*. *Journal of Medicinal Plants Studies*; **4**(5), 171-174.
- Anwar, S. A. and McKenry, M. V. (2010). Incidence and reproduction of *Meloidogyne incognita* on vegetable crops genotypes. *Pakistan Journal of zoology*, **42**(2):135-141.
- AOAC, (1990). Official Methods of Analysis. Association of Official Analytical Chemists.Food Compositor, additives natural Contaminants. AdrichRc (ed.) Vol. 2, 15th ed. Association of Official Analytical Chemist Inc. USA.
- Aubertot, J.-N., West, J.S., Bousset-Vaslin, L., Salam, M.U., Barbetti, M.J., Diggle, A.J., (2006). Improved resistance management for durable disease control: A case study of phoma stem canker of oilseed rape (*Brassica napus*). *European. Journal of Plant Pathology* **114**, 91-106.
- Ayanbimpe, G.M. and Fagbemi, O.I. (2005). Antifungal Activity of Extracts from a Hedge Plant- *Jatropha curcas* on Some Pathogenic Bacteria. *Nigerian Annals. Natural Science.*, **6**: 18-22.
- Ayres, M.P., Clausen, T.P., MacLean, S., Redman, A.M. and Reichardt, P.B. (1997). Diversity of Structure and Anti herbivore Activity in Condensed Tannins. *Ecology* **78**, 1696-1712.

- Bello, O.A. (2015). Influence of Hormones and Imbibition on the Growth and Yield of *Abelmoschus esculentus* (Okra). *Researcher*;7(11):73-76]. (ISSN: 1553-9865). <http://www.sciencepub.net/researcher>. 10. doi:10.7537/marsrsj071115.10.
- Berger, A. (2002). Using Natural Pesticides: Current and Future Perspective. A Report for the Plant Protection Improvement Program in Botswana Zambia and Tanzania. *Bioresource Tech* 98: 2057-2064.
- Bhatti, D.S. and Jain, R.K. (2013). Estimation of Losses in Okra, Tomato and Brinjal yield due to *Meloidogyne incognita*. *Indian Journal of Nematology*, **7**(1) 37-41.
- Bishop, A.H., Gowen S.R., Pembroke B. and Trotter J.R. (2007). Morphological and molecular characteristics of a New Species of *Pasteuria parasitic* on *Meloidogyne ardenensis*. *Journal of Invertebrate Pathology*, **96**: 28-33.
- Bisset, G.H. and Wichtl, M. (1994). Habal Drugs and Phytopharmaceuticals. Medpharm GmbH Scientific Publishers, *Stuttgart CRC Press*, Boca Raton, 91-95.
- Blouin, M.S., Yowell, C.A., Courtney, C.H., and Dame, J.B. (1995). Host Movement and the Genetic Structure of Populations of Parasitic Nematodes. *Genetic*, **141**, 1007-14
- Bolles, B. and Johnson, L. (2012). Nematode damage of Okra. University of Florida. IFAS Extension.
- Bremner, J.M. (1996). Nitrogen – Total In: Spark D.L. (ed.) *Methods of Soil Analysis, Part 3, Chemical Method. 2nd Edition, SSSA Book series* No. 5, SSSA, Madison, W.I. 1085-1121.
- Bridge, J., Plowright, R.A. and Peng, D. (2005) Nematode parasites of rice. In: Luc, M., Sikora, R.A. and Bridge, J. (eds) *Plant Parasitic Nematodes in Subtropical and Tropical Agriculture*, 2nd edn. CAB International, Wallingford, UK, 87–130.
- Brown, C.R., Mojtahedi, H., James, S., Novy, R.G. and Love, S. (2006). Development and evaluation of Potato breeding Lines with Introgressed resistance to Columbia Root-Knot nematode (*Meloidogyne chitwoodi*). *American Journal of Potato Research*, **83**, 1-8
- Brown, C.R., Mojtahedi, H., Zhang, L.H. and Riga. (2009). Independent Resistant Reactions Expressed in Root and Tuber of Potato Breeding Lines with Introgressed Resistance to *Meloidogyne Chitowoodi*. *Phytopathology*, **99**, 1085-1089.
- Carels, N. (2009). *Jatropha curcas*: A review. In Kader, J.C. & Delseny, M. (Eds), *Advances in Botanical Research*, **50** (9), 39-86.
- Castillo, P., Di Vito, M., Vovlas, N. and Jiménez-Díaz, R.M. (2001). Host-parasite relationships in root-knot disease of white mulberry. *Plant Disease*, **85**, 277-281.
- Charles O., Xavier and Deborah (2016). Plant Parasitic Nematodes in Corn. LSU College of Agriculture <https://www.isuagcenter.com>
- Che, J., Abawi, G.S. and Zuckerman, B.M. (2000). Efficiency of *Bacillus thuringiensis*, *Paecilomycesmarguandii* and *Streptomyces constaricanus* with and without organic amendment against *Meloidogyne hapla* Infecting Lettuce. *Journal of Nematology*, **32**, 70-77.

- Chitowood, B.G. (1949). Root-knot Nematodes part 1. A revision of Genus *Meloidogyne goeldi*, 1887 Proc. Heminth. Soc. *Klash*, **10** (2), 90-104.
- Claudius-Cole, A.O. (2018) Comparative Effect of *Rotylenchulus reniformis* and *Meloidogyne incognita* on the Productivity of okra in Nigeria. *Australian Journal of Basic and Applied Sciences*, 12(9): 20-25.
- Cookey, C.O. (2017). Susceptibility, productivity and selected cultural protection of some Cowpea varieties in Root-gall nematode endemic ultisol in Owerri, Nigeria. *PhD dissertation*, Federal University of Technology, Owerri
- Cui, J., Sartin, C.V., Pleiss, J.A. and Wolfne, M.F. (2013). Cytoplasmic Polyadenylation is a major mRNA regulator during Ogenesis and egg activation in Drosophila Development. *Bio*. **383**(1), 121-131.
- Dawuda, M.M. Boateng, P. Y. Hemeng O.B. and Nyarko, G. (2011). Growth and yield response of carrot (*Daucus carota* L) to different rates of soil amendmets and spacing. *Journal of Science and Technology*, 31(2), 11-20.
- De Waele, D. and Elsen A. (2007). Challenges in Tropical Plant Nematology. *Annual Review of Phytopathology*, **45**, 457-485.
- Dehgan, B. and Webster, G.L. (1979). Morphology and Infrageneric Relationships of Genus *Jatropha* (Euphorbiaceae). *University of California Publications in Botany*, **74** (79), 11-27.
- Devappa, R.K., Makkar, H.P.S., and Becker, K. (2010). *Jatropha* nematocidal- a review *Journal of Nematicidalology and Environmental Health, Part B*, 13, 476-507.
- Dimaandal, L.G, (2003). Antiseptic Property of the Alkaloid Content from Ethanol Extract of SamaneaSaman (Acacia) Leaves. Unpublished Master's Thesis BSU, Batanges City.
- Dudu, P.O. and Williams, J.O. (1991). Screening of Some Local Plants for their Insecticidal Effects on Stored Products Insects Nigerian Stored Product Institute. **13**: 23.
- Edeoga, D.H., Okwu, D.E. and Mbaebie, O.B. (2005). Phytochemical Constituents of Some Nigerian Medicinal Plants. *African Journal of Biotechnology*, **4**: 10-5897.
- Eisenback, J.D., Hirschmann, H., Sasser, J.N., and Triantaphyllou, A.C. (1981). A guide to the four most common species of root-knot nematodes (*Meloidogyne* spp) with a pictorial key. *A cooperative publication of North Carolina State University and USAID.*, pp: 48.
- El Diwani, G. (2009), Sh. El Rafie, S. Hawash Antioxidant activity of extracts obtained from residues of nodes leaves stem and root of Egyptian *Jatropha curcas*; *African Journal of Pharmacy and Pharmacology*, 3 (2009), 521-530.
- El-Nahhal, Y. (2004). Contamination and Safety Status of Plant Food in Arab Countries. *Journal of Applied Sciences*, **4**: 411-417.
- El-Olemy, M.M., Farid, J.A. and Abdel-fattah, A.A. (1994). Experimental Phytochemistry Laboratory Manual. College of Pharmacy King Saudi University, Riyadh, 3-61.

- Emeasor, K.C. Emosairue, S.O. and Mmegwa, V.V. (2002). Nematicidalological Assessment of Some Nigeria Seed Powders against Maize Weevil, *Sitophilus Zeamais*. *African Journal of Applied Zoological. Environmental Biology.*, **4**:82-86.
- Errico, F. P. and Di Maio, F.D. (2010). Effect of Some Organic Materials on Root-Knot Nematodes on Tomatoes in Field Preliminary Experiments. *Nematology. Meditarenian.* **8**:107-110.
- Federal, Department of Agriculture Land Resources (FDALR). (1985). Reconnaissance Soil Survey Reports of Anambra, Cross Rivers, Imo and Rivers States. FDALR, Kaduna.
- Food and Agricultural Organization (2001). *Guidelines on good practice for ground application of pesticides and Chemical Plant protection and the ecosystem. FAO pesticide Bull. Rome.* **40**, 13-18.
- Gebhardt, C. and Valkonen J.P.T. (2001). Organization of genes Controlling Disease Resistance in the Potato Genome. *Annual Review of Phytopathology*, **39**, 79-102.
- Gebissa, Y.W. (2021) Biology, Taxonomy, and Management of the Root-Knot Nematode (*Meloidogyne incognita*) in Sweet Potato. *Advances in Agriculture*, vol. 2021, Article ID 8820211, 13 p. <https://doi.org/10.1155/2021/8820211>
- Goeldi, E.A. (1887). Relatoria Sobre a Molestia do Cafeirona provincial de Rio de Janeiro Archos Nus hac Rio de Janeiro, 87-112.
- Gupta, D.D., Haque, E., Islam, N., Mondal, S.I., and Shibib, B.A. (2010). Antimicrobial and Cytonematicidal Activities of *Jatropha curcas* (Euphorbiaceae). *Dhaka University Journal of Pharmaceutical Science*, **9** (10), 139-142.
- Harbone, J.B., 1973. Phytochemical Methods. London. Chapman and Hall, Ltd., 49-188.
- Heller, J. (1996). Physic nut *Jatropha curcas* L., Promoting the Conservation and Use of Underutilised and Neglected Crops (1stEdn). International Plant Genetics and Crop Plant Research Institute, Gatersleben (IPGRI), Rome, Italy.
- Hendershot, E.H., Lalonde, H. and Duquette, M. (1993). Soil Reaction and Exchangeable Acidity. In: Carter, M.R. (ed.) Soil sampling and Methods of soil Analysis, Canadian Soc. Soil Sci., *Lewis Publishers, London.* 141-145.
- Hill, D.S. and Waller, J.M. (1982). Pests and Diseases of Tropical Crops Vol. 1 Principles and Methods of Control. Longman, U.K. 1-21.
- Hong, L, Li, G., Zhou, W., Wang, X., Zhang, K., (2007). Screening and isolation of a nematocidal sesquiterpene from *Magnolia grandiflora*. *Pest Managment. Science.* **63**, 301-305.
- Huber, M.D. (1980). The use of fertilizers and organic amendments in the control of plant disease. Handbook of Pest Management in Agriculture. Vol.1 (Pimentel. D. ed.) CRC Press, New York, 357-394.
- Hunt, D and Handoo, Z. (2009). Taxonomy, identification and principal species. © CAB International 2009. Root-knot Nematodes 55-97. (eds R.N. Perry, M. Moens and J.L. Starr)

- Ibrahim, I.D., Muhammad, I., Ashiru, S., Sani, I., Shehu, K., Aliero, A.A. and Aliyu, R.U. (2014) Qualitative and Quantitative Phytochemical Screening of Mimosa Pudica Plant Extracts (Touch Me Not). *American Journal of Biological Chemistry*, 2, 8-16.
- Ibrahim, M.A.R., and Srour, H. (2013). Saponins Suppress Nematode cholesterol Biosynthesis and inhibit Root-knot nematode Development in Tomato seedlings. *Nat. Prod. Chem. Res*, 2:123.
- Idorenyin A. Udo, Michael I. Uguru, Rufus O. Ogbuji and Donald A. Ukeh, (2008). Sources of Tolerance to Root-Knot Nematode, *Meloidogyne javanica*, in Cultivated and Wild Tomato Species. *Plant Pathology Journal*, 7: 40-44.
- Igbinosa, O.O., Igbinosa, E.O., and Aiyegoro, O.A. (2009). Antimicrobial Activity and Phytochemical Screening of Stem Bark Extracts from *Jatropha curcas* (Linn). *African Journal of Pharmacy and Pharmacology*, 3 (9), 58-62.
- Igbinosa, O.O., Igbinosa, I.H., Chigor, V.N., Uzunugbe, O.E., Oyedemi, S.O., Odjadjare, E.E., Okoh, A.L., and Igbinosa, E.O. (2011). Polyphenolic contents and antioxidant potential of stem bark extract from *Jatropha curcas* (Linn). *International Journal of Molecular Sciences*, 2958-2971.
- Ihejirika, G.O., Nwufu, M.I., Duruigbo, C.I., Onwerenadu, E.U., Obilo, O.P., Onuoha, E.R., and Ogbede, K.O. (2006). Effects of Plant Extracts and Plant Density on the Severity of Leaf Spot Disease of Groundnut in Imo State. *Journal of Plant Sciences*, 1(4), 374-377.
- IITA (1981). Proceedings of the Third Research Planning Conference on Root-Knot Nematodes, *Meloidogyne* spp. Ibadan, Nigeria: IITA.
- Ioannou, N. (2000). Soil Solarization as a Substitute for Methyl Bromide Fumigation in Greenhouse Tomato Production in Cyprus. *Phytoparasitica*, 28, 248-256.
- Irene, M.V. and Carino, F.A. (2011). Antimicrobial Activity of New Phorbins from *Jatropha curcas* Linn. (Euphorbiaceae) leaves. *Zeitschrift fur Naturforschung*, 66c (11), 441-446.
- Iwu, M.M. (1993). Handbook of African medicinal Plants. CRC Press, Florida, USA, 441-446.
- Janathan, E.I. and G. Rajendran, (2002). Assessment of avoidable yield loss in banana due to root-knot nematode *Meloidogyne incognita*. *Indian J. Nematol.*, 30: 162-164.
- Janssen, G.J.W., Scholten, O.E., Norel, A.V. and Hoogendoorn, C.J. (1998). Selection of Virulence in *Meloidogyne chitwoodi* to resistance in the Wild Potato *Solanum fendleri*. *European Journal of Plant Pathology*, 104, 645-651.
- Jenkins, W. R. and Malek, R. B. (1966). Influence of nematodes on absorption and accumulation of nutrients in Vetch. *Soil Science* 101, 46-49.
- Jesse, Y.A. Sule, A. and Philip, C.B. (2006). Doruwa fruit husk and hyptis leaves for controlling root-knot nematodes (*Meloidogyne incognita*) in Tomato. *Journal of Tropical Agriculture* 44 (1-2), 83-85.

- Jongschaap, R.E.E., Corre, W.J., Bindraban, P.S., and Brandenburg, W.A. (2007). Claims and Facts on *Jatropha curcas* L. Global *Jatropha curcas* Evaluation, Breeding and Propagation Programme. Plant Research International B.V., Wageningen, *The Netherlands*, pp. 1-4.
- Jongschaap, R.E.E., Corre, W.J., Bindraban, P.S., and Brandenburg, W.A. (2007). Claims and Facts on *Jatropha curcas* L. Global *Jatropha curcas* Evaluation, Breeding and Propagation Programme. Plant Research International B.V., Wageningen, *The Netherlands*, pp. 1-4.
- Jun, H.K., Park K.Y., and Jo, J.B. (1989). Inhibitory effects of ginseng saponins on aflatoxin production in culture. *Chemistry. Abstract.* **106**: 116-199.
- Kariuki, G.M. and Dickson, D.W. (2007). Transfer and Development of *Pasteuria penetrans*. *Journal of Nematology*, **39**, 55-61.
- Khan, A., Asif, M., Tariq, M., Rehman, B., Parihar, K. and Siddiqui, M.A. (2017). Phytochemical investigation, nematostatic and nematocidal potential of weeds extract against the root-knot nematode, *Meloidogyne incognita* in vitro. *Asian Journal of Biological. Science.* **10**: 38-46.
- Kiewnick, S., Dessimoz, M. and Franck, L. (2009). Effects of the Mi-1 and the N root-knot resistance gene on infection and reproduction of *Meloidogyne enterolobii* on tomato and pepper cultivars. *Journal of Nematology*, **41**, 134-139.
- Kimpinski, J., Arsenault, W.J., Gallant C.E., and Sanderson, J.B. (2000). The Effect of marigolds (*Tagetes* spp.) and Other Cover Crops on *Pratylenchus penetrans* and on Following Potato Crops. *Supplement to the Journal of Nematology*, **32**(45):531-536
- Kirkpatrick, T.L, Oosterhuis, D.M. and Wullschleger, S.D. (1991). Interaction of *Meloidogyne incognita* and water stress in two cotton cultivars. *J. Nematol.* **23**: 462-467.
- Koon-Hui, W., Cerruti, R.H. and Antoon, P. (2007). Protecting Crops from Nematode Pests: Using Marigold as an Alternative to Chemical Nematodes. Cooperative Extension Service College of Tropical Agriculture and Human Resources. *Plant Disease*, PD -35, 1-6.
- Krammer, R.P., Hindorf, H., Jha H.C., Kallage, J. and Zilliken, F. (1984). Antifungal Activity of Soyabean and Cowpea Isoflavones and their Reduced Derivatives. *Photochemistry.* **23**(10), 2203.
- Kuljanabhadgavad, T., and Wink, M. (2009). Biological activities and Chemistry of Saponins from *Chenopodium quinoa* Willd. *Phytochemical Review* 8:473-490
- Kumar, A. and Sharma, S. (2008). An Evaluation of Multipurpose Oil Seed Crop for Industrial Uses (*Jatropha curcas* L.): A Review. *Industrial Crops and Products*, **28** (8), 1-10.
- Kumar, D. and Singh, K.P. (2006). Assessment of predacity and efficacy of *Arthrobotrys dactyloides* for biological control of root knot disease of tomato. *J. Phytopathol.* 154, 1-5.
- Lasisi, O.T., Soetan, K.O., Fafunso, M.A. and Aiyelaagbe O.O. (2003). Effects of condensed saponins on hatching of bovine gastrointestinal nematodes in vitro. *Niger. Vet. J.* 24(3): 30-34.
- Maclean, E.V. (1982). Aluminum in Page, A.L. Miller, R. H. and Keeney D. R. (eds) Methods of Soil Analysis, Parts 2, *Am Soc Agron Madison W.I.* 978-998.

- Mahajan, R., Kaur, D.J. and Bajaj K.L. (1992). Nematicidal Activity of Some Phenolic Compounds against *Meloidogyne incognita*. *Nematiologia Mediterranea*, **20**:217-219.
- Maistrello, L., Vaccari, G. and Sasanelli, N. (2010). Effect of chestnut tannins on the root-knot nematode *Meloidogyne javanica* *Parasitological Institute of SAS, Helminthologia*, **47**, 1: 48 – 57.
- Makkar, H.P.S., Francis, G., and Becker, K. (2009). *Jatropha curcas*, a promising crop for the generation of biodiesel and value-added coproducts. *European Journal of Lipid Science and Technology*, **111**(9), 773-787.
- Maleita CM, Curtis RHC, Powers SJ, Abrantes I, (2012). Host status of cultivated plants to *Meloidogyne hispanica*. *European Journal of Plant Pathology*.
- Manpong, P., Douglas, S., Douglas, P.L., Pongamphai, S., Teppaitoon, W., Kaewprakaisangkul, O. (2009). Responses surface methodology applied to the extraction of phenolic compounds from *Jatropha curcas* Linn. Leaves using supercritical CO₂ with a methanol co-solvent. *Journal of Food Process Engineering*, **34** (2009), 1661-1681.
- Marais, M. (2012). *Meloidogyne enterolobii* (*Meloidogyne mayaguensis*): ‘n Gevallestudie van ‘n plant parasitiese nematode. Proceedings of the year Symposium of the Biological Sciences Division of the SA Academy of Arts and Sciences, North West University, Potchefstroom.
- Marshall, A.J. (2002). Sunn hemp (*Crotalaria juncea*) as an organic amendment in crop production. M.S. Thesis, University of Florida, Gainesville.
- Marull, J., Pinochet, J. and Rodrigues-Kabana, R. (1997). Agricultural and municipal compost residues for control of Root-knot nematodes in tomato and pepper. *Compost Science and Utilization* **5**, 6-15.
- Matsushashi R., Satou T. Koike K., Yokosuka A. Mimaki Y., Sashida Y. and Nikaido T. (2002). Nematicidal activity of isoquinoline alkaloids against a specie of Diplogastridae. *Planta Med.* **68**:169-171.
- Mba, O.I., Ohazuruike, N.C., and Okorochoa, E.A. (2005). An assessment of the nematicidal potential of some plant products in the control of root knot nematode (*M. incognita*, Kofoid and White) on tomato plant. *Proceedings of the 32nd Annual Conference of Nigeria Society for Plant Protection. 15th – 20th May, 2005. University of Port Harcourt, Nigeria*, 37-41.
- McSorley, R. and Gallaher, R.N. (1995). Effect of Yard Compost on Plant-Parasitic Nematode Densities in Vegetable Crops. *Journal of Nematology*, **27**, 545-549.
- Miller, R.W. and Donhue, R.L. (1990). Soils. An Introduction to Soils and Plant Growth, Sixth Edition Prentics-Hall, Inc Englewood Cliffs. N.J, USA. 1-10.
- Mitkowski, N.A. and Abawi. G.S. (2003). Root-knot nematodes. *The Plant Health Instructor*. DOI:10.1094/PHI-I-2003-0917-01.
- Moens, M. Perry, R.N. and Starr, J.L. (2009). *Meloidogyne species* – a diverse group of novel and important plant parasites. In Perry R.N., Moens M. and Starr J.L. (eds.), Root-knot nematodes, 1-17. CAB International, Wallingford UK.

- Mohamed, S. (2010). Biological, Chemical and Molecular Studies on the Systemic Induced Resistance in Tomato against *Meloidogyne incognita* caused by the endophytic *Fusarium oxysporum*, F0162. Institute of Crop Science and Resource Conservation, Faculty of Agriculture, University of Bonn, PhD Thesis.
- Mojtahedi, H., Santo, G.S., Hang, A.N. and Wilson, J.H. (1991). Suppression of Root-Knot Nematode Populations with Selected Rapeseed Cultivars. A Green Manure. *Journal of Nematology*, **23**: 170-17.
- Mujeebur, R.K. (2012). Nematodes, an Emerging Threat to Global Forests: Assessment and Management. *Plant Pathology Journal*, **11**: 99-113.
- Mukhtar, T., Hussain, M.A. and Kayani, M.Z. (2014). Yield responses of 12 okra cultivars to southern root-knot nematode (*Meloidogyne incognita*). *Crop Protection*, **56**: 25-30.
- Mukhtar, T., Israr, A., Zameer, M., Arshad, H.M., Kayani, S.B., Murad, R.A., and Muhammad, A. (2013). Estimation of Damage to Okra by Root-Knot Disease Mated by *Meloidogyne incognita*. *Pakistan Journal of Botany*, **45** (3): 1023 – 1027.
- Namuli, A., Abdullah, N., Sieo, C.C., Zuhainis, S.W., and Oskoueian, E. (2011). Phytochemical Compounds and Antibacterial Activity of *Jatropha curcas* Linn. Extracts. *Journal of Medicinal Plants Research*, **5** (11), 3982-3990.
- Nelson, D.W. and Sommer, L.E. (1982): Total Carbon, Organic carbon and organic matter. In page, A.L. Miller, R.H. and Keeney, D.R. (eds). *Methods of soil Analysis, Part 2*, Am SocAgron, Madison W.I. 539-579.
- Neuwinger, H.D. (1996). *African Ethnobotany: Poisons and Drugs; Chemistry, Pharmacology, Nematicidalology*. Chapman and Hall, New York. 500-509.
- Nico, A.L, Jimenez-Diaz, and Castillo, P, (2003). Solarization of soil in Piles for the Control of *Meloidogyne incognita* in Olive Nurseries in Southern Spain. *Plant Pathology*, **52**, 770-8
- Norshie, P.M., Been, T.H. and Schomaker, C.H. (2011). Estimation of Partial Resistance in Potato Genotypes against *Meloidogyne chitwoodi*. *Nematology*, **13**, 447-489.
- Nwokocha, A Blessing, I.O. Agbawa and Okoli, B.E (2011). Comparative Phytochemical Screening of *Jatropha* L. Species in the Niger Delta *Research Journal of Phytochemistry* **5**(2):107-114 DOI: [10.3923/rjphyto.2011.107-114](https://doi.org/10.3923/rjphyto.2011.107-114).
- Obasi, N.L., Ejikeme, M.P., and Egbuna, C.A.C. (2011). Antimicrobial and Phytochemical Activity of Methanolic Extract and its Fractions of *Jatropha curcas* Linn. (Euphorbiaceae) Stem Bark. *African Journal of Pure and Applied Chemistry*, **5**(11), 92-96.
- Ogbuji, R.O. (1981). Effect of Farm Yard Manure on Root-knot Nematode Population on Carrot Der. *Tropenlandwirth, Zetschrift for Dire Land Wirtschhft in enTropen and subtropen Jahrgang*. **82**, 25-29.

- Ogwulumba, S.I. (2011). The effects of aqueous extracts, soil amendments and coloured plastic mulches on the control of root-knot nematode (*Meloidogyne javanica* Treub) infections on tomato (*Solanum lycopersicon*). *Ph.d Dessertation*. Department of Crop Science. University of Nigeria, Nsukka.
- Ogwulumba, S.I., Ugwuoke K.I., and Iloba, C. (2008). Prophylactic Effect of Paw-paw Leaf and Bitter Leaf Extracts on the Incidence of Foliar Myco-pathogens of groundnut (*Arachis hypogea* L.) in Ishiagu, Nigeria. *African Journal of Biotechnology*, **7**(16): 2878-2880.
- Ohazurike, N. C., Omuh, M. O., and Emeribe, E. O. (2003). The use of seed extracts of the physic nut (*Jatropha curcas* L.) in the control of maize weevil (*Sitophilus zeamais* M.) in stored maize grains (*Zeamays* L.). *Global Journal of Agricultural Science*, **2**, 86– 88.
- Ojiako, F. O., Ihejirika, G. O. and Aguwa, U. O. (2015). Comparative bioactivity of different solvent extracts of the root and seeds of *Jatropha curcas* L. and Chlorpyrifos, against tailor ants (*Oecophylla longinoda* Latreille) (Hymenoptera: Formicidae). *FUTO Journal Series (FUTOJNLS)*. **1** (2); p-ISSN: 2467-8325; e-ISSN: 2476-8456.
- Ojiako, F.O., Ofoh, M.C., Esonu, B.O., Onweremadu, E.U., Ihejirika, G.O., Dialoke, S.A., Echecrobia, C.O., Adikuru, N.C., Okafor, O.E., Ogwudire, V.E., Nkwocha, V.I., and Chukweke, T.C. (2011). Preliminary Evaluation of Nursery and Early Field Propagation Practices for *Jatropha curcas* L. *Journal of Agricultural Research Development*, **10** (2).
- Oka, Y. S.; Nacar, E.; Putieusky, U.; Ravid, Y.; Zohara, A and Spiegel, Y. (2001). Nematicidal activity of essential oils and their components against the root-knot nematode. *Phytopathology*, **90**(7): 710-715.
- Okendi, E.M., Kariuki, G. M., Marais, M and Moleleki, L.N. (2014). The threat of root-knot nematodes (*Meloidogyne* spp.) in Africa; a review. *British Society for Plant Pathology*. Vol 63; Issue 4 pages 727-737
- Okeniyi, M. O., Fademi O. A., Orisajo S. B., Adio S.O., Otunoye, A. A and Adekule, O. (2010). Effect of Botanical Extracts on Root-Knot nematode Infection in Cacao seedlings. *Journal of Applied Biosciences*
- Okon, M.A., Osuji, G.E, Oweremadu, E.U, Agim, L.C., Uzoho, B.U, Osuaku, S.K and Ahukaemere, C.M (2014). Differences in Soil Physicochemical Properties on a Catenary Landscae in Owerri, Southeastern Nigeria. *International Journal of Applied Research and tech.* **3**(10), 11-15
- Okubo, K., Kudou S., Uchida T., Yoshiki, Y., Yoshikoshi, M., and Tonomura M. (1994). Soyabean Saponin and Isoflavonoids. Structure and Antiviral Activity against Human Immunodeficiency Virus in Vitro ACs Symp. Ser. Food Phytochem. *Cancer Prevent.* **1**: 330-339.
- Okwu, D.E. (2004). Phytochemicals and vitamin content of indigenous spices of South Eastern Nigeria. *Journal of Sustainable Agricultural environment*, **6**: 30-34.
- Oleszek, W., Price, K.R., Colquhoun, I.J., Jurzysta, M., Ploszynski, M. and Fenwick, G.R. (1990). Isolation and identification of Alfalfa (*Medicago sativa* L.) root saponins: their activity in relation to a fungal bioassay. *Journal of Agric Food Chemistry*, **38**:1810-1817.

- Olson, S.R. and Sommers, L.E. (1990). Phosphorus In: Page, A.L. (ed): Methods of Soil Analysis. Part 2, Agron, Monogr. No. 9, Madison, W.I. 403-431.
- Omar, S.A., Abdel-Massih M.I., Mohammed, B.E. (1994). Use of Saponin to control the root-knot nematode *Meloidogyne javanica* in tomato plants. *Bulletin of Faculty of Agriculture of Cairo*; **45**: 933-940.
- Onkendi, E.M. and Moleleki, L.N. (2013). Detection of *Meloidogyne enterolobii* in Potatoes in South Africa and Phylogenetic Analysis Based on Intergenic Region and the Mitochondrial DNA sequences. *European Journal of Plant Pathology*, **136**: 1-5.
- Ononuju C. C., Ekeoma P., Orihara C. C. and Ikwunagu E. A. (2015). Evaluation of the effect of some pesticides for the control of root-knot nematode (*Meloidogyne* spp) on *Telfairia occidentalis*. *European Journal of Experimental Biology*, 5(11): 1-5
- Ononuju, C.C. and Kpadobi, U.C. (2008). Effect of Plant Leaf Ash on the Control of *Meloidogyne incognita* in Soybean. *Indian Journal of Nematology*, **38**: 1.Pg. 9-14 Print ISSN: 0303-6960.
- Openshaw, K. (2000). A Review of *Jatropha curcas*: An Oil Plant of Unfulfilled Promise. *Biomass and Bioenergy*, **19** (20), 1-15.
- Oskoueian, E. N. Abullah, W.Z. Saad, A. Omar, S. Ahmed, W.B. Kuan, N.A. Zolkifli, R. Hendra, Y.W. (2011). Bioactive compounds and biological activities of *Jatropha curcas* L. kernel meal extract. *International Journal of Molecular Sciences*, 5955-5970
- Osman, A.A. and Viglierchio, D.R. (1988). Efficacy of Biologically Active Agents as Non-Traditional Nematicides for *Meloidogyne javanica*. *Revue Nematology*, **11**:93-98.
- Oyedeji, O., Oziegbe, M. and Taiwo, F.O. (2011). Antibacterial, Antifungal and Phytochemical Analysis of Crude Extracts from the Leaves of *Ludwigia abyssinica* A. Rich and *Ludwigia decurrens* Walter. *Journal of Medicinal Plants Research* 5(7): 1192-1199.
- Oyi, A.R., Onaolapo, J.A., Haruna, A.K., Morah, C.O. (2007). Antimicrobial Screening and Stability Studies of the Crude Extract of *Jatropha curcas* Linn Latex (Euphorbiaceae). *Nigerian Journal of Pharmaceutical Science*, **6** (7), 14-20.
- Parveen, K., A. Haseeb and P.K.I. Shukla, (2006). Pathogenic potential of *Meloidogyne incognita* on *Mentha arvensis* cv. Gomti. *Ind. J. Nematol.*, 36: 177-180.
- Patil, J., Yadav, S. and Sharma, M.K., (2017). Effect of Plant Extracts on Egg Hatching and Juvenile Mortality of Reniform Nematode, *Rotylenchulus reniformis*, *International Journal of Pure and Applied Biosciences*. **5**(2): 158-164
- Phillips, R. and Rix, M. (1995). *Vegetables* Macmillan References Books, London.1-7.
- Ranasing, N. (2007). Biopesticides: an economic approach for pest management. *Orrisa Review*, 77-79.
- Regnold, I.A., John A.D., Papendick I.P., Robert M.N., Parr, J. and James, O.N. (1990). Sustainable Agriculture. *Scientific American*, 122-120.

- Ruiz, C.P. (2003). A new means of control for *Pyricularia oryzae*, *Rhizoctonia solani*, and other important rice-disease pathogens in Colombia. *Pflanzenschutz-Nachrichten Bayer* 56, 399-416.
- Saetae, D. and Suntornsuk, W. (2010). Variation of Phorbol ester Contents in *Jatropha curcas* from different provinces in Thailand and the application of its seed cake for Starter broiler diets. *American-European Journal of Agriculture and Environmental Sciences*, 8(5):497-501
- Salim, H.A., Salman, I.S., Majeed, I.I., and Hussein, H.H. (2016) Evaluation of some plant extracts for their nematicidal properties against root-knot nematode, *Meloidogyne* sp. *Journal of Genetic and Environmental Resources conservation*, 4(3), 241-244.
- Sasser, J.N. (1989). Plant parasitic nematodes: The Farmer's Hidden Enemy. Co-operative Publication of the Department of Plant Pathology North Carolina State University and the consortium for International Crop Protection.
- Saufiuddin, S.S. Sheila and Shweta, S. (2011). Pathogenicity of root-knot nematode, *Meloidogyne incognita* and rootrot fungus, *Rhizoctonia solani* on okra (*Abelmoschus esculentus* L.) *e- Journal of Science and Technology*, 3(6).
- Savoia, D. (2012). Plant-derived Antimicrobial Compounds. Alternatives to Antibiotics. *Future Microbiology*, 7: 979-990.
- Schimel, D.S., Braswell, B.H., McKeown, R., Ojima, D.S., Parton, W.J. and Pulliam, W. (1996). Climate and Nitrogen Controls on the Geography and Timescales of Terrestrial Biogeochemical Cycling. *Global Biogeochem. Cycles*, 10, 677-692.
- Schmook, B. and Serralta-Peraza, L. (1997). *Jatropha curcas*: Distribution and Uses in Yucatan Peninsula of Mexico. G.M. Gubitz, M. Mittelbach, M. Trabi (Eds.), *Biofuels and Industrial Products from Jatropha curcas*, DBV Graz, 53-57.
- Sharma, H.K. and Prasad, D. (1995). Potentialities of a few botanical in Management of root-knot nematode. *M. incognita* on soybean. *Annals of Agricultural Research* 16:73-476
- Sharma, J., Painuli, R.M. and Gaur, R.D. (2010). Plants Used by the Rural Communities of District Shahjahanpur, Uttar Pradesh. *Indian Journal of Traditional Knowledge*, 9 (10), 798-803.
- Shimoyamada, A, Susulki M, Sonta H, Maruyama M, Okubo K (1990). Antifungal activity of the saponin fraction obtained from *Asparagus officinale* L. and its active principle. *Agric Bio. Chem.* 54(10): 2553- 2557.
- Siji, J.V., C.A.Jayaprakas,M.S. Sheela and C.Mohandas (2010). Efficacy of *Cleome viscosa*L. against *Meloidogyne incognita* infestation in okra (*Abelmoschus esculentus* L.). *Thai Journal of Agricultural Science* 43 (3): 151-156.
- Sikora, R.A. (1989). Importance of plant parasitic and entomopathogenic nematodes to vegetable production in the Philippines. *GTZ Report Eschborn*, 37P.
- Singh, S.K. and R.K. Khurma, 2007. Susceptibility of six tomato cultivars to the root-knot nematode, *Meloidogyne incognita*. *The South Pacific J. Natural Sci.*, 13: 73-77.

- Soetan, K.O., Oyekunle, MA, Aiyelaagbe, O.O, and Fafunso, M.A (2006). Evaluation of the antimicrobial activity of saponins extract of *Sorghum bicolor* L. Moench. *African Journal of Biotechnology* **5**(23): 2405-2407.
- Sopade, P., Ajisegiri, E. and Badau (1992). The Use of Peleg's Equation to Model Water Absorption in some Cereal Grains during Soaking. *Journal of Food Engineering* **15**:269-283.
- Spiegel, Y., Chet, I. and Cohn, E. (1987). Use of Chitin for controlling plant parasitic nematodes II. *Mode of action plant and Soil*,**98**:337-345.
- Stirling, G.R. (2009). Organic amendment for control of root-knot nematode (*Meloidogyne incognita* on Ginger. *Australasian Plant Pathology*, **18**(2)39-44.
- Strumeyer, D.H, and Malin, M.J. (1975). Condensed Tannins in grain sorghum Isolation, Fraction, and Characterization. *Journal of Agricultural and Food Chemistry*. **23** (5): 909-914.
- Subramanian, S.S and Nagarajan, S. (1969). Flavonoids of the seeds of *Crotolaria retusa* and *C. Striata*. *Currse*,**38**:65-68
- Tada, M., Kadoma, M., Inui, M. and Fuji, J. (1988). *Methods Enzymol.* **157**: 107-154.
- Tovignan, S., Vodoulie, S.D. and Dinhan, B. (2001). Cotton Pesticides Course More Deaths in Benin. *Pesticide News*, **52**: 12-14.
- Trease, G.E. and Evans, W.C. (2009). *Pharmacology*. 15thEdn. Saunders Publishers, London, 42-44
- Tsay, T.T., Wu,S.T. and Lin, Y.Y. (2004). Evaluation of Asteraceae plants for control of *Meloidogyne incognita*. *Journal of Nematology*, **36**: 36-41.
- Udo, I.A. (2004). Infectivity of *Meloidogyne incognita* on elite and local cultivars of tomato in humid tropics. *M.Sc Dissertation*, University of Nigeria, Nsukka.
- Udo, I.A., Uguru, M.I., Ogbuji, R.O. and Ukeh, D.A. (2008). Sources of Tolerance to Root-Knot Nematode, *Meloidogyne javanica* in Cultivated and Wild Tomato Species. *Plant Pathology Journal*, **7**, 40-44.
- Uma, M.S. (2015). Phytochemical Screening and antidiabetic Effects of Extracts of the Seeds of *Citrullus lanatus* in Alloxan induced Diabetiuc Albino Mice. *Journal of Applied. Pharmacological Science.*, **5**(03): 051-054.
- Vaghasiya, Y., Dave,R. and Chanda, S. (2011). Phytochemical analysis of some medicinal Plants from Western region of India. *Res. Journal of Medicinal. Plant*, **5**: 567-576.
- Wahab, S. (2009). Biotechnological Approaches in the Management of Plant Pests, Diseases and Weeds for Sustainable Agriculture. *Journal of Biopesticides*, **2**: 115-134.
- Walters, D. R. (2009). Are plants in the field already induced? Implications for practical disease control. *Crop Protection* **28**, 459-465.
- Wang, K.H., Spices, B.S. and Scmitt, D.P. (2001). Suppression of *Rotylenchus reniformis* by *Crotolaria juncea*, *Brassica napus* and *Target erecta*. *Nematropica*, **31**:237-251.

- Williamson, V.M. and Gleason, C. (2003). Plant-nematode interactions. *Curr. Opin. Plant Biology.*, 6: 327-333.
- Yang, H., Powell, N. T. and Barker, K. R. (1976). Interaction of concomitant species of nematodes and *Fusarium oxysporium* f. sp. *vasinfectum* on cotton. *Journal of Nematol.* 8:74-80.
- Yasmin, L., Rashid M.H., Nazim M., Uddin M.S., Hossain M.S., Hossain M.E. and Ahmed M.U. (2003). Use of Neem Extract in Controlling Root-Knot Nematode (*Meloidogyne javanica*) of Sweet-gourd. *Plant Pathology Journal*, 2: 161-168.