MANAGEMENT OF INSECT PESTS OF BAMBARA GROUNDNUT (*Vigna subterranean* (L.) Verdcourt.) WITH SOME PLANT OILS IN RAIN FOREST ZONE OF OWERRI, IMO STATE

BY

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Certification

This is to certify that this research work, "**Management of Insect Pests of Bambara Groundnut (Vigna subterranean (L.) Verdcourt.) With Some Plant Oil in Rain Forest Zone of Owerri, Imo State,**" was carried out by Nwankpa, Akachukwu Pius, with Registration number 20144919998 in the Department of Crop Science and Technology, School of Agriculture and Agricultural Technology, Federal University of Technology, Owerri.

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Dedication

This research work is dedicated to all those who contributed positively and encouraged me during the period of study.

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Abstract

Studies were conducted from March- June for the early season and August- November for the late season of 2016 and repeated same time in 2017 at the Postgraduate Teaching and Research Farm of the Department of Crop Science and Technology, Federal university of Technology, Owerri, Nigeria. A total of 60 treatment combinations were laid out in a 5 x 4 factorial arrangement with three replications fitted into a randomized complete block design (RCBD) for the field trials to evaluate the efficacy of the plant oils (Bush tea *Hyptis suaveolens*. (HEO), Stool wood *Alstonia boonei.* (AEO), *Jathropha tanjorensis* (JEO,) mixed plant oils from Jathropha, Bush tea and Stool wood bark (J+A+HEO) against field insect pests of Bambara groundnut. Population dynamics of insect pests of Bambara groundnut under control measures with plant oils were also studied. The oils were tested at four rates (0.00, 2.00, 4.00 and 6.00 ml/100 ml of H_2O per plot) and Cypermethrin 10EC at the rates of (0.00, 0.20, 0.40 and 0.60 ml/100 ml of water per plot). Some field insect pests including variegated grasshopper (*Zonocerus variegatus*), Flea beetle (*Podagrica uniformis and Podagrica sjostedti*), Leaf miner (*Aproaerima modicella*) and Aphids (*Aphids crassivora*) inflicted damage to the leaves of Bambara groundnut. The treatment materials provided effective protection against insect pests of Bambara groundnut at different levels when compared to the unsprayed plots. The unsprayed plots recorded highest number of damaged leaves at the vegetative phase, flowering and podding phase followed by the lowest application rates, while the highest application rates recorded the least damaged leaves by insect pests in 2016 and 2017 early and late planting seasons. The results on yield showed that the plant oils were able to reduce the population of insects which resulted in an increase in the 100 Seed and Pod weight (g), Seed and Pod yield (kg/ha, though they were not significantly different (P>0.05).

Keywords: Bambara groundnut, Plant oils, Cypermethrin, Insect pests, Population dynamics.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Bambara groundnut (*Vigna subterranean* (L.) Verdcourt) is a member of the *Leguminosaea* family. It is an important drought- tolerant grain legume that is cultivated for its subterranean pods as food crop mainly in Africa where it is reported to have originated from Jos plateau and Yola regions of North-eastern Nigeria and Garuoa in Northern Cameroon and possibly as far as the Central African Republic where its wild forms are found (Plant Resources of Tropical Africa, 2006; Oyiga and Uguru, 2011; Molosiwa, 2012). Bambara groundnut is one of most Africa's rural popular grain legumes, ranking third in importance after groundnut (*Arachis hypogaea* L.) and cowpea, (*Vigna unguiculata* (L.) Walpers) respectively (Zerihun, 2009). It is a geocarpic crop, a close relative of cowpea and morphologically fits same niche as groundnut, although compositionally, the seed is closer to chickpea (Cicer arietinum) (Halimi *et al.* 2019). The crop is highly nutritious, and the seeds contain fat, protein and carbohydrates thus serving as a source of rich diet for humans and feed for livestocks (Murevanhema and Jideani, 2013). Unlike soybean (Glycine max) which has received considerable scientific and financial support since its introduction, Bambara groundnut has received limited support from governmental or international agencies and has largely been ignored by the research community Oyeyinka *et al.* 2015). Unfortunately, leguminous crops which include Bambara groundnut suffer from heavy damage caused by pests, especially from insects (Muthomi *et al.*, 2008). Podagrica species especially *Podagrica unifoma* Jacoby and *Podagrica jostedti* Jacoby, Grass hopper (*Zonocerus variegatus)*, Flower thrips (*Megalurothrips jostedti* Trybom), the African bollworm (*Helicorverpa armigera* Hubner), the legume pod borer (*Maruca testulalis* Geyer), Aphids (*Aphids crassivora* Glover), the bruchid beetle (*Callosobruchus maculatus* F) are the major insect pests that are of economically and nutritionally important to leguminous grains, such as Bambara groundnut, *V.*

subterranean (Muthomi, *et al*., 2008); Magagula and Maina, 2012). Plant oils have been reported to possess multiple action mechanisms on the insects, such as acute toxicity, repellence, feeding reduction (deterrence), growth inhibition and limitations in development and reproduction (Carlos *et al.*, 2016). The essential oils of plant species belonging to the families of Asteraceae, Ranunculaceae, Myrtaceae, Brassicaceae, Apiaceae, Meliaceae, Piperaceae, Lamiaceae, Lauraceae and Verbenaceae have shown repellence against insect pests (Afonso *et al*., 2012; Hayat *et al*., 2015). Plants like Jatropha, *Jatropha tanjorensis* JL Ellis and Saroja (Euphorbiaceae). Bush tea, *Hyptis suaveolens*. Poit (Libiatae), and Stool/Pattern wood, *Alstonia boonei* De Wild (Apocynaceae) stand out among the plant species producing plant oils with insecticide potential for pest control. Although the previously mentioned species produce plant oils and their compositions have compounds with insecticide properties, little is known with respect to the effectiveness of these products in the control of insect pests of field crops. Thus, this study will be undertaken to evaluate the efficacies of the three plant oils extracted from leaves and barks in comparison to the controlplots and synthetic Cypermethrin 10EC against field insect pests of Bambara groundnut. This study investigated the extent of damage and yield losses caused by insect pests of Bambara groundnut in field, Population dynamics of insect pests of Bambara groundnut.

1.2 Problem Statement

Synthetic chemical insecticides have proved very effective in the control of insect pests, the problems associated with their uses such as health hazards, insect resistance, pest resurgence, residual toxicity, destruction of non-target organisms, wide spread of environmental hazards and increase in cost of application continue to drastically reduce their popularity (Oni, 2011). Akunyili and Ivbijaro, (2006) reported that usage of synthetic chemicals has been gravely associated with massive ecological damages and health hazards, for instance, to handlers/farmers and consumers during formulation or field application and in the food chain through consumption of treated commodities. These major negative effects have directed the search for alternatives that are effective, biodegradable and less toxic pesticides (Adedire *et al.*, 2011). The use of plant products inform of plant oils provides an opportunity to avoiding the use of synthetic chemicals as preservatives, insecticides and pesticide risks (Mohamed *et al*., 2012). The findings of Ileke and Olotuah, (2012); Njom and Eze, (2011) confirmed that extracts from different plants have been shown to possess insecticidal properties against wide range of insect pests. Olaniran *et al*., (2013) also indicated that botanical insecticides are promising alternatives in the protection of crops against insect pests. Rozman *et al.*, (2007) in their review stated that botanical insecticides causes less damage to human health and environment, degrade rapidly, do not accumulate in the body and environment, while some are very specific and do little or no damage to other non-target organisms. Plant oils of botanical origin have been reported to contain various monoterpenoids which have been explored as repellent and/or antifeedant due to their insecticidal properties. Most of the Monoterpenoids found in plant oils of various botanical plants are known neurotoxins (Stamopoulus *et al*., (2007) and most of them are volatile, thereby offering the prospect of their use against insect pests (Olaniran *et al*., 2013).

1.3 Objectives of Study

The broad objective of the study is management of insect pests of Bambara groundnut (*Vigna subterranean* (L) Verdcourt) with some plant oils in rain forest zone of Owerri, Imo State while the specific objectives of this research work were;

1. Study the population dynamics of insect pests of Bambara groundnut under control measures with plant oils.
2. Evaluate the efficacy of some plant oils against field insect pests of Bambara groundnut.
3. Assess yield (Kg/ha), and some components of Bambara groundnut under pest control measures with selected plant oils.

1.4 Justification for Study

Bambara groundnut is an underutilized crop that plays significant roles in food security despite the fact that they receive little scientific research. Its insect pests are not detailed but are categorized with those of Cowpea and other legumes. It is in attempt to fill the gap in our present knowledge that this research work was conducted to evaluate the potentials of these plant products as insecticides (bio-pesticides) on Bambara groundnut in the field.

1.5 Scope of Study

The scope of this study is to evaluate oils from *Jatropha tanjorensis* JL Ellis and Saroja (Euphorbiaceae). Bush tea, *Hyptis suaveolens*. Poit (Libiatae), and Stool wood, *Alstonia boonei.* De Wild (Apocynaceae) for the control of field insect pests of Bambara groundnut *V. subterranean.* And as well investigate population dynamics of insect pests that visited Bambara groundnut in 2016 and 2017 early and late cropping seasons.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Origin and distribution of Bambara groundnut

Plate 1a: Bambara groundnuts Plant

Plate 1b: Seeds of Bambara groundnuts

Onwubiko *et al*., (2011) confirmed in their findings that Bambara groundnut, (*Vigna subterranea (L) Verdc.)* is of West African origin and has been cultivated in tropical Africa for centuries. Basu *et al*., (2007) also mentioned that Bambara groundnut is an indigenous African leguminous crop and one of the most important Pulses grown on the continent. In Nigeria, it is called Okpa, with the pudding from its seed known as ntuchaor igba (Igbo), Epa-Roro (Yoruba), Kwaruru or Gurijiya (Hausa) (Ogbuagu *et al*., 2023). According to Oyiga and Uguru, (2011) and (Molosiwa, 2012), the crop is found to be widely cultivated in tropical regions since the seventeenth century and that the domestication of bambara groundnut is believed to have occurred within the area where the wild forms are found, which is the Jos plateau and Yola regions of Northerneastern Nigeria extending through Garuoa in Northern Cameroon and, possibly, as far as the Central African Republic. Recently, Olukolu *et al*., (2011), revealed in their work using both DArT molecular markers and phenotypic descriptors to provide evidence that pointed out Cameroon/Nigeria as the putative area of origin of Bambara groundnut. They also suggested in their work that the regions showed higher phenotypic diversity for both quantitative and qualitative characters compared to regions of East Africa, Central Africa and a combination of other countries in West Africa. Suwanprasert *et al*., (2006) in their findings opined that the crop is said to have been brought first to East Africa and Madagascar, then later to South and South East Asia, with the slave trade to Suriname, Brazil and later to the New World. Suwanprasert *et al*., (2006) further reported its cultivation in South and Central America, India, Indonesia, Malaysia, the Philippines, Sri Lanka and parts of northern Australia. Brink *et al*., (2006) stated in their work that it is found in the wild from central Nigeria eastwards to southern Sudan and is now cultivated throughout tropical Africa and to a lesser extent in tropical parts of America, Asia and Australia. Suwanprasert *et al*., (2006) also observed that Bambara groundnut was domesticated in the semi-arid zone of West Africa, probably around the headwaters of the Niger River, from where it spread and extended to Central Africa, and more recently to the Malagasy Republic, Asia and

South America. They also revealed that it was taken at an early date to Madagascar, probably by Arabs and it has reached Brazil and Surinam early in the seventeenth century and then was later taken to the Philippines and Indonesia.

2.2 Taxonomy and botanical description of Bambara groundnut

Molosiwa, (2012) observed in his study that Leguminosae are divided into three major groups, this division is mainly on the basis of their morphological and floral differences that is the Caesalpinioideae, Mimosoideae and Papilionoidaeae. According to Cannon *et al.*, (2009), Papilionoideae is the largest subfamily with approximately 70% of the Leguminosae species, it includes most of the crops and major model legume species. Vijaykumar *et al.*, (2009) revealed that it is subdivided into four large groups the galegoid, millettioids, dalbergioids and genistoids.

According the findings of Vijaykumar *et al*., (2009), Bambara groundnut (*Vigna subterranea*), Common bean (*Phaseolus vulgaris*), Soybean (*Glycine max*), Cowpeas (*Vigna unguiculata*), Pigeonpea (*Cajanus cajan*), Mungbean (*Vigna radiata*), Adzuki bean (*Vigna angularis*), Tepary bean (*Phaseolus acutifolius*), Lima bean (*Phaseolus lunatus*), Hyacinth bean (*Lablab purpureus*) and Hausa groundnut (*Macrotyloma geocarpum*) belongs to the milletioid clade. But at the genus level, the species *Vigna subterranea* belongs to the genus *Vigna*, and subtribe Phaseolinae, the tribe Phaseoleae and the family Papilionaceae (Mbosso *et al*., 2020); (Sato *et al.*, (2010); (Cannon *et al.,* 2009). According to Borget, (1992) Bambara groundnut was renamed *Vigna subterranea* in 1980, after having been known as *Voandzeia subterranea* for more than a century. In 1763, Linnaeus described it in *Species Plantarum*, and named it *Glycine subterranea*, in accordance with his system of nomenclature. Du Petit–Thouars (1806) also found the crop in Madagascar and proposed the name *Voandzeia subterranea (L) Thouars.* This name was widely used by subsequent researchers for over a century. Detailed botanical studies were undertaken by Maréchal *et al.,* (1978), who observed great similarities between Bambara groundnut and plant species of the genus *Vigna.* This Verdcourt seized the opportunity in 1980 to confirm his studies to propose the current name *Vigna subterranean (L) Verdc* (Goli, 1995). Olanipekun *et al*., (2012) mentioned that Bambara groundnut is a small herb that grows to about 0.30–0.35 m in height, and like the groundnut has compound leaves of three leaflets. That it occurs in both prostrate and erect forms. Basu *et al*., (2007) observed that the much–branched stems root at the nodes forms a bunched herbaceous annual with a thick taproot which also forms a profusion of lateral roots towards its tip. The plant generally appears bunchy, with leaves rising from branched stems which form a crown on the soil surface. Basu *et al*., (2007) also confirmed that stem branching begins very early, about one week after germination, and as many as twenty branches may be produced in the crop. Shiyam *et al*., (2016) stated that th plant has a bushy habit that consists of about ten running stems with very short internodes and the roots grow from the nodes at each stem. The leaves with erect petioles are alternate and trifoliate. They also confirmed in their findings that peduncles are auxiliary, elongating from the stem nodes, each peduncle bearing one to three flowers (usually two). Basu *et al*., 2007 revealed that pale yellow flowers are borne on the freely branching stems and after fertilization occurrence the stem of the flower then grows down towards the soil, where it takes the developing seed with it. Onwubiko *et al.*, (2011) indicated that the pod (1.25–2.5 cm in diameter) is drawn into the soil and ends up lying about 1 cm beneath the surface. The pods usually contain only a single seed, but sometimes there are two in a seed coat. Basu *et al*., (2007) also opined that mean temperature during the seasons influences the time taken to achieve physiological maturity.

Brink *et al.*, (2006) observed that the crop is indigenous to sub-Sahara Africa and there has been limited research into developing new varieties, so all varieties are considered to be traditional. They appear in colours of black, white, cream, brown, red and mottled. Several varieties are recognized in Africa differing in the shape of the leaves and the size, hardness and the colour of the seeds. They revealed that no cultivars of Bambara groundnut have been named, rather the genotypes are distinguished on the basis of seed attributes which includes colour, size, hardness and plant form which also include bushy or spreading types. They further explained that sometimes names are based on the location where the seed was collected.

2.3 Propagation and planting of Bambara groundnut

Berchie *et al*., (2010) obseved that the crop is mostly grown from seed and is sown in either mixed cultivation with cereals (pearl millet, root crops or other legumes) or in sole cultivation. Basu *et al.*, (2007) also opined that the crop may be grown either as a single stand or intercropped with groundnut, millet or sorghum. In rotation cultivations, it may be planted as an opening crop perhaps followed by cassava, or in the second year it may be intercropped with cereals, vegetables, groundnuts or other pulses. Doku, (1995) stated that there is also a trend towards mixed cropping with yams, that Bambara groundnut planted on yam mounds protect the mounds from erosion, and also conserves moisture and creates fewer temperature fluctuations in the mound. According to Brink *et al.*, (2006), the crop performs best on deeply ploughed field with a fine seedbed, which eventually allows the plant to bury its developing fruits. They also suggested that ridging is advisable if the soil is shallow or prone to water logging. Berchie *et al.*, (2010) also reported in their work that proper loosening of the soil helps pod penetration during fructification and improves the yield. PROTA, (2006) also mentioned that a well-prepared friable seed bed is required to enable the plants to bury their pods after fertilization. Effa, (2016) indicated that highest combined pod and seed yield were observed at the upper and middle population densities than at the lowest density are implicative of cumulative yield from larger number of plants contributing to total yield. The findings confirmed that middle density 30 x 40 cm (83,333 plants ha^{-1}) and highest density 30 x 50 (111,111 plants ha^{-1}) recorded higher yield than the lowest density 30 x 30 cm (69,400 plants ha^{-1}). Two seeds is sown per hole 3-5 cm deep. Seed rate varies in several location, that is 35 kg/ha in Tanzania; 25-45 kg/ha in Kenya; higher rate of 60-75 kg/ha in South Africa when rat damage is expected. PROTA, (2006) indicated that the normal seed rate is 30-60 kg/ha of shelled nut giving 150,000 plants/ha. That sowing dates vary considerably within locations. Brink *et al.,* (2006) stated that in Zambia and Botswana, for example, sowing takes place from November to February. Sometimes phased planting occurs, examples, in Skumaland, Tanzania. PROTA, (2006) indicated that in the derived savanna zone of Ghana, two cropping cultivations are possible, the first crop sown in May - June and the second crop in October. In the north the main planting period is between August–September. Hillocks *et al*., (2011) mentioned that in the Guinea savanna zone, the crop is usually grown during the minor season (September-November) when the rainfall is reliable. They also reported that in the Sudan Savanna zone, it is usually cultivated towards the end of the single long rainy season.

2.4 Growth and development of Bambara groundnut

Berchie *et al*., (2010) indicated that Bambara groundnut is adapted to wide climatic zones, it can be cultivated from sea-level to up to 1600 m altitude, and an average temperature of 20-28^{o}C is considered ideal for the crop. That it grows well on well-drained soils, but sandy loams with a pH of 5.0 to 6.5 are most suitable. They also suggested that growth period of 110 to 150 days is required for the crop to fully develop, although some records of reduced growth cycle landraces of approximately 90 days have been recorded in Ghana. According to Brink *et al.,* (2006), the optimum temperature for germination of Bambara groundnut is 30-35^{o}C. That emergence takes 5-21 days while vegetative development may continue after reproductive development has started. Flowering starts 30-55 days after sowing and may continue until the plant dies. After fertilization the pods form and reach their maximum size about 30 days. Effa, (2016) observed that the seeds expand and reach maturity during the following 10 days. The duration of the crop cycle is between 100-180 days.

The observations of Brink *et al.,* (2006) and Effa, (2016) shows that weeding of Bambara groundnut takes place 1-3 times, and often done with a hoe. Earthing up to cover the young pods is common, and may be done by hand, with a hoe or with ox-drawn equipment. They also suggested that earthing up improves yield but is labour intensive; it is often combined with weeding. Brink *et al.*, (2006) also reported in their findings that the rows are usually earthed up and in some areas are lightly covered with soil to promote fruit production. Effa, (2016) also mentioned that the plants are hand weeded when 10 cm high and mounded or earthed up at flowering time to encourage development of the pods underground.

2.5 Climate and soil requirements of Bambara groundnut

Berchie *et al*., (2010) observed that the crop does better than most other bean crops in poor soils and grows best with moderate rainfall and sunshine. Olugbemi and Adebosin, (2014) stated that under less favourable growing conditions, such as limited water supply and infertile soil, it yields better than other legumes, for example, groundnut. They are the least demanding for mineral elements and thrive in soils which are considered too marginal for groundnut and other legumes. They also indicated that it can be grown on a range of soils, especially light loams and sandy loams but may be successfully grown on heavier soils than groundnuts. Their report revealed that Bambara performs better on poor soils than groundnuts, that light soils make harvesting easier and soils rich in nitrogen may induce excessive vegetative growth which is undesirable for seed production. Berchie *et al.*, (2010) and Oyeleke *et al.*, (2012) further reported that the crop is the most drought resistant pulse, producing a crop under conditions of high temperature and low rainfall, where other pulses fail to thrive. Oyeleke *et al*., (2012) went further to suggest that Bambara groundnut tolerance of drought and ability to yield in soils too poor to support the growth of more favoured legumes are all factors which contribute to its continued popularity with poor farmers. Egbe *et al.*, (2009) stated in their findings that the crop is very drought–resistant but for good yields requires moderate rainfall of 750–1000 mm during the rainy season and a dry period for harvesting. Berchie *et al*., (2010) indicated that production can occur under rainfall of 600–700 mm per annum but optimum growth occurs with 900–1200 mm per annum. Egbe *et al*., (2009) further confirmed that yield of Bambara groundnut on low–fertility soils are generally higher than those of groundnuts grown on similar soil. That soil with a pH of 5.0–6.5, will produce satisfactory crops. Jørgensen *et al*., (2010) indicated that the cultivation of Bambara groundnut is of particular importance in semi – arid areas. Yakubu *et al*., (2010) indicated that farmers do not normally apply chemical fertilizer to Bambara groundnut fields. That the nitrogen requirement is met by natural N2 fixation, that according to several nodulation studies reported that Bambara groundnut can fix up to 28.42 kg N ha-1 in the Sudano-Sahelian zone of Nigeria. Toungos *et al.,* (2010) however, revealed through their finding that phosphorus is the most important limiting nutrient element that has to be applied to the crop. They went further to argue that nodules on their roots can fix atmospheric nitrogen and therefore ensure their nitrogen nutrient supply without recourse to nitrogen in the soil. There are some cases where assimilation for various reasons becomes poor and the application of nitrogen fertilizer has a positive effect particularly in the early period of growth when root development is rapid. That later application may suppress nodulation. Hence Bamabara groundnut increases its photosynthetic capacity through Rhizobium or Bradyrhizobium mediated biochemical sequences in the host plants roots causing nodulation and the fixing of nitrogen required by the plant. That the application dose normally ranges from 30 to 50 kg of nitrogen per hectare. According to the finding of Hubbell and Kidder, (2009), access to nitrogen allows the plant to produce leaves fortified with nitrogen that can be recycled throughout the plant which in turn yields nitrogen-rich seeds. (Egbe *et al.*, 2009); Alhassan *et al*., (2012) reported that that through these symbiotic relationships, Bambara groundnut fixes atmospheric nitrogen to the soil, thereby benefiting crop rotations and intercropping systems. According to the finding of Ellah and Singh, (2008), the crop does well on poor soils that are low in nutrients; though the application of phosphorus results in better nitrogen fixation and an increase in stover and kernel yield, as with almost all legumes, that Bambara groundnut is capable of symbiosis with nitrogen–fixing bacterial belonging to the genus Rhizobium. But suggested that the maximum quantity of nitrogen, which can be obtained by symbiotic fixation is 100 kg/ha. Toungos *et al*., (2010) and Nweke and Emeh, (2013) observed in their findings that Bambara groundnut can meet its nitrogen requirements, but it is known to respond favourably to application of about 250 kg/ha of single super phosphate applied before planting. Nweke and Emeh, (2013) went further in their finding to state that the addition of nitrogen at planting time or later at the rate of 60 kg/ha of sulphate of ammonia, approximately three weeks after sowing appears to be economic and, seeds are placed in holes containing cow dung.

Drought and heat Tolerance: Oyeleke *et al.*, (2012) indicated that Bambara groundnut is considered to be drought resistant. They further reported that farmers claim that in years when groundnut fails due to low rainfall, Bambara groundnut produces good returns. They also indicated that Bambara groundnut landraces have been shown to be able to tolerate drought as they can sustain leaf turgor pressure by employing a combination of osmotic adjustment, leaf area reduction and effective stomatal regulation of water loss. Collinson *et al*., 1999) in their findings observed some changes in the leaf orientation, which assist the crop to reduce incident radiation on the leaf surface, are reported in droughted landraces such as DipC from Botswana and DodR from Tanzania, thereby reducing water loss through transpiration. In findings made by Jørgensen *et al.*, (2010), it showed that drought response mechanisms of Bambara groundnut were revealed in two landraces, one from a drought-prone environment (Namibia), S19-3, while the other is from a high rainfall area (Swaziland), UniswaRed. According to their report, UniswaRed had a relatively higher transpiration rate under drought conditions compared to S19-3 which showed a delay in reduction in transpiration. They insisted that the mechanism allowed S19-3 to maximize its water use and escape drought better than UniswaRed. They further revealed that the crop will yield in unfavorable environments but there are few reports of its productivity in relation to water stress. That the well-developed root system of Bambara groundnut exploits the rhizosphere for moisture and the sink demand of the rather thin and much branched prostrate stem cannot offer any significant competition for assimilates relative to the developing pods. Alhassan and Egbe,

(2013) stated in their work that Bambara groundnut allocated a greater fraction of its total dry weight to roots than comparable groundnut crops irrespective of available soil moisture. That this strategy has a clear advantage when water is scarce, enabling a greater soil volume to be exploited for available water. They went further to suggest that the crop uses the available water frugally through slow leaf area development, thereby conserving water so that there is sufficient for the crop to survive through the reproductive period and gain yield. PROTA, (2006) made clearly report that in Africa, Bambara groundnut is confined to the dry regions, between the desert and the savanna (Southern fringe of the Sahara) and they are adapted to grow in areas of relatively high temperatures for many leguminous crops.

Response to Day Length: Hence it is very important to know at what period in the life cycle plants are sensitive to photoperiod. Berchie *et al*., (2010) reported that in the case of a flowering response to photoperiod, that three phases are distinguished between sowing and flowering, at the basic vegetative phase, plants are not sensitive to photoperiod, but at the inductive phase, the plants are sensitive to photoperiod while at post – inductive phase, during which flower buds develop into open flowers that photoperiod does not play a role anymore. Brink *et al., (*2006) in their own report showed that Bambara groundnut is not photoperiodic but a typical short–day plant and most cultivars are adapted to short days They went futher to report that there are considerable differences between genotypes in their response to photoperiod. They suggested that in many genotypes, flowering is photoperiod–insensitive, while the onset of podding is retarded by long photoperiods. While some genotypes both flowering and the onset of podding are delayed by long photoperiods. Berchie *et al*., (2010) went further to report that fruit development has been reported to be influenced by photoperiod. That long photoperiods delay or even prevent fruit set in some cultivars. They argued that flowering is considered day–neutral, but continuous light was shown to delay flowering by 6–11 days in a few genotypes. They concluded that many Bambara groundnut landraces have a specific day length requirement for pod filling, that allocation to yield will only begin at a particular day length. That photoperiod usually hve a stronger effect on the onset of podding than on the onset of flowering.

2.6 Pest and Diseases of Bambara ground nut

Few insect pests that have been reported to attack Bambara groundnut, some of them include groundnut leafhoppers (*Hilda patruelis* Stal), the larvae of *Diacrisia maculosa* L. and *Lamprosema indicate* Fabricius. Damage is sometimes caused by leaf hoppers *(Hilda patruelis and Empoasca facialis)*. Hillocks *et al.*, (2011) stated clearly in their findings that pest and diseses affecting Bambara groundnut in Namibia have not been identified but photos of the symtoms were aphids, harvester termites, leaf miner and a Lepidopteran pests. The most important fungal diseases are Cercospora leaf spot *(Cercospora spp.),* powdery mildew *(Erysiple polygoni)* and Fusaruim wilt (*Fusarium oxysporum*) (Brink *et al.*, 2006). Berchie *et al*., (2010) indicated that in dry weather, pod attacks by termites have been consistently observed and root knot nematode *(Meloidogyne javanica)* also attacks the roots of the plant in sandy soils).

Uddun *et al*., (2017) found that Bambara groundnut is attacked in the field by two predominant insect from the Orders Homoptera and Hemiptera, They reported that insect pests from above mentioned Order are associated with Bambara groundnut from the seedling to the podding stage while insects in the orders of Diptera, Coleoptera, Orthoptera and Hymenoptera also attacked the crop at a lesser degree.

2.7 Harvesting of Bambara groundnut

Egbe *et al*., 2009 indicated that harvesting begins about four months after sowing when the pods are mature and the plant leaves are beginning to yellow and dry. The plants are gradually but simply pulled out of the ground with the attached nuts. Harvest takes place in dry environments when the entire foliage dries up. While in humid ecosystems the podrotting or early seed germination while in the pod may take place when the leaves are still partially green. Yakubu *et* *al.*, (2010) in their findings recommended that harvest should be done before full foliage drying. They insisted that even though farmers may harvest the crop immature for immediate use, that Bambara groundnuts of commerce are available only as mature dry seeds.

2.8 Yield of Bambara ground nut.

In the report of Brink *et al.*, 2006, they indicated that highest recorded seed yield under field conditions is 4 t/ha. Average yields are 300–800 kg/ha but yields of less than 100 kg/ha are not uncommon. Alozie *et al.*, (2009) in their own finding stated that average yields of dry seeds may range between 300 and 800 kg/ha in traditional farming but usually exceed 3,000 kg in intensive farming. They also suggested that production environments are characterized by various abiotic and biotic stresses leading to low yields of Bambara groundnut. However, they insisted that under optimal conditions, the yields are variable and unpredictable and this is partly due to variability in growth and development of individual plants within landraces.

2.9 Uses and nutritional importance of Bambara groundnut

Hillocks *et al.*, (2012) reported that Bambara groundnut is the only leguminous crop whose seeds are referred to and used as complete food because they contain protein, carbohydrate and fat in sufficient proportions to provide a nutritious food. Dansi *et al*., (2012) and Olanipekun, *et al*., (2012) in their finding suggested that it has high potential for food and nutritional security among the pro-poor households due to its highly nutritious seeds which contains 55.5 –69.3 % carbohydrate , 5.3 –7.8 % fat, metabolizable energy value of 362 –414 kcal/100 g and 17 –24 % high quality protein. Bamshaiye *et al.*, (2011) also confirmed in their finding that Bambara groundnut contains high amounts of nutritional fibre, calcium and iron including such vitamins as thiamin, riboflavin, niacin, and carotene.

Alhassan *et al.* (2012) reported that experimental evidence and fragmentary research results conducted most recently suggested that the crop has great nutritional potential. Mazahib, *et al.*,

(2013) observed that Bambara nut contains high content of carbohydrate (65 %) and relatively high protein content (18 %) as well have as enough fat (6.5 %) this makes the crop to be ranked highly as a complete staple food. They went further to explain that its protein had been found to be subjugated by essential amino acids like lysine and leucine. That lysine enables the synthesis of carnitine, which converts fatty acids into energy and plays an important role in the production of hormones, antibodies and enzymes. Brink *et al.* (2006) in their work mentioned that dried leaves for fodder contain crude protein 15.9%, crude fibre 31.7%, ash 7.5% and fat 1.8%. Oyeleke *et al.* (2012) reported that the carbohydrate fractions of the seed contained reducing sugar, raffinose, stachyose and starch which could be used as a source of energy. Shiyam *et al.,* (2016) reported that seeds of Bambara groundnut are not sold on world markets, but they play important role in the diet of people in several West African countries where they are the third most important commodity after cowpea and groundnut in the national production and consumption statistics. They went further to say that Bambara nuts are utilized in various ways, fresh mature seeds are boiled and eaten like groundnut while dry seeds can either be roasted or fried and consumed as snacks. Alozie *et al*. (2009) observed that the dry seeds may be milled into flour and made into a paste and fried in hot oil as ‘akara’. Wheat can be substituted with up to 20 % Bambara flour in bread making and can also be used as composite flour in biscuits and cakes. Akande *et al.*, 2009 confirmed that the seeds can be canned like green beans and limited amounts of high-quality milk like soy milk can be processed from the seeds. Adumanya *et al*., (2012) reported that Bambara seeds are commonly used in the preparing ‘Okpa’ a highly cherished delicious and nutritious food that is popular especially in the eastern parts of Nigeria. Aremu and Ibrahim, (2014) indicated that the seeds of Bambara nut are rich in high content of minerals like calcium, iron, potassium and sodium. Olanipekun *et al.* (2012) opined that the oil extracted from bambara nut seeds is predominantly made of unsaturated fatty acids which are primarily used to produce hormone like substance that regulates a wide range of functions, for example, those that could help in the prevention of obesity, cardiovascular diseases, heart attack and inflammation response to injury infections. Afoakwa, *et al*. (2007) observed that the crop is grown mainly for its edible protein and not as an oil crop. They also reported that when dried, the seeds are very hard and can only be eaten when ground into flour. While the unriped seeds can be eaten fresh but mature seeds have to be soaked and boiled before eating. Lim, (2011) indicated that the nuts are boiled with pepper and salt in the preparation of "Aboboi" which, when served with "gari" (grated and roasted cassava) or "tatare" (mashed fried ripe plantain), makes a very delicious meal in Ghana. While Yao *et al*., (2015) confirmed that in Côte d'Ivoire, the seeds are used to make flour, which makes it more digestible and in East Africa, the beans are roasted, then pulverized, and used to make a soup with or without condiments. Abdualrahman *et al*., (2012) observed that bread made from Bambara groundnut flour has been reported in Zambia and Sudan while the leaves are prepared and are applied to abscesses and infected wounds, leaf sap is applied to the eyes to treat epilepsy, and the roots are sometimes taken as an aphrodisiac, and also pounded seeds mixed with water are administered to treat cataracts in Senegal. Brink *et al*., 2006 reported that the Zybo tribe in Nigeria uses the plant to treat venereal diseases and uses the leaves which are rich in protein and phosphorus are used as fodder for livestock.

2.10 Production and international trade Bambara ground nut

Bambara groundnuts are cultivated throughout tropical Africa and in Madagascar, found on the continents of America (Brazil, Paraguay and Surinam); Asia (India, Indonesia, Malaysia, the Philippines and Sri Lanka) and Oceania (Northern Australia and New Caledonia) but about 45–50% of world production comes from West Africa. Food and Agricultural Organization estimated in 2002 that the worldwide Bambara groundnut production was at 58,900 Metric tonnes and over 100,000 Metric tonnes in 2008 (FAO, 2009). Thereafter, Alhassan and Egbe, (2013) reported in their work that estimated production in Africa is about 330 000 tons. That Nigeria leads in production with 100 000 tons followed by Burkina Faso, Ghana, Mali, Cameroon and Ivory

Coast. They concluded that Bambara groundnut is grown at subsistence level in almost all the sub-Saharan countries in Africa. Reliable production figures for the crop are difficult to obtain, because the crop is grown mainly for home consumption and sale at local markets, However, reflecting the general case with underutilized crops, the accuracy of estimates of Bambara groundnut production are difficult to establish due to its widespread use in subsistence farming systems for which reliable data are not collected. Although Onwubiko *et al*., (2011) reported that intensive cultivation of the crop is carried out mainly under smallholder intercropping system with sorghum, millet, maize, groundnut, yams, and cassava in the Guinea –Sudan Savanna zone of the country in Benue, Taraba, Adamawa, Bauchi, Nasarawa, Kaduna, Niger, and Kogi states including Ebonyi, Enugu and parts of Cross River State.

2.11 Vital information on Stool wood *(Alstonia boonei)*

Plate 3: Stool wood Tree (*Alsonia boonei*) Showing the leaves, branches and stem bark

Adotey *et al*., (2012) reported that *Alstonia boonei* De Wild (Apocyanaceae) is an African large evergreen deciduous tree, 'Alstonia' is named after Dr C. Alston (1685-1760), a professor of botany at Edinburgh University. The plant is widely distributed in Angola, Benin, Cameroon, Central African Republic, Congo, Cote d'Ivoire, Democratic Republic of Congo, Equatorial Guinea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Nigeria, Senegal, Sierra Leone, Sudan, Togo, Uganda.

2.12 Names and botanic description of *Alstonia boonei*

English (stool wood, cheese wood, pattern wood, alstonia, emien); Igbo (egbu); Luganda (mujua, mubajangalabi, mukoge, musoga); Yoruba (awun). Ileke *et al*., (2014) indicated that *Alstonia boonei* is a large deciduous tree, up to 45 m tall and 1.2 m in diameter; bole often deeply fluted to 7 m, small buttresses present; bark greyish-green or grey, rough; slash rough-granular, ochre-yellow, exuding a copious milky latex; branches in whorls. Moronkola and Kunle, (2012) reported that the leaves in whorls of 5-8, simple, subsessile to petiolate, stipules absent; petiole 2-10 (max. 15) mm long, stout; blade oblanceolate to obovate, rarely elliptic, 7-26 x 3-9.3 cm; apex acute to rounded or sometimes emarginate; base narrowly cuneate; margins entire, sub-coriaceous to coriaceous, dark shiny green top surface, light green on under surface; midrib more prominent below. Inflorescence terminal, compound with 2-3 tiers of pseudo-umbels; primary peduncles 0.5-7 cm long, greyish pubescent; bracts ovate-triangular, 1-1.5 mm long, pubescent; pedicels about 5 mm long. Orwa *et al*., (2009) observed that flowers regular, hermaphrodite, pentamerous; calyx cupular tube about 1 mm long; lobes ovate, about 1.5 mm long, spreading; corolla pale green tube up to 14 mm long; lobes slightly obliquely ovate, up to 6 mm long and wide, pubescent outside. Fruit formed by 2 pendent green follicles up to 60 cm long, longitudinally striate, dehiscing lengthways while on the tree; seeds numerous, flat, about 4 x 2 mm, with tufts of hair at each end 10 mm long. According to Ileke *et al*., (2014), it is a crude medicinal tree that shed its leaves annually and possesses roots, stems, barks, leaves, fruits, seeds, flowers, and latex, with a straight and fluted stem, having no buttress roots which are claimed to have medicinal values in some cultures in African countries. Opeku and Akoto (2015) also reported that the plant stem bark and its latex are applied in traditional medicine for treating many diseases. Orwa *et al.*, (2009) confirmed that records of flowering and fruiting are few, even in areas of its natural range. But it would appear that the tree sheds it leaves at the end of the rainy season and flowers immediately in October and November, after which new leaves grow. That the fruits mature in January and February. They also indicated that the seeds have hairs on both ends, which facilitate wind dispersal.

2.13 Ecological distribution of *Alstonia boonei*

According to Orwa *et al.*, (2009) in Nigeria, the plant occurs in moist lowland forest but may extend into drier types which include gentle to steep, rocky hillsites in Liberia, but most commonly found scattered or in small groups in wet or marshy places that are occasionally inundated. They reported that it is a tree of the swampy high forest in West Africa and can tolerate a wide range of sites, from rocky hillsides to seasonal swamps. They also reaveled that the tree prefer damp situations, but it grows satisfactorily on well-drained slopes and requires large amounts of light and colonizes gaps in the forest. It also has plenty of natural regeneration in young secondary forest. Orwa *et al.*, 2009; Iyiola *et al*., (2011) reported that the plant thrives very well in damp riverbanks. Orwa *et al*., (2009) stated in their work that the collar stumps of *A. boonei* are attacked by the fungus *Irpex flavens*. They also stated *A. boonei* requires altitude: 550-1000m, Mean annual rainfall: 1500-2000 mm, Soil type: Moist to well-drained soils can lead to its rapid growth, and it is not uncommon for an annual increment of 1.8 m to occur in the sapling stage. It grows in a succession of crowns and should not be pruned but left to develop secondary crowns, which will later kill off the lower ones. They concluded that matured trees are often damaged by wind and decay but are fast growing and coppice readily from the base, the tree snaps easily in strong wind and therefore should not be planted near buildings.

2.14 Medicinal importance of *Alstonia boonei*

Akinmoladun *et al*., (2007) reported that *A. boonei* contains important minerals like calcium, phosphorus, iron, sodium, potassium, and magnesium. Orwa *et al.*, (2009) indicated that an infusion of the stem bark in cold water is drunk as a cure for venereal disease, worms, snakebites, and rheumatic pains and to relax muscles. Akinmoladun *et al*., (2007) stated that the root and stem bark decoctions are used as a remedy for asthma while the stem bark and fruit decoctions are taken daily to treat impotence. Idu *et al*., (2010) indicated that the bark and the root are used in Nigeria to treat malaria, ulcer, and sores while the bark is also used as an antidote in persons hit by poisoned arrow. Orwa *et al.*, (2009) reported that in India, that the bark is used for treatment of malaria and chronic diarrhea, while In Cote d'Ivoire, it is used in treating sores and fractures. They also reported that the bark, leaves, and root are all used to relieve rheumatic pain and also used in treating tooth ache and given after childbirth to promote expulsion of placenta. The essential oil compositions of the leaf, stem bark, and root have been reported by Moronkola and Kunle, (2012), (*Z*)-9-Octadecenoic acid was found to be the most abundant volatile oil in the leaf and stem bark while methyl (7 E)-7-octadecenoate was most abundant in the root. Akinmoladun *et al*., (2007) suggested that Alkaloids, Triterpenes, and other chemical compounds isolated from the plant have been demonstrated to possess some pharmacological activities. Orwa *et al*., (2009) also stated that Echitamine (main alkaloid) and other alkaloids, and the triterpenes β-amyrin, lupenol, and ursolic acid have all been isolated from leaves and stem bark. That some of the alkaloids isolated from the plant have been shown to possess diuretic, spasmolytic, and hypotensive properties while the triterpenes demonstrated anti-inflammatory activity. Majekodunmi *et al.*, (2008) indicated that there is formulation of the extract of the stem bark of *A. boonei* as tablet dosage form, that the specie is highly priced, especially in situations where affordable antimalarial drugs are found ineffective, due to drug-resistant malaria parasites. They state that plant stem bark or leaves are administered as decoction or "teas" and sometimes as an ingredient in malaria "steam therapy". They also confirmed that the stem bark extract was formulated into tablets, and made available as an antimalarial remedy. According to Moronkola and Kunle, (2012), the plant stem bark and its latex are applied in traditional medicine for treating many diseases.

2.15 Economic importance of *Alstonia boonei*

Orwa *et al.*, (2009) reaved that the plant is of varios economic importance such as;

Fuel: This species provides firewood.

Timber: The sapwood, which is not differentiated from the heartwood, is very wide, up to 200 mm, soft, and light in weight when dried. The wood weighs about 400 kg/cubic m. It is nearly yellowish-white when freshly cut, the timber darkens on exposure. It has a low lustre and no characteristic odour or taste. It has local potential for stools, carvings, domestic utensils, toys, masks, canoes, horns, light carpentry, boxes and wood wool for packing bananas.

Latex or rubber: The latex gives an inferior resinous coagulate, which has been used to adulterate better rubbers. It has been used as birdlime.

Poison: The latex is dangerous to the eyes and can cause blindness.

2.16 Use of Stool wood (*Alstonia boonei)* in integrated pest management

Moronkola and Kunle, (2012) reported that the chemical compounds isolated from *A. boonei* include alkaloids, tannins, saponins, flavonoids, iridoids, cardiac glycosides and triterpenoids. Adotey *et al*., (2012) observed that six alkaloids namely: echitamine (1), echitamidine, voacangines, akuammidine, Nα- formylechitamidine and Nα-formyl-12-methoxyechitamidine have been isolated from the stem bark of *A. boonei*. Arivoli and Tennyson (2013) opined that the quantification of antifeedant effect of botanicals is of great importance in the field of insect pest management. Oigiangbe *et al.,* (2007) in their findings revealed that extracts of *A. boonei* leaf showed insecticidal activity against *Sesamia calamistis* Hampson (Lepidoptera: Noctuidae) previously. Ileke, *et al*., (2014) reported that stem bark powder of *A. boonei* effectively served as protectant to Cowpea against Bruchid beetles *Callosobrochus maculatus.*

Oigiangbe *et al.*, (2013) in their study reported a bioactivity of alkaloid isolated from fresh leaves of *A. boonei* against *Maruca vitrata* under a laboratory bioassay and study indicated multiple effects of *A. boonei* leaf alkaloid on the larval survival, weight, pupation and adult emergence, the pupal deformity or abnormality were observed may be due to some sub-lethal effects of the alkaloid.

2.17 Vital information on Bush tea *Hyptis suaveolens*

Sharma *et al*., (2013) reported that *Hyptis suaveolens* (L.) Poit, is member of the Lamiaceae or Labiatae family, a common weed of roadsides and waste grounds. That *H. suaveolens* (pignut) is generally described as annual, perennial forb or herb or subshrub or vine.

2.18 Origin and distribution of Bush tea *Hyptis suaveolens*

According to Shaikat *et al.*, (2012), this Dicot (dicotyledonous) is native to tropical America, is an annual herb that occupies roadsides, rail tracks, wastelands, watercourses, pastures and open forests where the soil is well drained. It can form dense thickets in all areas of growth. Prasanna and Koppula 2012; Sharma *et al*., 2013; Umedum *et al*., (2014) indicated in their findings that *H. suaveolens* is widespread in Australia (northern territory and Queensland), China, Indonesia, Papua New Guinea, Solomon Islands, French Polynesia, Federated States of Micronesia (Chuuk and Yap Islands), Niue Islands, and Guam and the Hawaiian Islands in the USA. It is widespread in West and Central Africa where it is considered an insidious species in some countries like; Benin, Kenya, Nigeria, Sudan, and Cameroon.

2.19 Names and botanic description of Bush tea *Hyptis suaveolens*

According to Umedum *et al.*, (2014), *Hyptis suaveolens* (L.Poit) commonly called bush mint, bush tea, pignut. Horehound,wild spikenard, or chanis known as vilayati tulsi in hindi; konda thulasi in Telugu; bhustrena in Sanskrit; daddoya-ta-daji in Hausa; efiriin Yoruba; nchuanwu in Ibo; and tanmotswangi-eba in Nupe. Sharma *et al*,. (2013) reported that it is known as Hyptis a odeur in French, Alfavaca-brava,Betonica-brava (Portuguese, Brazil), Chao, Hierba de las muelas, hortela do campo (Spanish), Wilaiti tulsi (Hindi), bhustrena, darp tulas, jungli tulas (Marathi), sirna tulasi (Telugu), bilati tulas (Bengali), Ganga tulasi (Oriya), bhustrena (Sanskrit).It is an erect and strappingly aromatic annual herb reproducing by seeds. Prasanna and Koppula (2012) observed that the stem is woody hairy and bears glandular dots. They further indicated that *Hyptis* is a strong-scented herb, which grows up to 2 m in height, with quadrate hairy stems and ovate to obviate leaves (3-5 cm long and 2-4cm wide). That the margins of the leaves are serrulate and the lower surface is densely hairy. Mbatchou *et al*., (2010) stated that the petioles are up to 3 cm long. That the flowers grow in small cymes along branch ends with reduced leaves. The calyx is 5 mm long in flower and 10 mm long in fruit and is ribbed; corolla is blue in colour. Nutlets (a small nutlike fruit or seed) are about 1.2-1.5 mm long and slightly notched at the end. They also reported that the seeds are dispersed through the movement of water, animals, and vehicles. It has a wide range of pollinators and, hence, seed production is enormous. The seed can remain dormant for many years and the plant can sprout vigorously from rootstocks following rains. Morphologicallyits features resembles with *Ocimum species*.

Plate 4: Bush tea (*Hyptis suaveolens* (L.Poit) showing the leaves and flower

2.20 Nutritional importance of Bush tea *Hyptis suaveolens*

Umedum *et al.*, (2014) indicated that *H. suaveolens* has been reported to contain basic food nutrients: protein, carbohydrates, fats and fibre and phytonutrients such as alkaloids, tannins, saponins, flavonoids and terpenoids. The plant is also rich in some mineral elements like potassium (K), calcium (Ca), magnesium (Mg), nitrogen (N), sodium (Na) and phosphorus (P). They also reported that studies on the proximate analysis of *Hyptis suaveolens* leaves conducted by many researchers revealed that the plant contains appreciable amount of the basic food nutrients: protein (10.00-14.22)% carbohydrate(66.61-75.05)%, fat(2.00-4.46)%, and fibre (5.15-9.04)% [8,9,10] as presented in Tables 1 and 2. That the high content of carbohydrates shows that it is a good source of energy and can help in the oxidation of fats. A diet rich in fibre is desirable because fibre has a physiological effect on the gastrointestinal function. It also has a biochemical effect on the absorption and re-absorption of bile acids and consequently the absorption of dietary fats and cholesterol. Thus, it can serve as a source of nutritional dietary supplements. Aguirre et al., (2012) revealed analysis of the protein composition of the seeds showed the presence of globulins (39%), glutelins (36%), albumins (24%) and prolamins (1%). The content of branched amino acids is higher in *H. suaveolens* than in maize and other cereals. Thus, it could provide a good supply of almost all the essential amino acids for different age groups. This medicinal plant therefore has great potential for benefiting people in countries suffering from poverty and malnutrition. Although there has not been any report on the extensive use of this plant as food, but it is used in Asian food recipes as an appetizer due to the presence of its essential oil has been reported by Aguirre *et al*., (2012); Sulta and Annamalai, (2013). It therefore serves as an edible aromatic flavouring addictive for food.

2.21 Medicinal importance of Bush tea *Hyptis suaveolens*

Mozhiyarasi and Anuradha, (2016) revealed in their study that *H. suaveolens* has medicinal properties and the chemical contituence are responsible for its effecientcy in antimicrobial activity. Umedum *et al*., (2014) reported that leaf extracts cure swellings, abscesses and haemorrhoids. In India the plant is considered to be stimulant, carminative, sudorific and lactogogue. Infusion is used in infections of the uterus; leaf juice is taken in cases of colic and stomachache. The shoot tops of the plant are edible and also used for flavouring purposes. Leaves are used in the preparation of mint flavoured beverages. Roots are chewed with betel nuts as a stomachic and its decoction is used as an appetizer while some parts of the plant are used for the treatment of headache. Indians used to take it in the morning soup which is made by mixing it with corn. Tea made from the roots of *H. Suaveolens* is used to purify the blood and is also used as a remedy for the "diseases" of women. In Indonesia, the plant infusion is used to treat catarrhal (inflammation of mucous membranes, especially of the nose and throat) conditions, affections of the uterus, parasitic cutaneous diseases while the leaves are used as stomachic. In Philippines, the leaves are used for the antispasmodic, anti-rheumatic and antisoporific. In West Africa the leaves of *H. suaveolens* are employed as antifertility agents. In case of a burning sensation when passing urine (Dysuria) and other urinary complaints, dry seeds of *H.suaveolens* are soaked overnight in a glass of water and taken in the morning on an empty stomach along with small amounts of sugar for about a week. The very strong aromatic mint/thyme-like smell leads to the use of the plant as an insectifuge. As its English name bush tea implies, *H. suaveolens* serves in West Africa as an acceptable substitute in infusion for tea (Umedum *et al*., 2014). It is carminative, sudorific (causing or increasing sweat), lactogenic, anti-catarrhal and antiparasitic. The plant has been reported to possess antifertility, anti-inflammatory and antiplasmodial properties.

Tumor, Malaria, Head Ache, Cancer, Expectorant, Fever, Stomach Ache, Cold, Yellow Fever, Rheumatism, Analgesic, Spasm,Antispasmodic, Constipation, Urethritis, Liver Stimulant, Antisudorific, Depurative, Stomachic,Aperitifs, Dyspepsia, Menorrhagia, Sudorific, Be´chic (relieving a cough), Epistaxis, Nausea, Tea, Bilious, Pacifier, Palsy, Carminative, Flu,Poison(Veterinary), Repellent (Insect) Lactogogue Catarrh.

2.22 Insecticidal activity of *Hyptis suaveolens* in integrated pest management

According to the findings of Adda *et al.*, (2011), botanical insecticides have long been touted as alternatives to synthetic chemical insecticides for pest management because they pose little threat to the environment and human health. Conti *et al*., (2012) reported that bush tea *Hyptis suaveolens.*L possess bioactive compounds with prominent ovicidal, larvicidal and adulticidal properties against insect pests. While Peer *et al*., (2018) opined that these bioactive compounds have been field tested on crop plants to assess their efficacy as raw extracts on common lepidopteron larvae. Adda *et al*., (2011) also stated that *H. suaveolens* is used as an effective pesticide capable of controlling serious pests like *Sesamia calamistis, Helicoverpa armigera and Spodoptera litura* (Fab). Musa *et al.,* (2009) reported that it has been used for control of *Trogoderma granarium* (Coleoptera: Dermestidae) in stored groundnut. Aguirre *et al*., (2009); Adda *et al*., (2011) also said that other reports have shown that methanolic extracts of the plant were effective in the biological control of *Sitophilus oryzae* (rice weevil), *Sitophilus zeamais* (maize weevil), and *Callosobruchus maculatus* which are serious stored product pests that attack various economically important crops. Benelli e*t al*., (2012) indicated that the essential oil has also been reported to be effective against the adult granary weevil *Sitophilus granaries*. Peer *et al.*, (2018) also confirmed in their findings that a protease inhibitor isolated from the seeds of *Hyptis suaveolens* has been reported to have a high activity against the intestinal trypsin-like proteases from different insect pests, particularly against the insect *Prostephanus truncatus*, a most important insect pest of maize. They reported that *H. suaveolens* was found to be toxic to the third, fourth and fifth larvae of Rice moth, *Corcyra cephalonica.* Research conducted by Abgali and Alavo, (2011) on its use for protection against mosquito bites has shown that it is as effective as DEET (N, N-dimethyl-3-methyl benzamide), one of the well-known arthropod repellents. (Shaikat *et al.*, 2012) carried out phyto chemical screening of *H. suaveolens* and identified the presence of alkaloids, glycosides, saponins, tannin and flavonoids in ethanolic extracts of the leaves. According to Peer *et al*., (2018), presence of heavy metals like arsenic, cadmium, copper, chromium, lead and zinc were recorded in leaf, flower, stem and seeds of *H. suaveolens* and potentiate it as insecticides. They concluded that the ability of *Hyptis suaveolens* to act as an effective insecticide or pesticide has been attributed to its essential oils.

2.23. Phytoconstituents of Bush tea *hyptis suaveolens*

According to Mozhiyarasi and Anuradha, (2016), *Hyptis suaveolens* is an important source of essential oils, alkaloids, flavonoids, phenols, saponins, terpenes, and sterols, for example diterpenes: suaveolic acid, suaveolol, methyl suaveolate, two steroids: β-sitosterol, β- sitosterol glycoside two phenolic constituents: rosamarinic acid and methyl rosmarinate along with some other important constituents, Jain *et al.*, (2010) reported presence oleanolic acid or oleanic acid, ursolic acid, 3β-hydroxy-lup-12-en-28-oic acid, urs-12-en-3β-ol-27-oic acid1,19adihydroxy-urs-2(3),12-dien-28-oic acid and 3β-hydroxyl lup-20-en-27-oic acid. They also stated that *H. suaveolens* contains many diverse phytochemicals like α-Phellandrene , which is a monocyclic terpene with a pleasing aroma, α - pinene a terpene having very reactive four membered rings,4,11,11-Trimethyl-8-Methylene-Bicyclo{7.2.0}-Undec-4-ene , α-Caryophyllene , 3-cyclohexen-1-carboxaldehyde, 5α-androst-2,11-dione , 5α-androst-9-en-12-one , 4-methyl-1-(1-methylethyl)-3-cyclohexen-1-ol, Thujane , 1 8 cineole.

2.24 Vital Information on Jathtropha plant *Jatropha tanjorensis*

Osuchukwu *et al*., (2016) reported that *Jatropha tanjorensis* is a common weed of field crops, bush re-growth and a gregarious shrub of about 1.8 meters in height and are usually grown in the higher rainfall forest zones in West Africa. That it belongs to the family Euphorbiaceae and is widely grown in Southern Nigeria. Atansuyi *et al*., (2012) in their work stated that it has been given different local names by different folks from different geographical regions and some of these names include Iyana-Ipaja, lapalapa, and “hospital too far” or catholic vegetable which it is popularly called by the local folks in Benin, Nigeria.

2.25 Taxonomy and botanical description of *Jatropha tanjorensis*

According to Ameloko, (2015), *Jatropha tanjorensis* belongs to the family “Euphorbiacea”. Other species are *Jatropha curcas, Jatropha glandulifera*, *Jatropha gossypifolia, Jatropha multifida*, *Jatropha podagrica* and *Jatropha intergerrima*. It is a bushy, gregarious shrub of about 1.8meters in height. Osuchukwu *et al.*, (2016) reported that the leaves are 3-5 lobed, palmately, 20cm glandular hair. They went futher to say that *J. tanjorensis* is a perenual shrub that is up to about 15ft (5m) tall with a thick green glabrous stem. It is mostly herbaceous or somewhat succulent, becoming woody at the base. Oliveira *et al*., (2013) reported that the leaves are alternate with long petiole, palmate veined, the leaves margin are irregular or with 3.5 shallow lobes. That the flower is point which is acute to obtuse, small, yellow, unisexual that clusters in leaf axils, mostly hidden in foliage. The fruits are ovoid with 3-locular capsule which are initially green and fleshy, which turns brown or almost black and dry at maturity. Osuchukwu *et al.*, (2016) stated that the taxonomy and common names are: Kingdom- Plantea, Division- Magnoliophyta, Class- Magnoliopsida, Oder- Malpighiales, Family- Euphobiaceae, Subfamily- Crotonoideae, Tribe- Jatropheae, Genus- Jatropha species.

Ameloko, (2015) reported that it is called Bindazugu in Hausa, Lapalapa in Yoruba, it is called Ncheogbo in Igbo and Ochiga in Igbirra.

2.26 Uses and nutritional importance of *Jatropha tanjorensis*

According to Ameloko, (2015), *Jatropha tanjorensis* is a native of Central America and has become naturalized in many tropical and subtropical countries, including India, Africa and North America. Its primary use is for fencing while its secondary uses are as a source of edible leafy vegetable and as medicine. Osuchukwu *et al.*, (2016) reported that the plant leaves were initially and popularly consumed in Nigeria as soups and as a tonic with the claim that it increases blood volume. That in some parts of Nigeria the leaves of *Jatropha tanjorensis* are locally consumed as vegetable added to daily meal. They are also grown in the premises of the catholic churches as ornamentals plants.

According to the analysis of Oboh and Masodje, (2009), the dominant constituent of *J. tanjorensis* leaves is water, which accounted for 78.77% of their weight. Fresh leaves have a protein content of 2.01% and an ash content of 0.51%. That the leaves have moisture content similar to published values of cassava 80.0%, cabbage 79.0% and cowpea 85.0 % and sweet potatoes leaves. Protein content of the leaves was lower than published values for cabbage, cassava, cowpea and sweet potato leaves. Ochulor *et al.*, (2018) reported that proximate analysis on *J. tanjorensis* leaves contain Carbohydrates and have high levels of crude fibre, fat and oils, and ash while its moisture andprotien are low. They also reaveled that mineral analysis shows that the leaves have higher sodium which is the most abundant, followed by iron, copper, manganese in decreasing other while molybdenum is the least adundant mineral. They also stated that in the analysis of selected vitamins, that vitamin A recorded the highest (48.215± 2.790mg/ 100g) followe by vitamin B (0.0201.215± 0.001/ 100g), and vitamin C (0.0347± 0.000/ 100g) while vitamin E was not dectected.

Oboh and Masodje, (2009) also reported that Phosphorus constituent of fresh *J. tanjorensis* leaves is 77.0µg /g (that is 0.59% of the RDA of phosphorous is present in 100g of leaves). While selenium constituent in *J. tanjorensis* leaves is 0.0054µg/g. Thus about 0.1% of the RDA for selenium 0.54µg is present in 100g of leaves. That zinc constitutes 6.1µg/g of fresh leaves (4.1% of the RDA for zinc is present in 100g of leaves). iron content in *J.tanjorensis* is 9.4µg/g i.e 53-9.5% of RDA of iron is present in 100g of leaves. They concluded that *J. tanjorensis* contain a modest amount of phosphorous and also appear to be a modest dietary source of trace element selenium and a good source of iron and zinc.

Plate 5: Jathropha plant (*Jatropha tanjorensis*)

2.27 Medicinal uses of *Jatropha tanjorensis*

Osuchukwu *et al.*, (2016) reported that different parts of *Jatropha tanjorensis* have been found useful in the treatment of fever, eczema, itches, visceral diseases, stomachache, and sores on the tongues of babies. Findings of Oyewole and Akingbala, (2011); Omigie and Agoreyo, (2014) also reported that in the Southern Nigeria the leaves of *Jatropha tanjorensis* have been used for the treatment of diabetes mellitus as it is said to possess anti hyperglycaemic effect. Orhue *et al.*, (2008) reported in their work that the leaf extract has hypoglyceamic and antioxidant properties that make it a popular remedy for the treatment of diabetics, malaria and hypertension in this region. They also reported that administration of *Jatropha tanjorensis* leaf powder to rabbits resulted in improvement in haematological indices which revealed an enhancement of bone marrow function. Osuchukwu *et al.*, 2(016) observed that although plant based natural medicines are popularly acclaimed to be safe, scientists advocate for proper toxicological studies in order to ensure safety in their use. Oluwole *et al*., (2012) claimed in their work that the plant is no longer safe for use and that it could be toxic to organs in the body, that it has also been said by these same consumers that the leaves have a negative effect of damaging the liver and causing liver enlargement. Although, Oliveira Simone *et al*., (2013) indicated that it has been said that consumption of the seeds of *Jatropha curcas* can causes acute abdominal pains, burning sensation in the throat, diarrhea and vomiting.

Osuchukwu *et al.*, (2016) suggested that the leaf is used as heart tonic and remedy for hypertension in some parts of Nigeria, however there is no sufficient scientific validation of these claims. However, Omobuwajo *et al*., (2011) indicated that toxicity and histopathological studies of the leaf extract on rats revealed no significant abnormalities in the tissues except for mild effects on the lungs and liver.

Findings of Orhue *et al.*, 2008; Omoregie and Osagie, (2011) reported that the leaves are also employed traditionally in the treatment of anaemia (as a haematinic agent), diabetes and cardiovascular diseases. Omoregie and Osagie, (2011) observed that the leave extract has hypoglycemic activities, and it is taken as medicine for diabetes symptoms. They reported that the antioxidant potential of the leaf extract has been investigated and was discovered to have anti-oxidative potential against reactive oxygen species produced in protein energy malnutrition.

2.28 Phytoconstituents of *Jatropha tanjorensis*.

The medicinal value of a plant depends on its bioactive phytochemical constituents that produce definite physiological action in the body. Ochulor *et al*., (2018) reported that the qualitative and quantitative anti-nutritional analysis they carried out in their study revealed that alkaloids are the major antinutritional constituents followed by Saponnin, Phytate, Flavonoids, Phenolics, Cyanide and Oxalate. Krishnaiah, D., Devi, T., Bono, A. and Sarbatly, R. (2009) gave similar observation that some of the most important bioactive phytochemical constituents include alkaloids, flavonoids, phenolics, essential oils, tannins and saponins. Several authors have evaluated the phytochemical composition of *J.tanjorensis*. Oluwole and Akingbala, (2011); Ilondu and Enwa, (2013) revealed the presence of saponins, cardiac glycosides, flavonoids, terpenoids and tannins in the leaf extract. Venkatalakshmi *et al*., (2012) observed that nature has been a source of medicinal agents for thousands of years and an impressive number of modern drugs have been isolated from natural sources. Omonkhelin *et al*., (2007) revealed that plant based traditional medicinal system continues to play an essential role in health care, with about 80% of the world's inhabitants relying mainly on traditional medicines for their primary health care. Mishra *et al*., (2009) observed that it is well known that these plants generally contain those secondary metabolites (flavanoids, saponins, alkaloids, and tannins) which have been associated with numerous physiological activities in mammalian cells in various studies.

2.29 Description and economic importance of Plant extracts (Phytochemicals) in Pest management.

According to the World Health Organization, a medicinal plant is any plant which, in one or more of its organs, contains substances that can be used for therapeutic purposes, or which are precursors for chemo-pharmaceutical semi synthesis (Doughari, 2012). Such a plant will have its parts including leaves, roots, rhizomes, stems, barks, flowers, fruits, grains or seeds, employed in the control or treatment of pests and diseases conditions and therefore contains chemical components that are medically active. These non-nutrient plant chemical compounds or bioactive components are often referred to as phytochemicals ('phyto-'from Greek – meaning 'plant') or phytoconstituents and are responsible for protecting the plant against microbial infections or infestations by pests (Doughari *et a*l., 2009; Doughari, 2012). The study of natural products on the other hand is called phytochemistry. Phytochemicals have been isolated and characterized from fruits such as grapes and apples, vegetables such as broccoli and onion, spices such as turmeric, beverages such as green tea and red wine, as well as many other sources (Doughari and Obidah, 2008; Doughari *et al.*, 2009). Different plant parts and components (roots, leaves, stem barks, flowers or their combinations, essential oils) have been employed in the treatment of infectious pathologies in the respiratory system, urinary tract, gastrointestinal and biliary systems, as well as on the skin (Adekunle and Adekunle, 2009). Plant synthesize a wide array of compounds that are generally thought to be involved in plant- insect interactions, such compounds of secondary metabolism as alkaloids, terpenoids, phenols, flavonoids, steroids, etc. are important for mediating interactions between plants and their biotic environment and do not have apparent function in physiological or biochemical proceses (Acheuk and Doumandji- Mitiche, 2013). Most of these compounds have potent effects on insect pests, low mammalian toxicity, lack of neurotoxic activity, low persistence in the environment, high biodegradability and an excellent alternative to persistent synthetic insecticides (Acheuk and Doumandji- Mitiche, 2013). Santos *et al*., (2016) reported effects of flavoniods in their work that *Tagetes erecta* and *Tagetes patula* have phytotoxic flavonoids that can promote and expand their use as a natural insecticide. Hikel et al., (2017) confirmed that alkaloids are the most important group of natural products playing an important role in insecticidal. Wachira *et al*., (2014) observed that pyridine alkaloids extracted from *Ricinus communis* against the malaria vector *Anopheles gambiae*. Nobsathian *et al*., (2019) indicated that efficiency and effectiveness of *Holothuria atra* extractions and triterpene glycoside compounds against *Spodoptera litura* shows their potential use in integrated pest management programs and sources of insecticidal compounds. Jin *et al*., (2015) reported that insecticidal activity was enhanced when *Bacillus thuringensis* subsp. Kurstaki KB100 strain containing insecticital activity against *Spodoptera exigua* was mixed with tannic acid, a protease inhibitor. According to Hussein *et al*., (2005): De Geyter *et al*., (2007), Saponins give rise to increased mortality levels, lowered food intake by making food less attractive by repellent or deterrent activity, weight reduction, retardation in development, disturbances in development and decreased reproduction in insect pests. Scalerandi *et al*., (2018) reported a synergetic combination of terpenes from 1,8-Cineole, citronellol, citronellic acid, linalool, (R)- limonene, (R)-a-pinene, (S)-β-pinene, (R)-pulegone, α-terpinenene, γ-terpinene, thymol and PBO in unequal proportions to avoid metabolization of most toxic compound increased toxicity by 2-31 times compared to the corresponding individual terpenes against *Musca domestica.*

2.30 Mechanism of action of phytochemicals

According to Omojate *et al.*, (2014), different mechanisms of action of phytochemicals have been suggested. They may inhibit microorganisms, interfere with some metabolic processes or may modulate gene expression and signal transduction pathways. Koul, (2008) indicated that phytochemicals may either be used as chemotherapeutic or chemo preventive agents with chemoprevention referring to the use of agents to inhibit, reverse, or retard tumorigenesis. In this sense chemo preventive phytochemicals are applicable to cancer therapy, since molecular mechanisms may be common to both chemoprevention and cancer therapy. They also reported that the known active plant-based antifeedants belong to groups like chromenes, polyacetylenes, saponins, quassinoids, cucurbitacins, cyclopropanoid acids, phenolics, alkaloids, various types of terpenes and their derivatives etc., and each insect species may process these allomones in a thoroughly idiosyncratic way, so that the same compound may have very different fates and consequences in different species of insects, thus pointing to different mechanisms involved in antifeedant action. They also indicated that it can also be visualized that insect feeding deterrents may be perceived either by stimulation of specialized deterrent receptors or by distortion of the normal function of neurons, which perceive phagostimulating compounds. Some plant antifeedants influence the feeding activity through a combination of these two principal modes of action. Plant extracts and essential oils may exhibit different modes of action against bacterial strains, such as interference with the phospholipids bilayer of the cell membrane which has consequently a permeability increase and loss of cellular constituents, damage of the enzymes involved in the production of cellular energy and synthesis of structural components, and destruction or inactivation of genetic material. Phytochemicals elicit chemotherapeutic or chemoprophylactic properties against an array of infectious enteric diseases. Kotzekidou *et al*., (2008) reported that many mechanisms of antimicrobial action of phytochemicals have been suggested by different researchers (Phytochemicals may act by inhibiting microbial growth, inducing cellular membrane perturbations, interference with certain microbial metabolic processes, modulation of signal transduction or gene expression pathways. According to Kotzekidou *et al.*, (2008) and Omojate *et al*., (2014), Plant-based constituents may exhibit different modes of action against enterotoxigenic bacterial strains which range from interference with the phospholipoidal cell membranes, which has as a consequence of increasing the permeability profile and loss of cellular constituents, damage of the enzymes involved in the production of cellular energy and synthesis of structural components, and destruction or inactivation of genetic material. In general, the mechanism of action is considered to be the disturbance of the cytoplasmic membrane, disrupting the proton motive force, electron flow, active transport, and coagulation of cell composition.

2.31 Toxicological studies of Phytochemicals

Doughari, (2012) reported that these studies are often carried out to determine the toxicity of a plant part. Usually animal models such as mice, guinea pigs or rabbits are often employed. In these procedures, the LD50 of the extracts in the experimental animal is often determined via either oral or intradermal administration. They also indicated that the toxic response of experimental animals to the administration of plant alkaloids is usually detected by assay of the serum Alanine aminotransferase (ALT) and Aspartate aminotransferase (AST) of the animal as sensitive indicators of hepatocellular damage. Firn, (2010) indicated that any toxicity usually results in distortion of hepatocytes membrane integrity due to hepatocellular injury and plasma levels rise, because of high toxin levels present within hepatocytes.

2.32 Safety concerns for Phytochemicals

According to Mattson, (2008), plants are natural reservoirs of medicinal agents almost free from the side effects normally caused by synthetic chemicals. Yadav and Dixit, (2008) reported that the World Health Organization estimates that herbal medicine is still the main stay of about 75-80% of the world population, mainly in the developing countries for primary health care because of better cultural acceptability, better compatibility with the human body, and lesser side-effects. The overuse of synthetic drugs with impurities resulting in higher incidence of adverse drug reactions, has motivated mankind to go back to nature for safer remedies. They went ahead to say that due to varied locations where these plants grow, coupled with the problem of different vernacular names, the World Health Organization published standards for herbal safety to minimize adulteration and abuse.

Rizvi *et al*., (2009) revealed that several modern drugs have been isolated from natural sources and many of these isolations were based on the uses of the agents in traditional medicine. Antimicrobial properties of crude extracts prepared from plants have been described and such reports had attracted the attention of scientists worldwide (El-Mahmood and Amey, (2007); El-Mahmood, (2009). Mattson, (2008) reported that herbs have been used for food and medicinal purposes for centuries and this knowledge has been passed on from generation to generation. (El-Mahmood, 2009) indicated that this is particularly evident in the rural areas where infectious diseases are endemic and modern health care facilities are few and far thus, compelling the people to nurse their ailments using local herbs. Herbal treatments have been judged to be relatively safe.

Rizvi *et al., (*2009) said that another advantage with phytochemicals is that, among an estimated 10,000 secondary products (natural pesticides), it has been proposed that human ancestors evolved a generalized defense mechanism against low levels of phytochemicals to enable their consumption of many different plant species containing variable levels of natural pesticides (carcinogens) without subsequent ill health. Mattson, (2008) indicated that traces of phytochemicals found in fruits and vegetables may potentiate the immune system and help to protect against cancer. Works of Yadav and Dixit, (2008); Maurya *et al.*, (2010) confirm that phytochemicals show biphasic dose responses on mammalian cells. Though at high concentrations they can be toxic, sub-toxic doses may induce adaptive stress response. This includes the activation of signaling pathways that result in increased expression of genes encoding cytoprotective proteins. Mattson, (2008) therefore suggested that hormetic mechanisms of action may underlie many of the health benefits of phytochemicals including their action against cancer drug resistance.

2.33 Description of the term Plant oils

Martinez *et al.*, (2008) indicated that plant oils are the odorous and volatile products of various plant and animal species. Plant oils have a tendency to evaporate on exposure to air even at ambient conditions and are therefore also referred to as volatile oils or ethereal oils.

They mostly contribute to the odoriferous constituents or ‘essences’ of the aromatic plants that are used abundantly in enhancing the aroma of some spices. Firn, (2010) reported that the plant oils are either secreted either directly by the plant protoplasm or by the hydrolysis of some glycosides and structures such as directly plant structures associated with the secretion of plant oils include: glandular hairs (Lamiaceae example is *Lavandula angustifolia*), oil tubes (or vittae) (Apiaceae example is *Foeniculum vulgare*, and *Pimpinella anisum* (Aniseed), modified parenchymal cells (Piperaceae example is *Piper nigrum* - Black pepper), schizogenous or lysigenum passages (Rutaceae example Pinus palustris- Pine oil. They also confirmed that plant oils have been associated with different plant parts including leaves, stems, flowers, roots or rhizomes. Chemically, a single volatile oil comprises of more than 200 different chemical components, and mostly the trace constituents are solely responsible for attributing its characteristic flavour and odour.

Plant oils can be prepared from various plant sources either by direct steam distillation, expression, extraction or by enzymatic hydrolysis. Direct steam distillation involves the boiling of plant part in a distillation flask and passing the generated steam and volatile oil through a water condenser and subsequently collecting the oil in florentine flasks. Depending on the nature of the plant source the distillation process can be either water distillation, water and steam distillation or direct distillation.

According to Doughari, (2012), expression or extrusion of volatile oils is accomplished by either by sponge method, scarification, rasping or by a mechanical process. In the sponge method, the washed plant part e.g. citrus fruit (example, orange, lemon, grapefruit, bergamot) is cut into halves to remove the juice completely, rind turned inside out by hand and squeezed when the secretary glands rupture. The oozed volatile oil is collected by means of the sponge and subsequently squeezed in a vessel. The oil floating on the surface is separated. For the scarification process the apparatus Ecuelle a Piquer (a large bowl meant for pricking the outer surface of citrus fruits) is used. It is a large funnel made of copper having its inner layer tinned properly. The inner layer has numerous pointed metal needles just long enough to penetrate the epidermis. The lower stem of the apparatus serves two purposes; first, as a receiver for the oil; and secondly, as a handle. Now, the freshly washed lemons are placed in the bowl and rotated repeatedly when the oil glands are punctured (scarified) thereby discharging the oil right into the handle. The liquid, thus collected, is transferred to another vessel, where on keeping the oil clear may be decanted and filtered. For the rasping process, the outer surface of the peel of citrus fruits containing the oil gland is skillfully removed by a grater. The 'raspings' are now placed in horsehair bags and pressed strongly so as to ooze out the oil stored in the oil glands. Initially, the liquid has a turbid appearance but on allowing it to stand the oil separates out which may be decanted and filtered subsequently.

They also confirmed that the mechanical process involves the use of heavy-duty centrifugal devices so as to ease the separation of oil/water emulsions invariably formed and with the advent of modern mechanical devices the oil output has increased impressively. The extraction processes can be carried out with either volatile solvents (example is hexane, petroleum ether or benzene) resulting into the production of 'floral concretes'- oils with solid consistency and partly soluble in 95% alcohol, or non-volatile solvents (tallow, lard or olive oil) which results in the production of perfumes. Examples of volatile oils include amygdaline (volatile oil of bitter almond), sinigrin (volatile oil of black mustard), and eugenol occurring as gein.

2.34 Cypermethrin 10EC

According to Prodhan *et al*., (2010) Cypermethrin is a synthetic pyrethroid insecticide that is extremely effective against a wide range of insect pests. The insecticide is both a stomach poison and a contact poison that affects the nervous system of vertebrates and invertebrates

2.35 Description of chemical of Cypermethrin

Siegfried, (1993) gave a description of Cypermethrin 10EC as follows:

Generic Name: Cypermethrin

Common Name: Cypermethrin,

Trade Name: Cypermethrin 10%EC.

Number: 67375- 30- 8,

Chemical Family: Pyrethroid,

Empirical formular: C 22 H19 CL 2NO 3 Mol.

Chemical Name: Cyno (3-phenoxylpheny) methyl - 3 - (2, 2 - imethylcyclopropanecarboxylate).

Chemical composition: Cypermethrin Tech. (based on50%w/ w a.i.) 20.00% w/ w

Emulsifiers- 8.80%w/ w, Xylene- 71.20% w/ w, Total- 100.00% w/ w.

Chemical description: Cypermethrin 10% EC is a Non-Systemic, contact and stomach emulsifiable concentrate formulation based on Cypermethrin Technical 10% w/ w EC and controls Bollworms, borers, and Diamond Black Moth etc of various crops like, Cotton, Wheat, oilseeds, sugarcane, Vegetables, coffee, cocca ,Paddy etc. It also controls other pests viz, cockroaches and flies in animal houses and public health. It should be used in accordance with climatic conditions and the approval of local authorities.

2.36 Uses and formulation of Cypermethrin

Prodhan *et al*., (2010) reported that it is used to control many pests including lepidopterous pest of fruits and vegetable crops. It is available as emulsifiable concentrates or wettable powders.

2.37 Chemical and physical characteristics of Cypermethrin

Walker and Keith, (1992) indicated that Cypermethrin appears thus:

Physical Appearance: White crystalline solid.

Molecular weight is 416.3 and a melting point of 78 - 81^{o}c. Relative density of 1.12, flashing point ≥ 80^{0}c and boiling: Decomposes or degradation, microbes play and significant role in the degradation of Cypermethrin, it degrades more slowly under anaerobic and waterlogged conditions. Hydrolysis and photolysis play major roles in the degradation of Cypermethrin in the soil.

Tang and Siegfried, (1995) reported that the vapor pressure is at 23 x 10 - 2m pa / 20^{0}c, it has a very low vapor pressure and almost has no tendency to volatilize from an aqueous solution into the atmosphere.

According to Siegfried, (1993), the water solubility of Cypermethrin is very low, 4 ppb at 200^{0}C. Cypermethrin is extremely hydrophobic and will quickly move from an aqueous solution to suspended particulates. Even though Cypermethrin has a high lipo affinity, it is not significantly stored in fatty tissues and is excreted primarily intact.

2.38 Toxicological characteristics of Cypermethrin

Jin and Webster, (1998) has suggested that Cypermethrin is much more toxic to insects than mammals because the insect’s metabolism rate is much slower. They further explained that it is extremely toxic to fish and aquatic organisms. The persistent nature of pesticides has impacted our ecosystem to such an extent that pesticides have entered various food chains and into the higher trophic levels such as that of humans and other large mammals. Some of the acute and chronic human illnesses have now emerged as a consequence of intake of polluted water, air or food.

Rahman, (2013) observed that;

Rat – (oral acute) LD50 – 247 mg / kg (males)

- (oral acute) LD50 - 309 mg / kg (females)

Rabbit – (acute dermal) LD50 > 2460 mg / kg

Malfard Duck (oral acute) LD50 > 10,000 mg/ kg

Chicken (acute oral) LD50 > 2000 mg / kg

Bluegill sum fish (95 hrs) LC50 is 1.78 ppm

Honeybee LD50 – 0.025 mg / bee

Acute Toxicity: Rat (cutaneous) LD50 mg / kg

Choronic Toxicity: No effect dose on rat is 60 ppm.

Metabolism: Cypermethrin is readily excreted by rats and mice leaving low residue after 8 days (Jin and Webster, 1998).

Mutagenicity: This chemical has been determined to be non-mutagenic.

2.39 Mode of action of Cypermethrin

Jin and Webster, (1998); Rahman, (2013) observed in their findings that cypermethrin acts mainly on the nervous system of vertebrates and invertebrates. Cypermethrin is both a stomach poison and a contact insecticide.

Siegfried, 1993) reported that primary action of Cypermethrin in the peripheral nervous system is to induce noticeably repetitive activity and produce trains of nerve impulses as a result of altering ion permeability of nerve membranes. Vijverberg and Van den Bereken, (1990) suggested that these long-lasting trains can cause hundreds to thousands of repetitive nerve impulses in the sense organs. This repetitive activity is induced by pyrethroid damage to the voltage-dependent sodium channel, causing sodium channels to stay open much longer than normal.

Siegfried, (1993) indicated that Cypermethrin has been shown to inhibit ATP as enzymes involved movement of ions against a concentration gradient which are regulated by active transport, that it possibly affects ion movement and the ability to maintain ion balance, and disrupt respiratory surface, indicating that cypermethrin is inherently more toxic to aquatic organisms.

2.40 Environmental impact assessment of Cypermethrin

Hossen (2008) reported in their finding that cypermethrin residue was detected in tomato samples up to 5 Days After Sowing and the quantities were over Maximum Residue Limits (MRLs) up to 3 DAS. Whereas Prodhan *et al*., (2010) observed cypermethrin residue in yard-long bean which was above the MRLs up to 5 DAS. According to Gil *et al*., (2008), the pesticide losses in the air applied on the vine type of plant ranged from 10-20%. De Rudnicki *et al*., (2010) confirmed in their finding that pesticide loss depends upon the canopy coverage, shape, slope and the height of the plant and spray loss may be 14-45% in field depending on different spraying system. Gil *et al.,* 2008 suggested that up to 90% spray losses of pesticide were commonly seen during a typical spray in the air and soil through drifting. Hewitt *et al.*, (2002) reported that the different micro meteorological factors such as temperature, wind velocity, relative humidity etc., are also found to hamper the spray during application and causes the loss of pesticide.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Field experimentation

Field trials were conducted from March- June for the early season and August- November for the late season of 2016 and repeated same time in 2017 at the Postgraduate Teaching and Research Farm of the Department of Crop Science and Technology, Federal University of Technology, Owerri, Nigeria. The area is located between latitude 05^0 27^0N and longitude 07^0 02^0E. The meteorological data on mean annual rainfall and temperature of Owerri in 2016 and 2017 (Table 1) were collected from Nigerian Meteological Center at Sam Mbakwe International Cargo Airport, Owerri.

3.2 Source of planting Bambara groundnut and botanicals plants

Seeds of Bambara groundnut was purchased from Department of Crop Sciences, University of Nigeria Nsukka, Enugu State. The plant materials used for extraction were collected from different locations. Stool wood, *Alstonia boonei* were collected at Okpuala junction along Aba-Owerri Road Ngor Okuala Local Government Area, Imo State. Bush tea, *Hyptis suaveolens* were collected at the Back of Post Graduate School Building, Federal University of technology, Owerri, Imo State, while Jathropha Plant, *Jatropha tanjorensis* were collected from Premises of Ministry of Agriculture, Aba South Local Government Area, Abia State.

3.3 Land preparation, field layout and planting.

The land area measuring 15 m x 48 m (720 m^2) was mapped out into three blocks using measuring tape (50.00 m), pegs and garden lines to get the total land area, then cleared using cutlass and tilled with the use of spade. Each plot measured 2 m x 2 m with 1 m pathway between the plots and blocks to give a total of 60 plots. Two seeds were sown per hole at the spacing of 0.35 m x 0.50 m inter and intra row spacing to give 48 plants per plot (Plate 7).

3.4 Experimental design and treatment allocation

Treatments were laid out in a 5 x 4 factorial in RCBD with three replications for the field trials. Factor A consisted of five treatment materials namely: (1) *Jatropha tanjorensis* JL Ellis and Saroja (Euphorbiaceae) (JEO). (2) Bush tea *Hyptis suaveolens*. Poit (Libiatae) (HEO), (3) Stool wood *Alstonia boonei*. De Wild (Apocynaceae) (AEO). (4) Mixture of Jathropha, Bush tea and Stool wood bark (J+A+HEO) (5) Cypermethrin 10 EC (CYP) was used as a standard. Factor B is comprised of four rates of application (1) 0.00 ml (2) 2.00 ml / 0.20 ml in litre of H_20 (3) 4.00 ml / 0.40 ml in litre of H_20 (4) 6.00 ml / 0.60 ml in litre of H_20. The treatments were randomly allocated with each treatment represented in all three replications. The Treatment allocation in the field is presented in the Appendix I.

3.5 Germination tests

For the viability test, 50 seeds of Bambara groundnut were selected from the purchased Bambara seeds.Ten seed each were placed in five Petri- dishes whose bases were lined with Whatman's No.44 filter paper moistened with water. This experiment was left for 4- 7 days to ensure that all the viable seeds germinated. Numbers of emerged seedling per Petri- dishes were recorded 4- 7 days after set-up. The germination percentage was calculated with the following formula as propounded by El balla *et al*., (2011).

$$Percentage\ germination = \ No\ of\ germinated\ seed\ \times 100$$

$$No\ of\ seeds\ sown \quad \times\ 1$$

3.6 Soil test

Soils from the experimental site were collected randomly from 3 different locations in the experimental site with soil auger before the experinment at the depth of 20- 30cm after removing debris from the topsoil. The soil samples were bulked to form a composite sample, air dried and analyzed to reveal detailed chemical and physical status of the soil.

3.7 Preparation of the test plant materials and extraction of plant oils

Fresh leaves of *Jatropha tanjorensis*, leaves of Bush tea *Hyptis suaveolens*, and Stem bark of Stool wood *Alstonia boonei* were peeled out, thoroughly washed, chopped into bits and air dried under shade and processed within one week of collection to prevent rotting or other problems that may lead to loss of active principles as described by Ojiako and Kayode, (2014). The air-dried plant materials were subsequently sorted and grinded separately into fine powders using a Binatone electric blender (BLG 450). Eight hundred gram (800g) of powder from each plant material were soaked in 2litres of petroleum ether for 18 hours in a covered plastic, due to high volatile nature of the solvent; the plastic containers were well cocked at room temperature of 35^0C.This represent 40% extraction and later were transferred inside 3 liters thick plastic containers. The aqueous mixtures were then filtered using muslin cloth to remove the uncrushed pieces of plant materials and later transferred into the thimble apparatus. Subsequently, the oil was extracted with petroleum ether in a soxhlet extractor at a boiling temperature of 60^0C. Each of the plants extracts were placed in a 250 ml bottle covered and labeled accordingly. Cypermethrin 10 EC (a.i) was purchased from an Agro-chemical company, Swiss Biostald in Aba, Abia State.

3.8 Qualitative phytochemical analysis of the plant materials

Chemical screening was carried out on the plant extract using the standard procedures for identification of phytochemical constituents as described by Harborne (1973) and Sofowora (1993). The extracted solutions from fresh leaves of *Jatropha tanjorensis*, leaves of Bush tea *Hyptis suaveolens*, and Stem bark of Stool wood *Alstonia boonei* were prepared by dissolving 25g of extracts in 100ml of methanol and allowed for 24hours, followed by boiling until the volume was reduced to one-third to the original volume. The crude extracts were obtained by filtration and stored in a refrigerator at 4^0C (Lin *et al*., 2004).

- **Test for Alkaloid**

Tests for alkaloids were carried out using Mayer test described by Harborne (1973). Three (3) drops of reagents was added to 1g of the extracts from leaves of *Jatropha tanjorensis,* leaves of Bush tea *Hyptis suaveolens*, and Stem bark of Stool wood *Alstonia boonei* in each test tube. Green precipitation occurred and indicated the presence of alkaloids.

- **Test for Flavanoids**

Test for flavanoids were conducted using Soduim Hydroxide test as described by Trease and Evans, (1983). Three (3) drops of aqueous HaOH were added to 5m of each of the extracts from leaves of *Jatropha tanjorensis,* leaves of Bush tea *Hyptis suaveolens*, and Stem bark of Stool wood *Alstonia boonei*/, a yellow colouration occurred which shows that flavaniods were present.

- **Test for Glycosides**

Keller- Killani test were used as described by Edeoga *et al*., (2005). Five (5ml) of each of the extracts from leaves of *Jatropha tanjorensis*, leaves of Bush tea *Hyptis suaveolens*, and Stem bark of Stool wood *Alstonia boonei* were treated with 2m of glacial acetic acid containing onedrop of ferric chroride solution. This was underplayed with 1 ml of concentrated sulphuric acid. A brown ring of interface indicates deoxysugar characteristic of cardenolides. A violet ring appears below the brown ring, while the acetic acid layer, a greenish ring forms just gradually throughout the thin layer.

- **Test for Saponins**

Test for saponins were conducted using Fronthing test as described by Sofowora (1993), 1g of each extract from leaves of *Jatropha tanjorensis*, leaves of Bush tea *Hyptis suaveolens*, and Stem bark of Stool wood *Alstonia boonei* were dissolved in 10ml of distilled water. They were vigorously shaked for 30 seconds and were allowed to stand for 30 minutes. A honeycomb formed indicated the presence of saponin.

- **Test for Tannins**

In testing for tannins, procedure described by Harborne (1973) were used, Lead acetate solution was addaed in 3 drops to the solutions of each extract from leaves of *Jatropha tanjorensis*, leaves of Bush tea *Hyptis suaveolens*, and Stem bark of Stool wood *Alstonia boonei* . A red precipitate indicated the presence of tannins.

- **Test for Terpenoids**

Terpenoids were determined Using Salkowki test as described by Edeoga *et al.*, (2005), 5 ml of of each extract from leaves of *Jatropha tanjorensis*, leaves of Bush tea *Hyptis suaveolens*, and Stem bark of Stool wood *Alstonia boonei* were mixed in 2 ml of chloroform, and concentrated H_2SO_4, 3 ml of each were carefully mixed to form a layer. A redish brown colouration of the interface was formed to show positive results for the presence of terpenoids.

Plate 6 a: Stem bark of Stool wood

Plate 6b: Leaves of *Jatropha tanjorensis*

6c: Leaves of Bush tea *Hyptis suaveolens*

3.9 Field application of treatments.

The plant oils at the rates of 2.00 ml, 4.00 ml and 6.00 ml were dissolved separately in 100 ml of H_20 and sprayed for foliar application. Spraying was done weekly with hand sprayer (1litre capacity) after insect count, according to Dialoke *et al.*, (2014).

3.10 Weeding

Weeding and removal of debris were done manually by hoeing at 3, 6 and 9 weeks after sowing.

3.11 Data collection/Assessment of parameters

Data were collected regularly from the 10 Bambara groundnut plants, that is 5 plants selected at random from two (2) border rows per plot. Assessments were on:

3.12 Insect Count

Insects were sampled during the vegetative, flowering and podding phase of Bambara groundnut. Counts were taken on 10 randomly selected Bambara plants per plot except from the border rows by visual observation. The numbers of insects present on the plants per plot were counted and recorded. Counting was done early in the morning between 6.30 am to 7.30 am when the insects were less active, and the numbers of each insect species were recorded separately. Insect pests were collected using a sweep net and preserved in a specimen bottle containing 95.00% ethyl ethanol. The collected insects were categorized and identified using samples in the Department of Crop Science and Technology, Federal University of Technology, Owerri and confirmed with samples from insect museum at Ahmedu Bello University, Zaria.

3.13 Days to first flower bud initiation

The number of days it took the plant from sowing to first flower bud initiation was recorded.

3.14 Days to flower opening

The number of days for the plants to open flower was noted and recorded.

3.15 Days to 50% flowering

The number of days from sowing for the plants to reach 50% flowering was recorded.

3.16 Days to 100% pod maturity

The number of days from sowing to the time 100% plants leaves have turned brown was recorded.

3.17 Plant height

The plant height at vegetative, flowering and podding phases were determined using the meter rule. The heights of the plant were measured from the base to the last fully opened leaf of the plant.

3.18 Number of damaged leaves

Leaves with window opening, skeletonization, scarification/defoliation and circular holes, were assessed by checking, counting and recording damaged leaves from the 10 plants from the border rows at vegetative, flowering and podding phases.

3.19 Pod/seed damage assessment

Pod damage was assessed at maturity by counting 100 pods/seeds produced per plot. Pod/seed damage were determined as follows; discoloration, shriveling, and presence of entry/exit holes.

3.20 Yield parameter

Pod yield from each treatment plot were threshed, weighed, recorded and calculated. 100 Pod and Seed weight per plot (g), Pod yield and seed yield per plot (g), and total yield (g) were weighted, calculated, recorded and converted to kg/ha.

3.21 Statistical analysis

All the data collected were subjected to Analysis of Variance (ANOVA) using Genstat (Third edition) and significant difference between means were determined by use of Least Significant Difference (LSD) at $P \leq 0.05$ level of significance.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Meteorological data of the research area for 2016 and 2017 farming season.

The Meteorological data of the research area for the periods of 2016 and 2017 farming season is presented in the Table 1

4.2 Routine soil physico- chemical properties of the research area for 2016 and 2017 early and late farming season

Routine physical and chemical properties of the soil used for the study in early and late farming in 2016 and 2017 are presented in Table 2.

4.3 Characteristics of poultry manure used for the study

The chemical analysis of the poultry manure used for the study is shown in Table 3.

4.4 Qualitative phytochemical analysis of plant materials

The phytochemical analysis of plant materials used for this study is presented in Table 4.

Table 1; Meteorological data of the research area for 2016 and 2017 farming season (January-December)

Monthly mean 2016(Owerri)				**Monthly mean 2017(Owerri)**			
Months	**Max temp(ºc)**	**Min temp(ºc)**	**Rainfall (mm)**	**Months**	**Max temp(ºc)**	**Min temp(ºc)**	**Rainfall (mm)**
January	34.60	20.20	0.00	January	34.40	21.40	8.80
February	36.80	23.10	29.40	February	36.40	22.50	0.00
March	33.90	24.10	192.30	March	34.50	23.40	80.10
April	33.50	24.10	143.90	April	33.60	23.70	228.40
May	32.60	23.70	157.40	May	31.80	23.10	198.40
June	31.00	22.90	272.60	June	31.40	23.10	213.40
July	29.60	22.80	378.10	July	29.60	22.80	367.50
August	29.30	22.80	409.40	August	28.50	22.40	391.20
September	30.20	22.90	423.80	September	29.50	22.70	609.50
October	31.80	22.80	144.70	October	32.10	15.00	3.10
November	33.50	23.30	12.20	November	29.90	21.50	1.00
December	34.10	21.50	10.30	December	30.10	21.90	0.20

Source: Meteorological center, Sam Mbakwe international Cargo airport, Owerri Imo State.

Table 2;Routine soil physico- chemical properties of the experimental site for 2016 and 2017 early and late farming season (0-30cm)

Soil Property	Quantity			
	2016 Early season	2016 Late season	2017 Early season	2017 Late season
pH in H_2O	5.20	5.10	5.10	5.20
pH in Kcl	4.80	4.80	4.60	4.70
Organic matter(%)	1.60	1.50	1.57	1.45
Organic Carbon(%)	0.94	0.91	0.91	0.92
Nitrogen (%)	0.40	0.50	0.75	0.20
Phosphorus $mgkg^{-1}$	29.10	10.01	21.01	29.10
Magnesium(Cmol kg^{-1}	1.20	0.96	0.96	1.00
Sodium(Cmol/kg)	0.40	0.50	0.58	0.40
Potassium (Cmol/kg)	0.10	1.20	1.31	0.10
Calcium (Cmol/kg)	3.80	2.74	5.74	4.80
Moisture content (%)	0.93	1.40	1.12	1.20
Bulk density *g/cm^3)	1.26	1.20	1.24	1.17
Silt (%)	4.70	3.96	4.40	4.70
Clay (%)	8.00	13.30	14.40	10.00
Sand (%)	87.30	82.74	81.20	85.30
Exchangable Acid (EA) (Cmol/kg)	0.40	0.30	0.30	0.40
Cation Exchangable Capacity (ECEC) (Cmol/kg)	12.88	12.74	12.74	10.11
% BS	96.89	94.32	94.32	93.91
Textural Class	Sandy loam	Sandy loam	Sandy loam	Sandy loam

Table 3; Properties of the poultry manure used for the field trials

Poultry manure		Characteristics
pH (H_2O)		7.78
Organic matter (%)		39.30
Total Nitrogen (%)		4.58
Organic carbon (%)		22.80
Available P	**($mg\ kg^{-1}$)**	41.82
Potassium	**($Cmol\ kg^{-1}$)**	2.51
Calcium	**($Cmol\ kg^{-1}$)**	4.81
Magnesium	**($Cmol\ kg^{-1}$)**	1.42
Sodium	**($Cmol\ kg^{-1}$)**	0.51
Aluminum	**($Cmol\ kg^{-1}$)**	1.39
Hydrogen	**($Cmol\ kg^{-1}$)**	3.22

Table 4; Qualitative phytochemical determination of methanolic extracts from leaves of *Jatropha tanjorensis*, leaves of Bush tea *Hyptis suaveolens*, and Stem bark of Stool wood *Alstonia boonei*

Parameters	Plant extracts		
	AEO	HEO	JEO
Alkaloids	+	+	+
Flavonoids	+	+	+
Glycosides	+	+	+
Saponins	+	+	-
Tanins	+	+	+
Terpenoids	+	+	+

Key: Present (+), Absent (-)

AEO- Stool wood *Alstonia boonei*, HEO- Bush tea *Hyptis suaveolens*,JEO- *Jathropha tanjorensis*

All the phytochemicals (alkaloids, flavonoids, glycosides, saponins, tannins and terpenoids) are found in all the plant materials except saponin that was not found in *Jathropha tanjorensis* leaves.

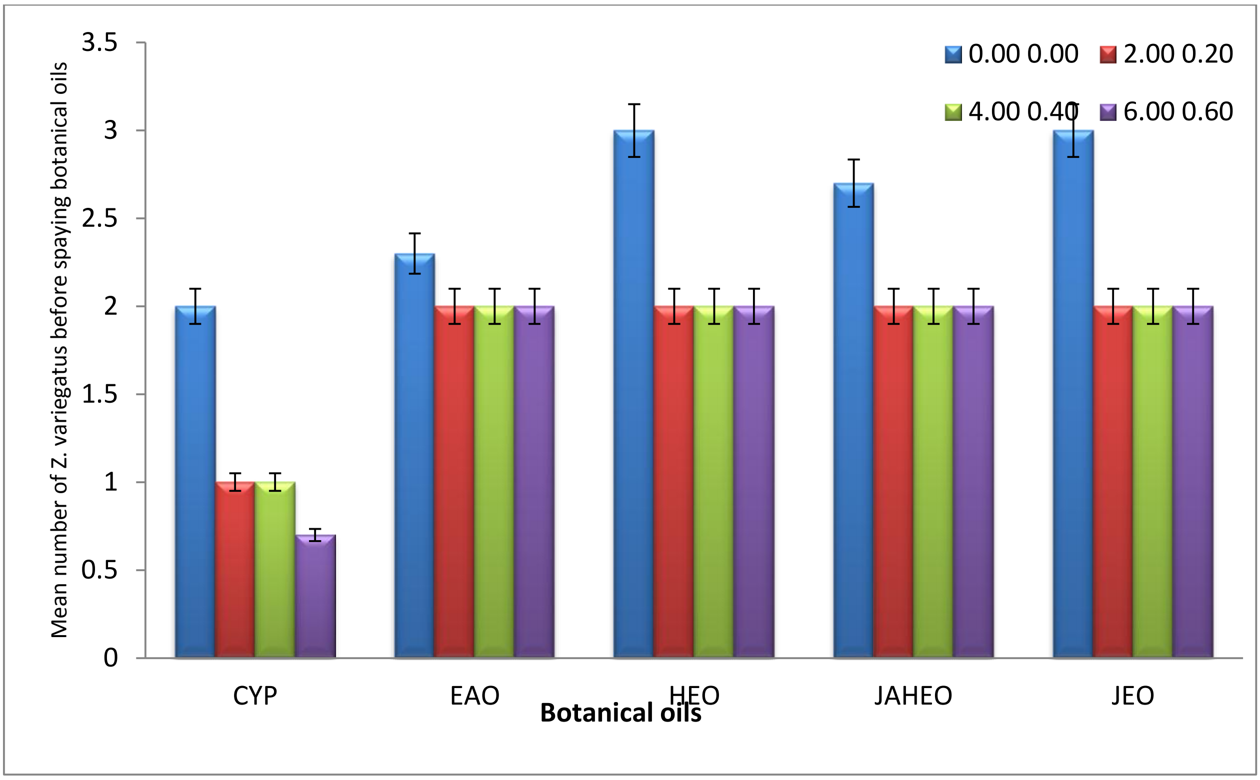
Plate 7 (a): Early season planting 2016 **(b): Late season planting 2016**

(c): Early season planting 2017 **(d): Late season planting 2017**

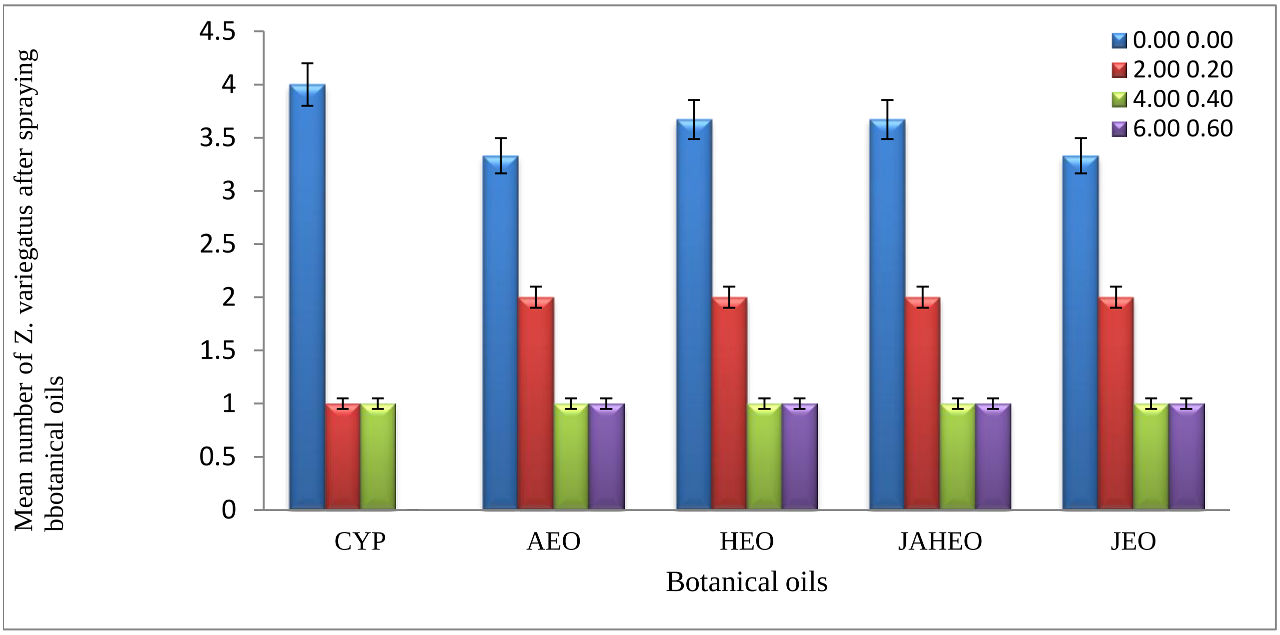
4.5 Comparison of number of Grass hopper (*Zonocerus variegatus*) on bambara groundnut at vegetative, flowering and podding phase in 2016 and 2017 early and late farming season

The results of the figures 1 to 12 showed that variegated grass hopper were present at vegetative, flowering and podding phase in 2016 and 2017 early and late season. The plots sprayed with Cypermethrin (CYP) recorded the least mean number of *Z. variegatus* at Vegetative, Flowering and Podding phase in

2016 and 2017 early and late farming seasons. This was followed by plots sprayed with mixed plant oils (JAHEO) while plots sprayed with *Alstonia boonei* oil (AEO) recorded lower mean number of variegated grass hopper than Jathropha oil (JEO) and *Hyptis suaveolens* oil (HEO) that mostly recorded the highest mean number of variegated grass hopper at vegetative, flowering and podding in 2016 and 2017 early and late season. Effects of application rate of botanical oils on variegated grass hopper were dose dependent. The highest application rates (6.00/0,60ml) recorded the least number of variegated grass hopper, this was followed by the medium rates (4.00/0.40ml) and least application rates (2.00/0.20) respectively, while the control rates (0.00/0.00) recorded the highest mean number of *Z. variegatus* in 2016 and 2017 early and late seasons. Least mean number of *Z. variegatus* were recorded in at the podding phase followed the vegetative phase, while the flowering phase recorded the highest mean number of *Z. variegatus* in 2016 and 2017 early and late seasons. Although mean number of *Z. variegatus* were higher before spray but significantly reduced immediately after spray while there were no reduction but significant increase in number of *Z. variegatus* in the control plots at vegetative, flowering and podding phase in 2016 and 2017 early and late seasons.



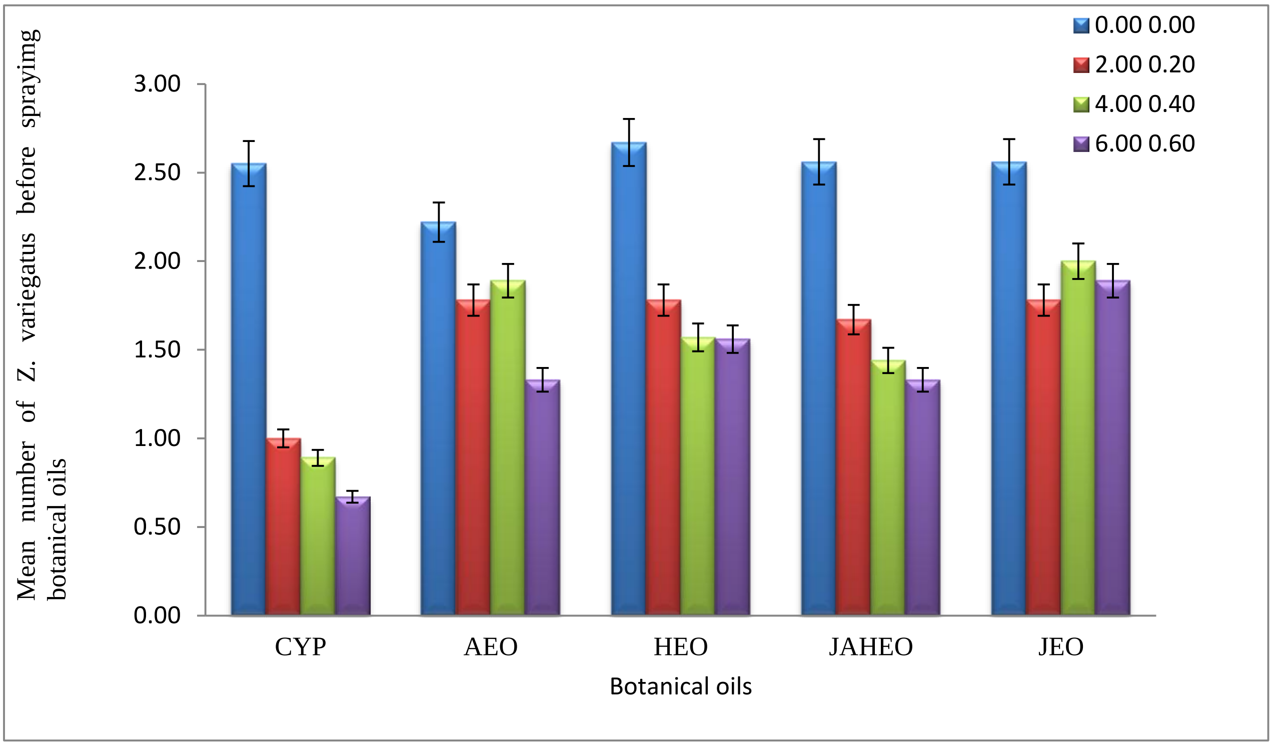
(a) Before spray at vegetative phase early 2016



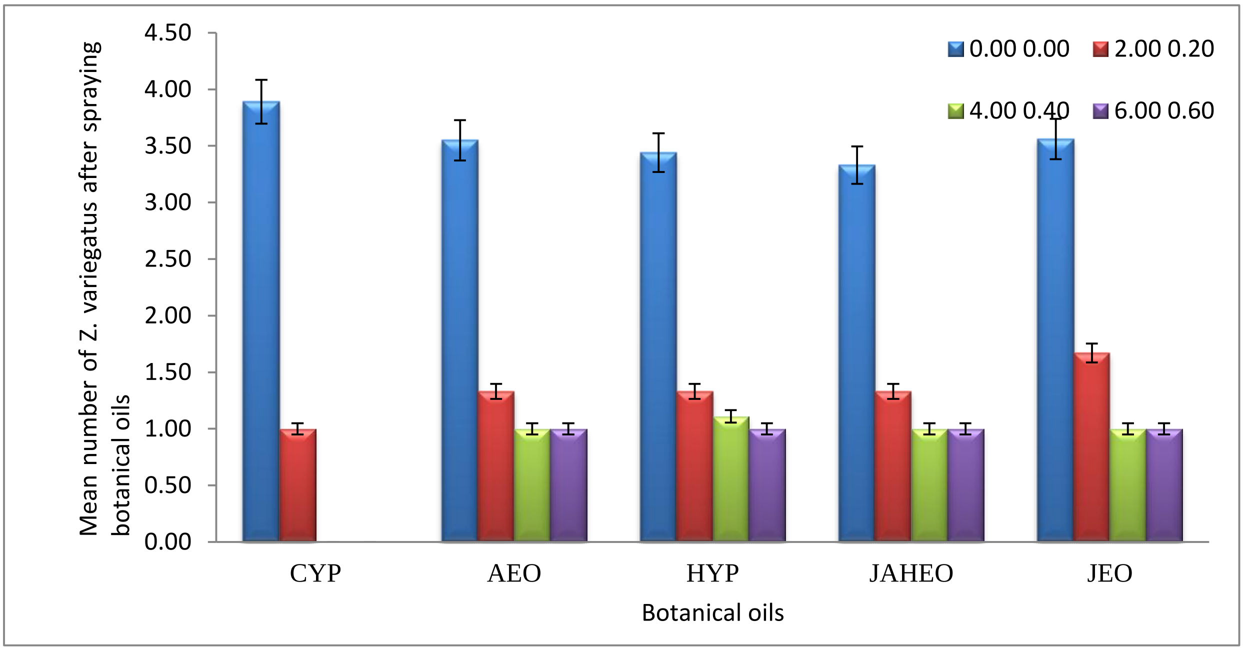
(b) After spray at vegetative phase early 2016

FIG 1; Comparison of number of *Z. variegatus* on bambara groundnut at vegetative phase before and after spray during 2016 early farming season

Key: CYP-Cypermethrin 10EC, AEO- Stool wood *Alstonia boonei*. oil, HEO- Bush tea *Hyptis suaveolens* oil, JAHEO- Mixed plant oils from Jathropha, Bush tea and Stool wood, JEO- *Jathropha tanjorensis* oil



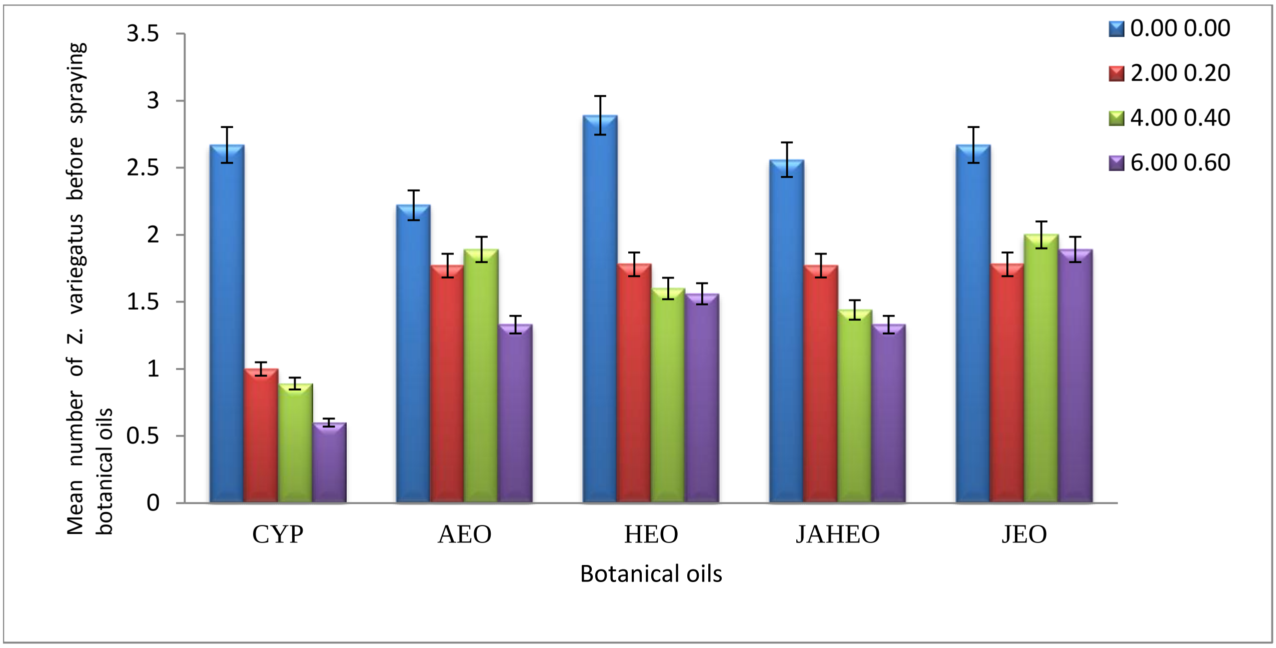
(a) Before spray at vegetative phase Late 2016



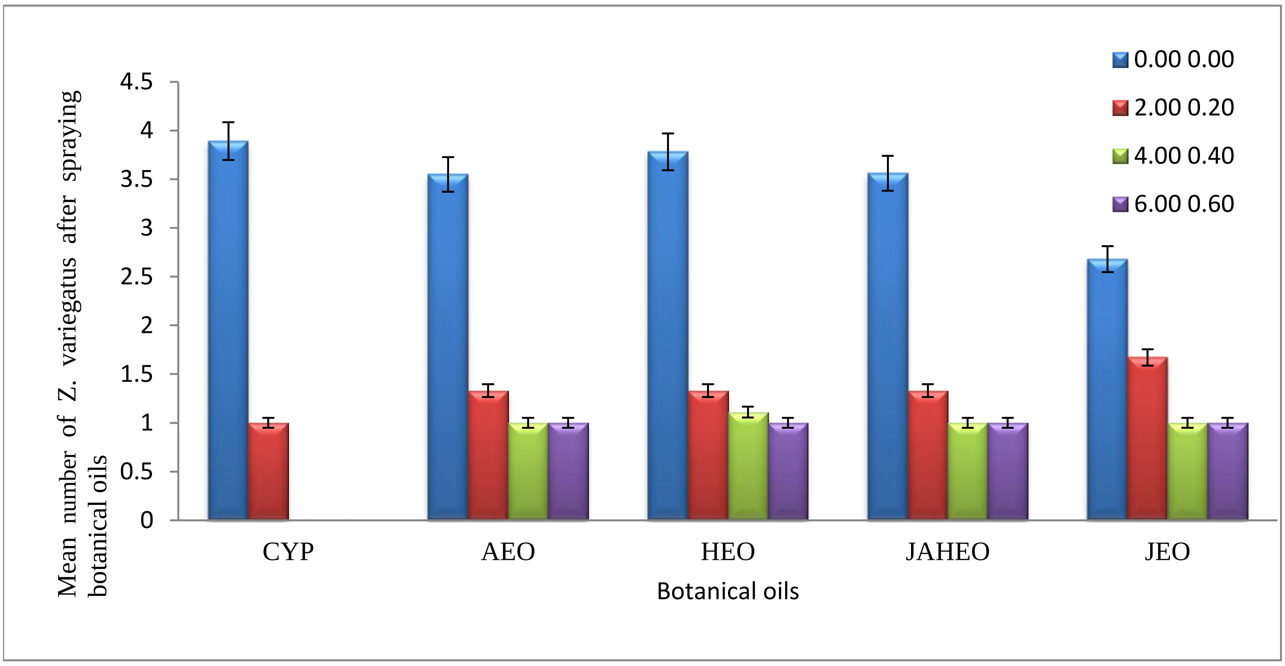
(b) After spray at vegetative phase late 2016

FIG 2 Comparison of number of *Z. variegatus* on bambara groundnut at vegetative phase before and after spray during late 2016 farming season

Key: CYP-Cypermethrin 10EC, AEO- Stool wood *Alstonia boonei.* oil, HEO- Bush tea *Hyptis suaveolens* oil, JAHEO- Mixed plant oils from Jathropha, Bush tea and Stool wood, JEO- *Jathropha tanjorensis* oil

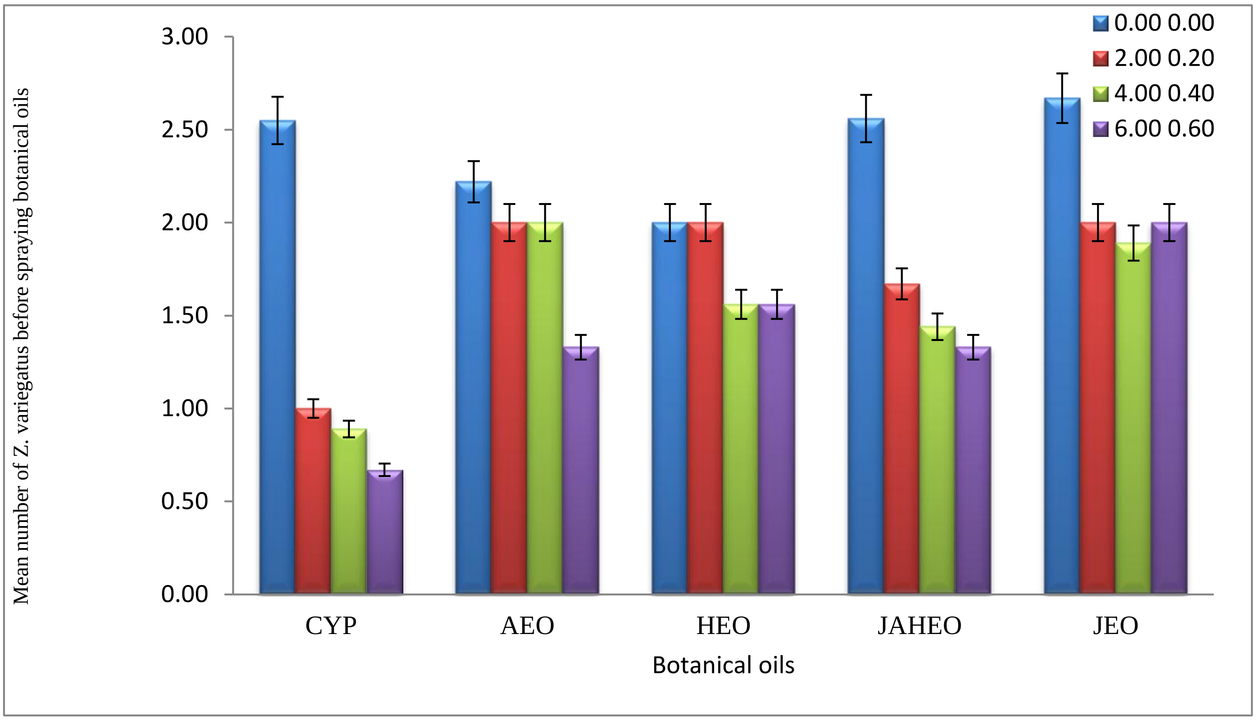


(a) Before spray at vegetative phase early 2017

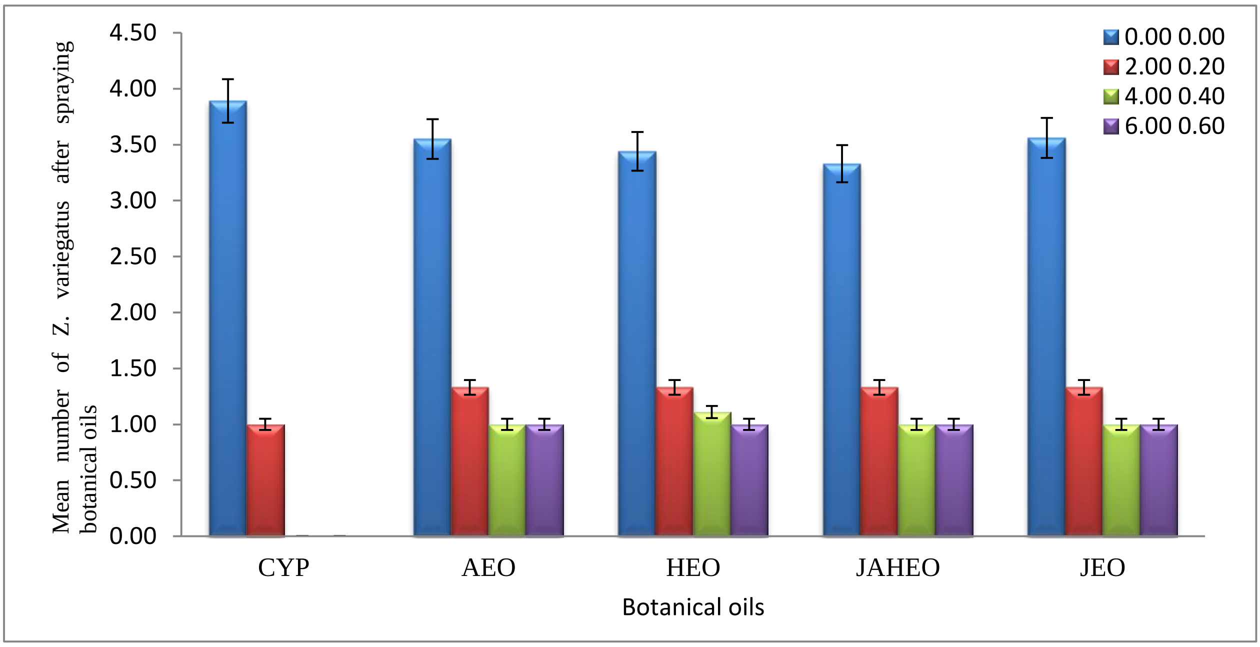


(b) After spray at vegetative phase early 2017

FIG 3; Comparison of number of *Z. variegatus* on bambara groundnut at vegetative phase before and after spray during early 2017 farming season



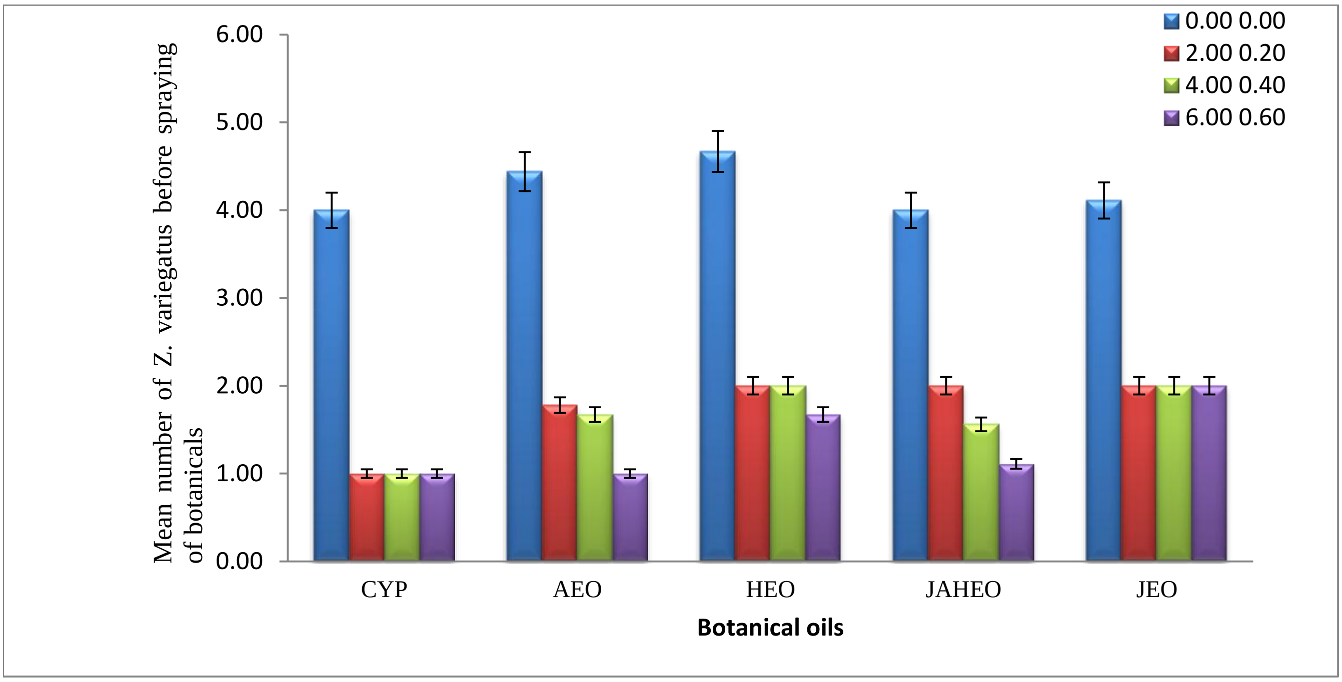
(a) Before spray at vegetative phase late 2017



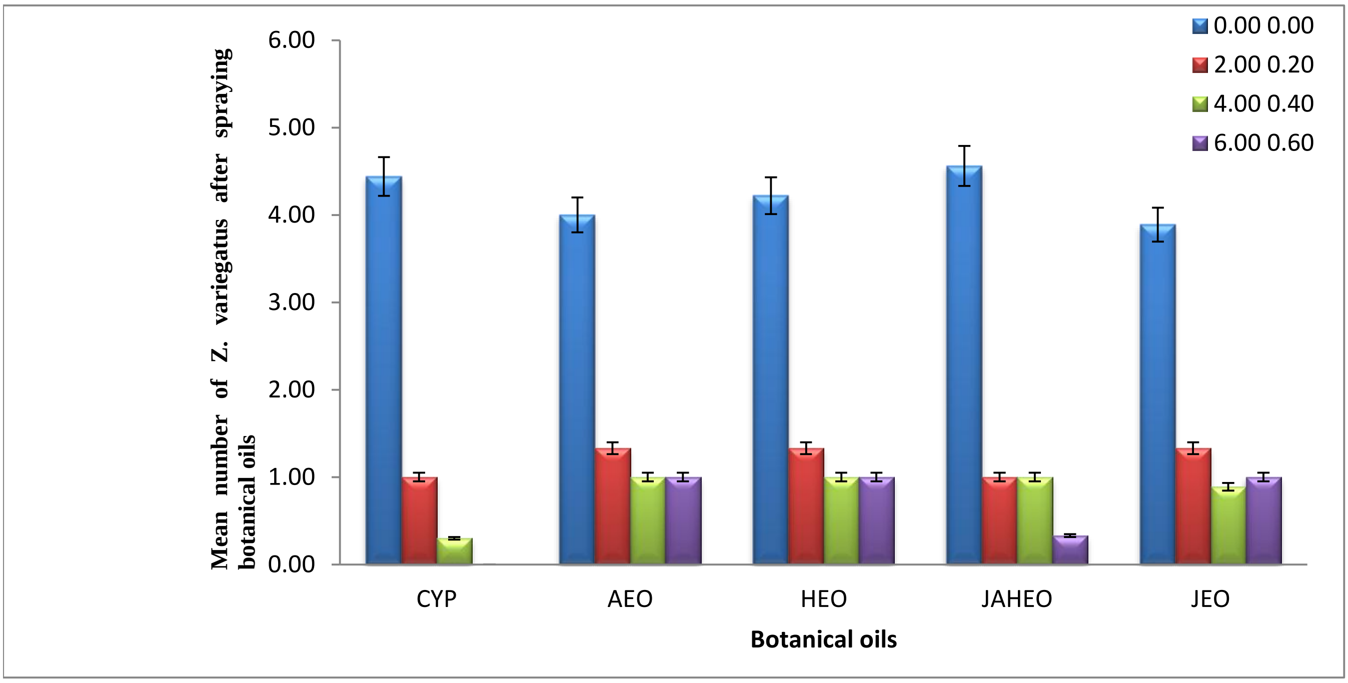
(b) After spray at vegetative phase late 2017

FIG 4; Comparison of number of *Z. variegatus* on bambara groundnut before and after spray at vegetative phase during late 2017 farming season

Key: CYP-Cypermethrin 10EC, AEO- Stool wood *Alstonia boonei.* oil, HEO- Bush tea *Hyptis suaveolens* oil, JAHEO- Mixed plant oils from Jathropha, Bush tea and Stool wood, JEO- *Jathropha tanjorensis* oil



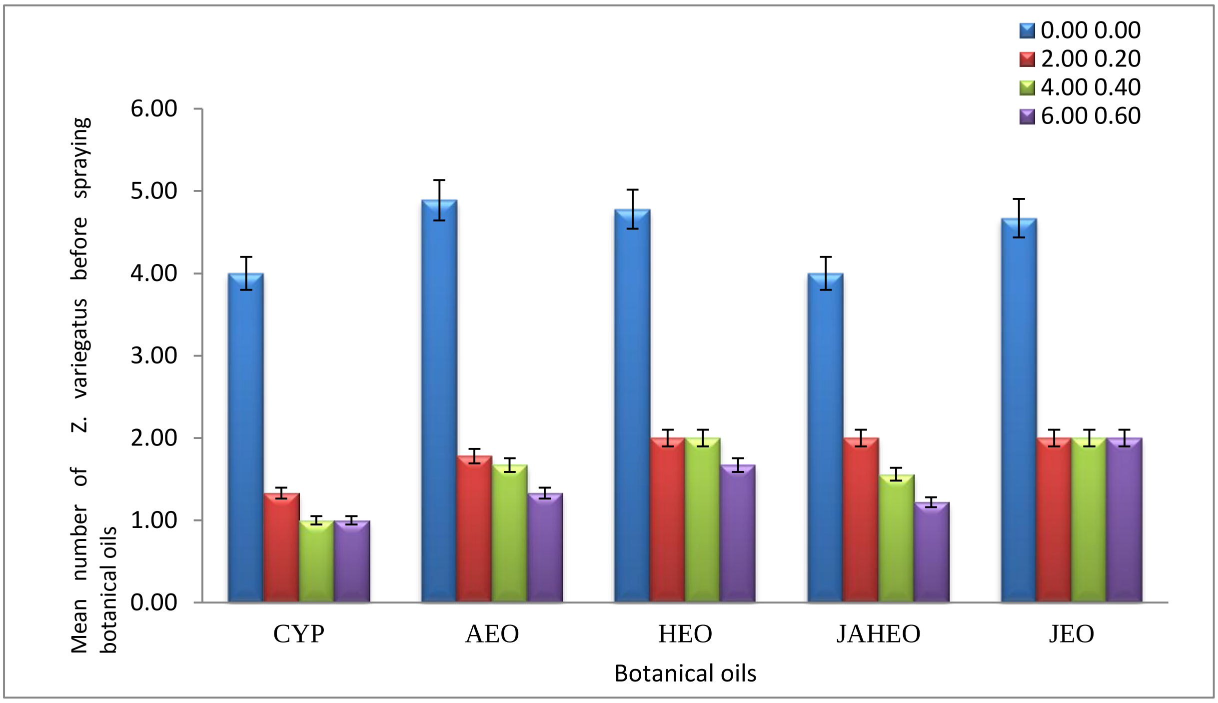
(a) Before spray at flowering phase early 2016



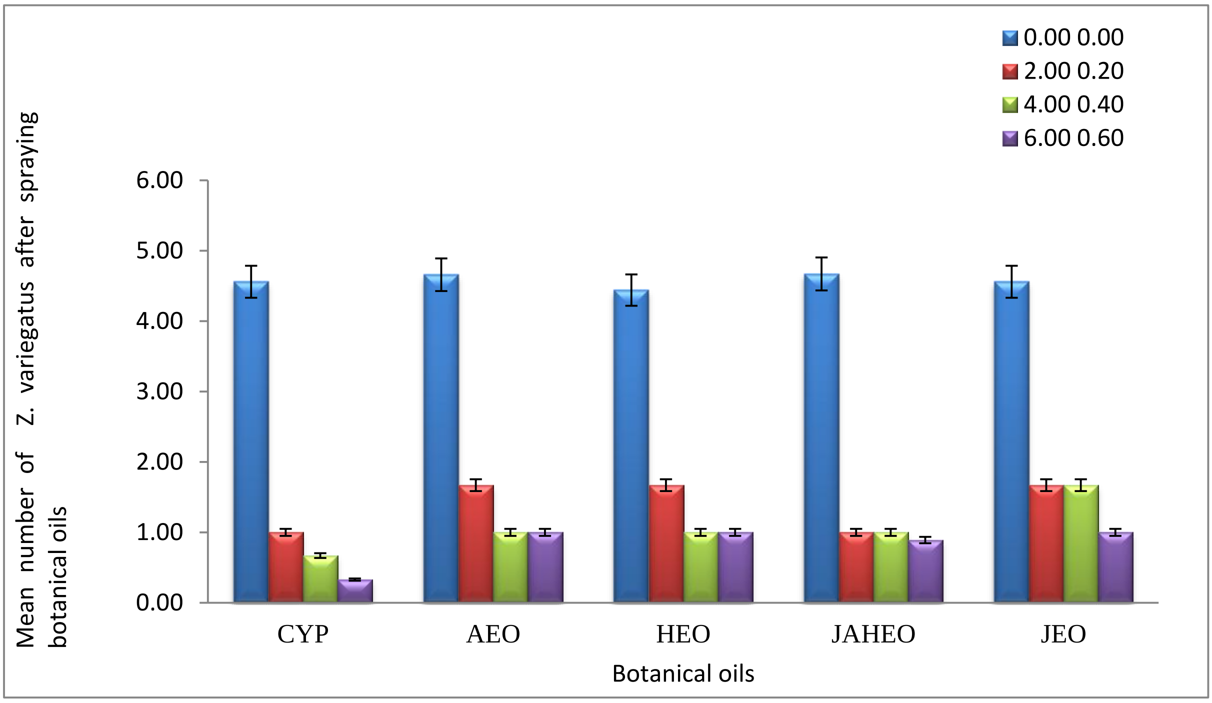
(b) After spray at flowering phase early 2016

FIG 5; Comparison of number of *Z. variegatus* on bambara groundnut before and after spray at Flowering phase during early 2016 farming season

Key: CYP-Cypermethrin 10EC, AEO- Stool wood *Alstonia boonei.* oil, HEO- Bush tea *Hyptis suaveolens* oil, JAHEO- Mixed plant oils from Jathropha, Bush tea and Stool wood, JEO- *Jathropha tanjorensis* oil



(a) Before spray at flowering phase late 2016



6(b) After spray at flowering phase late 2016

FIG 6; Comparison of number of *Z. variegatus* on bambara groundnut after spray at Vegetative Phase during 2016 late farming season

Key: CYP-Cypermethrin 10EC, AEO- Stool wood *Alstonia boonei*. oil, HEO- Bush tea *Hyptis suaveolens* oil, JAHEO- Mixed plant oils from Jathropha, Bush tea and Stool wood, JEO- *Jathropha tanjorensis* oil

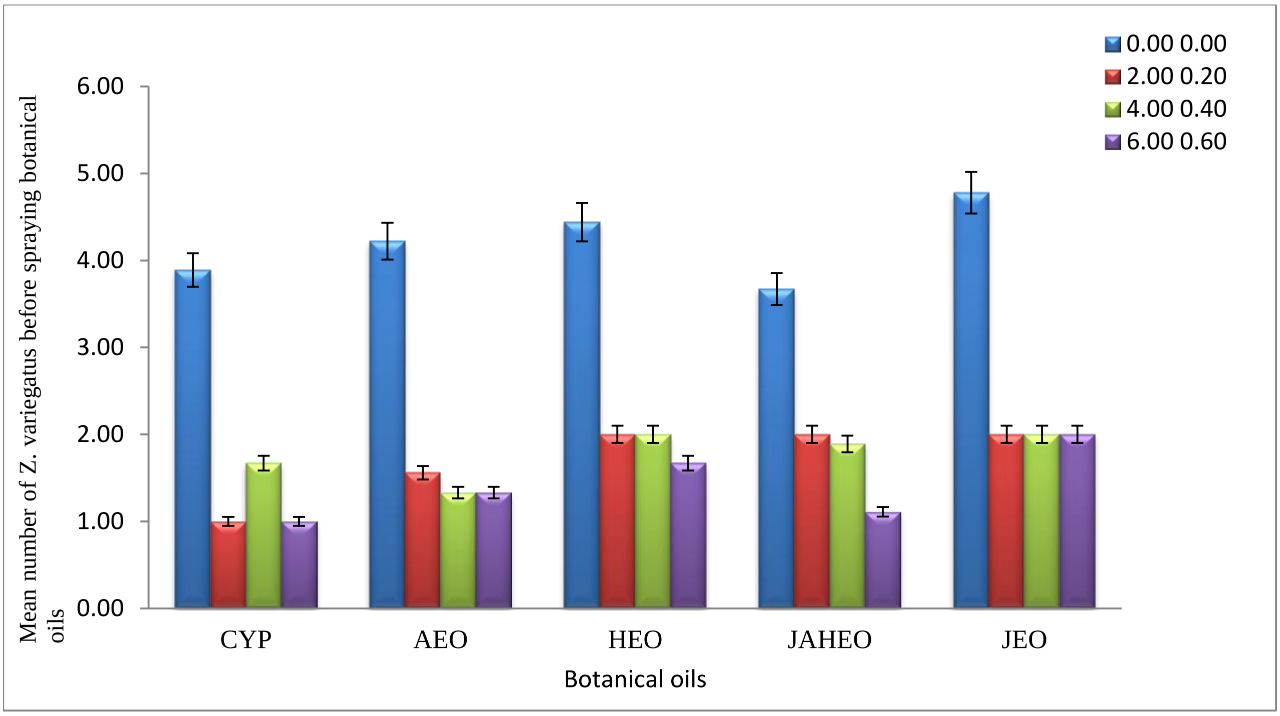


Fig 7 (a) Before spray at flowering phase during early 2017

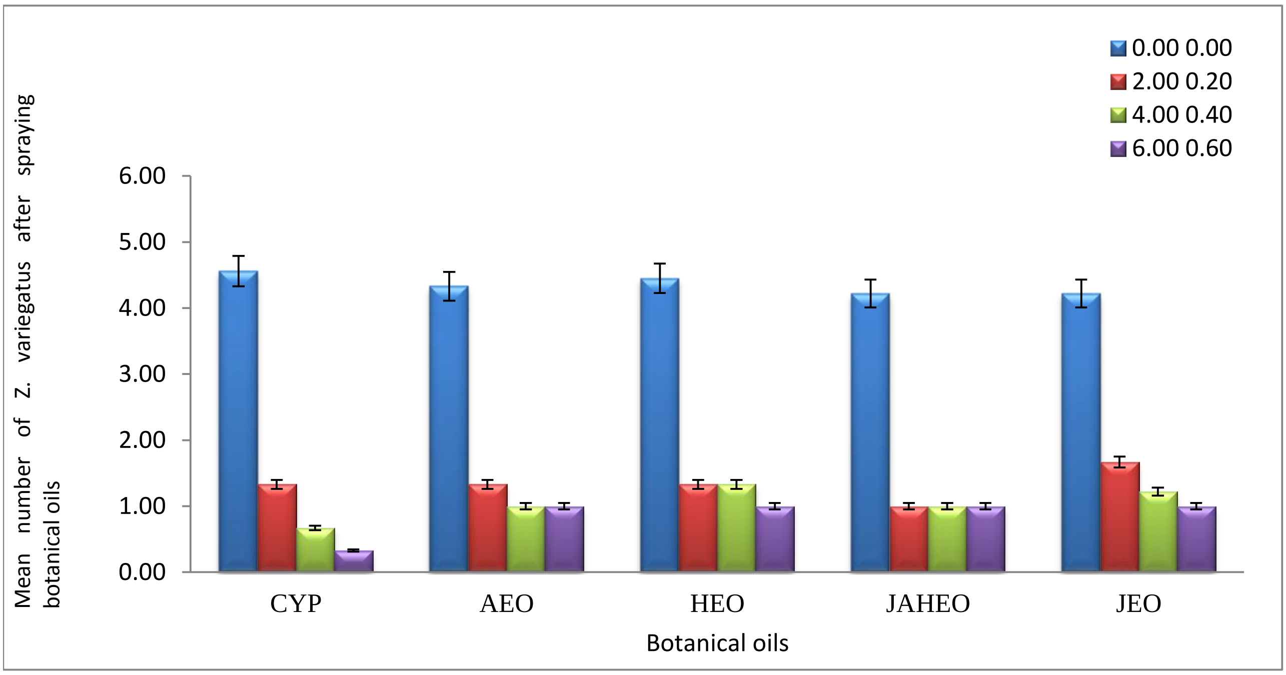
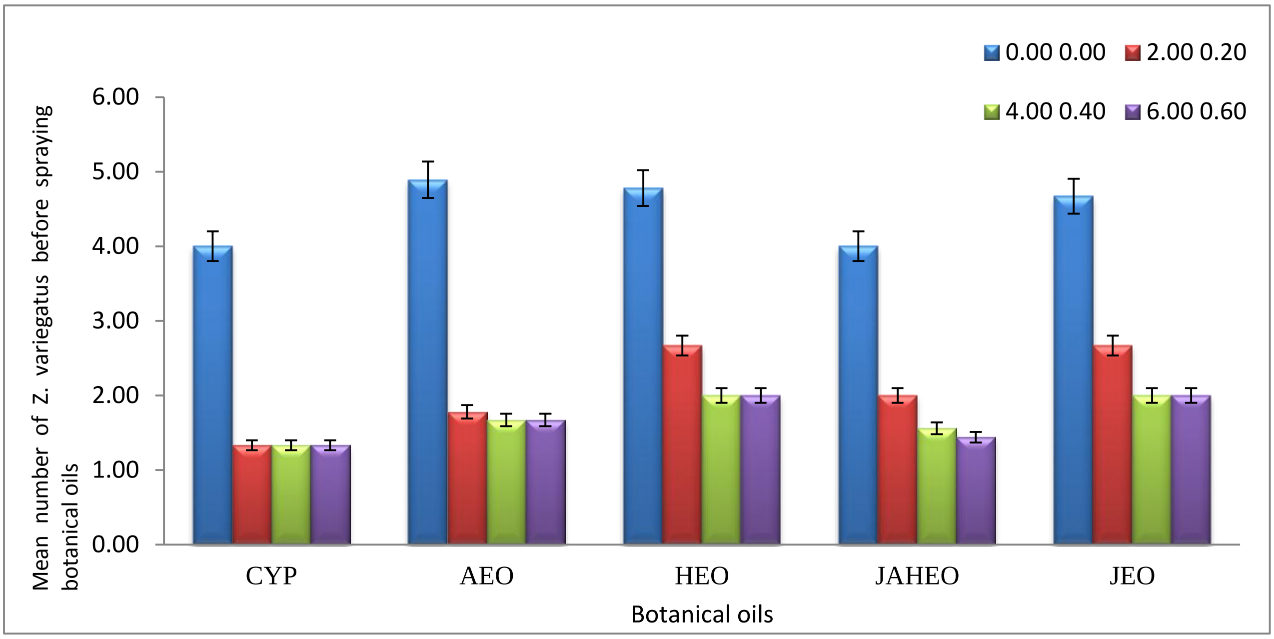
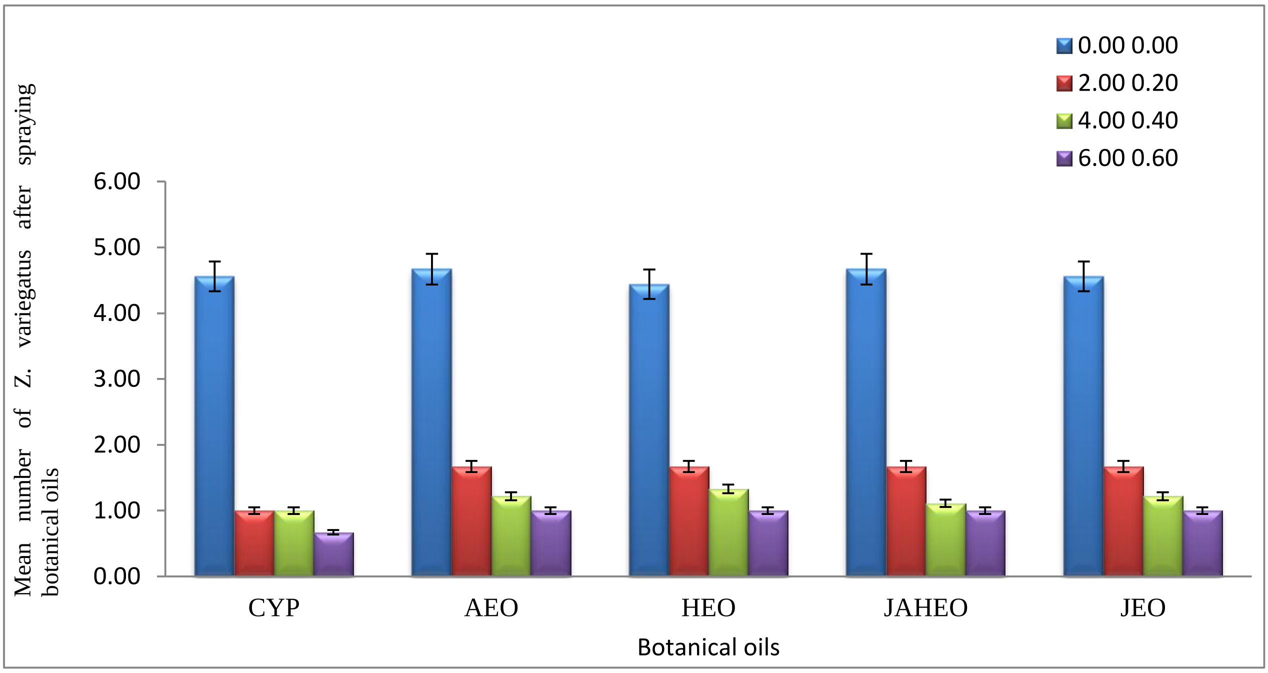


Fig 7(b) After spray at flowering phase during early 2017

FIG 7; Comparison of number of *Z. variegatus* on bambara groundnut before and spray at Flowering phase during early 2017 farming season



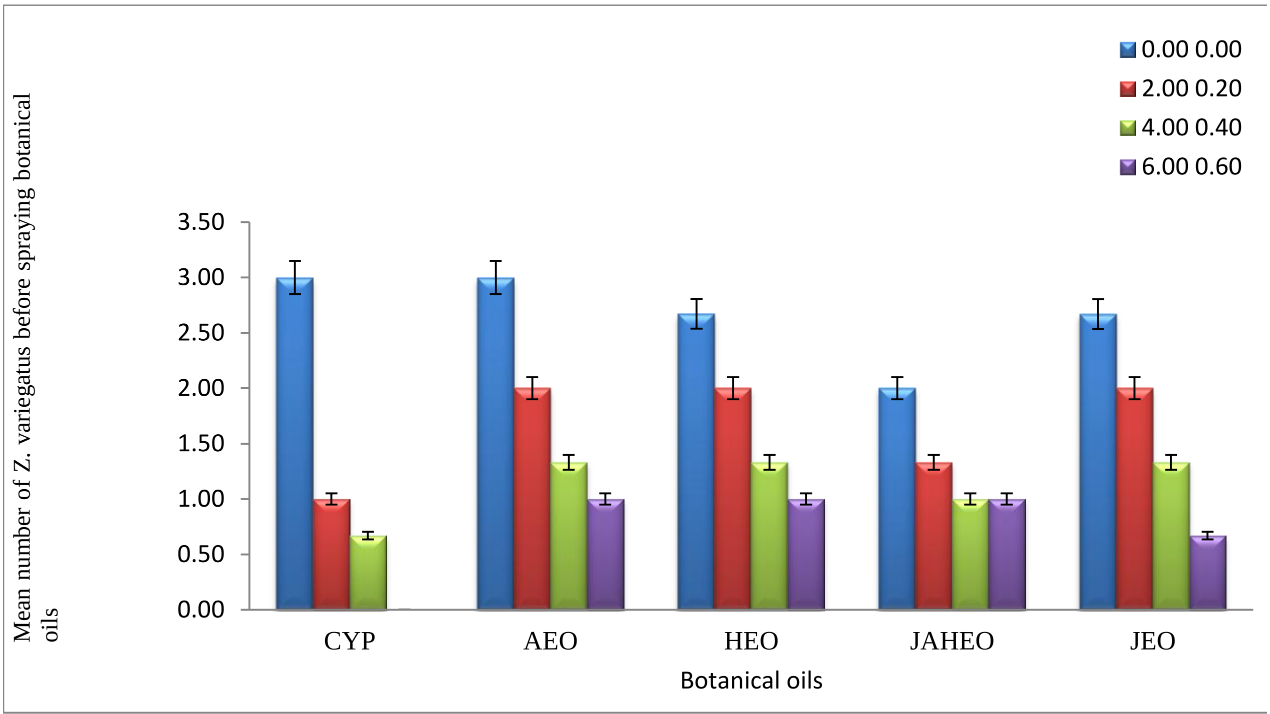
(a) Before spray at flowering phase during late 2017



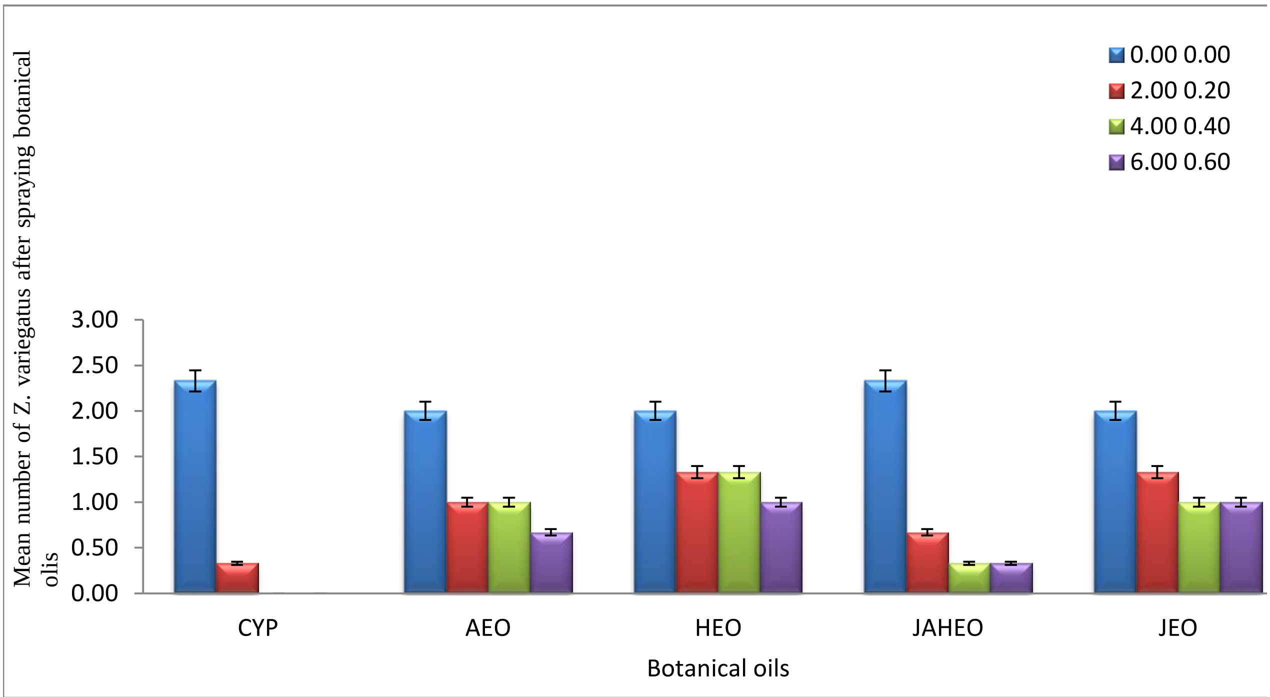
(b) After spray at flowering phase during late 2017

FIG 8; Comparison of number of *Z. variegatus* on bambara groundnut before and after spray at Flowering phase during late 2017 farming season

Key: CYP-Cypermethrin 10EC, AEO- Stool wood *Alstonia boonei.* oil, HEO- Bush tea *Hyptis suaveolens* oil, JAHEO- Mixed plant oils from Jathropha, Bush tea and Stool wood, JEO- *Jathropha tanjorensis* oil

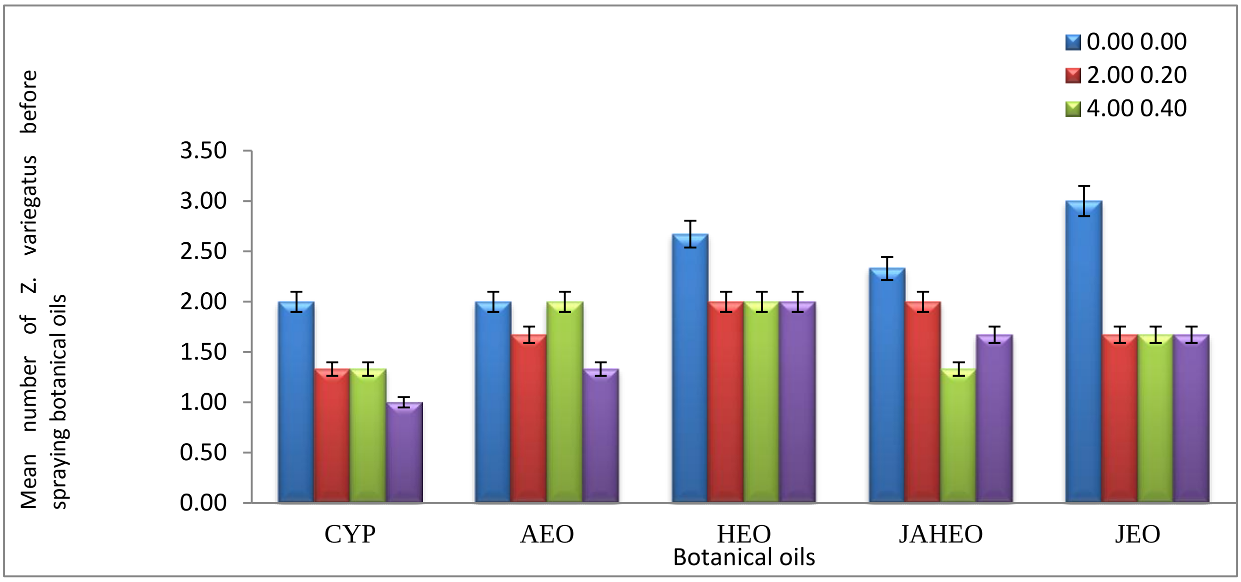


(a) Before spray at podding phase during early 2016

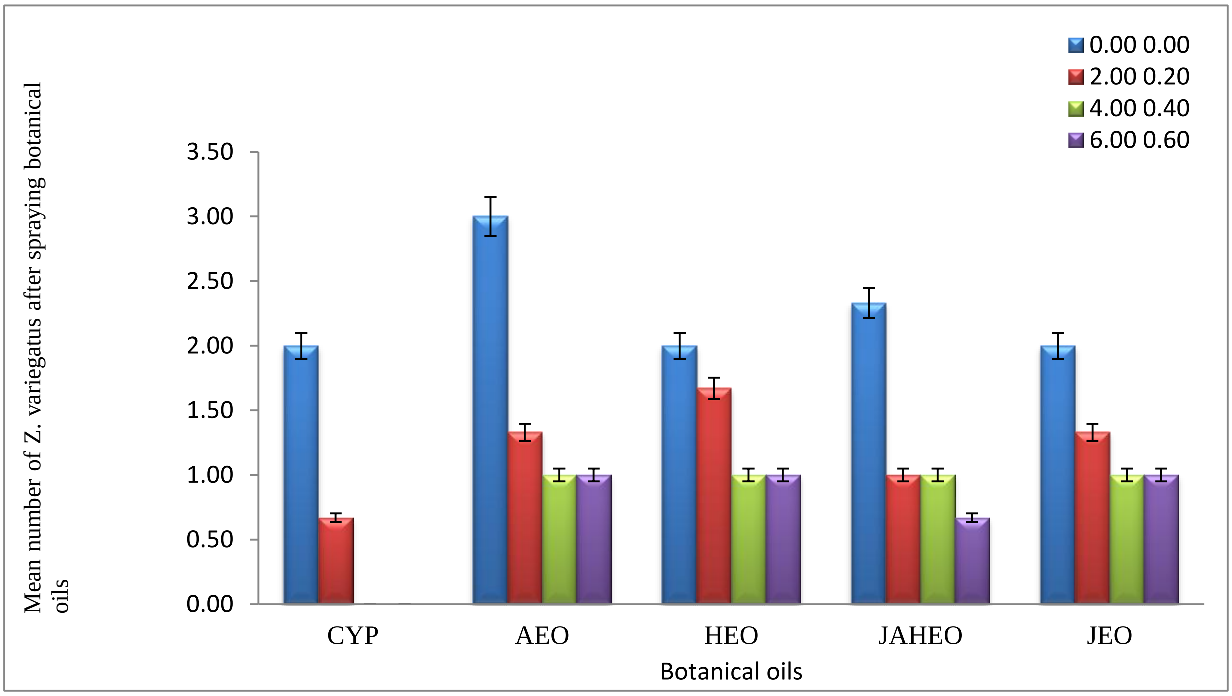


(b) After spray at podding phase during early 201
FIG 9; Comparison of number of *Z. variegatus* on bambara groundnut before and after spray at Podding phase during 2016 early farming season

Key: CYP-Cypermethrin 10EC, AEO- Stool wood *Alstonia boonei.* oil, HEO- Bush tea *Hyptis suaveolens* oil, JAHEO- Mixed plant oils from Jathropha, Bush tea and Stool wood, JEO- *Jathropha tanjorensis* oil



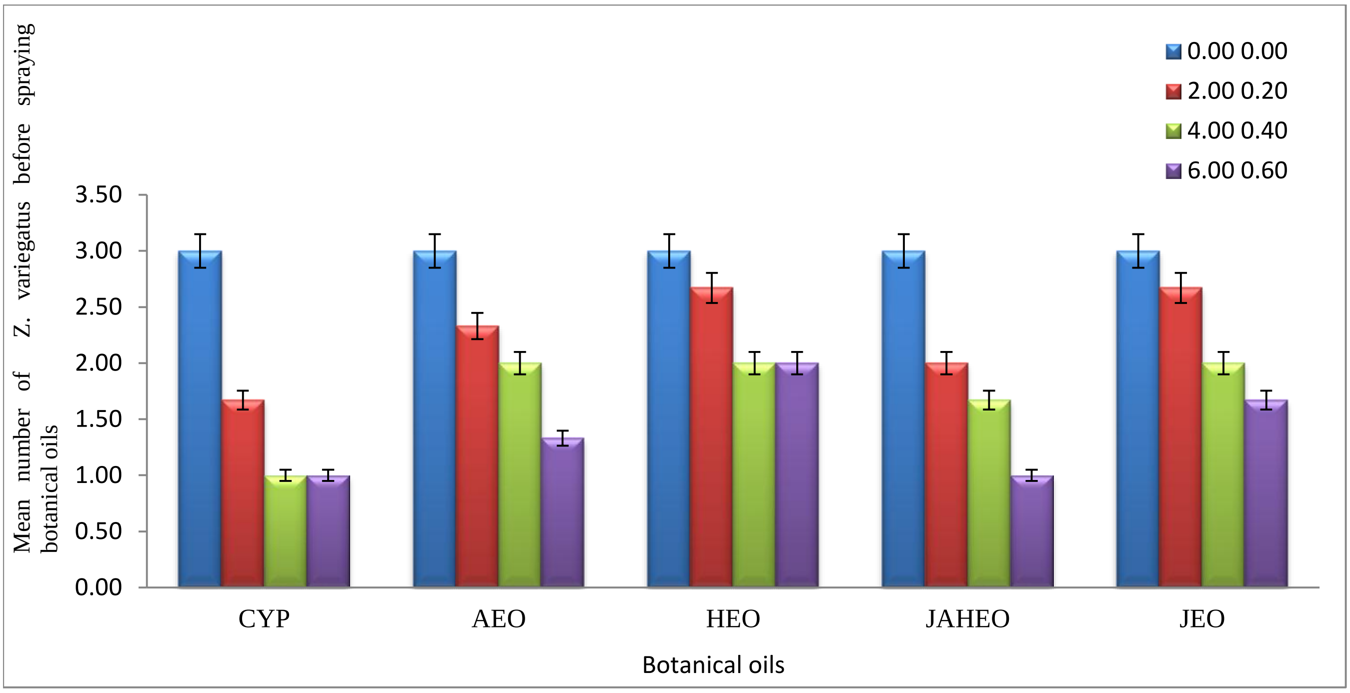
(a) Before spray at podding phase during late 2016



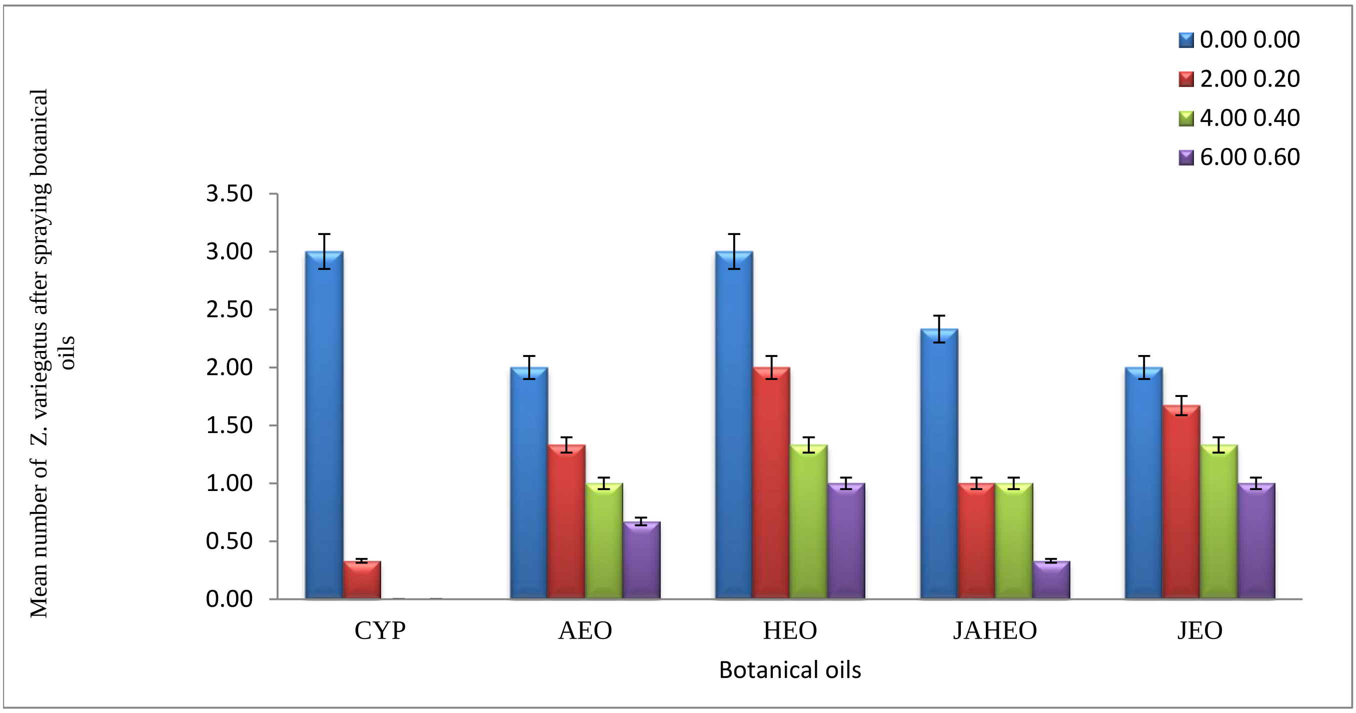
(b) After spray at podding phase during late 2016

FIG 10; Comparison of number of *Z. variegatus* on bambara groundnut before and after spray at Podding phase during late 2016 farming season

Key: CYP-Cypermethrin 10EC, AEO- Stool wood *Alstonia boonei*. oil, HEO- Bush tea *Hyptis suaveolens* oil, JAHEO- Mixed plant oils from Jathropha, Bush tea and Stool wood, JEO- *Jathropha tanjorensis* oil



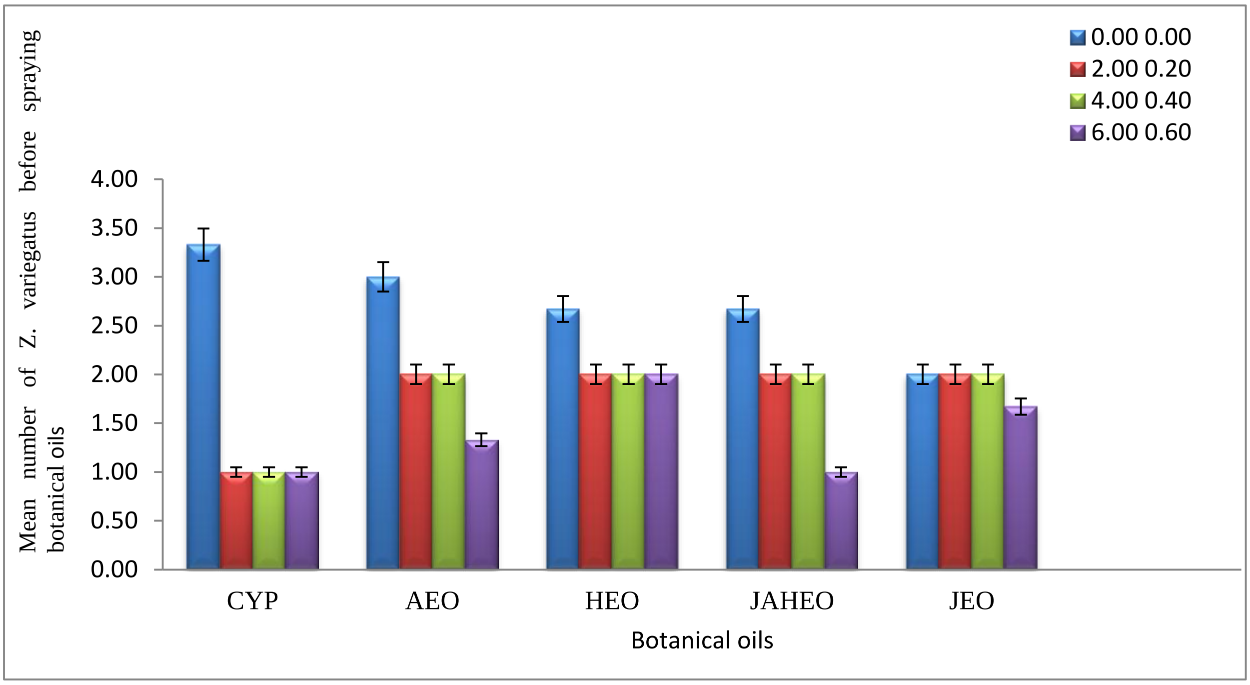
(a) Before spray at podding phase during early 2017.



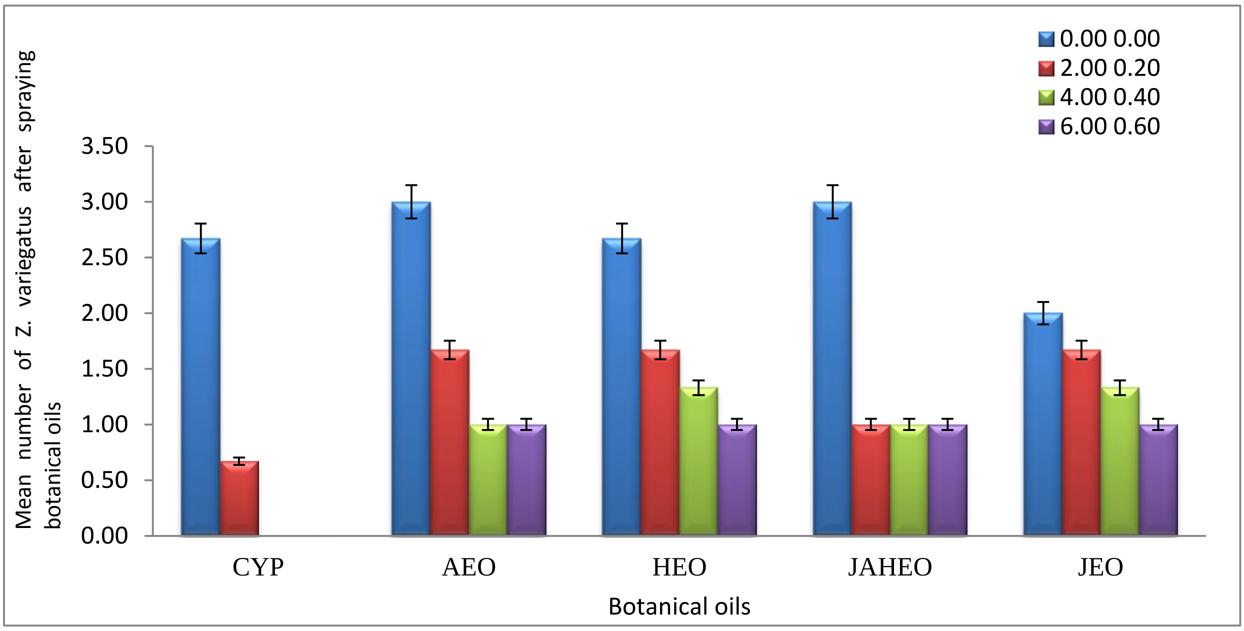
(b) After spray at podding phase during early 2017

FIG 11; Comparison of number of *Z. variegatus* on bambara groundnut before spray at Flowering Phase during 2017 early farming season

Key: CYP-Cypermethrin 10EC, AEO- Stool wood *Alstonia boonei.* oil, HEO- Bush tea *Hyptis suaveolens* oil, JAHEO- Mixed plant oils from Jathropha, Bush tea and Stool wood, JEO- *Jathropha tanjorensis* oil



(a) Before spray at podding phase during late 2017.

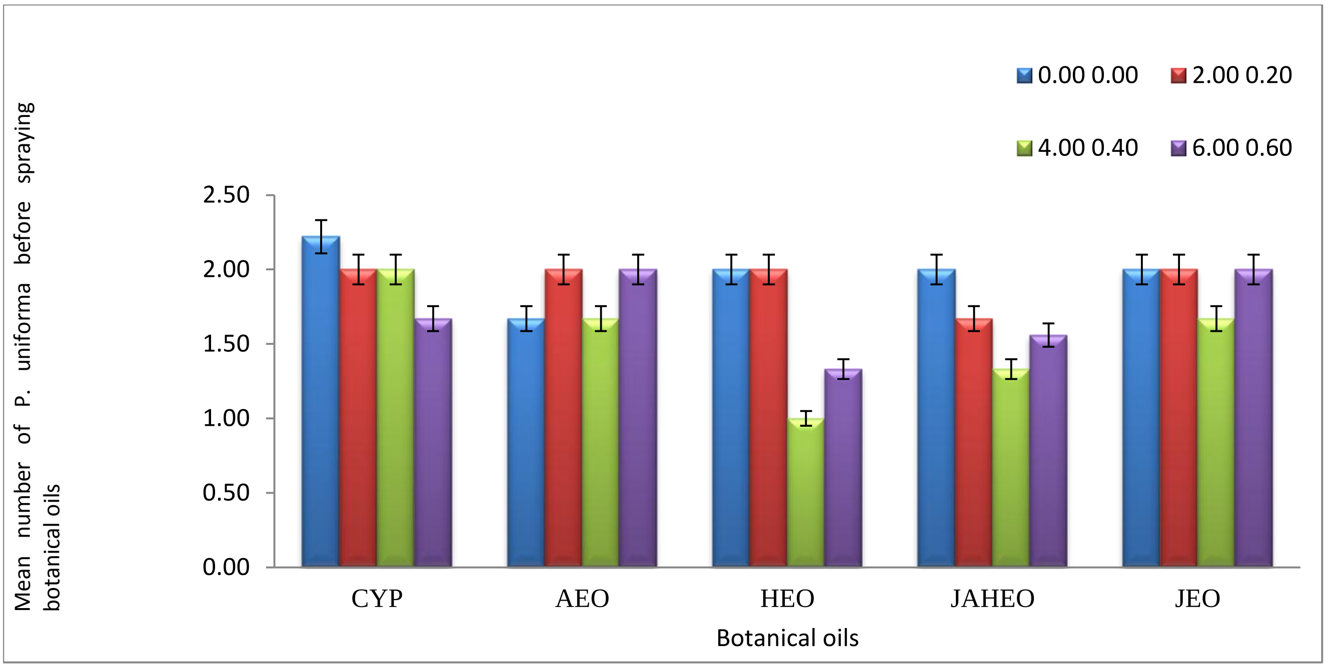


(b) After spray at podding phase during late 2017

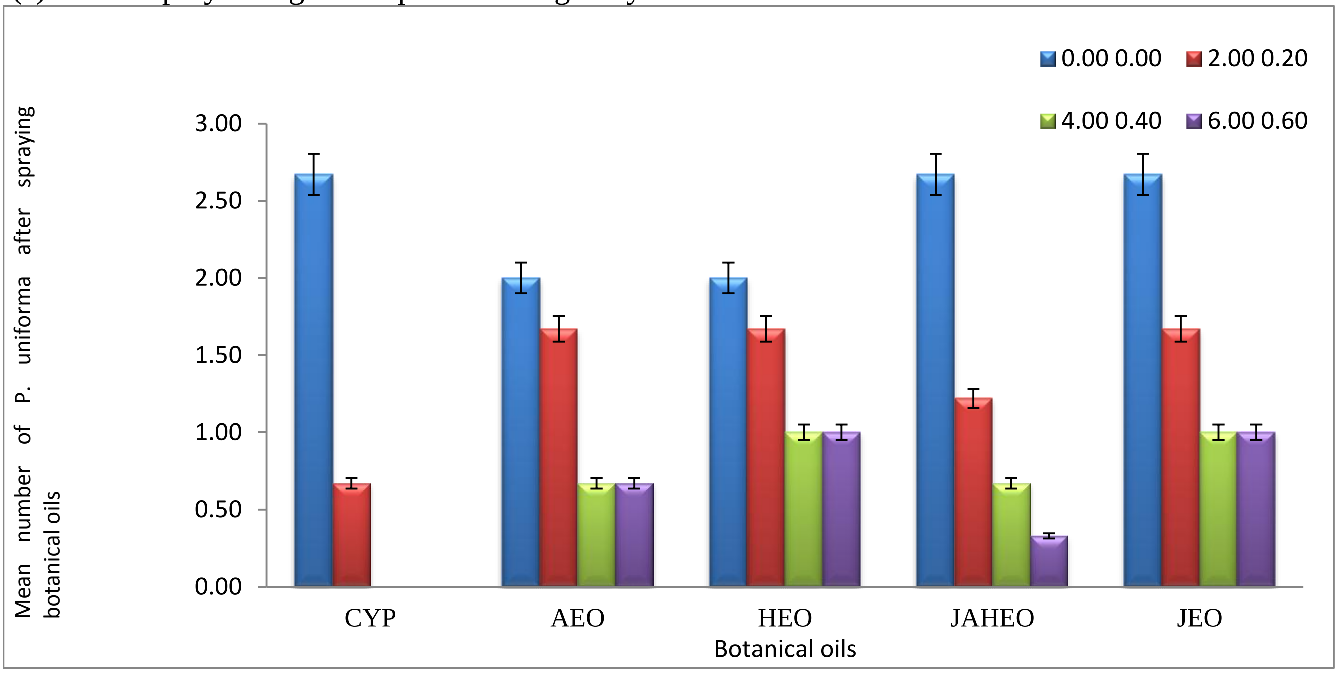
FIG 12; Comparison of number of *Z. variegatus* on bambara groundnut before and after spray at podding phase in late 2017 farming season

Effects of Botanical oils on *Podagrica uniforma* at vegetative, flowering and podding phase in 2016 and 2017 early and late farming season

The results in Figure 13 to 24 showed that *Podagrica uniforma* were present at vegetative, flowering and podding phase in 2016 and 2017 early and late season. The plots sprayed with Cypermethrin (CYP) recorded the least mean number of *Podagrica uniforma* at vegetative, flowering and podding phase in 2016 and 2017 early and late farming seasons. This was followed by plots sprayed with Mixed plant oils (JAHEO) while plots sprayed with *Alstonia boonei* oil (AEO) recorded lower mean number of *Podagrica uniforma* than Jathropha oil (JEO) and *Hyptis suaveolens* oil (HEO) that mostly recorded the highest mean number of variegated grass hopper at vegetative, flowering and podding in 2016 and 2017 early and late season. Effects of application rate of botanical oils on *Podagrica uniforma* were dose related. The highest application rates (6.00/0,60ml) recorded the least number of *Podagrica uniforma*, this was followed by the medium rates (4.00/0.40ml) and least application rates (2.00/0.20) respectively, while the control rates (0.00/0.00) recorded the highest mean number of *Podagrica uniforma* in 2016 and 2017 early and late seasons. Least mean number of *Podagrica uniforma* were recorded at the podding phase followed the flowering phase, while the vegetative phase recorded the highest mean number of *Podagrica uniforma* in 2016 and 2017 early and late seasons. Although mean number of *Podagrica uniforma* were higher before spray but significantly reduced immediately after spray while there were no reduction but significant increase in number of *Podagrica uniforma* in the control plots at vegetative, flowering and podding phase in 2016 and 2017 early and late seasons.



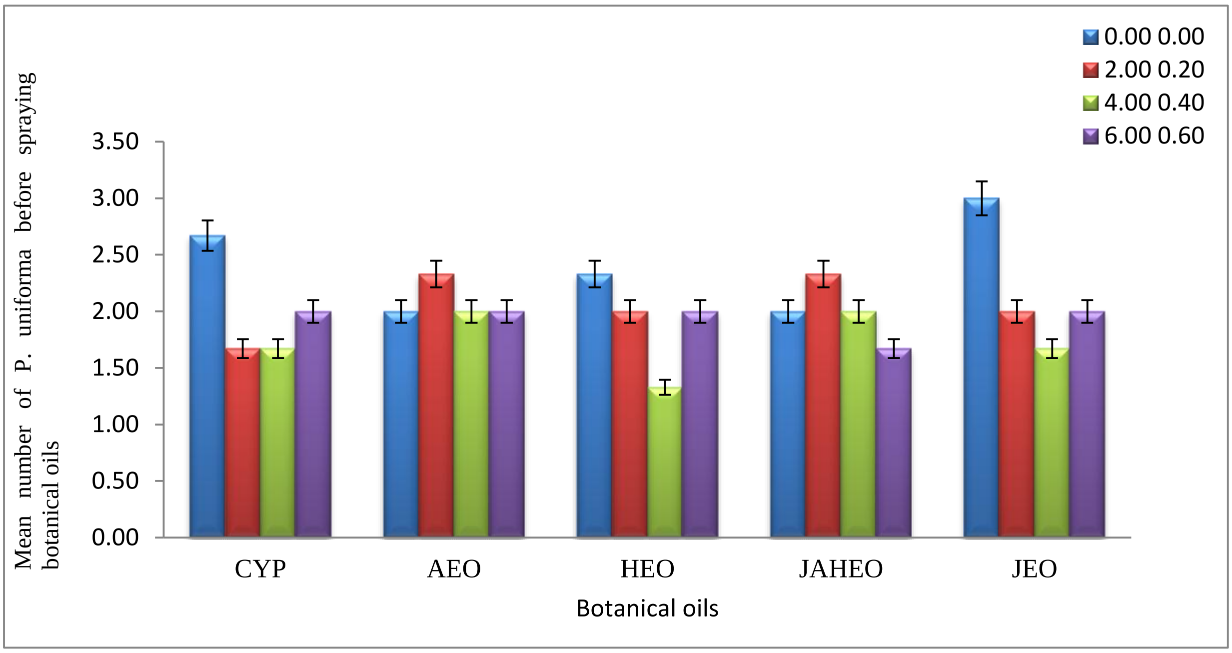
(a) Before spray at vegetative phase during early 2016.



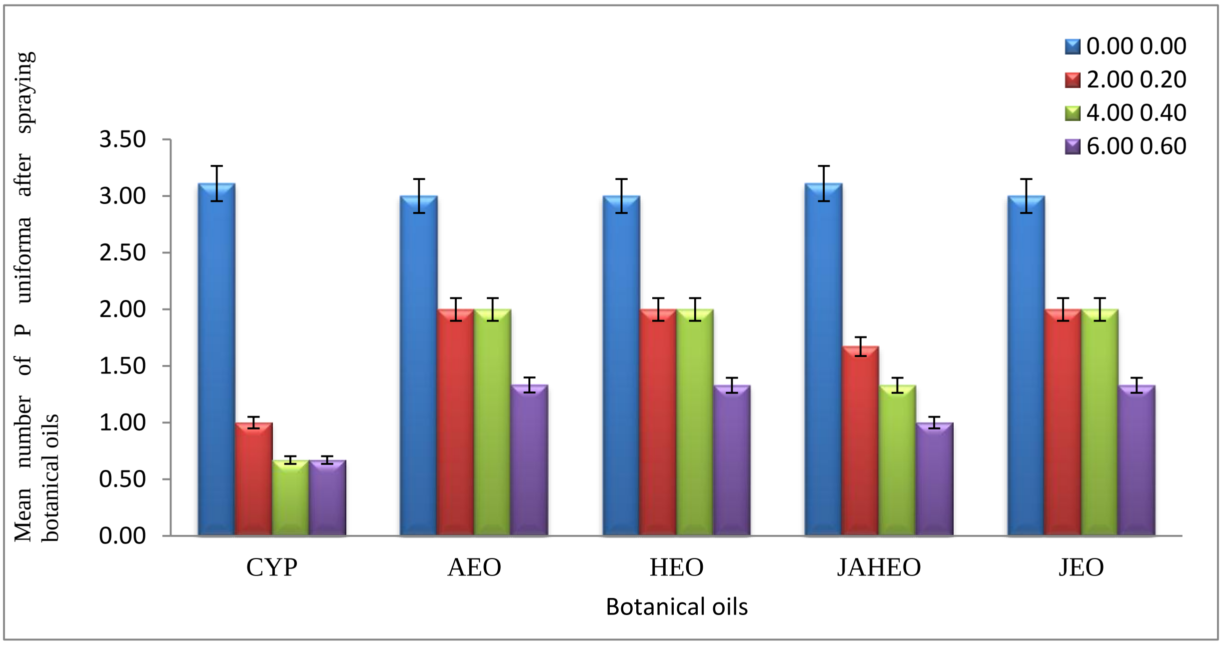
(b) After spray at vegetative phase during early 2016

FIG 13; Comparison of number *Podagrica uniforma* on bambara groundnut before and after spray at vegetative phase during 2016 early farming season

Key: CYP-Cypermethrin 10EC, AEO- Stool wood *Alstonia boonei.* oil, HEO- Bush tea *Hyptis suaveolens* oil, JAHEO- Mixed plant oils from Jathropha, Bush tea and Stool wood, JEO- *Jathropha tanjorensis* oil



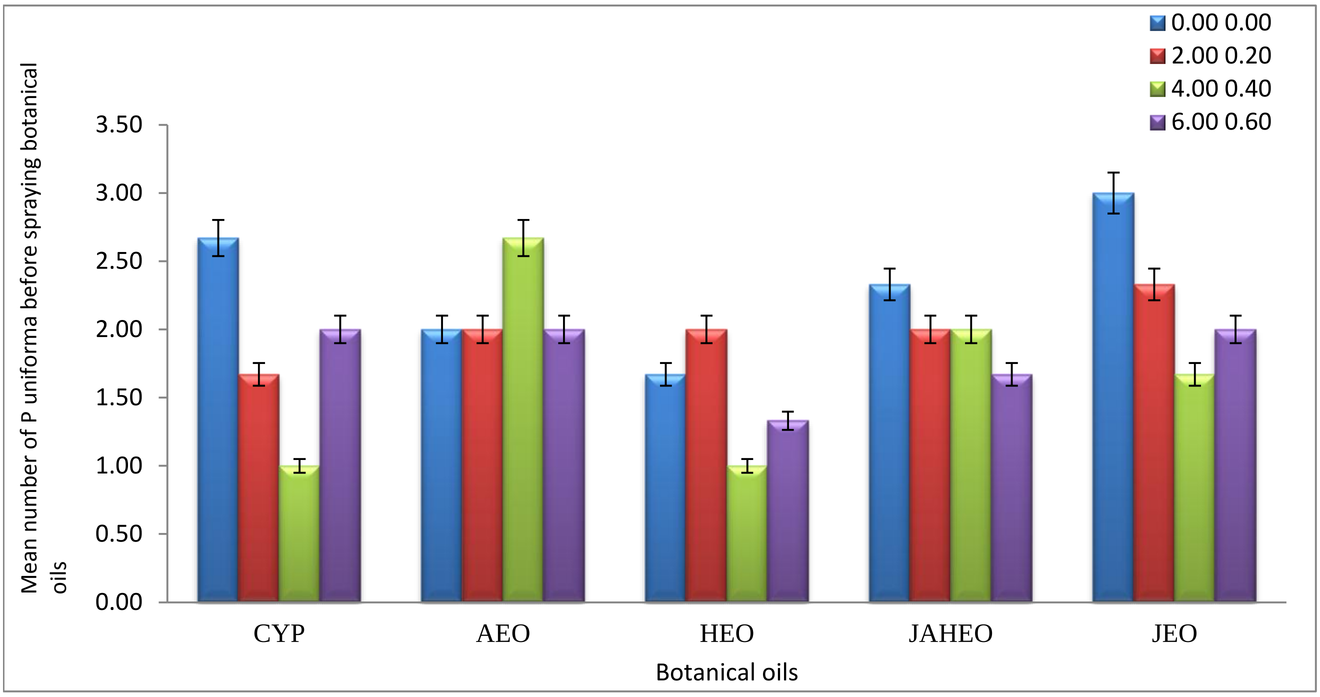
(a) Before spray at vegetative phase during late 2016.



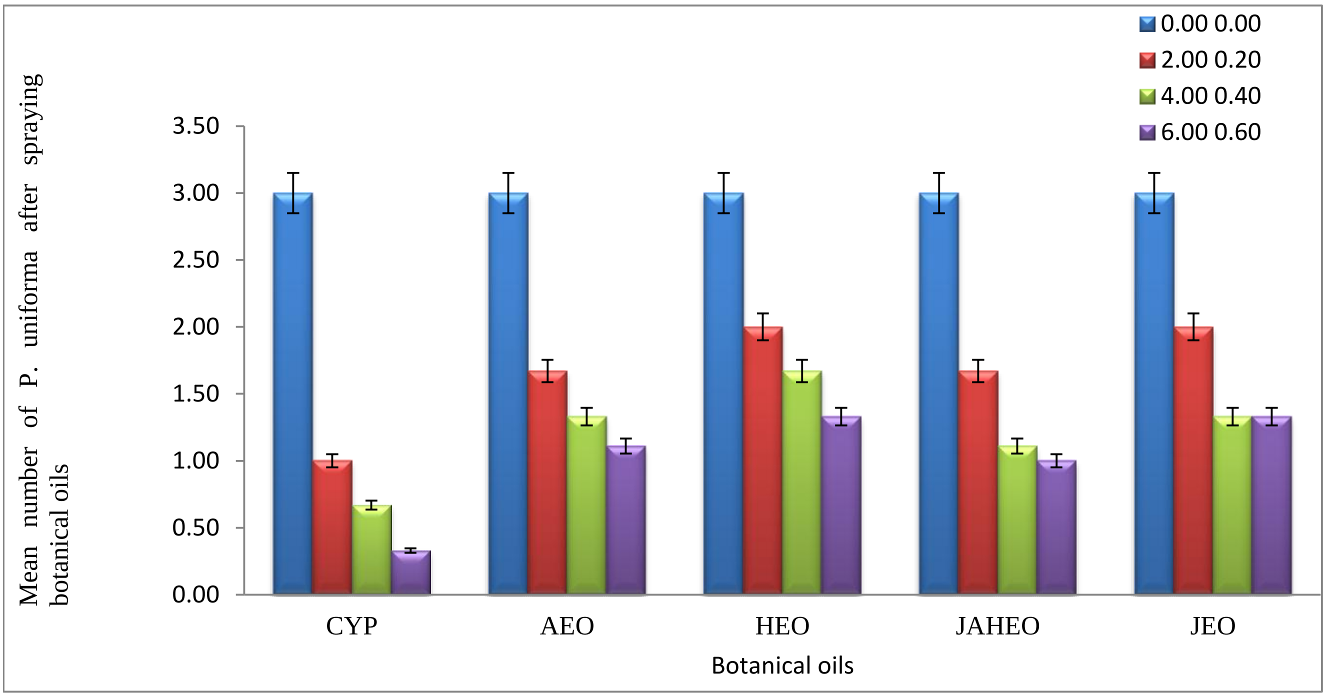
(b) After spray at vegetative phase during late 2016

FIG 14; Comparison of number *P. uniforma* on bambara groundnut after spray at vegetative phase during late 2016 late farming season

Key: CYP-Cypermethrin 10EC, AEO- Stool wood *Alstonia boonei.* oil, HEO- Bush tea *Hyptis suaveolens* oil, JAHEO- Mixed plant oils from Jathropha, Bush tea and Stool wood, JEO- *Jathropha tanjorensis* oil



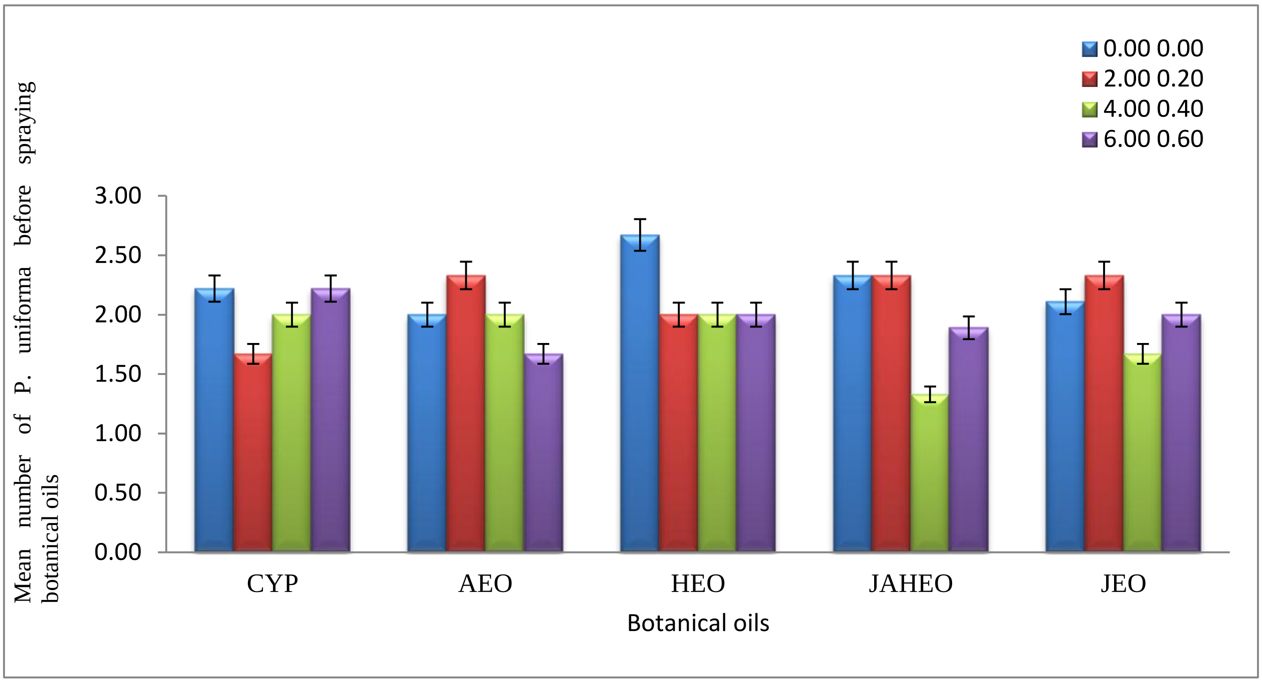
(a) Before spray at vegetative phase during early 2017.



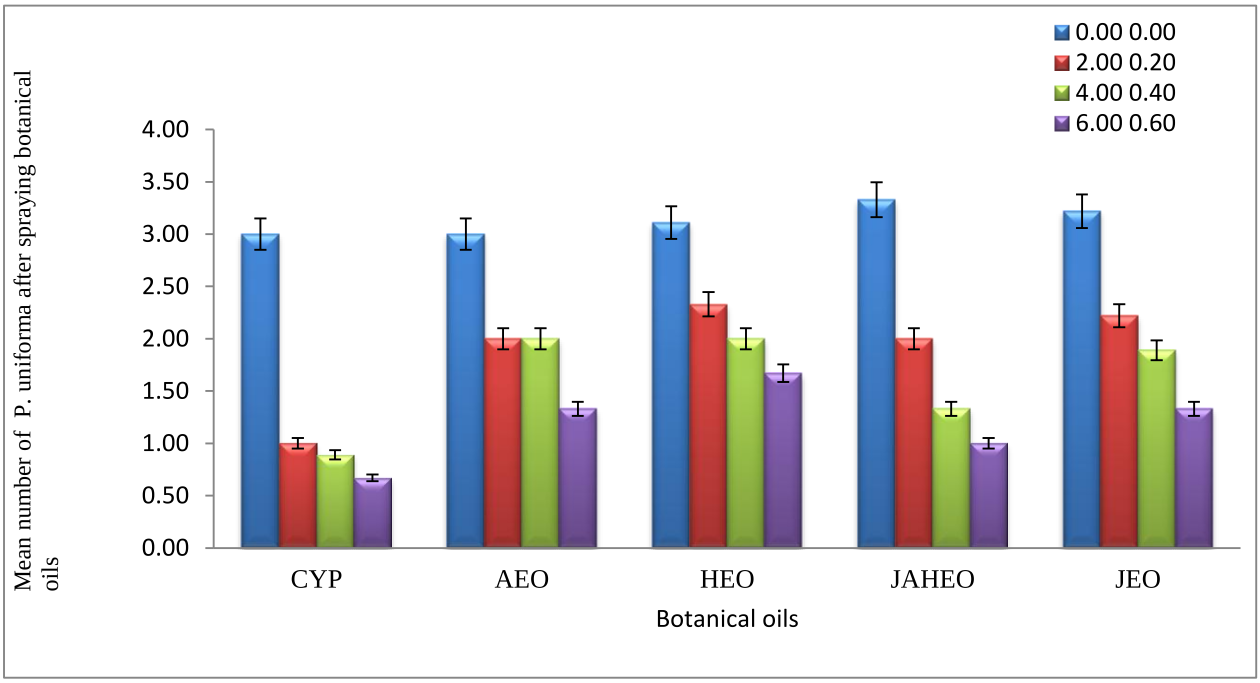
(b) After spray at vegetative phase during early 2017

FIG 15; Comparison of number *P. uniforma* on bambara groundnut before and after spray at vegetative phase during early 2017 farming season

Key: CYP-Cypermethrin 10EC, AEO- Stool wood *Alstonia boonei.* oil, HEO- Bush tea *Hyptis suaveolens* oil, JAHEO- Mixed



(a) Before spray at vegetative phase during late 2017.



(b) After spray at vegetative phase during late 2017

FIG 16; Comparison of number *P. uniforma* on bambara groundnut before and after spray at vegetative phase during late 2017 farming season

Key: CYP-Cypermethrin 10EC, AEO- Stool wood *Alstonia boonei.* oil, HEO- Bush tea *Hyptis suaveolens* oil, JAHEO- Mixed plant oils from Jathropha, Bush tea and Stool wood, JEO- *Jathropha tanjorensis* oil

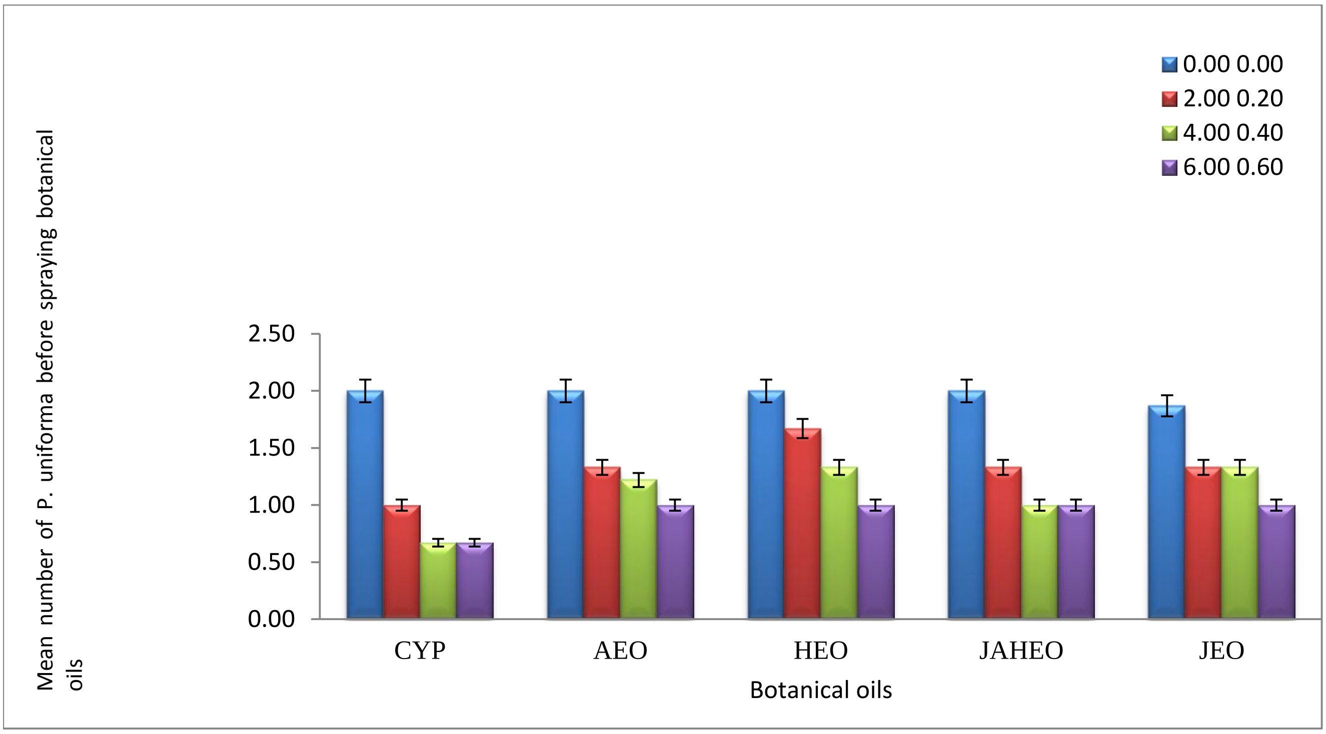
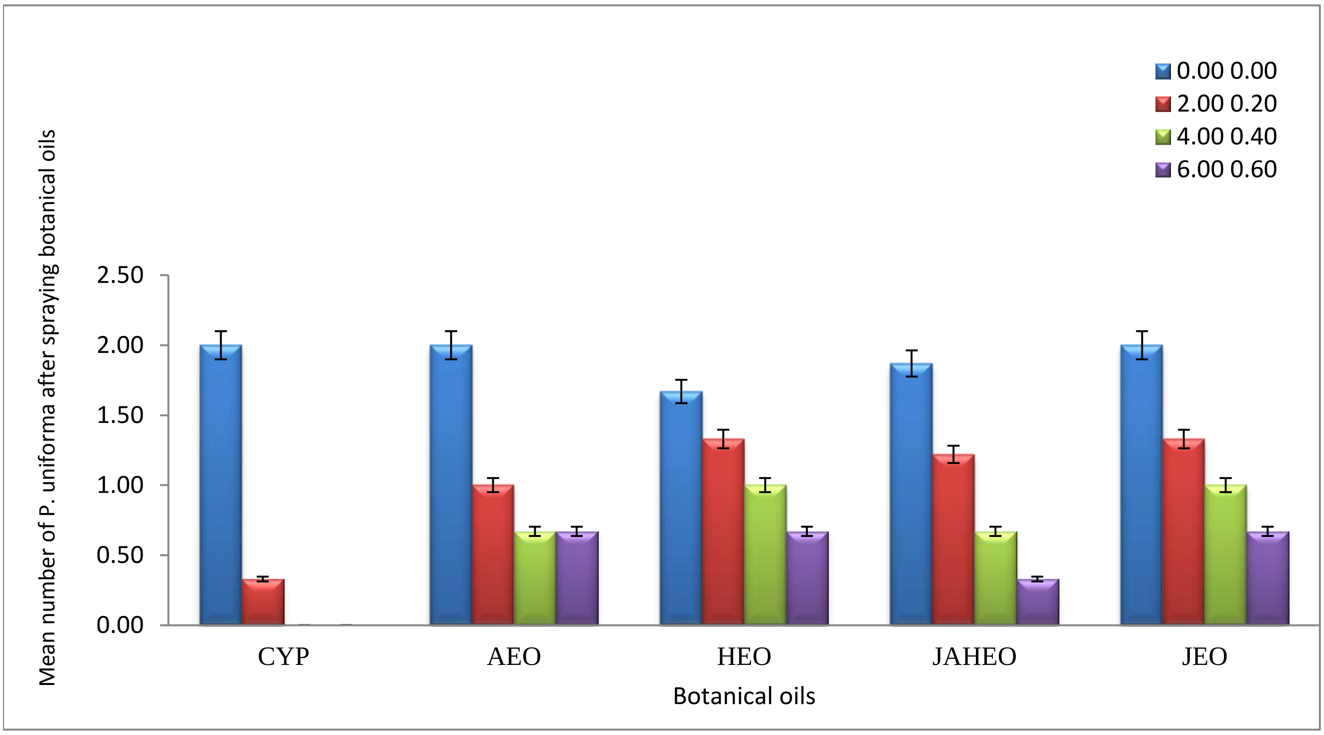
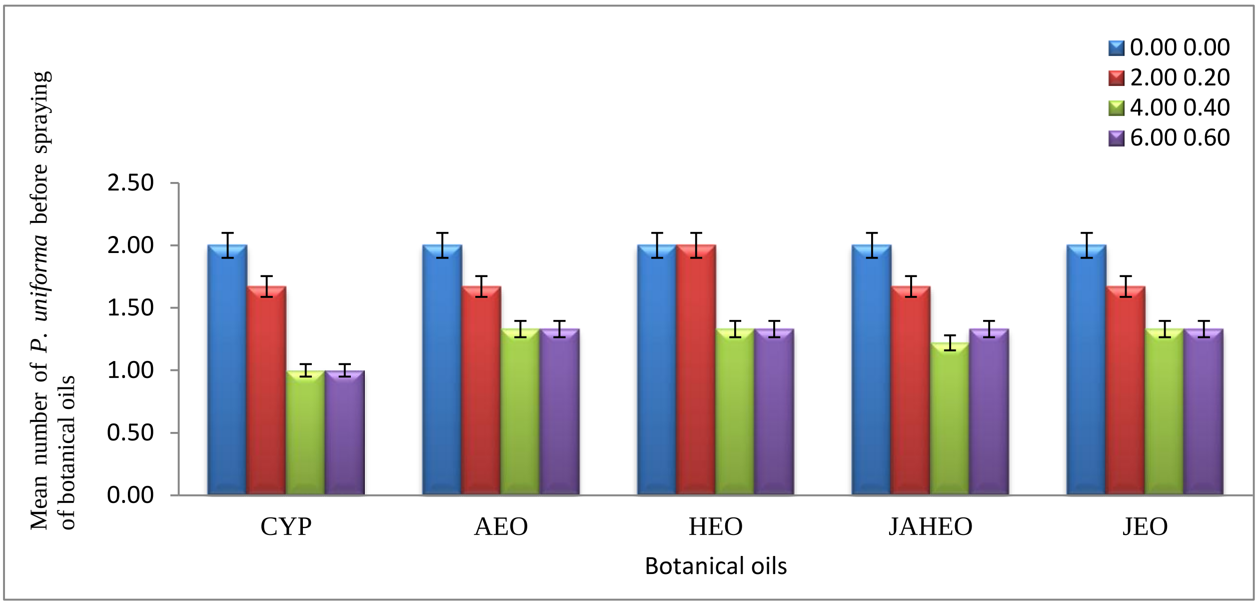


Fig 17 (a) Before spray at flowering phase during early 2016.

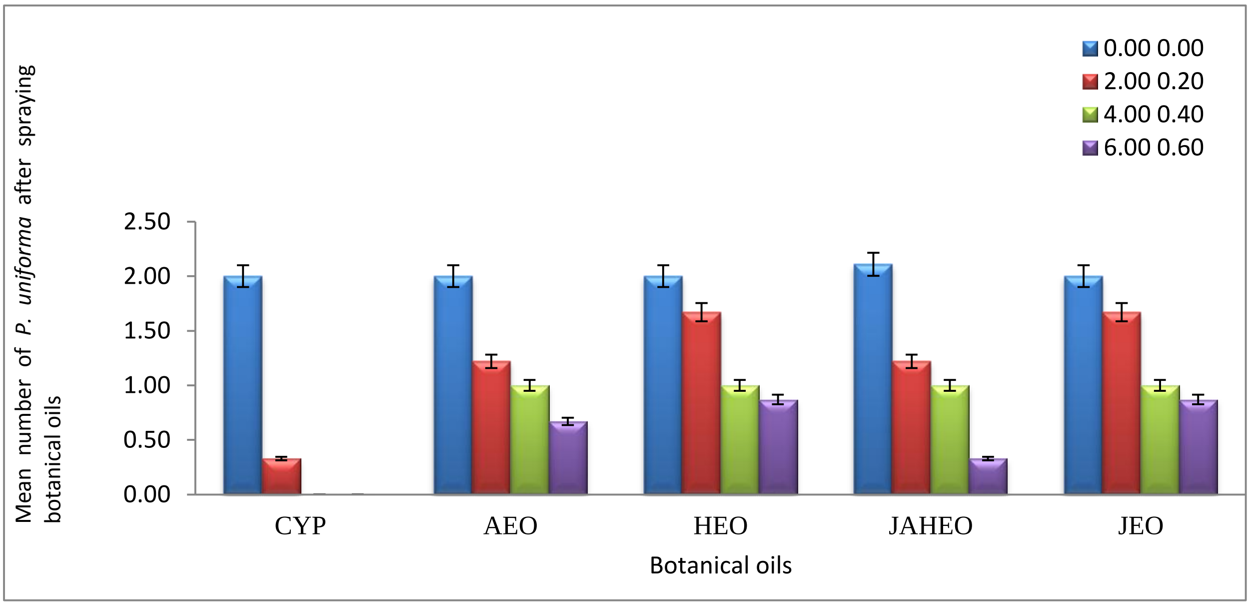


(b) After spray at flowering phase during early 2016

FIG 17; Comparison of number *P. uniforma* on bambara groundnut before and after spray at Flowering phase during 2016 early farming season.



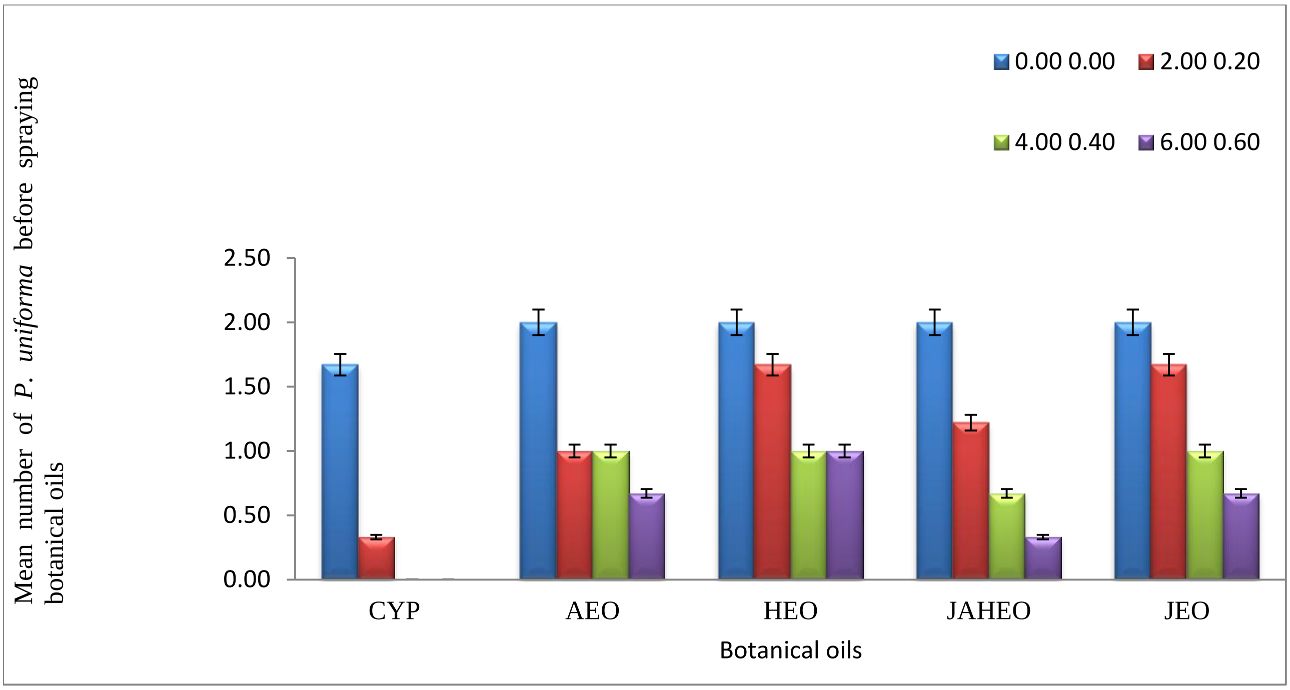
(a) Before spray at flowering phase during late 2016.



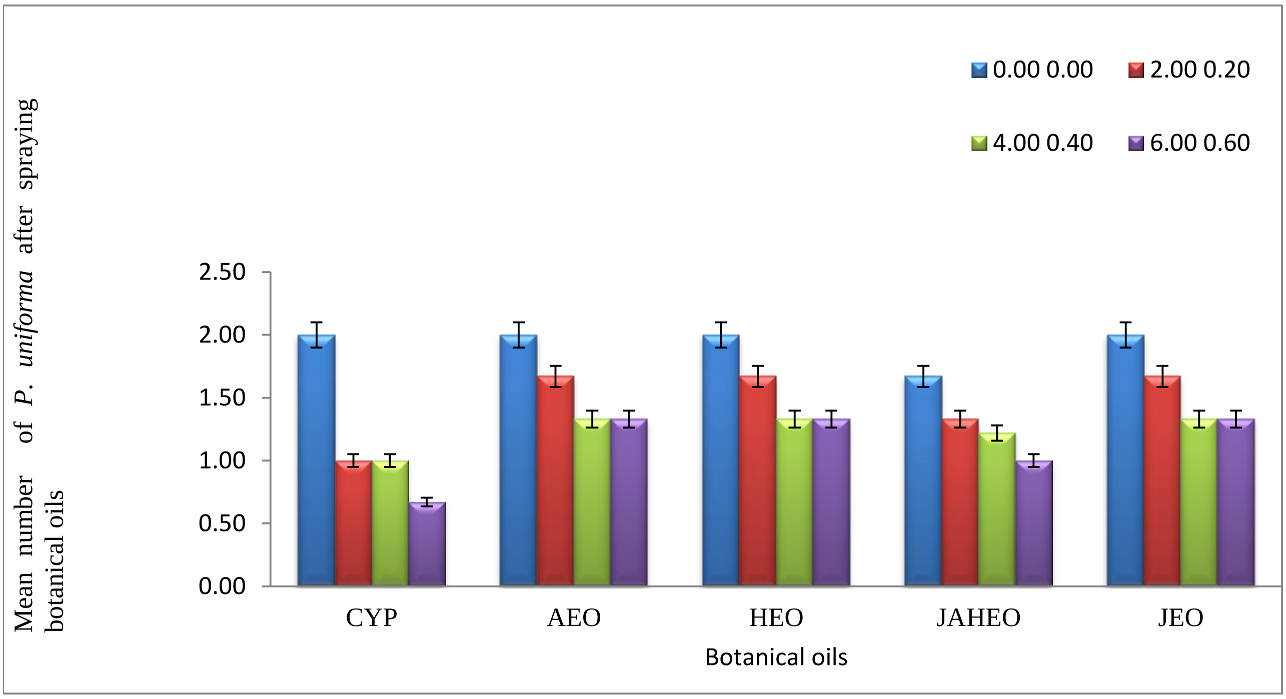
(b) After spray at flowering phase during late 2016

FIG 18; Comparison of number *P. uniforma* on bambara groundnut before and after spray at flowering phase during 2016 late farming season

Key: CYP-Cypermethrin 10EC, AEO- Stool wood *Alstonia boonei.* oil, HEO- Bush tea *Hyptis suaveolens* oil, JAHEO- Mixed plant oils from Jathropha, Bush tea and Stool wood, JEO- *Jathropha tanjorensis* oil



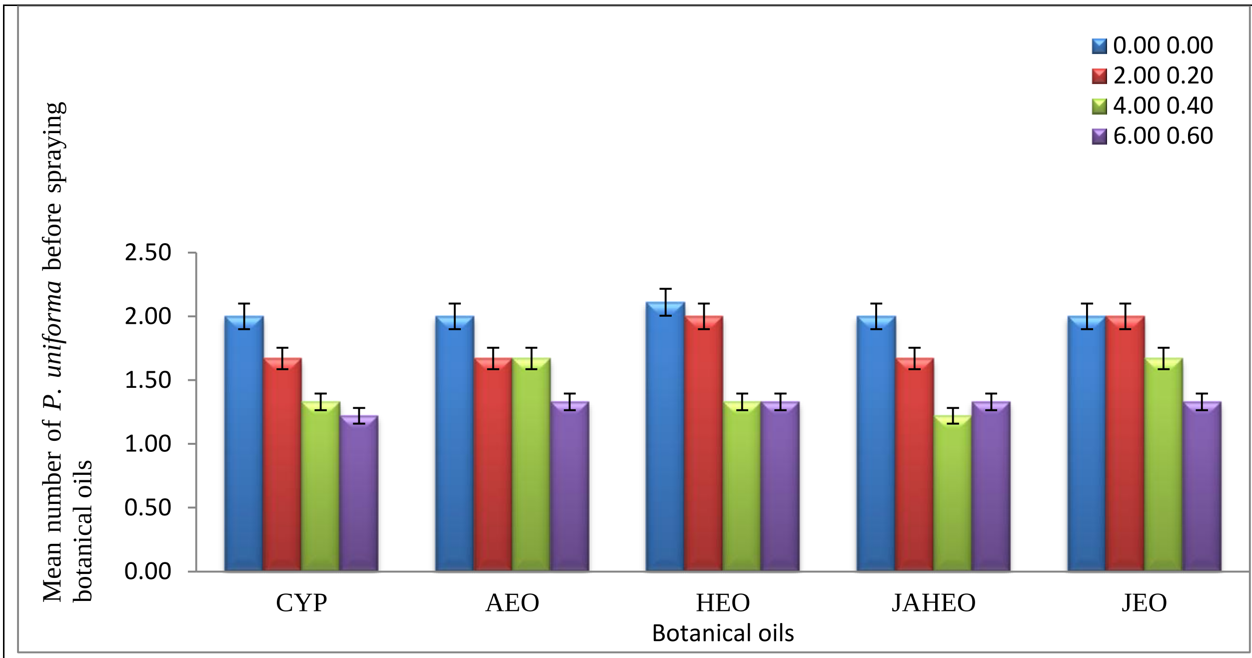
(a) Before spray at flowering phase during early 2017.



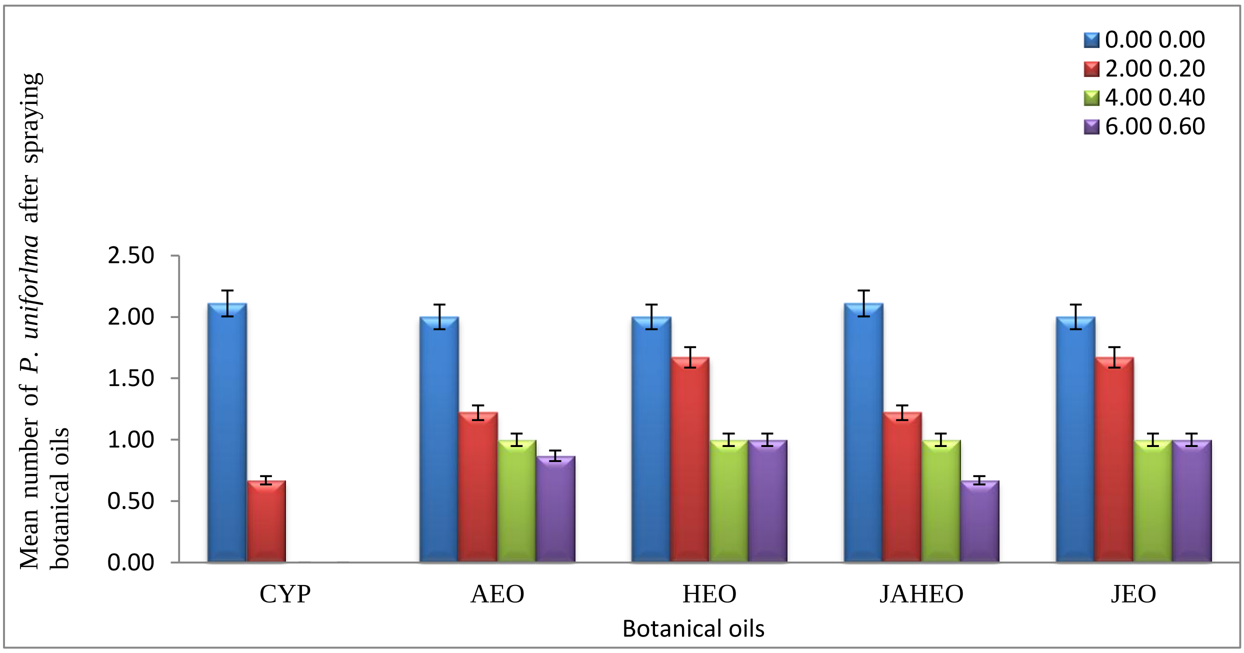
(b) After spray at flowering phase during early 2017

FIG 19; Comparison of number *P. uniforma* on bambara groundnut before and after spray at flowering phase during 2017 early farming season

Key: CYP-Cypermethrin 10EC, AEO- Stool wood *Alstonia boonei.* oil, HEO- Bush tea *Hyptis suaveolens* oil, JAHEO- Mixed plant oils from Jathropha, Bush tea and Stool wood, JEO- *Jathropha tanjorensis* oil



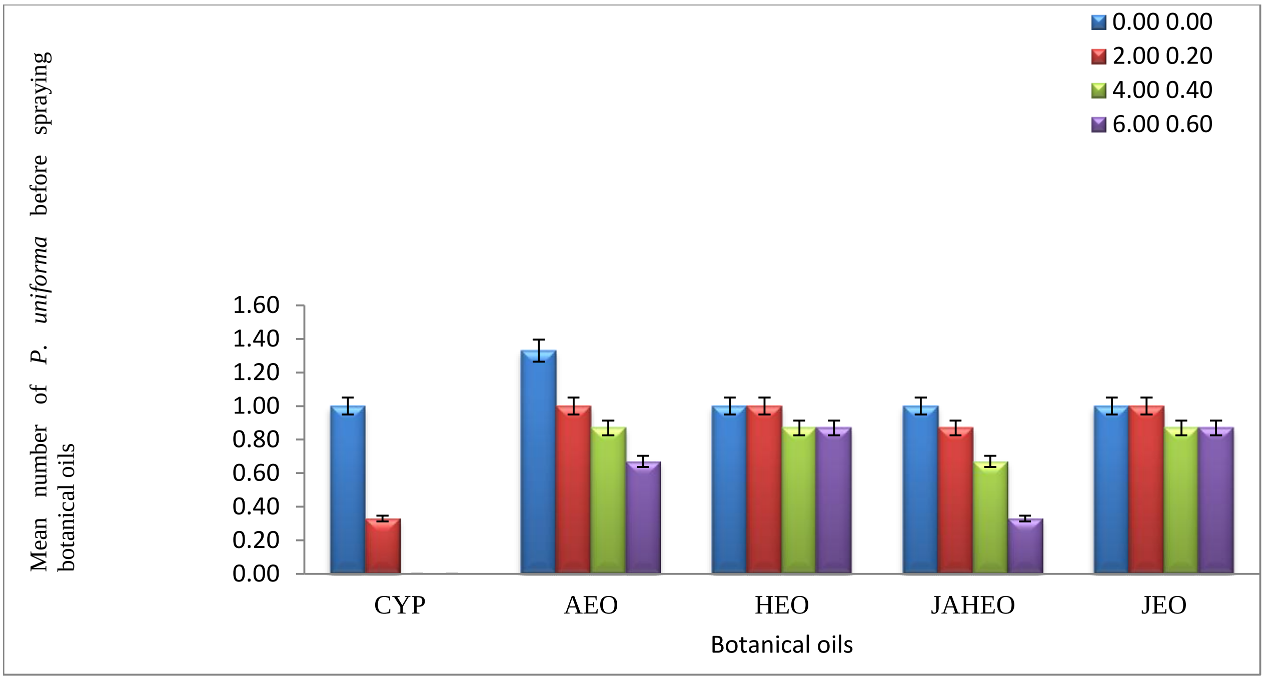
(a) Before spray at flowering phase during late 2017.



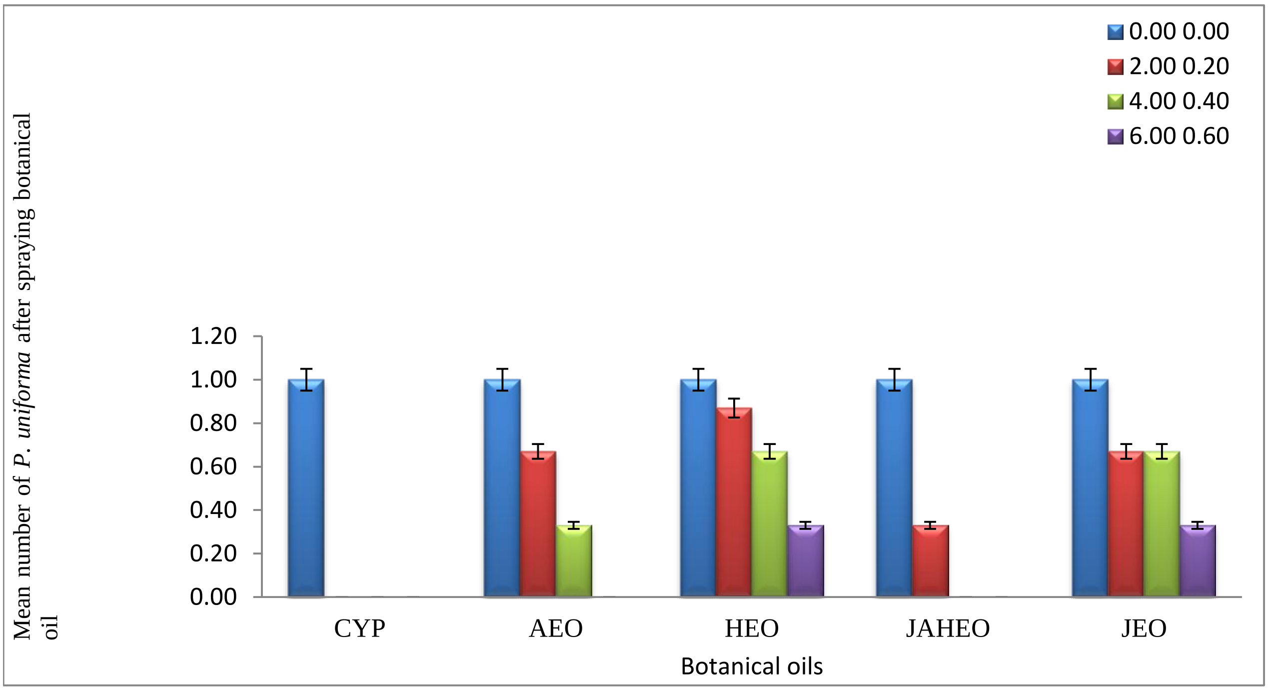
(b) After spray at flowering phase during late 2017

FIG 20; Comparison of number *P. uniforma* on bambara groundnut before and after spray at flowering phase during 2017 late farming season

Key: CYP-Cypermethrin 10EC, AEO- Stool wood *Alstonia boonei*. oil, HEO- Bush tea *Hyptis suaveolens* oil, JAHEO- Mixed plant oils from Jathropha, Bush tea and Stool wood, JEO- *Jathropha tanjorensis* oil



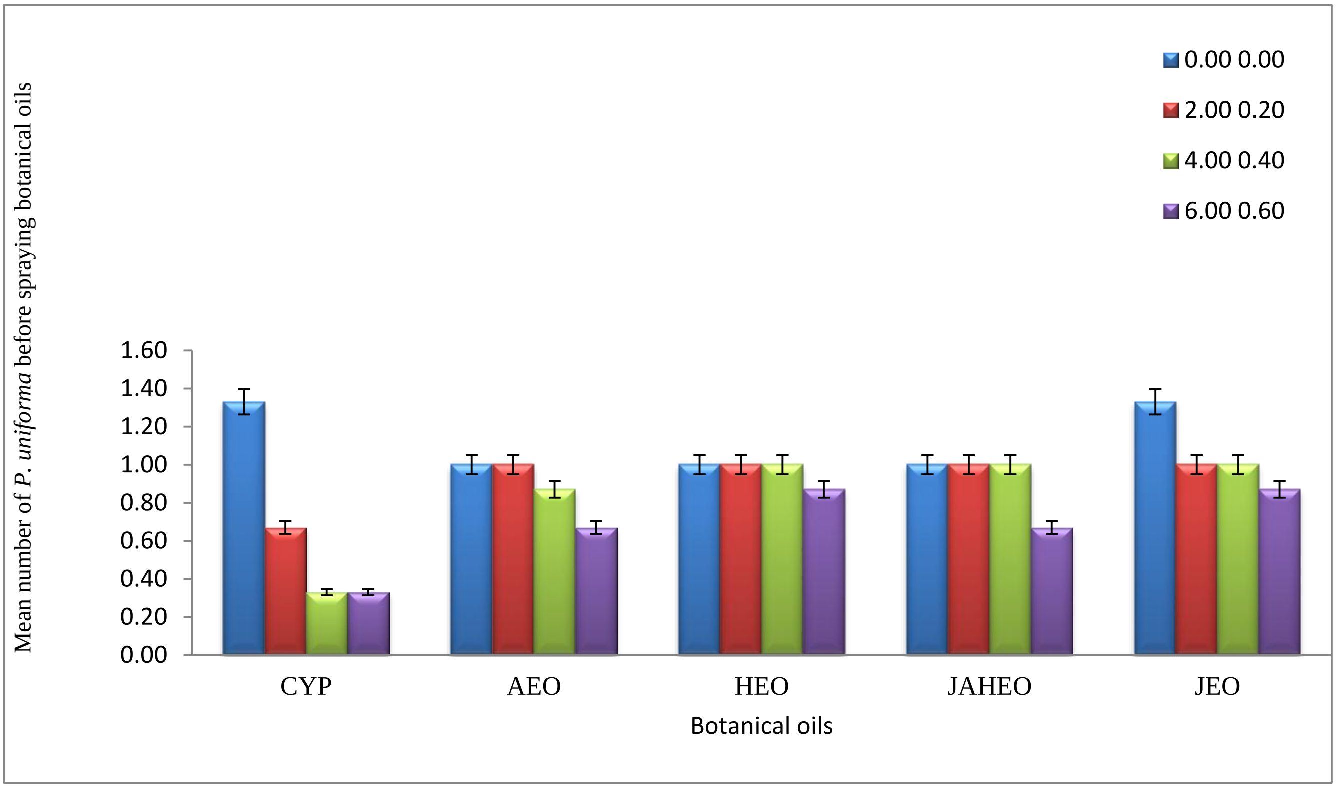
(a) Before spray at podding phase during early 2016.



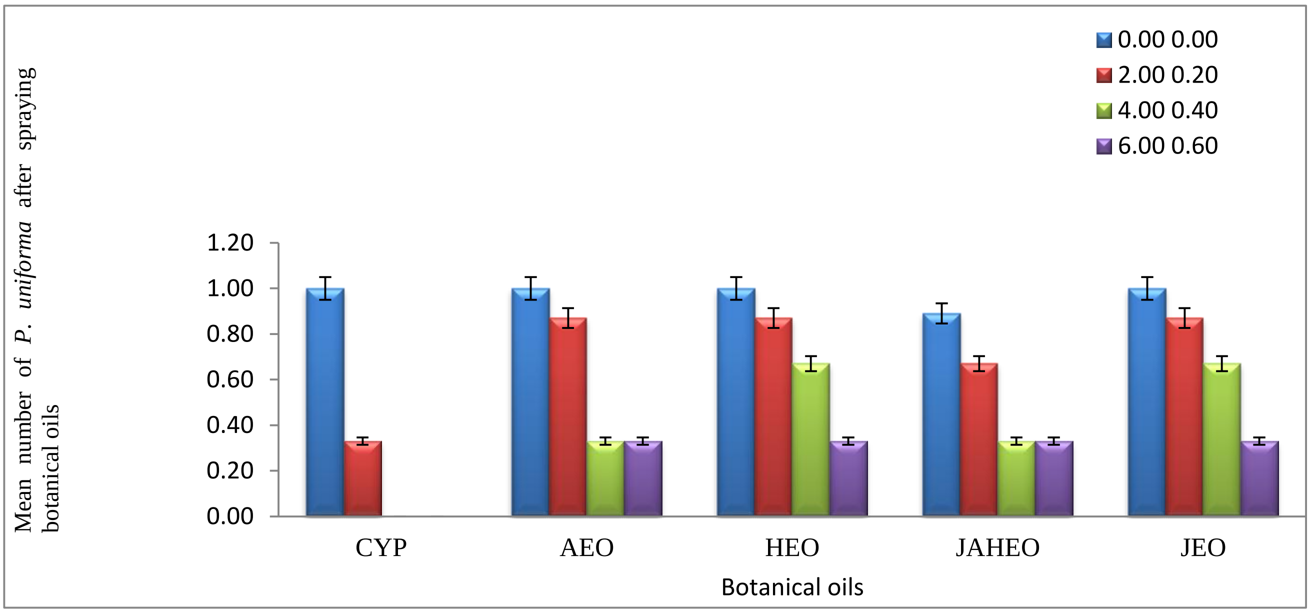
(b) After spray at podding phase during early 2016

FIG 21; Comparison of number *P. uniforma* on bambara groundnut before and after spray at podding phase during 2016 early farming season

Key: CYP-Cypermethrin 10EC, AEO- Stool wood *Alstonia boonei.* oil, HEO- Bush tea *Hyptis suaveolens* oil, JAHEO- Mixed plant oils from Jathropha, Bush tea and Stool wood, JEO- *Jathropha tanjorensis* oil

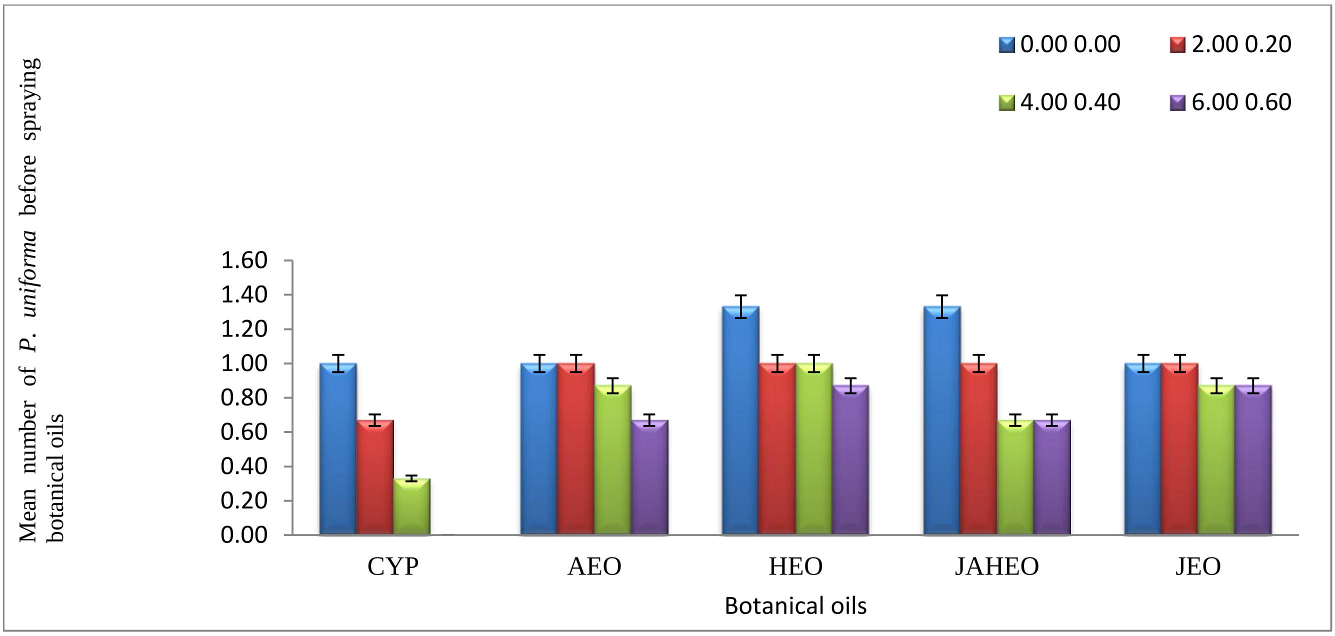


(a) Before spray at podding phase during late 2016.

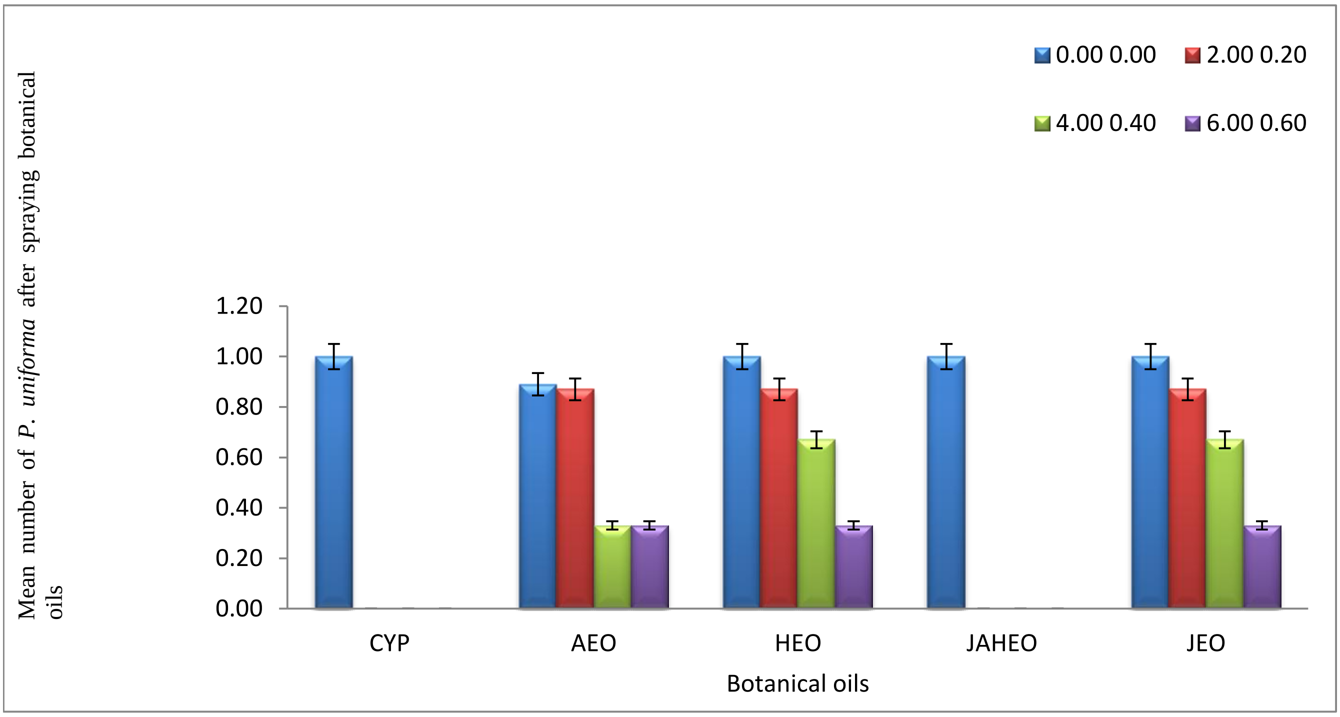


(b) After spray at podding phase during late 2016
FIG 22; Comparison of number *P. uniforma* on bambara groundnut after spray at podding phase during 2016 late farming season

Key: CYP-Cypermethrin 10EC, AEO- Stool wood *Alstonia boonei.* oil, HEO- Bush tea *Hyptis suaveolens* oil, JAHEO- Mixed plant oils from Jathropha, Bush tea and Stool wood, JEO- *Jathropha tanjorensis* oil



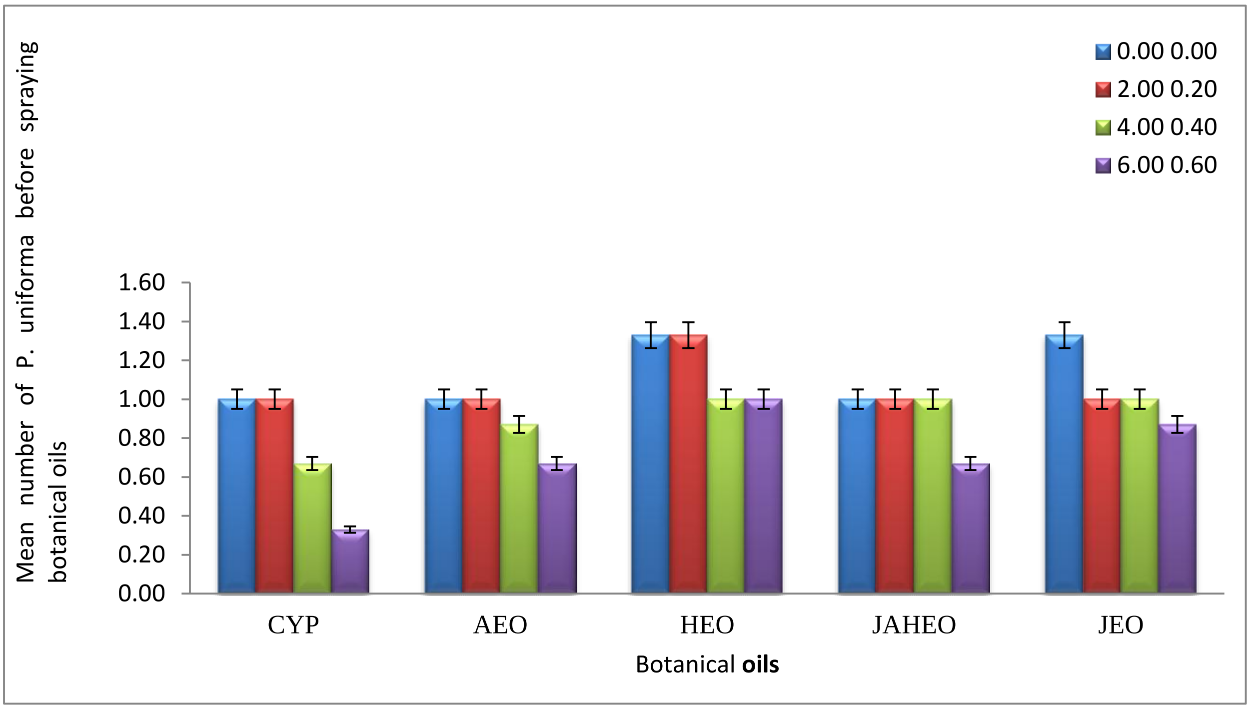
(a) Before spray at podding phase during early 2017.



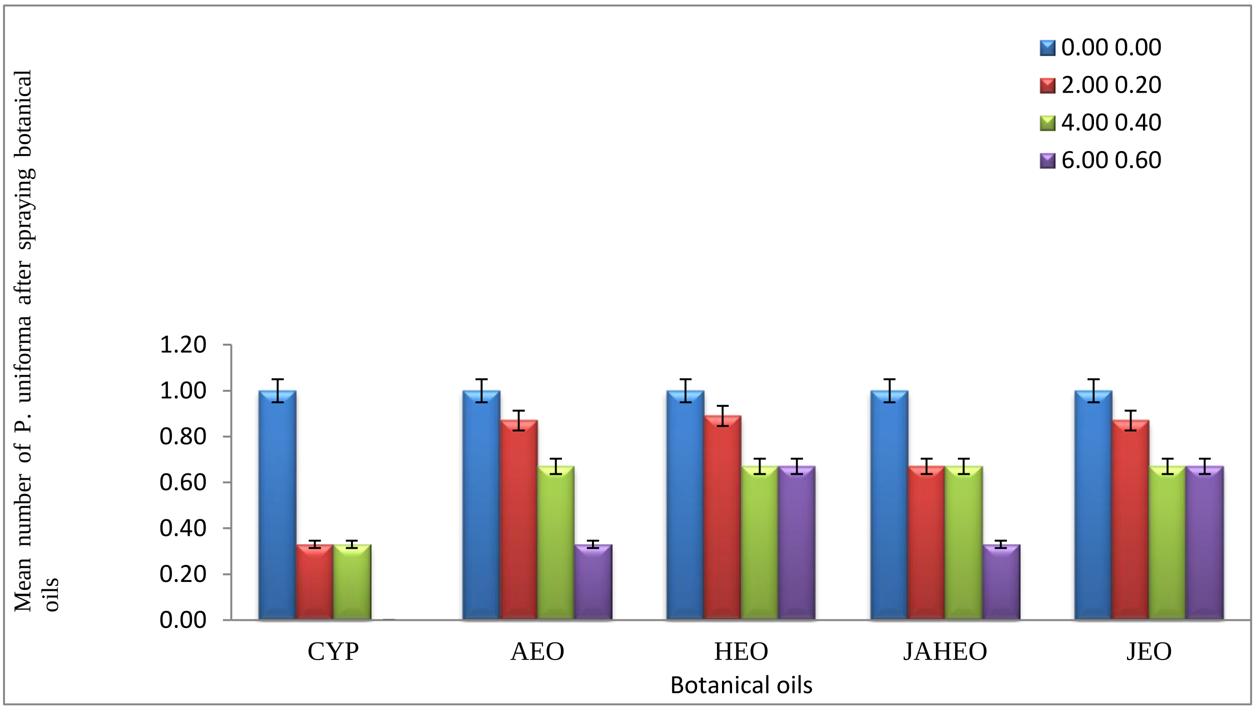
(b) After spray at podding phase during early 2017

FIG 23; Comparison of number *P. uniforma* on bambara groundnut before spray at podding phase during 2017 early farming season

Key: CYP-Cypermethrin 10EC, AEO- Stool wood *Alstonia boonei*. oil, HEO- Bush tea *Hyptis suaveolens* oil, JAHEO- Mixed plant oils from Jathropha, Bush tea and Stool wood, JEO- *Jathropha tanjorensis* oil



(a) Before spray at podding phase during late 2017.



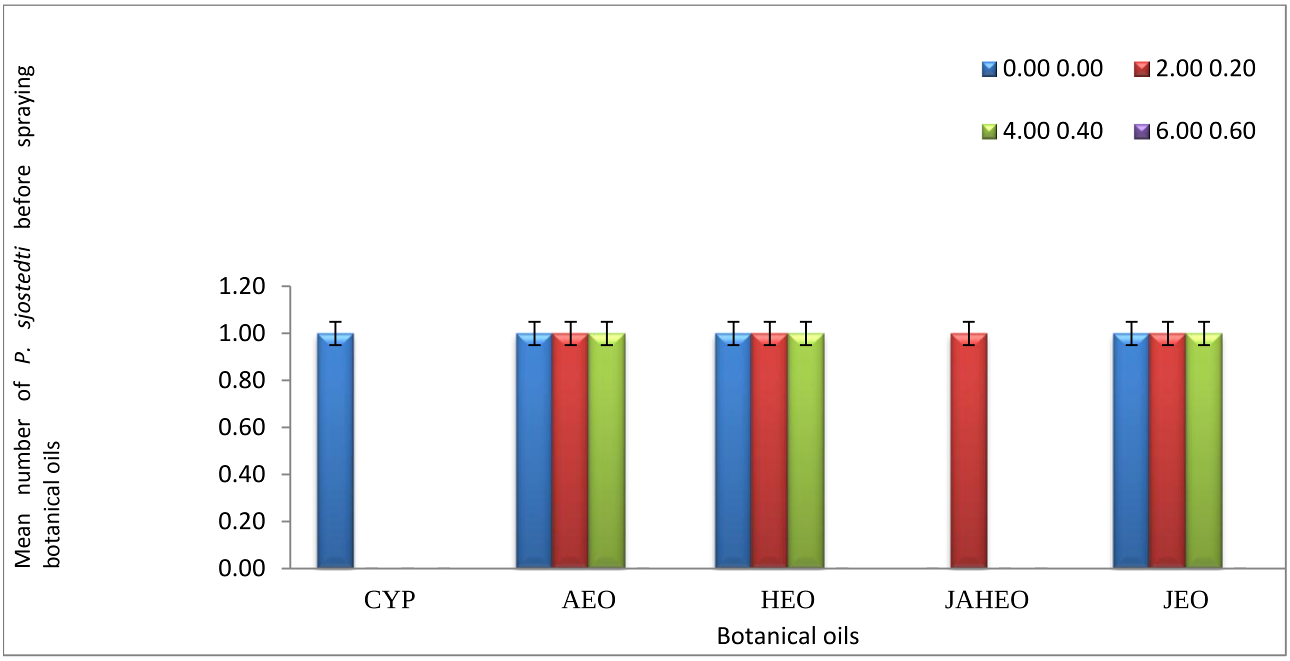
(b) After spray at podding phase during late 2017

FIG 24; Comparison of number *P. uniforma* on bambara groundnut before and after spray at podding phase during 2017 late farming season

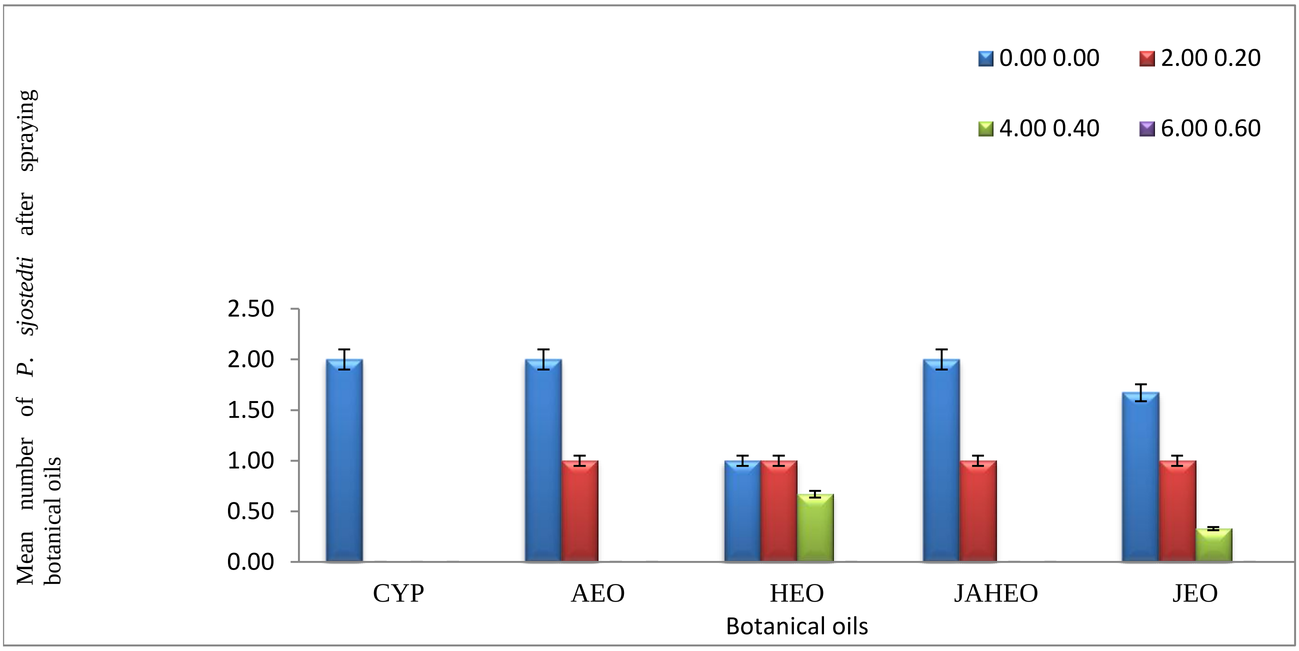
Key: CYP-Cypermethrin 10EC, AEO- Stool wood *Alstonia boonei.* oil, HEO- Bush tea *Hyptis suaveolens* oil, JAHEO- Mixed plant oils from Jathropha, Bush tea and Stool wood, JEO- *Jathropha tanjorensis* oil

4.7 Effects of Botanical oils on *Podagrica jostedti* at vegetative, flowering and podding phase in 2016 and 2017 early and late farming season

The results in Figures 25 to 36 showed that *Podagrica jostedti* were present at vegetative, flowering and podding phase in 2016 and 2017 early and late season. The plots sprayed with Cypermethrin (CYP) recorded the least mean number of *P. sjostedti* at Vegetative, Flowering and Podding phase in 2016 and 2017 early and late farming seasons. This was followed by plots sprayed with Combination of plant oils (JAHEO) while plots sprayed with *Alstonia boonei* oil (AEO) recorded lower mean number of *P. sjostedti* than Jathropha oil (JEO) and *Hyptis suaveolens* oil (HEO) that mostly recorded the highest mean number of *P.sjostedti* at vegetative, flowering and podding in 2016 and 2017 early and late season. Effects of application rate of botanic oils on *P.s jostedti* were dose related. The highest application rates (6.00/0,60ml) recorded the least number of *P. sjostedti,* this was followed by the medium rates (4.00/0.40ml) and least application rates (2.00/0.20) respectively, while the control rates (0.00/0.00) recorded the highest mean number of *P.sjostedti* in 2016 and 2017 early and late seasons. Least mean number of *P.sjostedti* were recorded in at the vegetative phase followed the podding phase, while the flowering phase recorded the highest mean number of *P.sjostedti* in 2016 and 2017 early and late seasons. Although mean number of *P. sjostedti* were higher before spray but significantly reduced immediately after spray while there were no reduction but significant increase in number of *P.sjostedti* in the control plots at vegetative, flowering and podding phase in 2016 and 2017 early and late seasons.



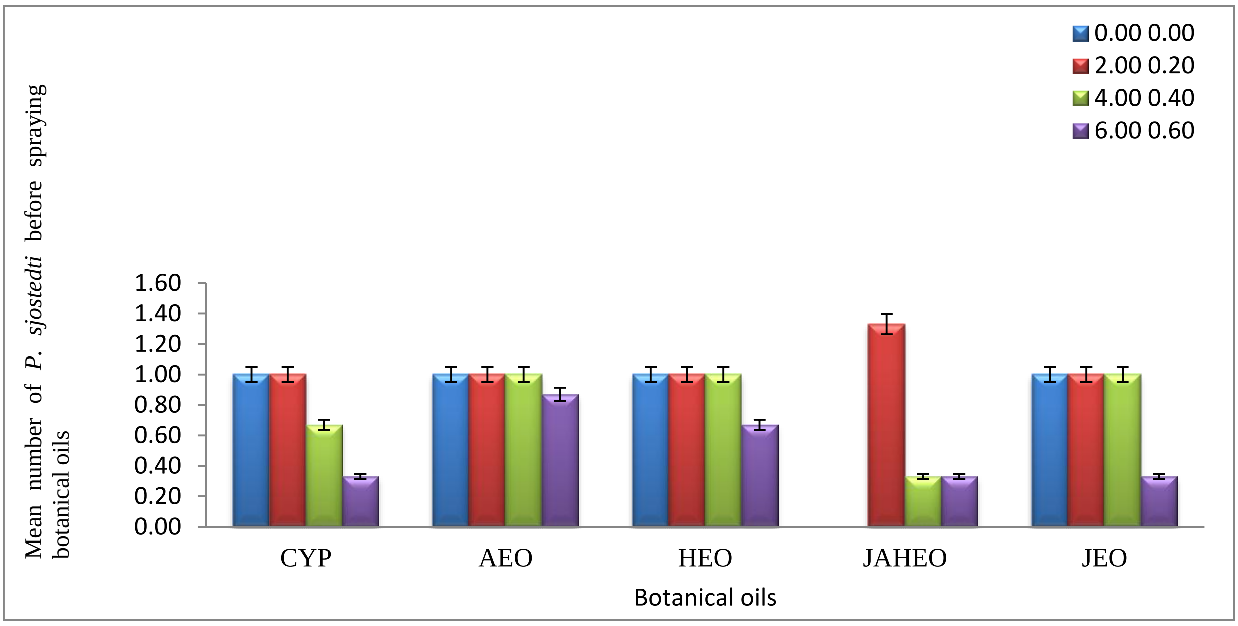
(a) Before spray at vegetative phase during early 2016.



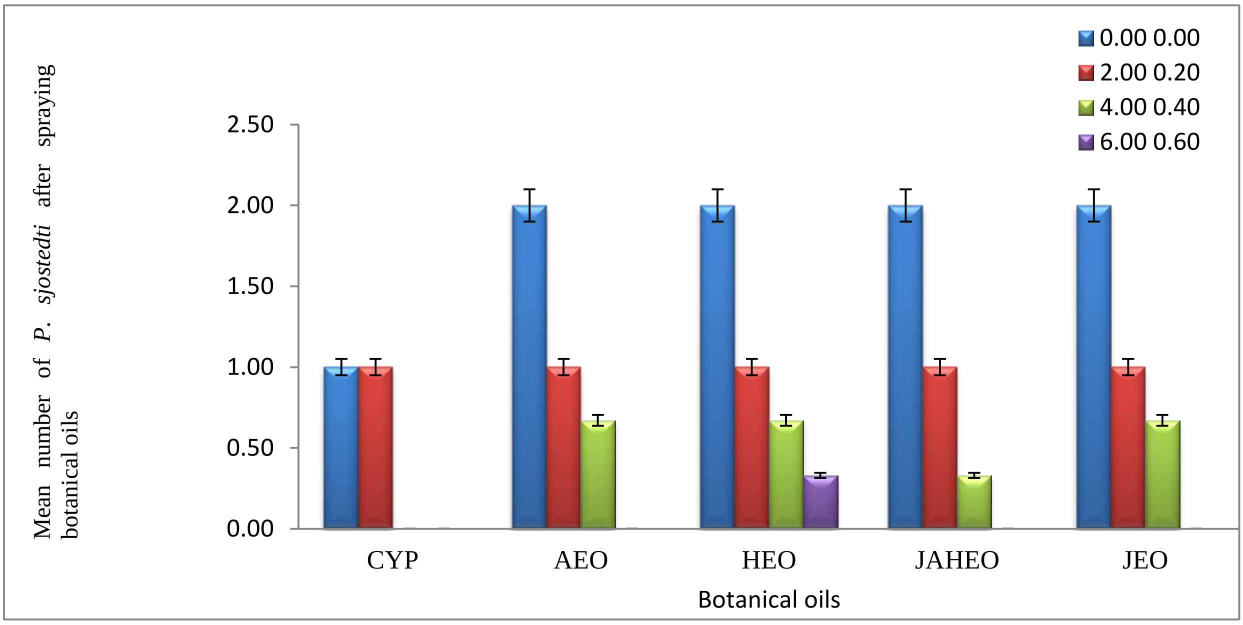
(b) After spray at vegetative phase during early 2016

FIG 25; Comparison of number of *P.sjostedti* on bambara groundnut before and afterspray at vegetative phase during 2016 early farming season

Key: CYP-Cypermethrin 10EC, AEO- Stool wood *Alstonia boonei.* oil, HEO- Bush tea *Hyptis suaveolens* oil, JAHEO- Mixed plant oils from Jathropha, Bush tea and Stool wood, JEO- *Jathropha tanjorensis* oil



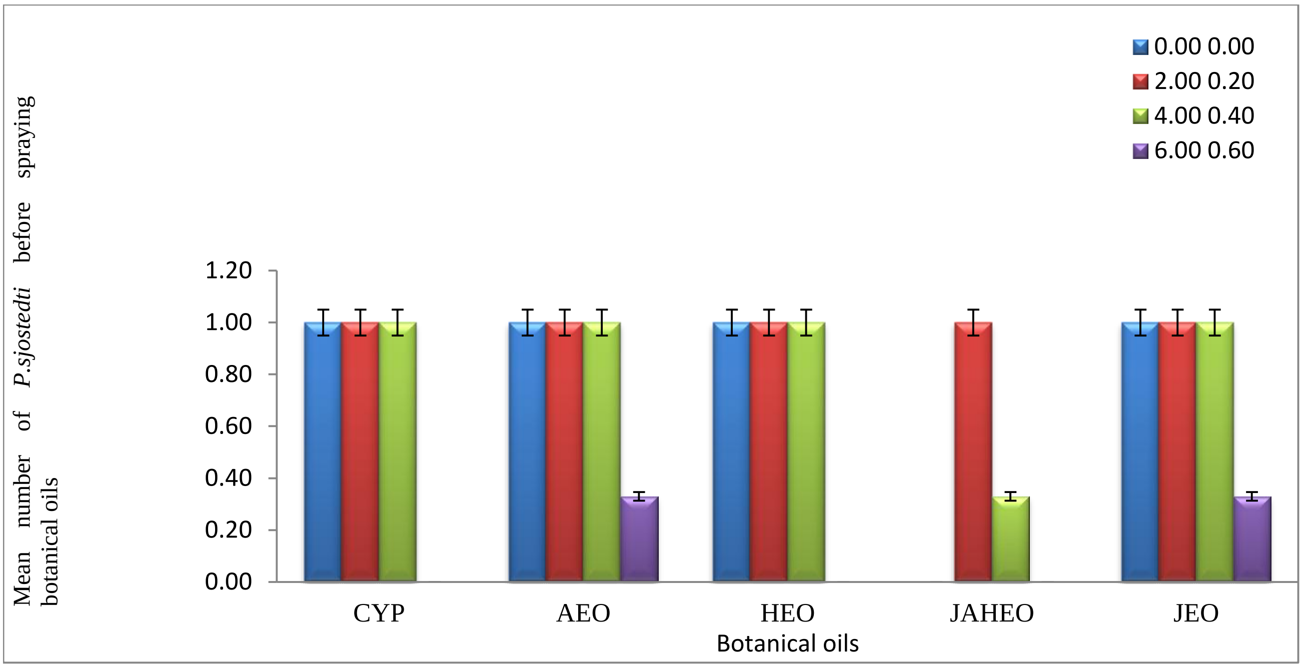
(a) Before spray at vegetative phase during late 2016.



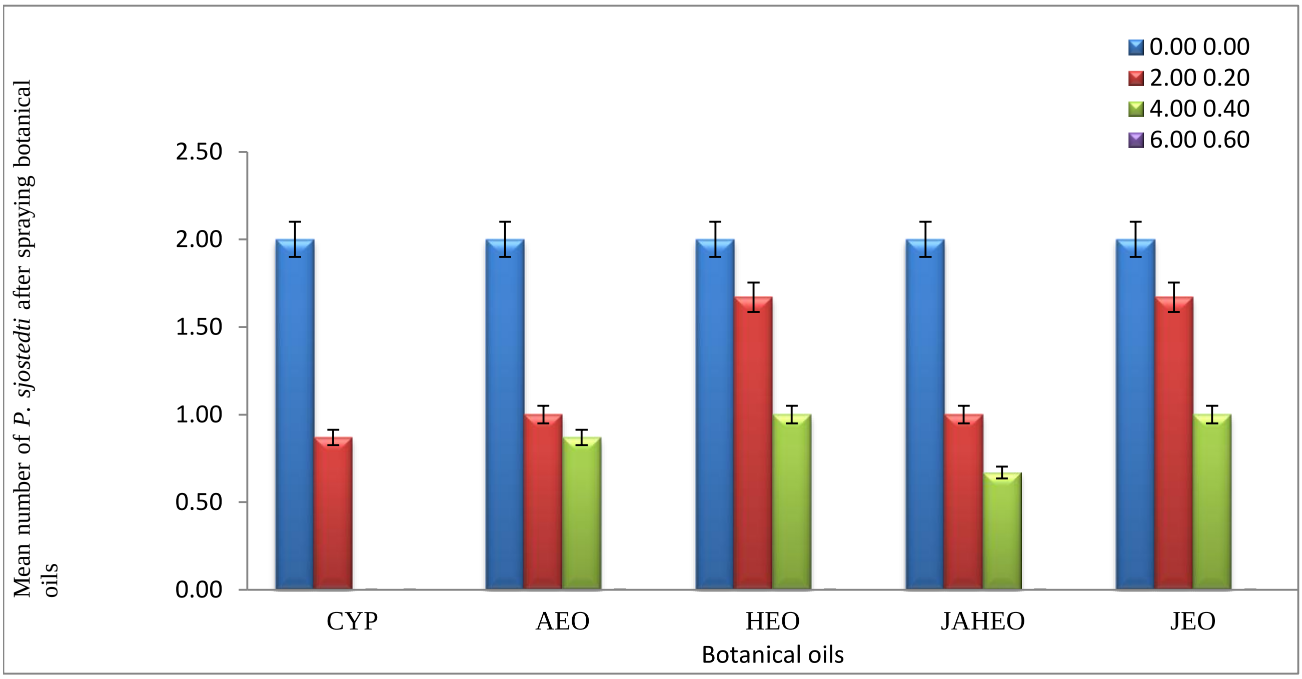
(b) After spray at vegetative phase during late 2016

FIG 26; Comparison of number of *P.sjostedti* on bambara groundnut after spray at vegetative phase during 2016 late farming season

Key: CYP-Cypermethrin 10EC, AEO- Stool wood *Alstonia boonei.* oil, HEO- Bush tea *Hyptis suaveolens* oil, JAHEO- Mixed plant oils from Jathropha, Bush tea and Stool wood, JEO- *Jathropha tanjorensis* oil



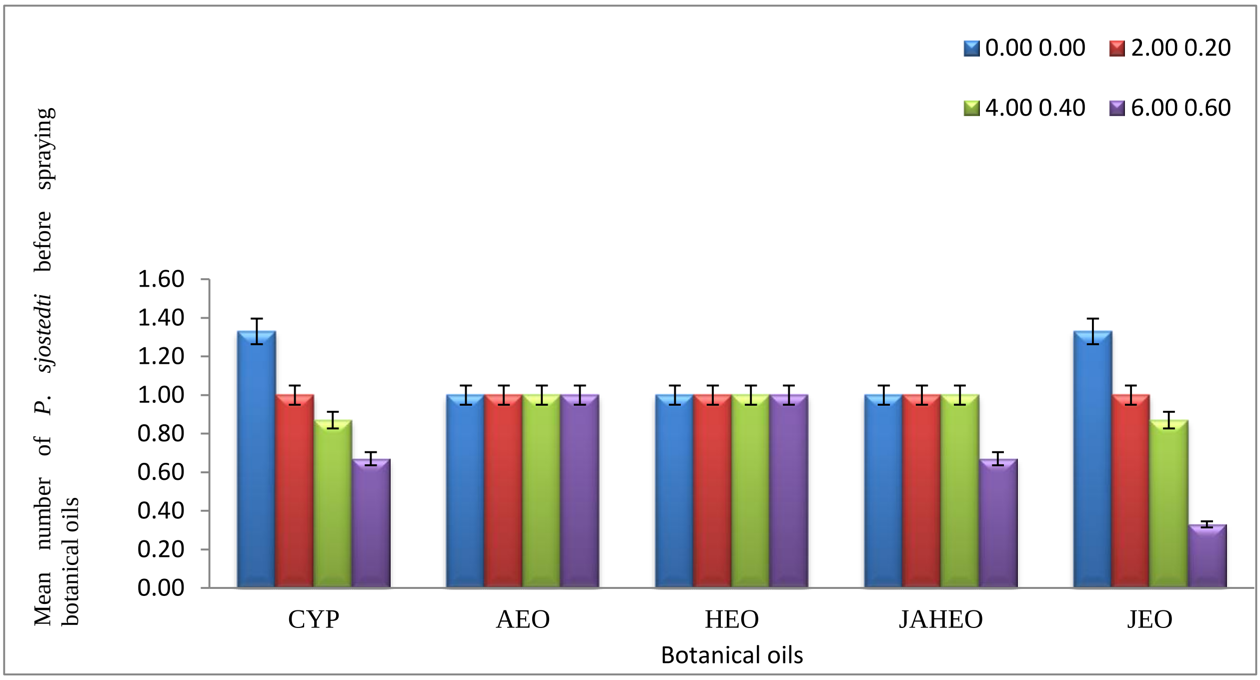
(a) Before spray at vegetative phase during early 2017.



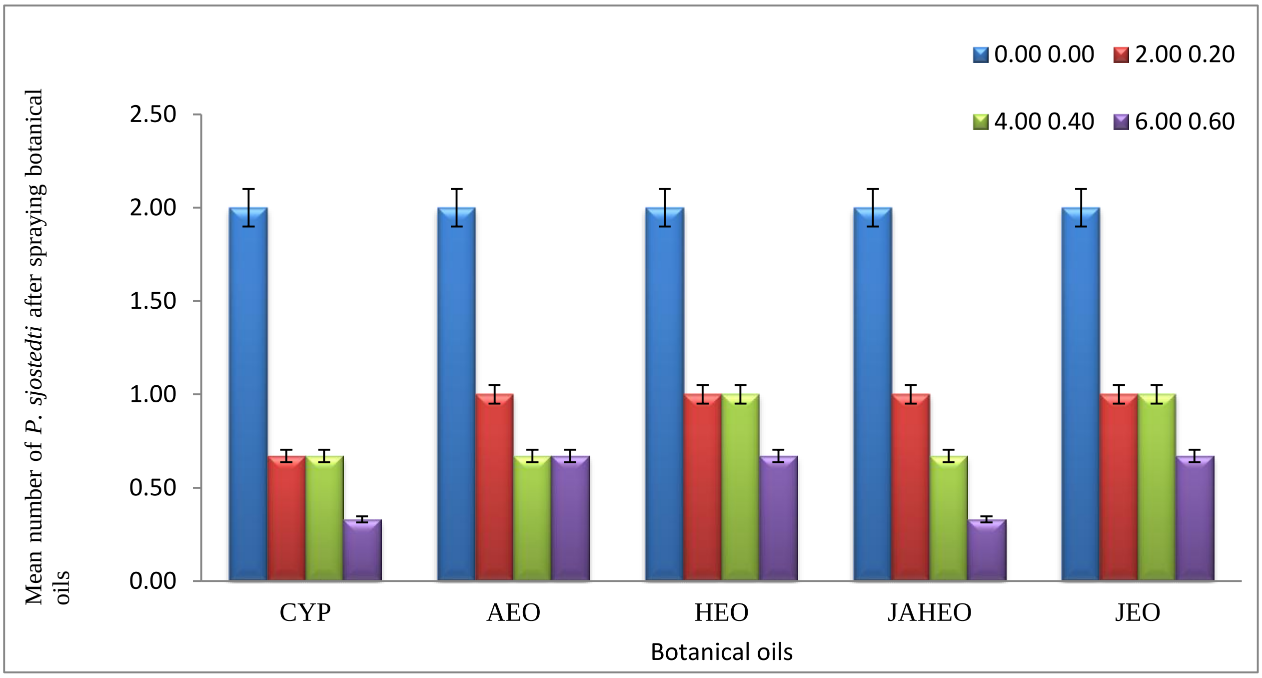
(b) After spray at vegetative phase during early 2017

FIG 27; Comparison of number of *P.sjostedti* on bambara groundnut before and after spray at vegetative phase during 2017 early farming season

Key: CYP-Cypermethrin 10EC, AEO- Stool wood *Alstonia boonei.* oil, HEO- Bush tea *Hyptis suaveolens* oil, JAHEO- Mixed plant oils from Jathropha, Bush tea and Stool wood, JEO- *Jathropha tanjorensis* oil



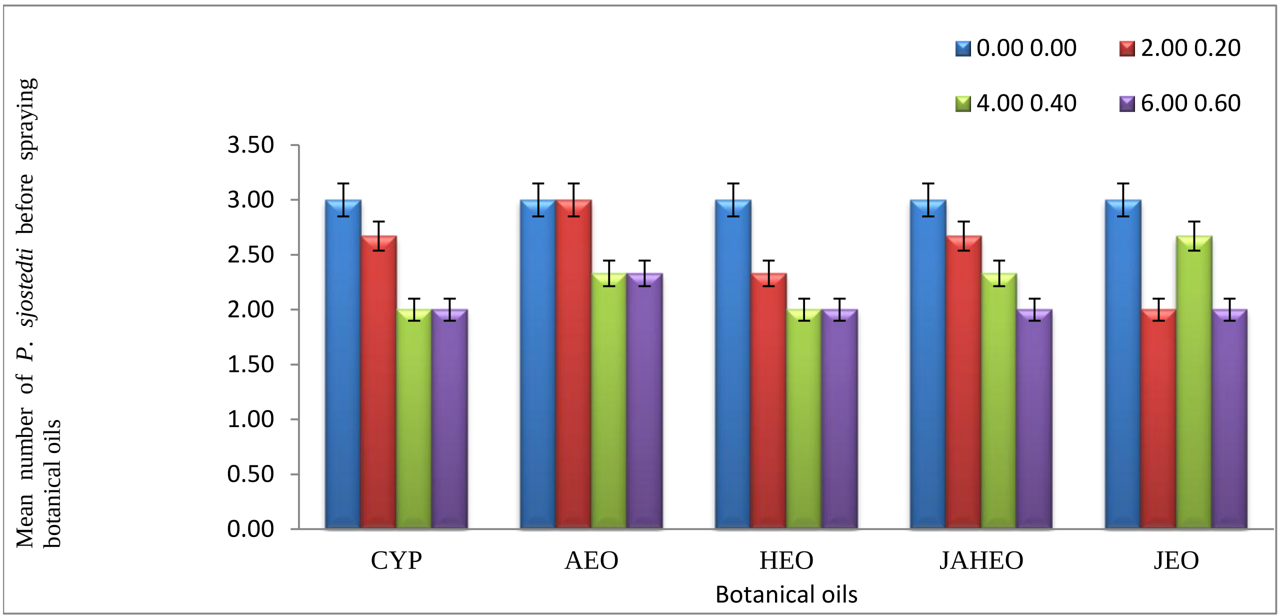
(a) Before spray at vegetative phase during late 2017.



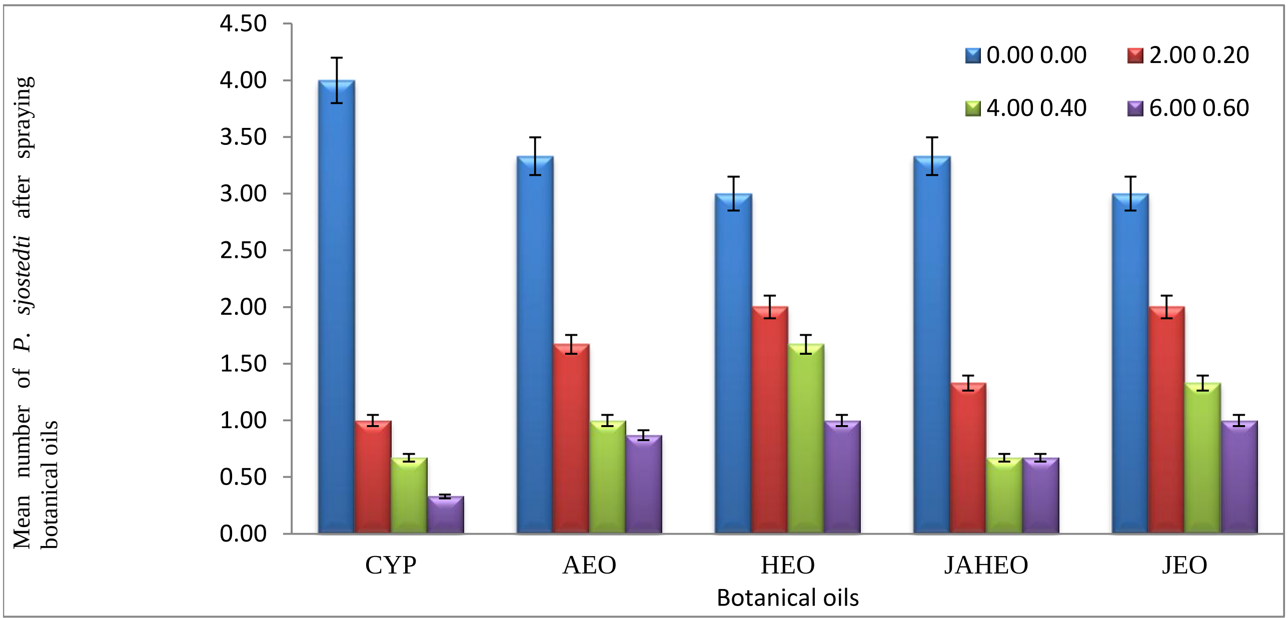
(b) After spray at vegetative phase during late 2017

FIG 28; Comparison of number of *P. sjostedti* on bambara groundnutbefore and after spray at vegetative phase during 2017 late farming season

Key: CYP-Cypermethrin 10EC, AEO- Stool wood *Alstonia boonei.* oil, HEO- Bush tea *Hyptis suaveolens* oil, JAHEO- Mixed plant oils from Jathropha, Bush tea and Stool wood, JEO- *Jathropha tanjorensis* oil



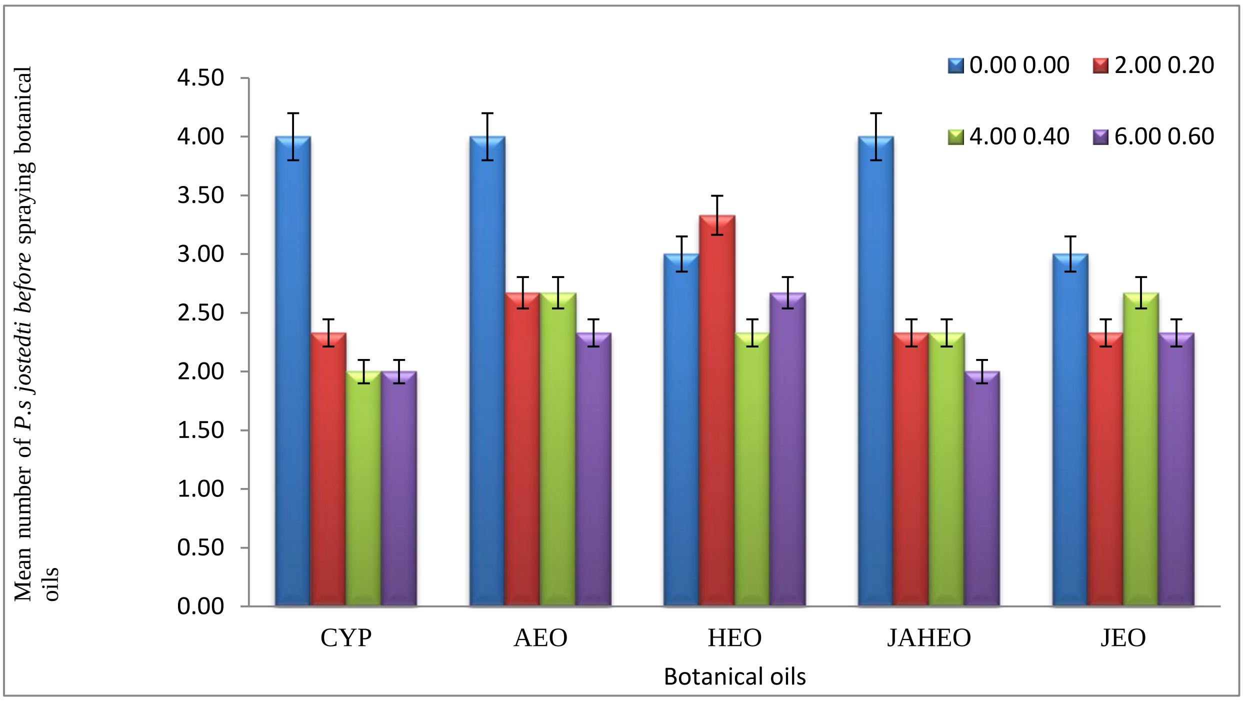
(a) Before spray at flowering phase during early 2016.



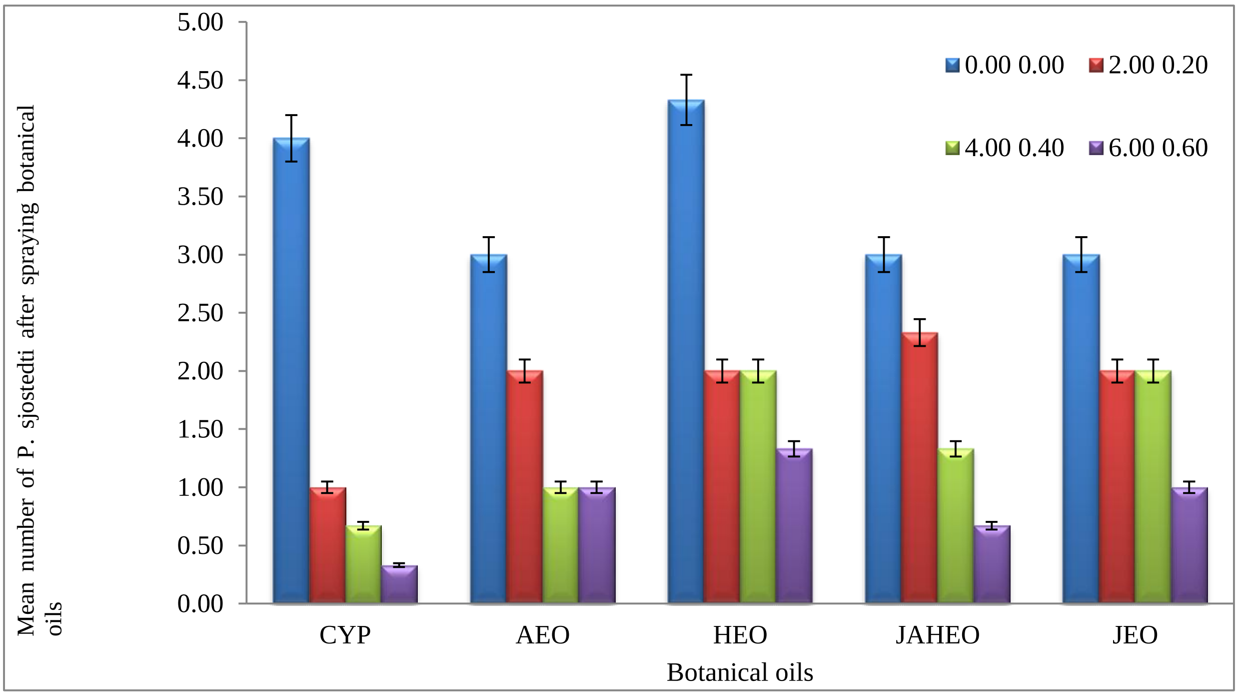
(b) After spray at flowering phase during early 2016

FIG 29; Comparison of number of *P. sjostedti* on bambara groundnut before and after spray at flowering phase in 2016 early farming season

Key: CYP-Cypermethrin 10EC, AEO- Stool wood *Alstonia boonei*. oil, HEO- Bush tea *Hyptis suaveolens* oil, JAHEO- Mixed plant oils from Jathropha, Bush tea and Stool wood, JEO- *Jathropha tanjorensis* oil



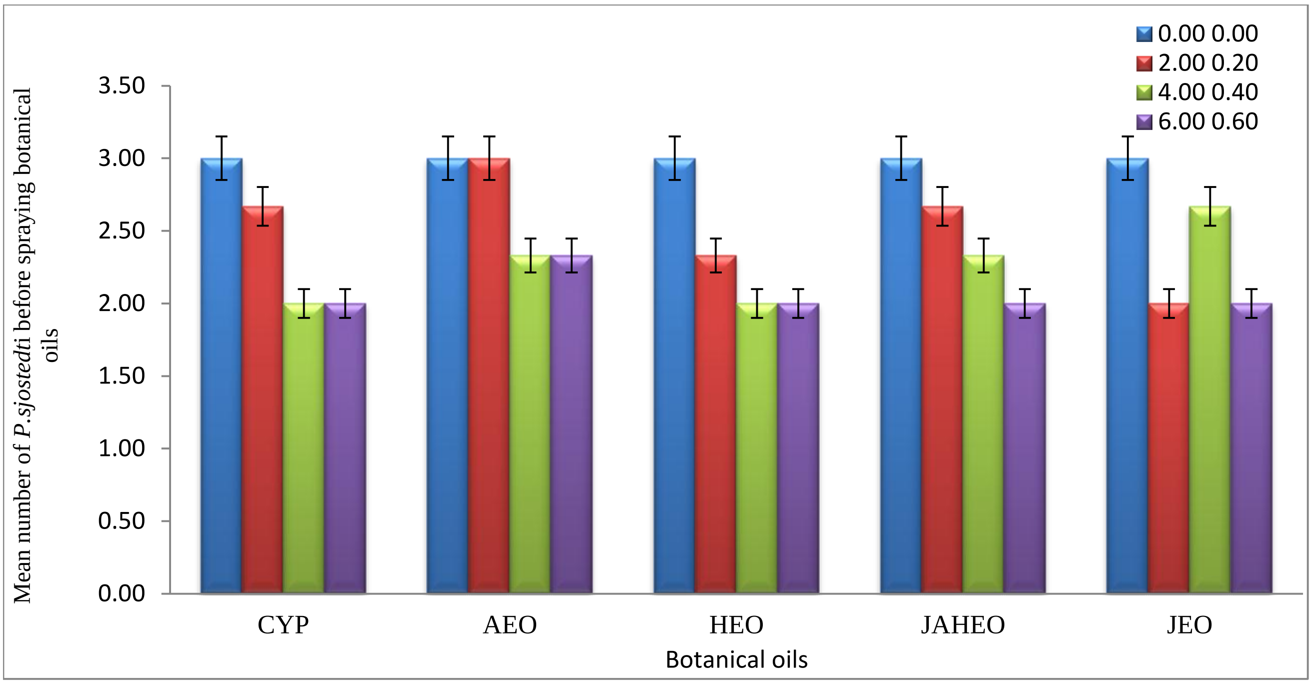
(a) Before spray at flowering phase during late 2016.



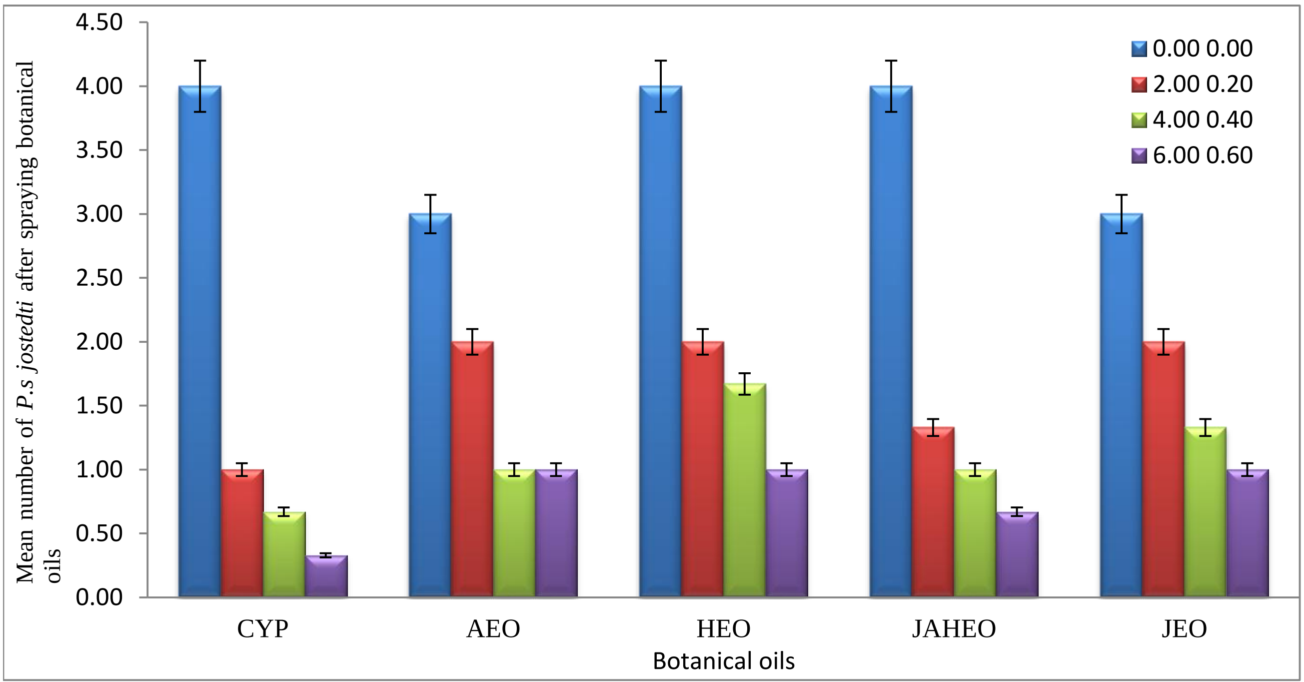
(b) After spray at flowering phase during late 2016

FIG 30; Comparison of number of *P.sjostedti* on bambara groundnut before and after spray at flowering phase during 2016 late farming season

Key: CYP-Cypermethrin 10EC, AEO- Stool wood *Alstonia boonei*. oil, HEO- Bush tea *Hyptis suaveolens* oil, JAHEO- Mixed plant oils from Jathropha, Bush tea and Stool wood, JEO- *Jathropha tanjorensis* oil



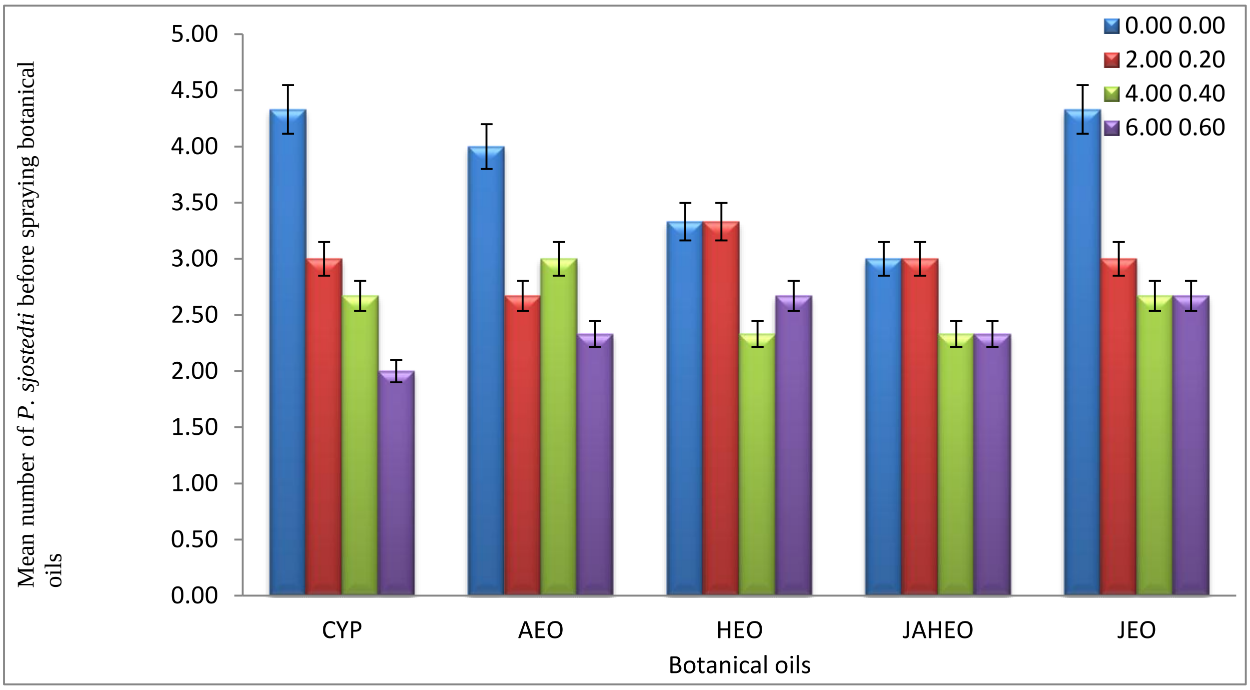
(a) Before spray at flowering phase during early 2017.



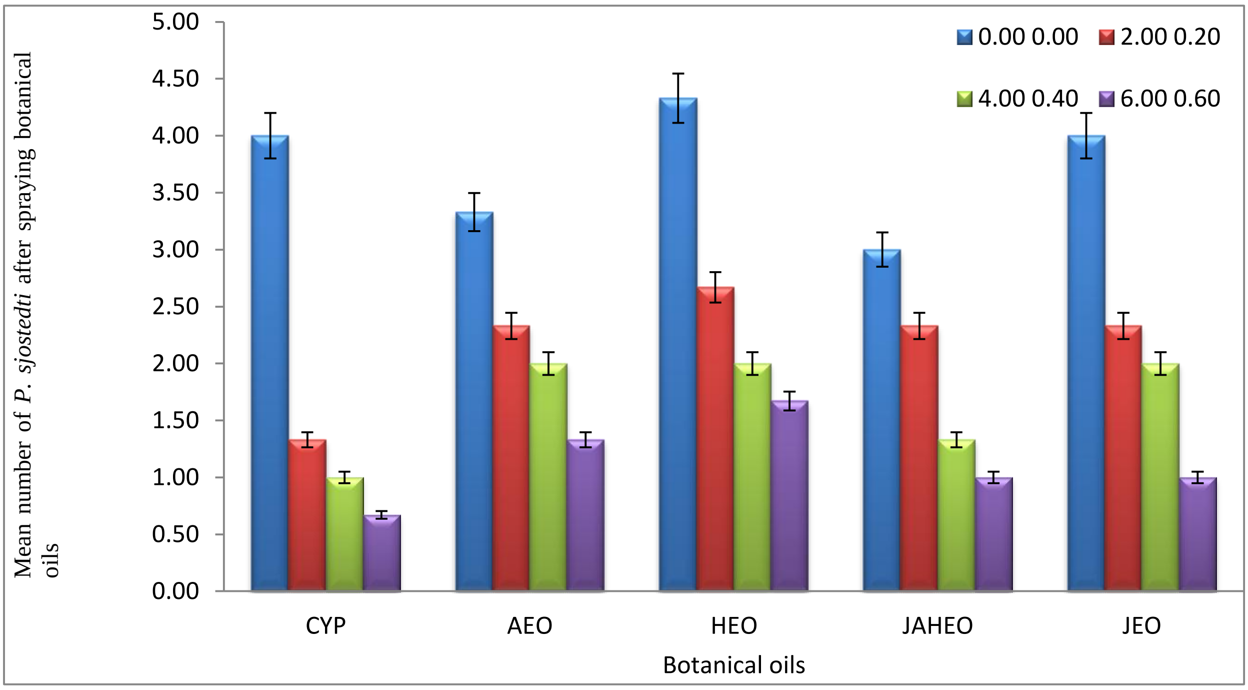
(b) After spray at flowering phase during early 2017

FIG31; Comparison of number of *P. sjostedti* on bambara groundnut before and after spray at flowering phase during 2017 early farming season

Key: CYP-Cypermethrin 10EC, AEO- Stool wood *Alstonia boonei.* oil, HEO- Bush tea *Hyptis suaveolens* oil, JAHEO- Mixed plant oils from Jathropha, Bush tea and Stool wood, JEO- *Jathropha tanjorensis* oil



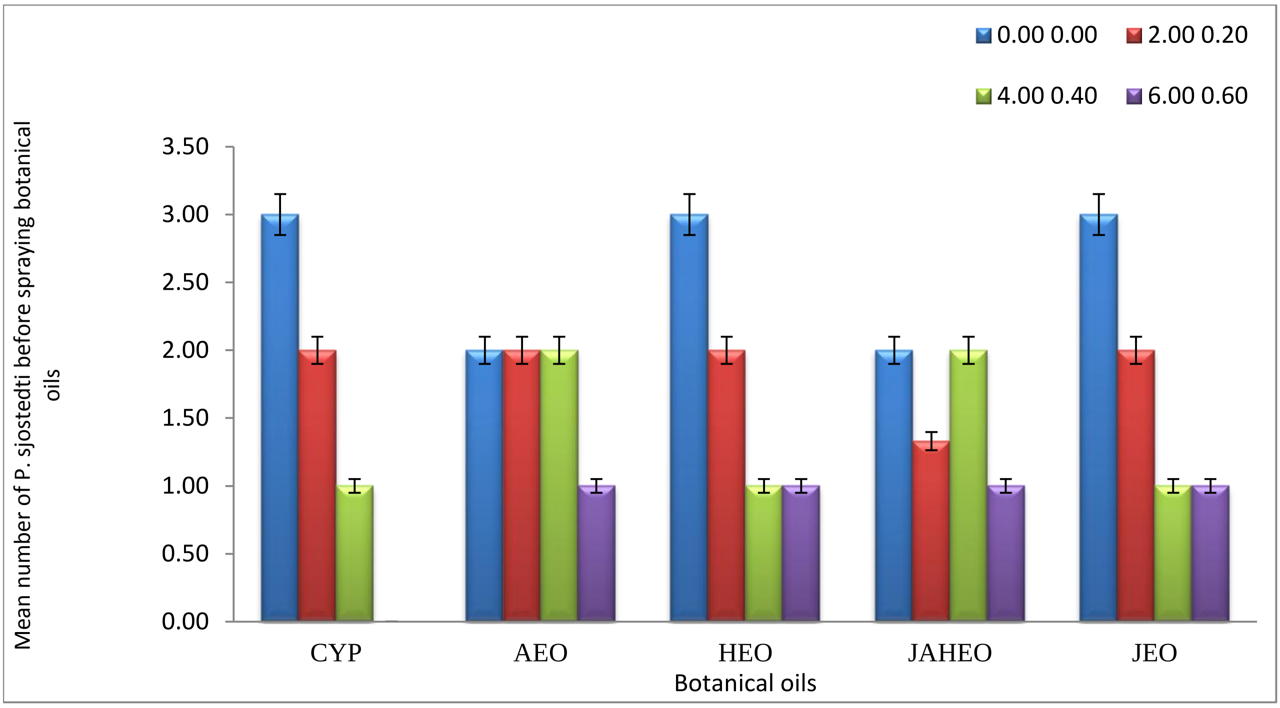
(a) Before spray at flowering phase during late 2017.



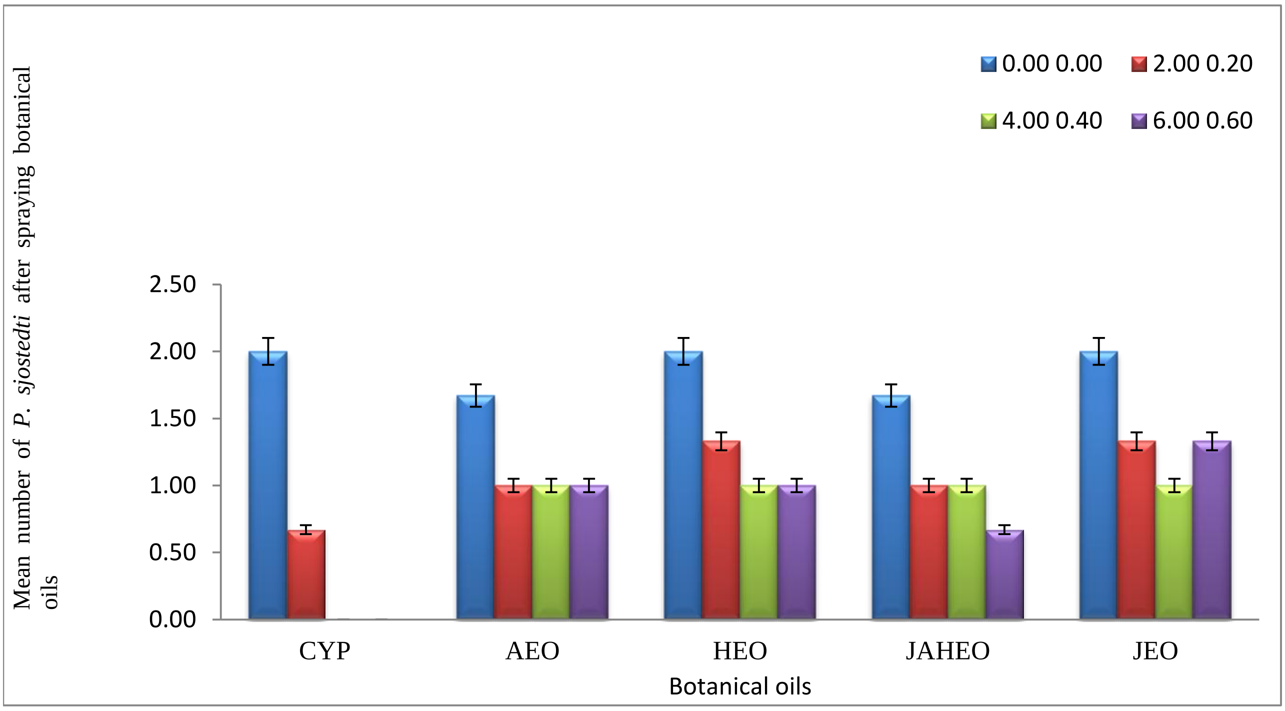
(b) After spray at flowering phase during late 2017

FIG 32 Comparison of number of *P. sjostedti* on bambara groundnut before and after spray at flowering phase during 2017 late farming season

Key: CYP-Cypermethrin 10EC, AEO- Stool wood *Alstonia boonei.* oil, HEO- Bush tea *Hyptis suaveolens* oil, JAHEO- Mixed plant oils from Jathropha, Bush tea and Stool wood, JEO- *Jathropha tanjorensis* oil



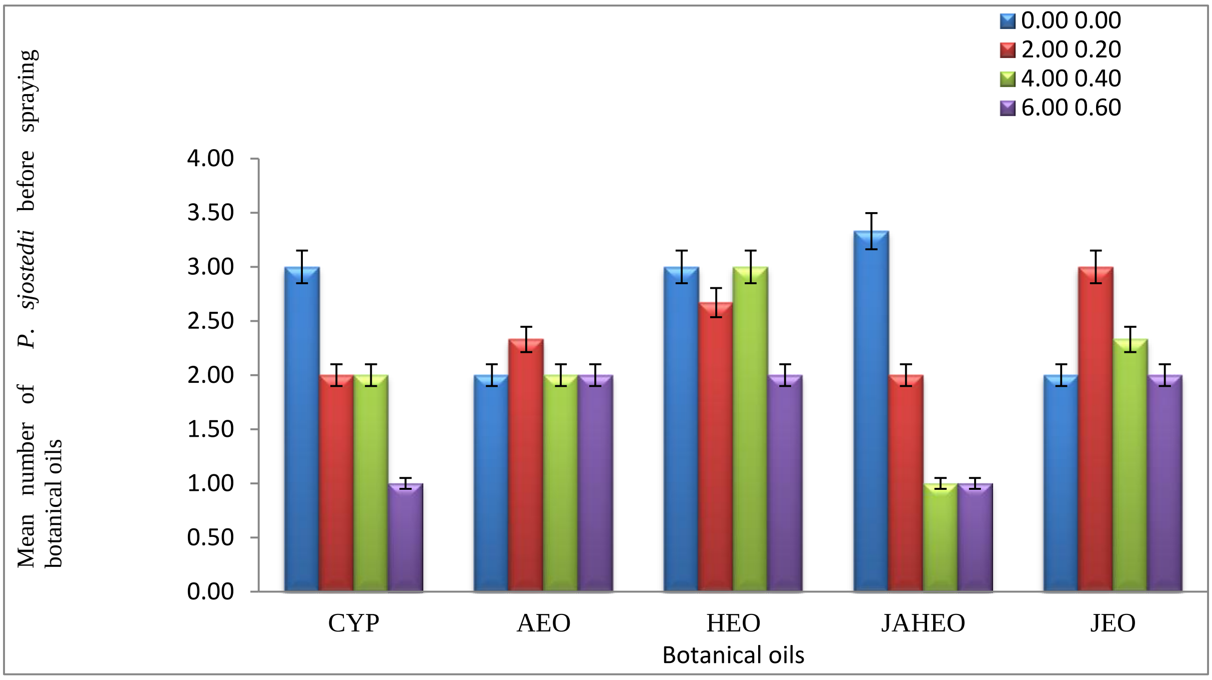
(a) Before spray at flowering phase during early 2016.



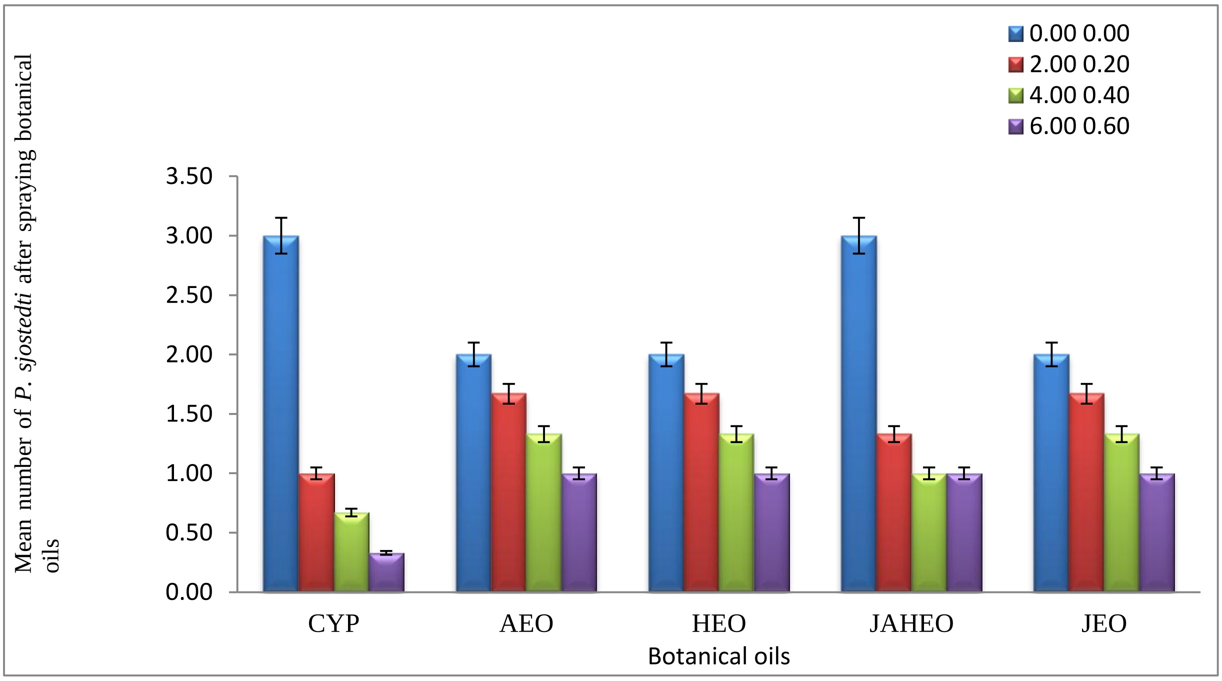
(b) After spray at flowering phase during early 2016

FIG 33; Comparison of number of *P.sjostedti* on bambara groundnut before and after spray at podding phase during 2016 early farming season

Key: CYP-Cypermethrin 10EC, AEO- Stool wood *Alstonia boonei.* oil, HEO- Bush tea *Hyptis suaveolens* oil, JAHEO- Mixed plant oils from Jathropha, Bush tea and Stool wood, JEO- *Jathropha tanjorensis* oil**.**



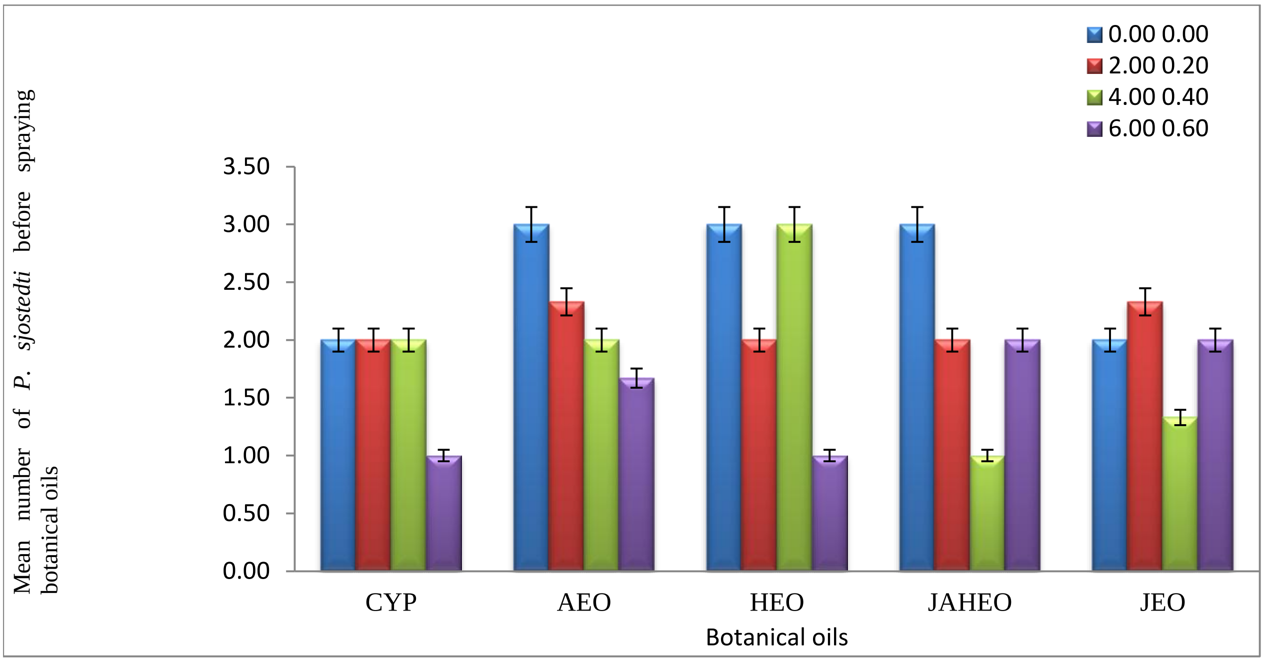
(a) Before spray at podding phase during late 2016.



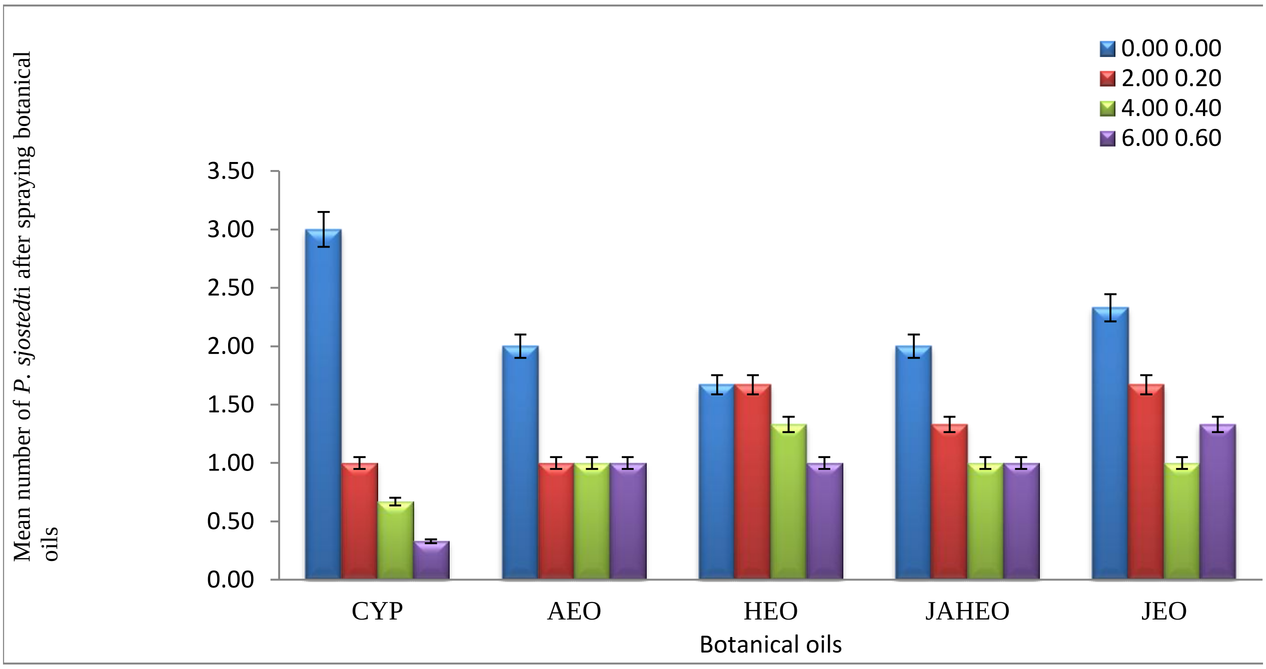
(b) After spray at podding phase during late 2016

FIG 34; Comparison of number of *P.sjostedti* on bambara groundnut after spray at podding phase in 2016 early farming season

Key: CYP-Cypermethrin 10EC, AEO- Stool wood *Alstonia boonei.* oil, HEO- Bush tea *Hyptis suaveolens* oil, JAHEO- Mixed plant oils from Jathropha, Bush tea and Stool wood, JEO- *Jathropha tanjorensis* oil



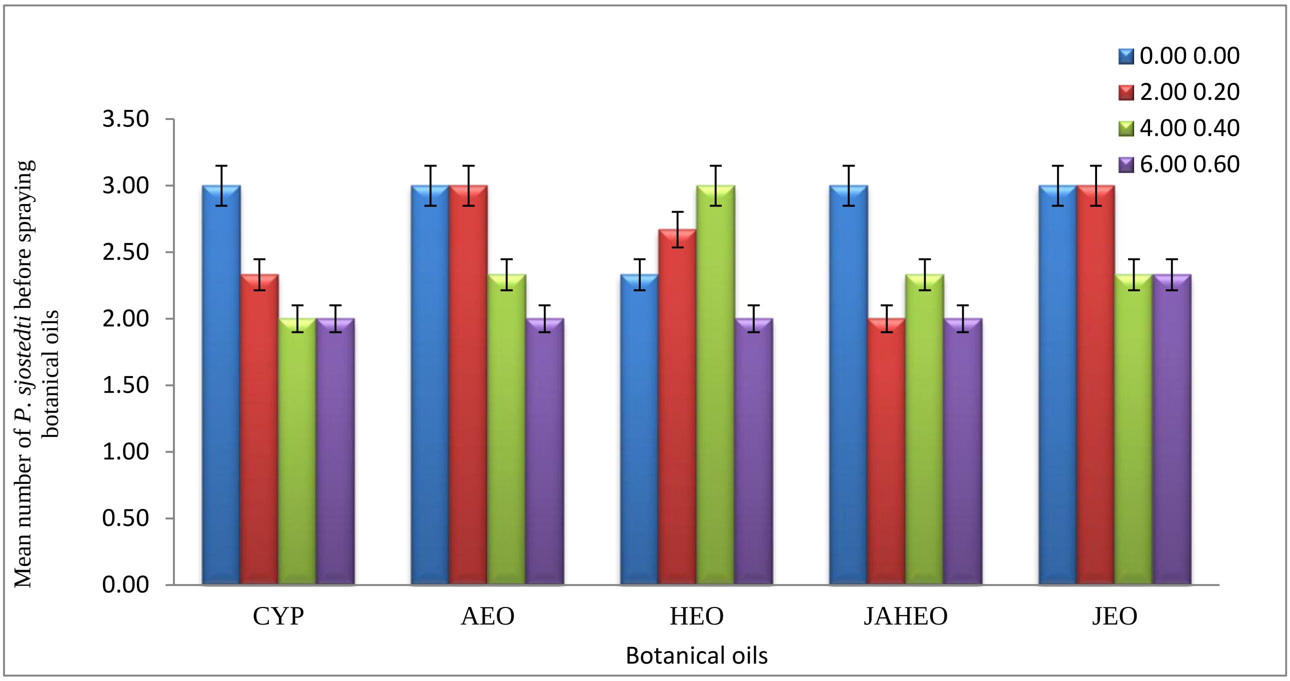
(a) Before spray at podding phase during early 2017.



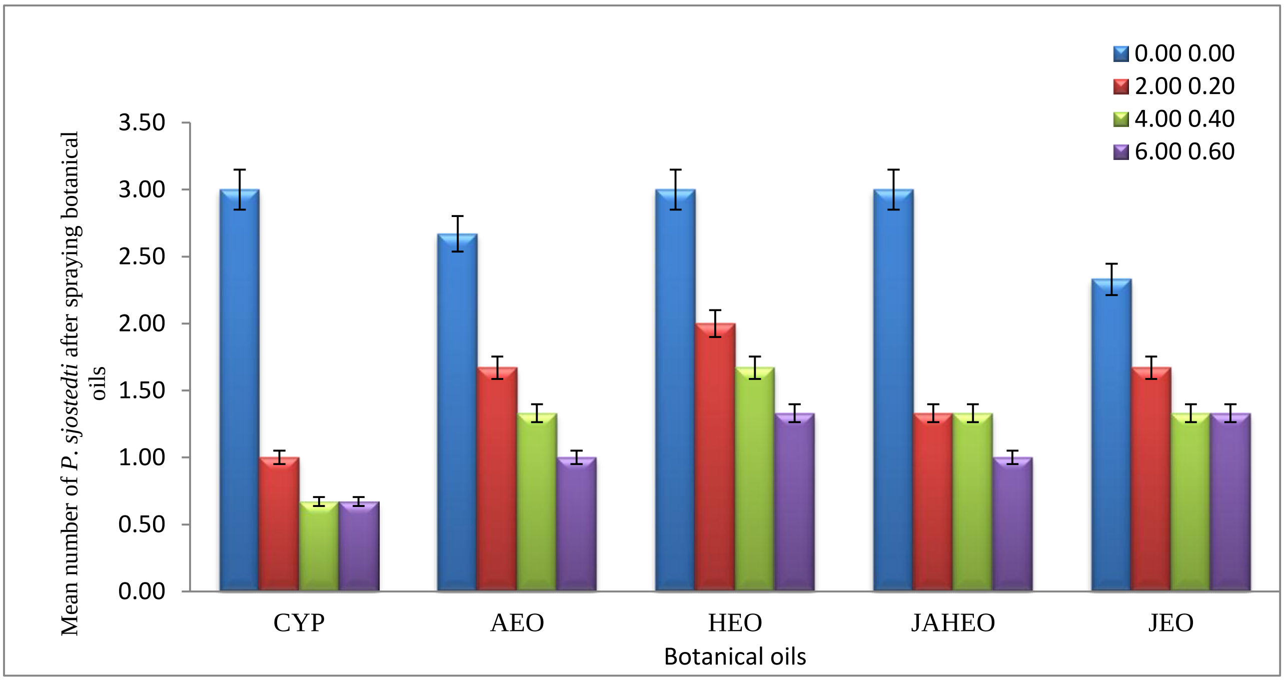
(b) After spray at podding phase during early 2017

FIG 35; Comparison of number of *P.sjostedti* on bambara groundnut before and after spray at podding phase in 2017 early farming season

Key: CYP-Cypermethrin 10EC, AEO- Stool wood *Alstonia boonei.* oil, HEO- Bush tea *Hyptis suaveolens* oil, JAHEO- Mixed plant oils from Jathropha, Bush tea and Stool wood, JEO- *Jathropha tanjorensis* oil



(a) Before spray at podding phase during late 2017.



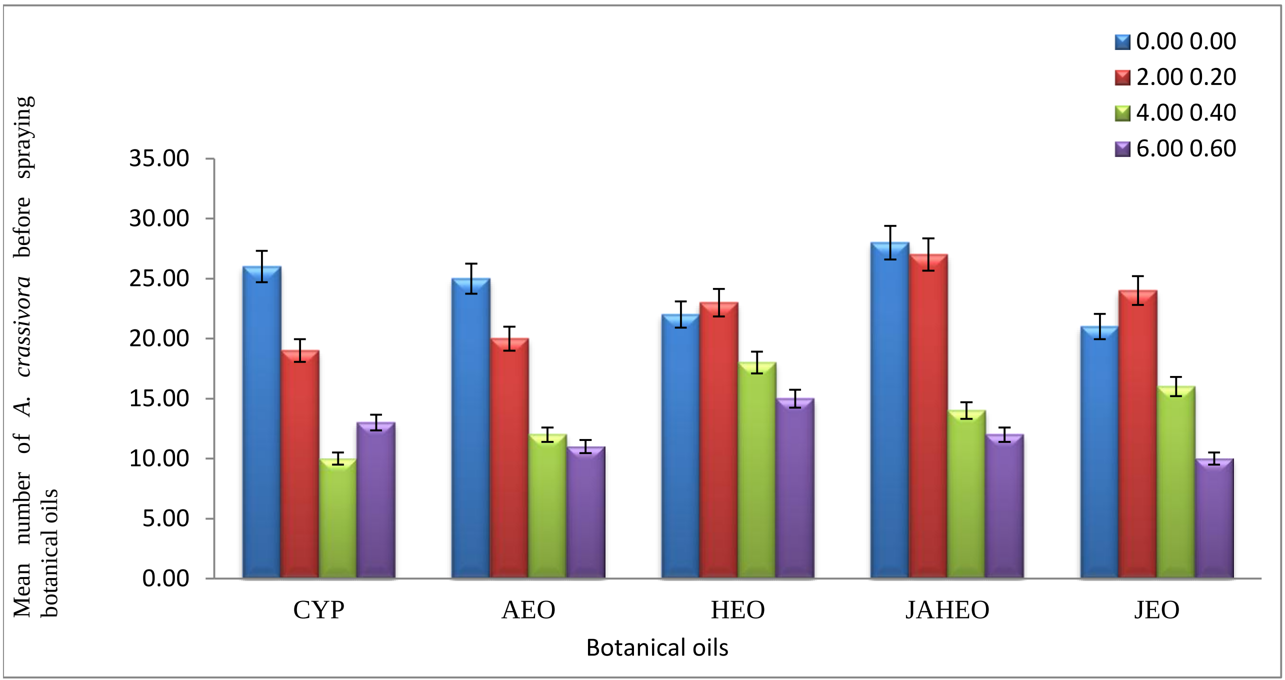
(b) After spray at podding phase during late 2017

FIG 36; Comparison of number of *P.sjostedti* on bambara groundnut before and after spray at podding phase in 2017 late farming season

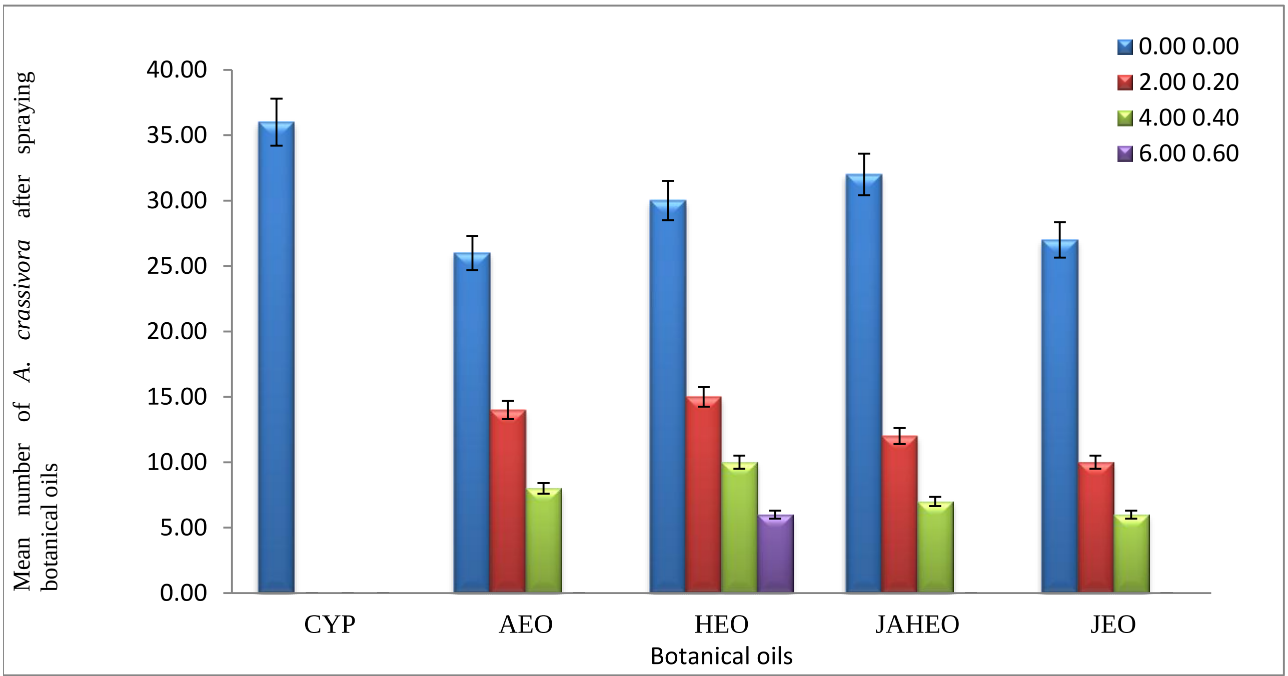
Key: CYP-Cypermethrin 10EC, AEO- Stool wood *Alstonia boonei.* oil, HEO- Bush tea *Hyptis suaveolens* oil, JAHEO- Mixed plant oils from Jathropha, Bush tea and Stool wood, JEO- *Jathropha tanjorensis* oil

4.8 Effects of botanical oils on Aphids (*Aphis crassivora*) at vegetative, flowering and podding phase in 2016 and 2017 late farming season

The results in Figures 37 to 42 showed that *Aphis crassivora* were present at vegetative, flowering and podding Phase in 2016 and 2017 late season. The plots sprayed with Cypermethrin (CYP) recorded the least mean number of *A. crassivora* at vegetative, flowering and podding phase in 2016 and 2017 late farming seasons. This was followed by plots sprayed with mixed plant oils (JAHEO) while plots sprayed with *Alstonia boonei* oil (AEO) recorded lower mean number of *A. crassivora* than Jathropha oil (JEO) and *Hyptis suaveolens* oil (HEO) that mostly recorded the highest mean number of *A. crassivora* at vegetative, flowering and podding in 2016 and 2017 late season. Effects of application rate of botanical oils on *A. crassivora* were dose dependent. The highest application rates (6.00/0,60ml) recorded the least number of *A. crassivora*, this was followed by the medium rates (4.00/0.40ml) and least application rates (2.00/0.20) respectively, while the control rates (0.00/0.00) recorded the highest mean number of *A. crassivora* in 2016 and 2017 late seasons. Least mean number of Aphids were recorded in at the podding phase followed the vegetative phase, while the flowering phase recorded the highest mean number of *A. crassivora* in 2016 and 2017 late seasons. Although mean number of *A. crassivora* were higher before spray but significantly reduced immediately after spray while there were no reduction but significant increase in number of *A. crassivora* in the control plots at vegetative, flowering and podding phase in 2016 and 2017 late seasons.



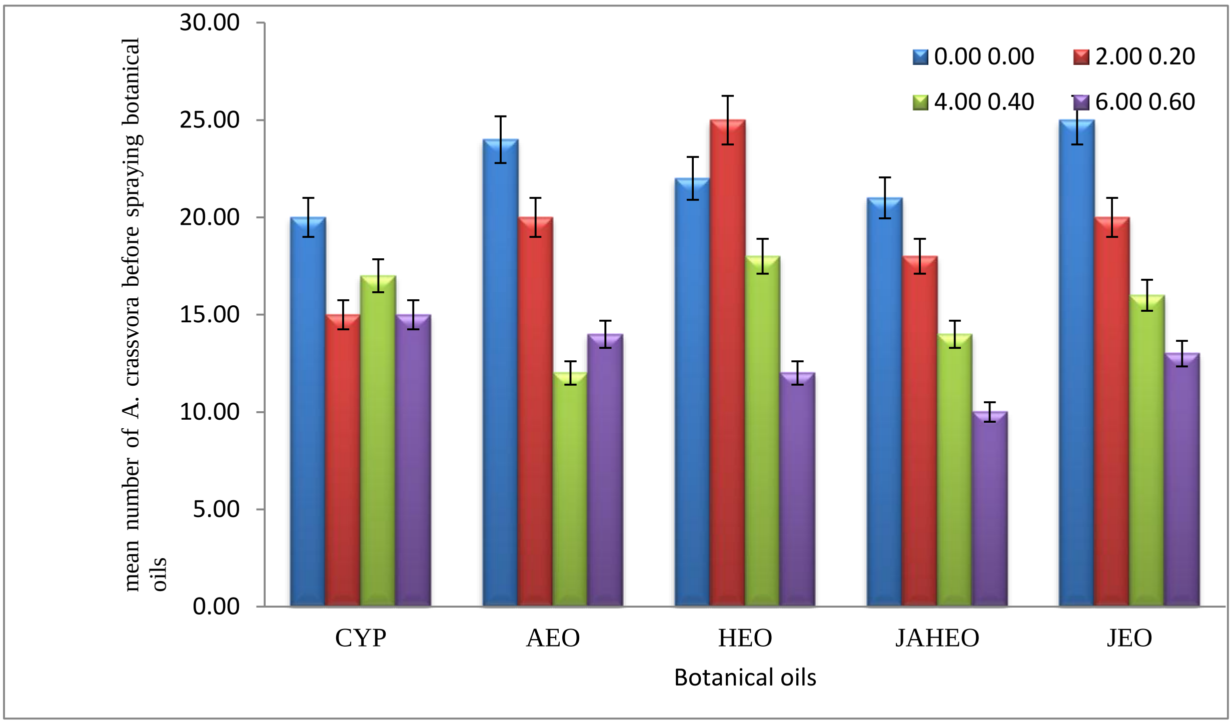
(a) Before spray at vegetative phase during late 2016.



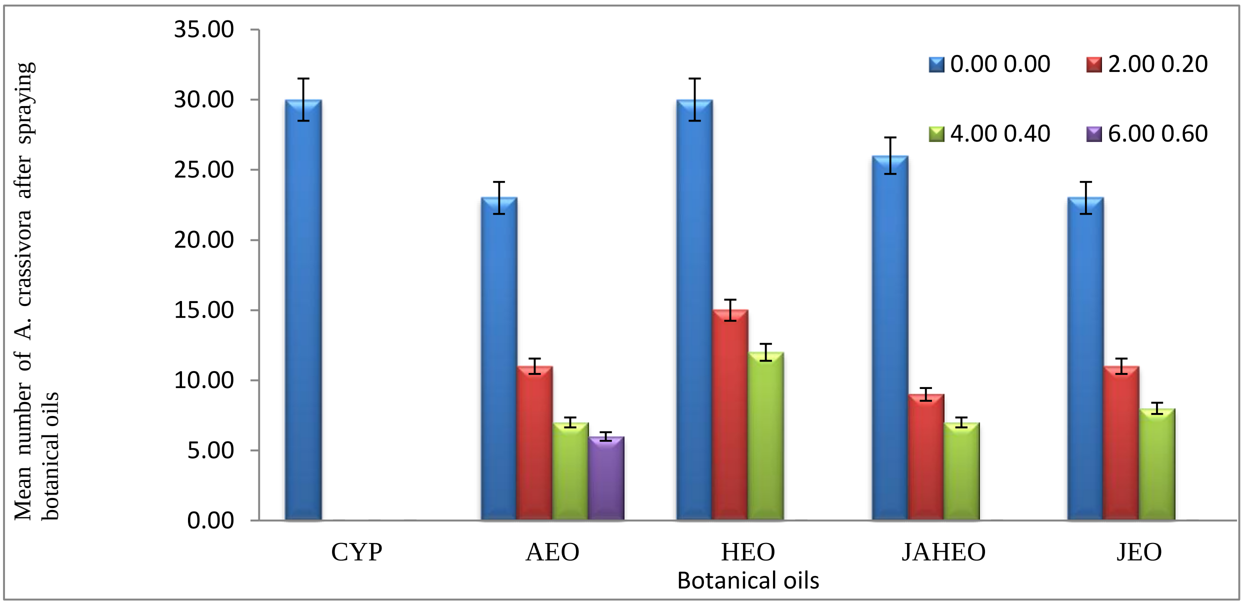
(b) After spray at vegetative phase during late 2016

FIG 37; Comparison of number of Aphids (*Aphis crassivora*) on Bambara groundnut before and after spray at vegetative phase in 2016 late farming season

Key: CYP-Cypermethrin 10EC, AEO- Stool wood *Alstonia boonei*. oil, HEO- Bush tea *Hyptis suaveolens* oil, JAHEO- Mixed plant oils from Jathropha, Bush tea and Stool wood, JEO- *Jathropha tanjorensis* oil



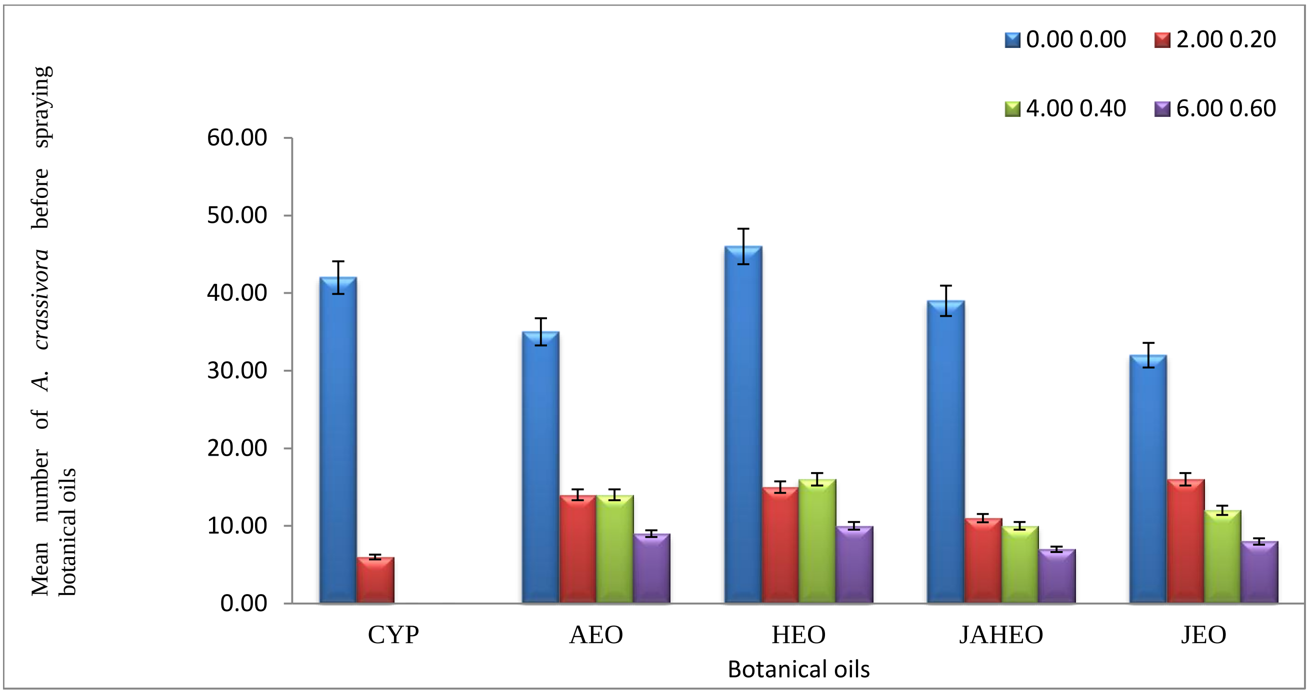
(a) Before spray at vegetative phase during late 2017.



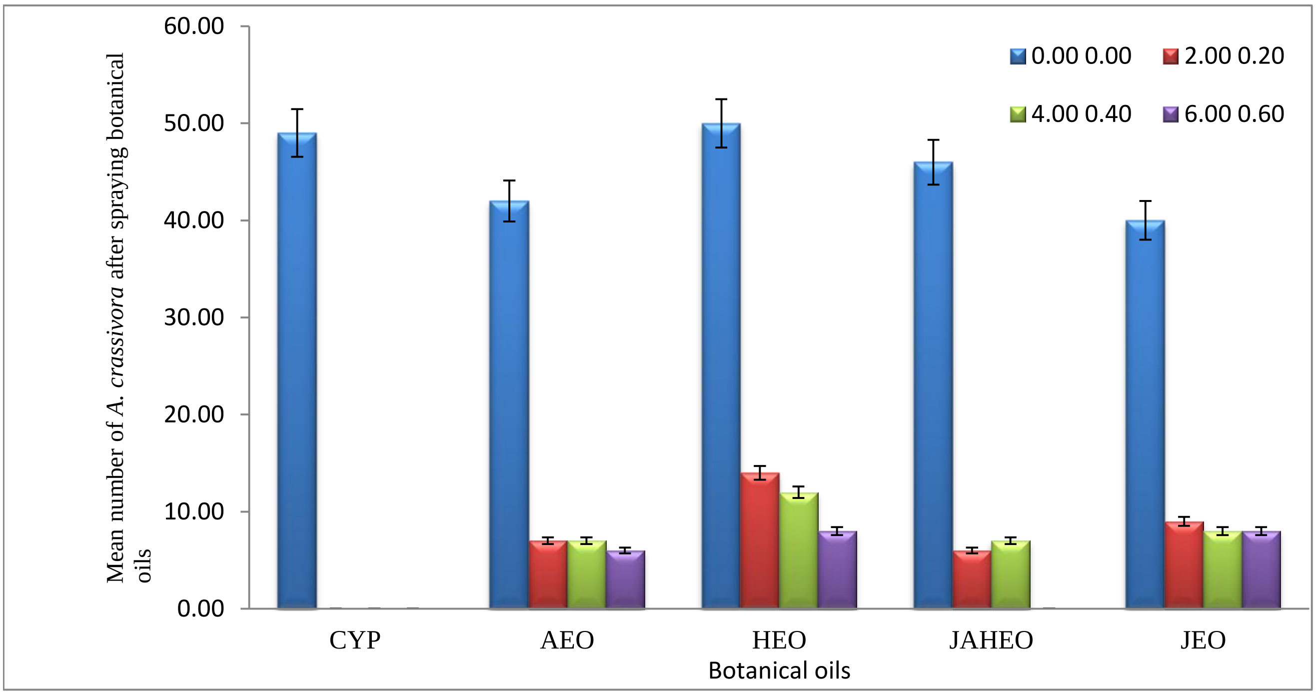
(b) After spray at vegetative phase during late 2017

FIG 38; Comparison of number of *A. crassivora* on Bambara groundnut before and after spray at vegetative phase in 2017 late farming season

Key: CYP-Cypermethrin 10EC, AEO- Stool wood *Alstonia boonei.* oil, HEO- Bush tea *Hyptis suaveolens* oil, JAHEO- Mixed plant oils from Jathropha, Bush tea and Stool wood, JEO- *Jathropha tanjorensis* oil



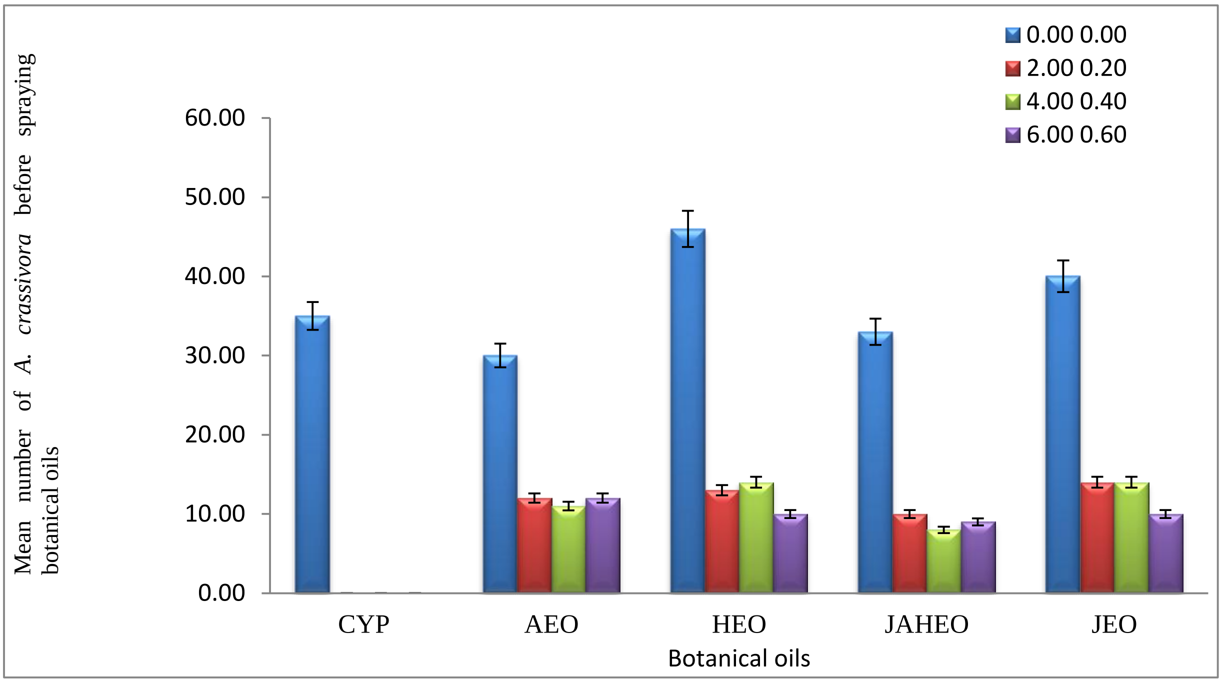
(a) Before spray at flowering phase during late 2016.



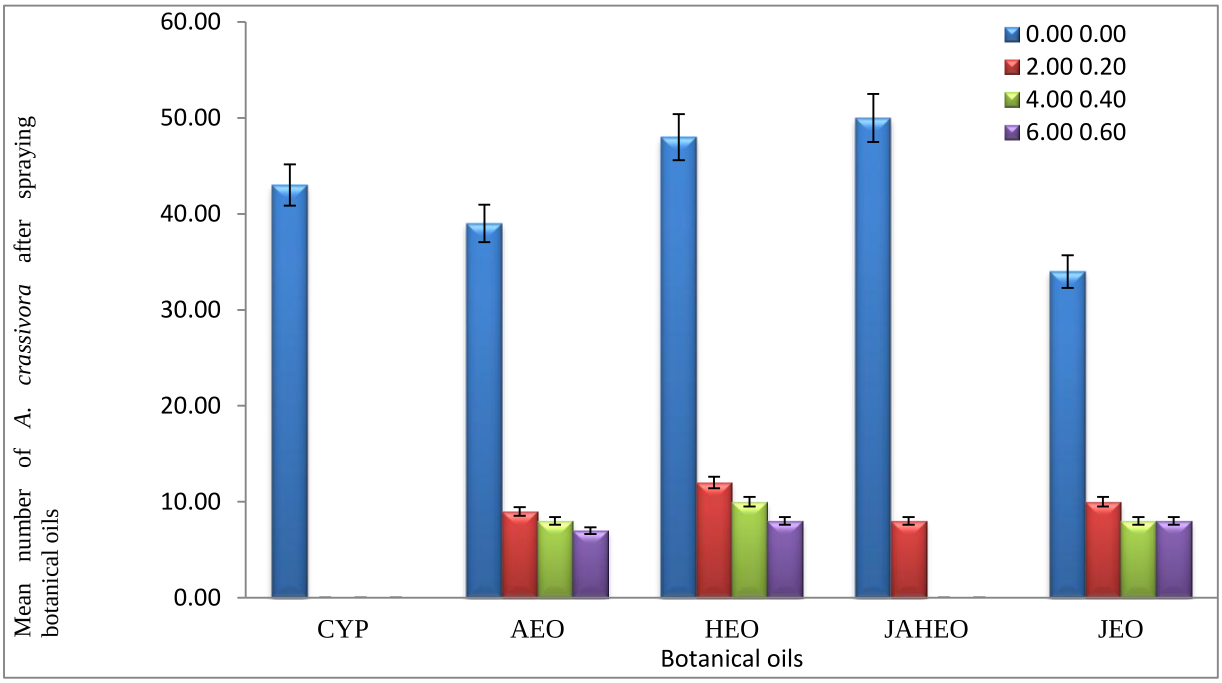
(b) After spray at flowering phase during late 2016

FIG 39; Comparison of number of *A. crassivora* on bambara groundnut before and after spray at flowering phase in 2016 late farming season

Key: CYP-Cypermethrin 10EC, AEO- Stool wood *Alstonia boonei*. oil, HEO- Bush tea *Hyptis suaveolens* oil, JAHEO- Mixed plant oils from Jathropha, Bush tea and Stool wood, JEO- *Jathropha tanjorensis* oil



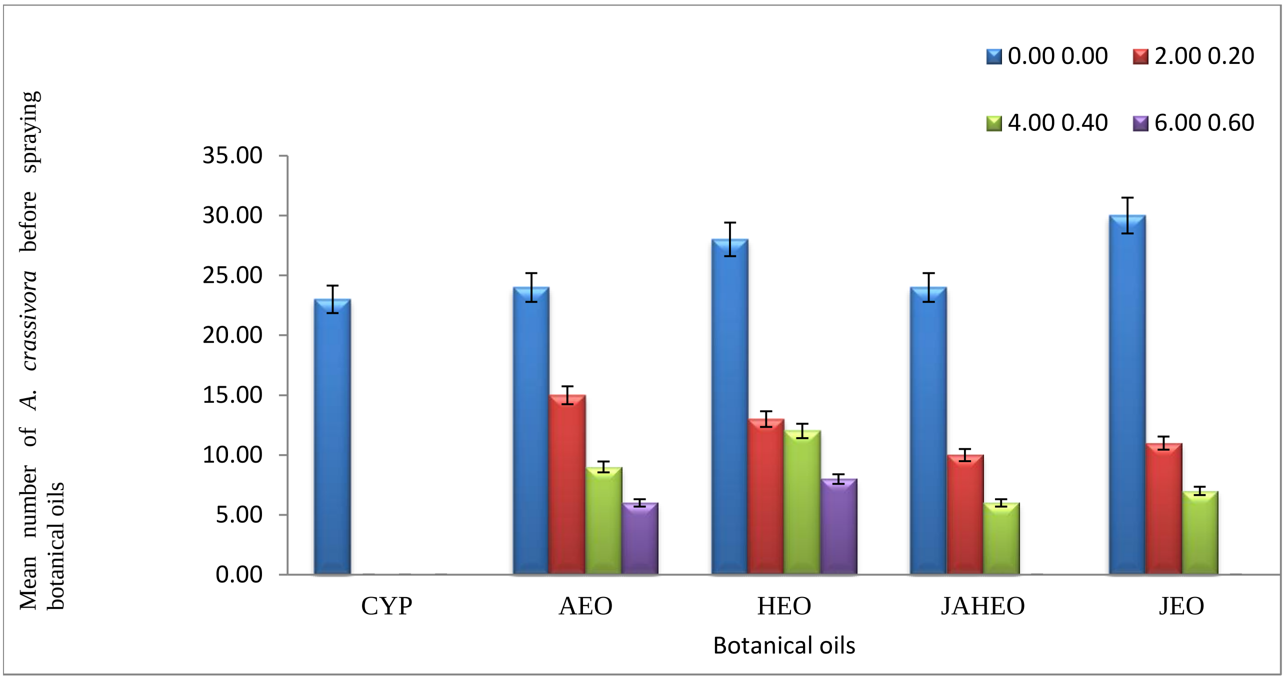
(a) Before spray at flowering phase during late 2017.



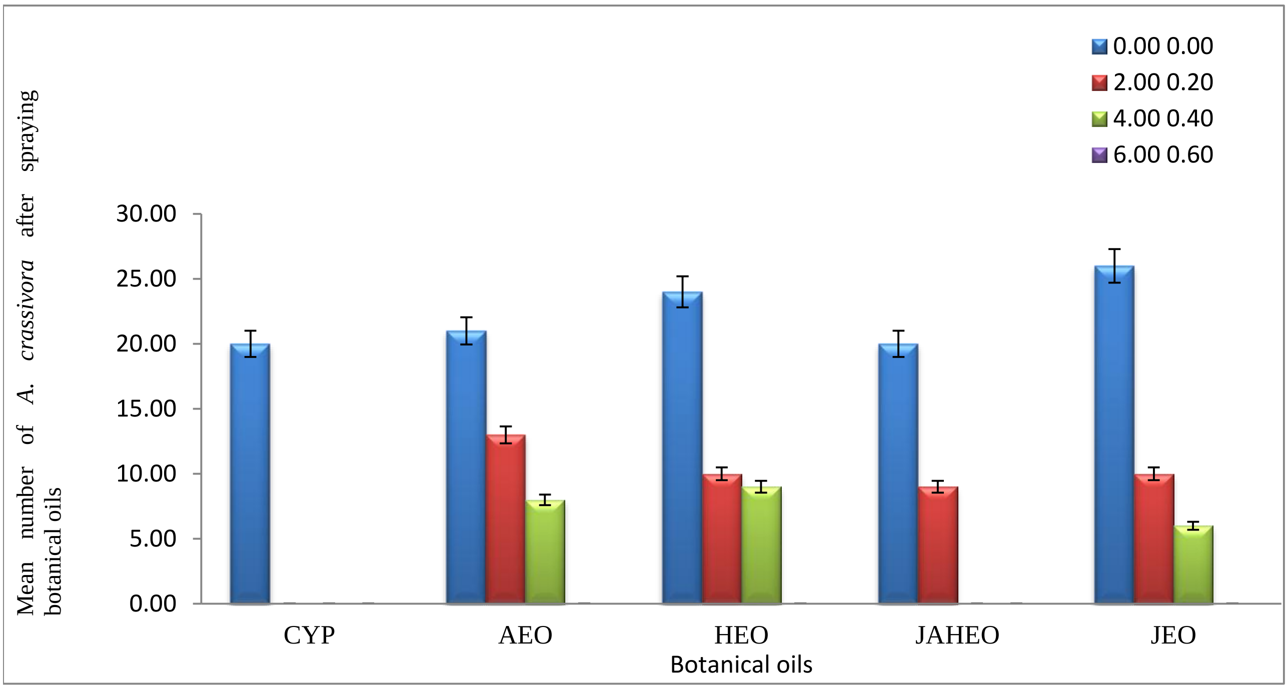
(b) After spray at flowering phase during late 2017

FIG 40; Comparison of number of *A. crassivora* on bambara groundnut before and after spray at flowering phase in 2017 late farming season

Key: CYP-Cypermethrin 10EC, AEO- Stool wood *Alstonia boonei.* oil, HEO- Bush tea *Hyptis suaveolens* oil, JAHEO- Mixed plant oils from Jathropha, Bush tea and Stool wood, JEO- *Jathropha tanjorensis* oil



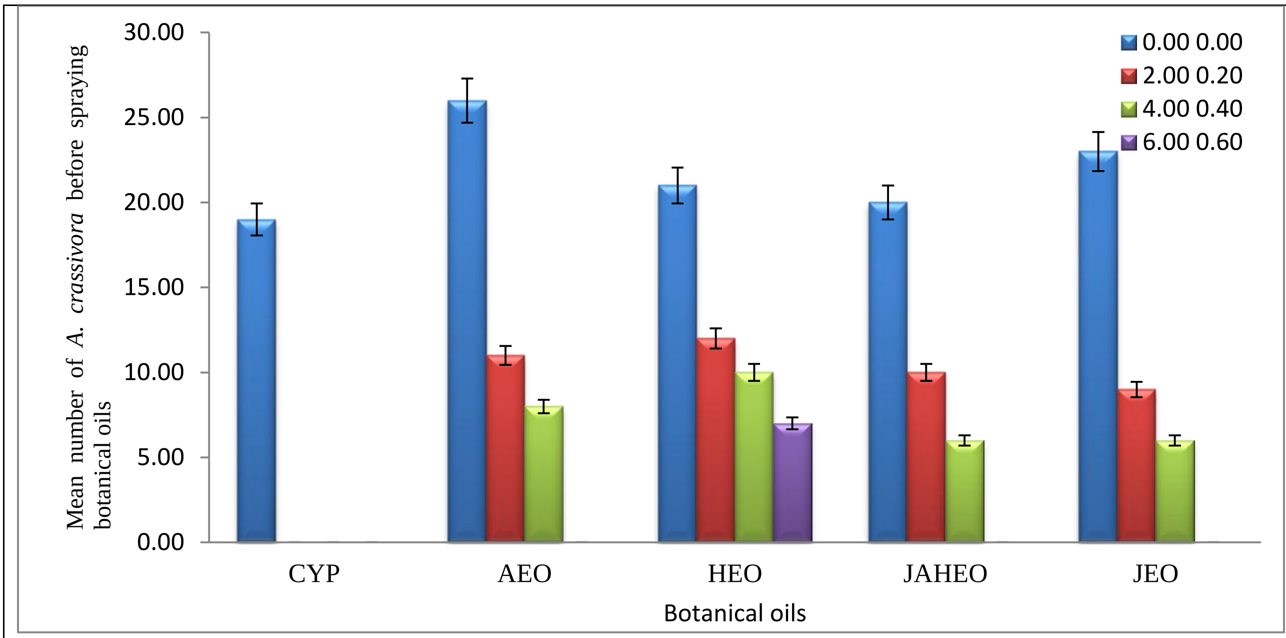
(a) Before spray at podding phase during late 2016.



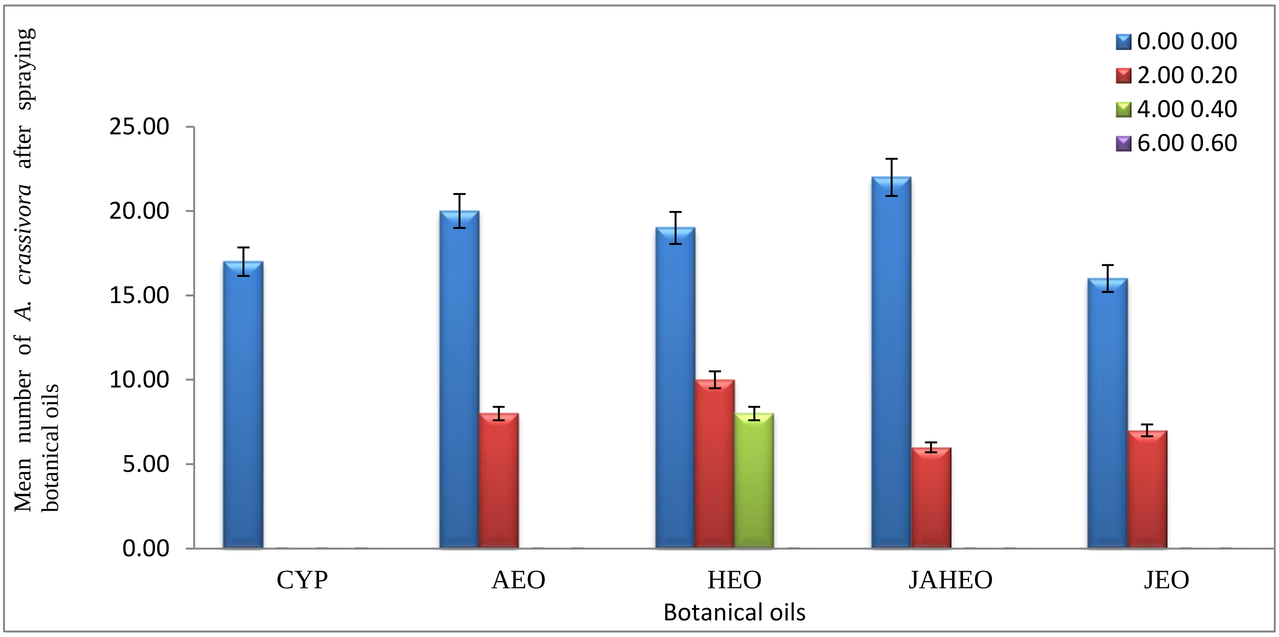
(b) After spray at podding phase during late 2016

FIG 41; Comparison of number of *A. crassivora* on bambara groundnut before and after spray at podding phase in 2016 late farming season

Key: CYP-Cypermethrin 10EC, AEO- Stool wood *Alstonia boonei.* oil, HEO- Bush tea *Hyptis suaveolens* oil, JAHEO- Mixed plant oils from Jathropha, Bush tea and Stool wood, JEO- *Jathropha tanjorensis* oil



(a) Before spray at podding phase during late 2017.



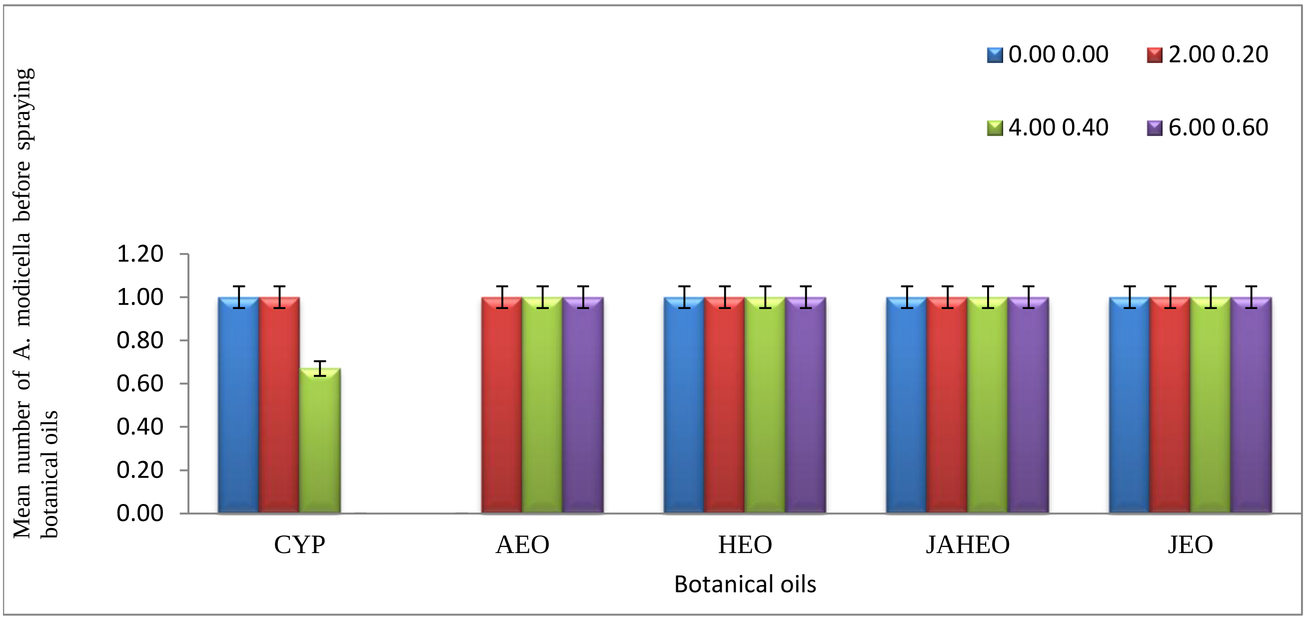
(b) After spray at podding phase during late 2017

FIG 42; Comparison of number of *A. crassivora* on bambara groundnut before and after spray at Podding Phase in 2017 late farming season

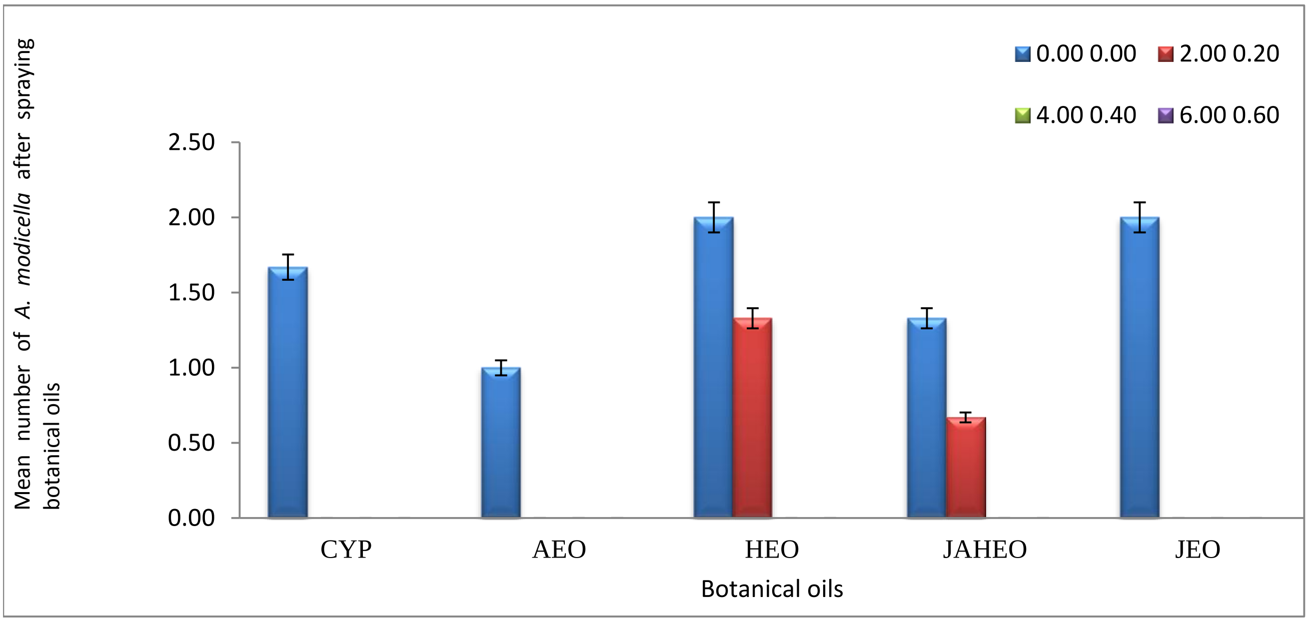
Key: CYP-Cypermethrin 10EC, AEO- Stool wood *Alstonia boonei.* oil, HEO- Bush tea *Hyptis suaveolens* oil, JAHEO- Mixed plant oils from Jathropha, Bush tea and Stool wood, JEO- *Jathropha tanjorensis* oil

4.9 Effects of botanical oils on Leaf miner (*Aproarema modicella*) at vegetative, flowering and podding phase in 2017 early farming season

The results in Figures 43 to 45 showed that Leaf miner were present at vegetative, flowering and podding phase in 2017 early season. The plots sprayed with Cypermethrin (CYP) recorded the least mean number of leaf miner at vegetative, flowering and podding phase 2017 early farming seasons. This was followed by plots sprayed with mixed plant oils (JAHEO) while plots sprayed with *Alstonia boonei* oil (AEO) recorded lower mean number of leaf miner than Jathropha oil (JEO) and *Hyptis suaveolens* oil (HEO) that mostly recorded the highest mean number of leaf miner at vegetative, flowering and podding 2017 early season. Effects of application rate of botanical oils on leaf miner were dose related. The highest application rates (6.00/0,60ml) recorded the least number of leaf miner, this was followed by the medium rates (4.00/0.40ml) and least application rates (2.00/0.20) respectively, while the control rates (0.00/0.00) recorded the highest mean number of leaf miner in 2017 early seasons. Least mean number of leaf miner was recorded in at the podding phase followed the vegetative phase, while the Flowering phase recorded the highest mean number of leaf miner in 2017 early seasons. Although mean number of leaf miner were higher before spray but significantly reduced immediately after spray while there were no reduction but significant increase in number of leaf miner in the control plots at vegetative, flowering gradually declined at the podding phase in 2017 early seasons.



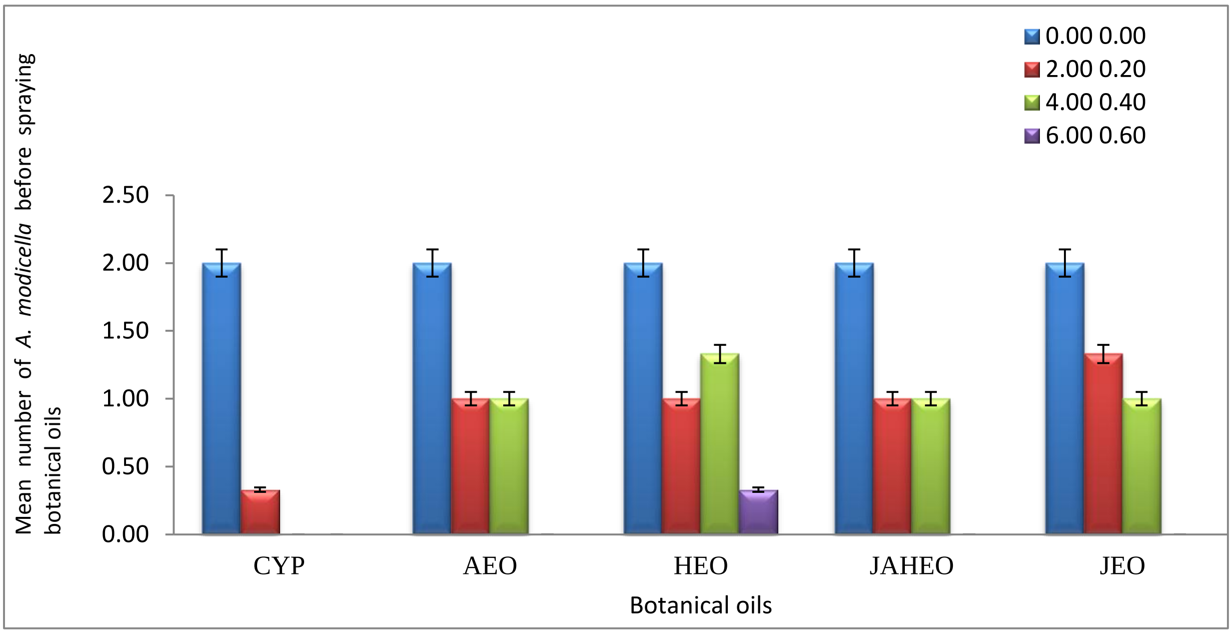
(a) Before spray at vegetative phase during early 2017.



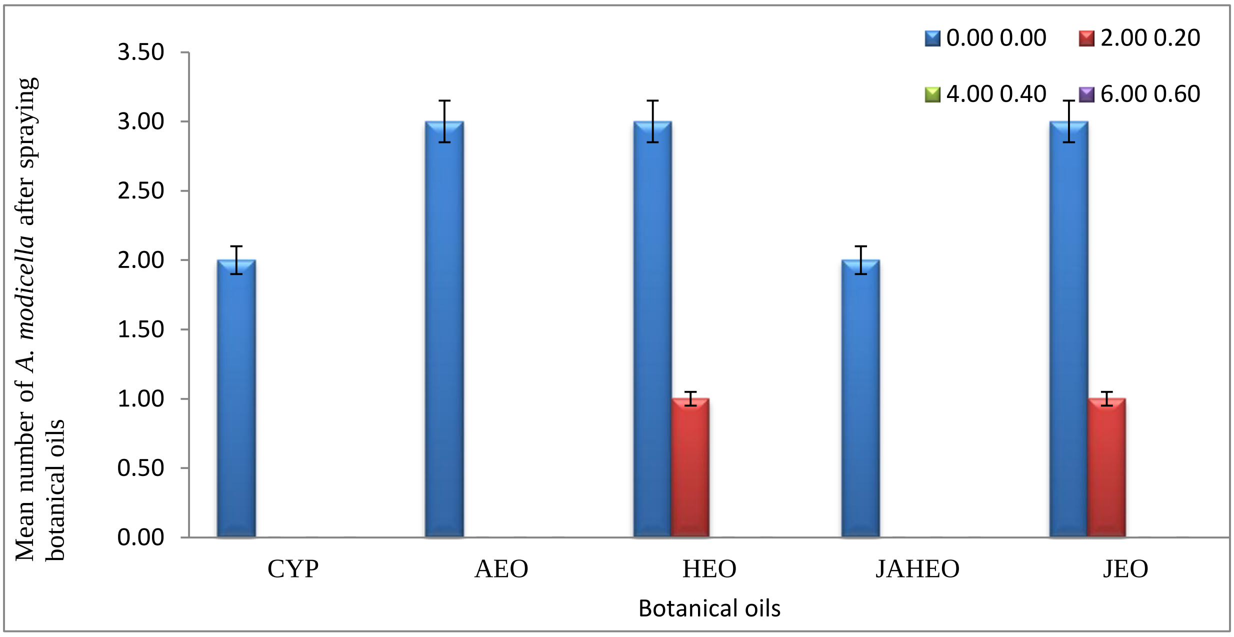
(b) After spray at vegetative phase during early 2017

FIG 43; Comparison of number of Leaf miner (*Aproarema modicella*) on bambara groundnut before spray at vegetative phase in 2017 early farming season

Key: CYP-Cypermethrin 10EC, AEO- Stool wood *Alstonia boonei*. oil, HEO- Bush tea *Hyptis suaveolens* oil, JAHEO- Mixed plant oils from Jathropha, Bush tea and Stool wood, JEO- *Jathropha tanjorensis* oil



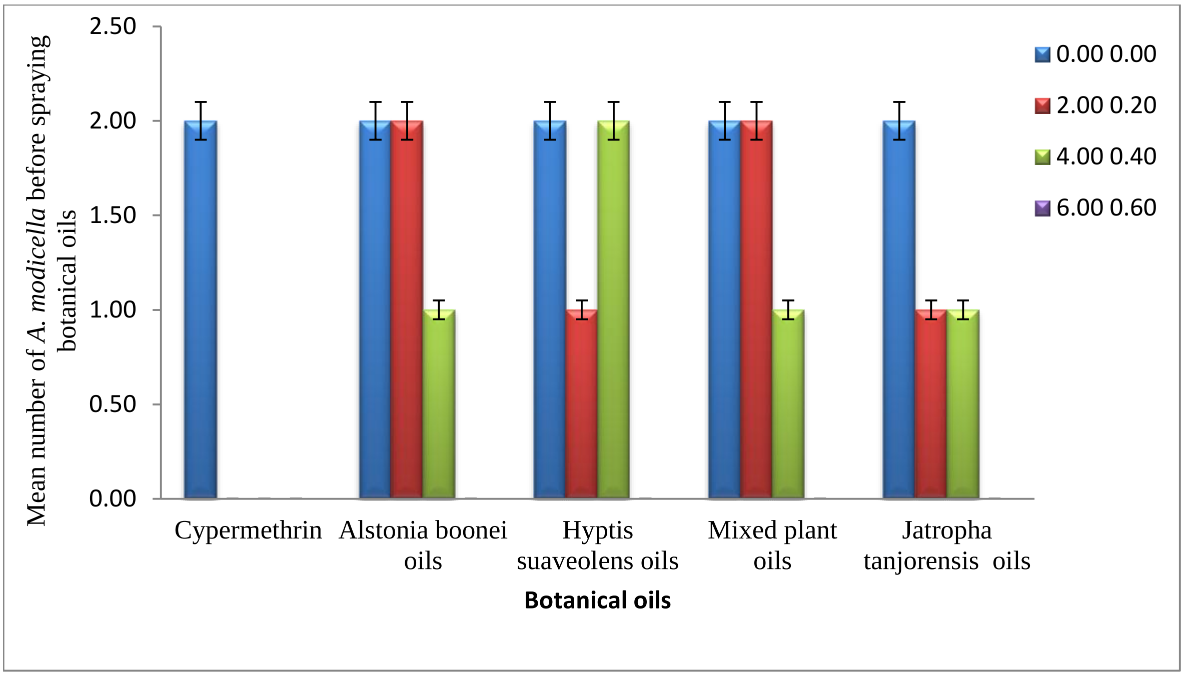
(a) Before spray at flowering phase during early 2017.



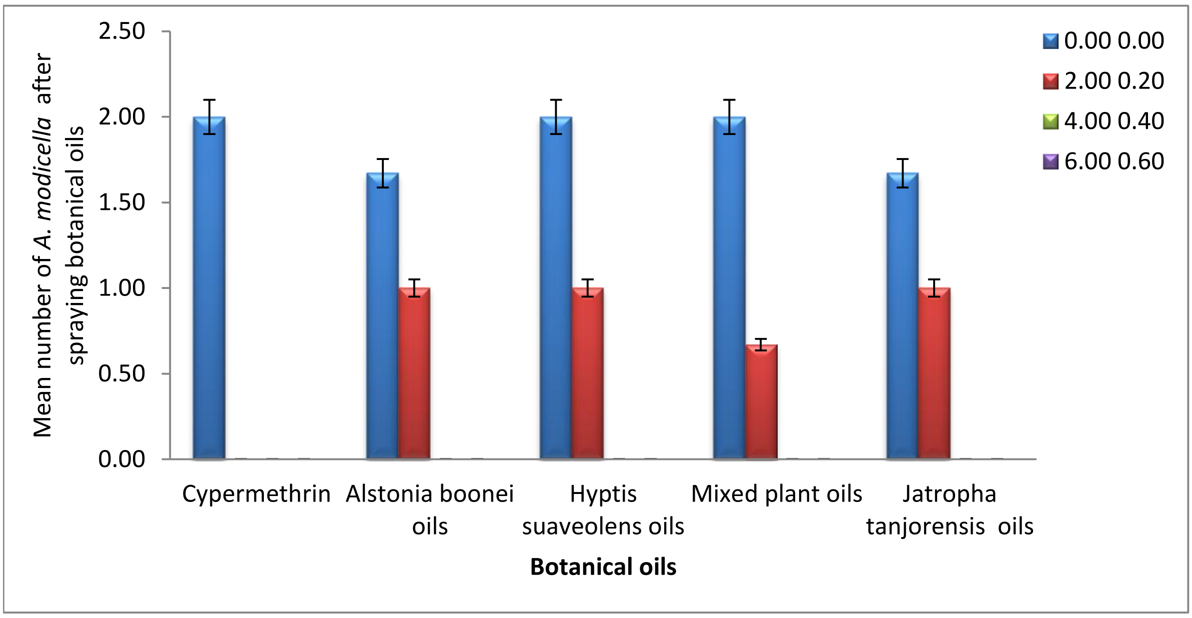
(b) After spray at flowering phase during early 2017

FIG 44; Comparison of number of *A. modicella* on bambara groundnut after spray at flowering phase in 2017 early farming season

Key: CYP-Cypermethrin 10EC, AEO- Stool wood *Alstonia boonei*. oil, HEO- Bush tea *Hyptis suaveolens* oil, JAHEO- Mixed plant oils from Jathropha, Bush tea and Stool wood, JEO- *Jathropha tanjorensis* oil



(a) Before spray at podding phase during early 2017.



(b) After spray at flowering phase during early 2017

FIG 45; Comparison of number of *A. modicella* on bambara groundnut before spray at podding phase in 2017 early farming season

Key: CYP-Cypermethrin 10EC, AEO- Stool wood *Alstonia boonei.* oil, HEO- Bush tea *Hyptis suaveolens* oil, JAHEO- Mixed plant oils from Jathropha, Bush tea and Stool wood, JEO- *Jathropha tanjorensis* oil

4.10 Effects of botanical oils on days to first flower bud initiation in 2016 and 2017 early and late farming Seasons

The effects of botanical oils on days to first flower bud initiation in 2016 and 2017 early and late farming Season is presented in Table 5. In 2016 early farming season, the result showed that plots sprayed with *H. suaveolens* oil (HEO) recorded the lowest mean days to first flower bud initiation at 36.42, this was followed by plots sprayed with Jathropha oil (JEO) at 36.59, plots sprayed with Cypermethrin (CYP) and mixed plant oils (JAHEO) recorded 36.67, while plots sprayed with *A. boonei* oil (AEO) recorded the highest mean days to first flower bud initiation at 36.92, which didn't differ significantly from each other ($P \leq 0.05$). The highest application rates (6.00/0.60) recorded the lowest mean day to first flower bud initiation at 36.47. This was followed by the least application rates (2.00/0.20) and the control rates (0.00/0.00) at 36.60. The medium application rates (4.00/0.40) recorded the highest mean days to first flower bud initiation at 37.13. There were significant differences between the rates of application ($P \leq 0.05$). The interaction between the botanical oils and rates of application indicated that there is no significant difference between the botanical oils and rates of application ($P \leq 0.05$).

In 2016 late farming season, the result revealed that plots sprayed with *A. boonei* oil (AEO) recorded the lowest mean days to first flower bud initiation at 34.42, this was followed by plots sprayed with Jathropha oil (JEO) at 34.67, plots sprayed with mixed plant oils (JAHEO) recorded 34.83 and plots sprayed with Cypermethrin (CYP) recorded 34.92, while plots sprayed with *H. suaveolens* oil (HEO) recorded the highest mean days to first flower bud initiation at 35.08, which didn't differ significantly from each other ($P \leq 0.05$). The highest application rates (6.00/0.60) recorded the lowest mean days to first flower bud initiation at 34.00. This was followed by the least application rates (2.00/0.20) and the medium application rates (4.00/0.40) at 35.00, while the control rates (0.00/0.00) recorded the highest mean days to first flower bud initiation at 35.67. There is no significant difference between the rates of application ($P \leq 0.05$). The interaction between the botanical oils and rates of application indicated that there is no significant difference between the botanical oils and rates of application (P≤0.05).

In 2017 early farming season, the result indicated that plots sprayed with mixed plant oils (JAHEO) recorded the lowest mean days to first flower bud initiation at 36.42, this was followed by plots sprayed with *A. boonei* oil (AEO) at 36.59, plots sprayed with Cypermethrin (CYP) recorded 36.84 and plots sprayed with Jathropha oil (JEO) recorded 36.92, while plots sprayed with *H. suaveolens* oil (HEO) recorded the highest mean days to first flower bud initiation at 37.00, which didn't differ significantly from each other (P=0.05). The control rates (0.00/0.00) recorded the lowest mean days to first flower bud initiation at 36.53. This was followed by the least application rates (2.00/0.20) at 37.10. The medium application rates (4.00/0.40) and the highest application rates (6.00/0.60) recorded the highest mean days to first flower bud initiation at 37.33. There is no significant difference between the rates of application (P≤0.05). The interaction between the botanical oils and rates of application indicated that there is no significant difference between the botanical oils and rates of application (P≤0.05).

In 2017 late farming season, the result revealed that plots sprayed with Jathropha oil (JEO) recorded the lowest mean days to first flower bud initiation at 34.75, this was followed by plots sprayed with mixed plant oils (JAHEO) at 34.84, plots sprayed with Cypermethrin (CYP) recorded 34.92 and plots sprayed with *H. suaveolens* oil (HEO) recorded 35.00, while plots sprayed with *A. boonei* oil (AEO) recorded the highest mean days to first flower bud initiation at 35.08, which didn't differ significantly from each other (P≤0.05). The medium application rates (4.00/0.40) recorded the lowest mean days to first flower bud initiation at 34.53. This was followed by the control rates (0.00/0.00) at 34.87 and the least application rates (2.00/0.20) at 35.13, while the highest application rates (6.00/0.60) recorded the highest mean days to first flower bud initiation at 35.67. There is no significant difference between the rates of application

($P \leq 0.05$). The interaction between the botanical oils and rates of application indicated that there is no significant difference between the botanical oils and rates of application ($P \leq 0.05$).

4.11 Effects of botanical oils on days to first flower bud opening in 2016 and 2017 early and late farming Seasons

The effects of botanical on days to first flower bud opening in 2016 and 2017 early and late farming season is presented in Table 6. In 2016 early farming season, the result showed that plots sprayed with *H. suaveolens* oil (HEO) recorded the lowest mean days to first flower bud opening at 41.42, this was followed by plots sprayed with Jathropha oil (JEO) at 41.59, plots sprayed with Cypermethrin (CYP) recorded 41.83 and mixed plant oils (JAHEO) recorded 41.92, while plots sprayed with *A. boonei* oil (AEO) recorded the highest mean days to first flower bud opening at 42.10, which didn't differ significantly from each other ($P \leq 0.05$). The least application rates (2.00/0.20) recorded the lowest mean day to first flower bud opening at 41.60. This was followed by the control rates (0.00/0.00) at 41.67. The highest application rates (6.00/0.60) recorded 41.73 while the medium application rates (4.00/0.40) recorded the highest mean days to first flower bud opening at 42.13. There is no significant difference between the rates of application ($P \leq 0.05$). The interaction between the botanical oils and rates of application indicated that there is no significant difference between the botanical oils and rates of application ($P \leq 0.05$).

In 2016 late farming season, the result revealed that plots sprayed with Jathropha oil (JEO) recorded the lowest mean days to first flower bud opening at 39.00, this was followed by plots sprayed with Cypermethrin (CYP) at 39.67, plots sprayed with *A. boonei* oil (AEO) recorded 40.00, while plots sprayed with *H. suaveolens* oil (HEO) and mixed plant oils (JAHEO) recorded the highest mean days to first flower bud initiation at 40.67, which didn't differ significantly from each other ($P \leq 0.05$). The control rates (0.00/0.00) recorded the lowest mean days to first flower bud opening at 39.47. This was followed by the medium application rates (4.00/0.40) and the at

39.80 and least application rates (2.00/0.20) at 39.87 , while the highest application rates (6.00/0.60) recorded the highest mean days to first flower bud opening at 40.00. There is no significant difference between the rates of application (P≤0.05). The interaction between the botanical oils and rates of application indicated that there is no significant difference between the botanical oils and rates of application (P≤0.05).

In 2017 early farming season, the result indicated that plots sprayed with Jathropha extracted oil (JEO) and *H. suaveolens* oil (HEO) recorded the lowest mean days to first flower bud opening at 41.10, this was followed by plots sprayed with mixed plant oils (JAHEO) at 41.58 and plots sprayed with *A. boonei* oil (AEO) recorded 41.57 while plots sprayed with Cypermethrin (CYP) recorded the highest mean days to first flower bud opening at 41.84, which didn't differ significantly from each other (P≤0.05). The control rates (0.00/0.00) recorded the lowest mean days to first flower bud initiation at 41.60. This was followed by the highest application rates (6.00/0.60) at 41.80 and medium application rates (4.00/0.40) at 41.93. The least application rates (2.00/0.20) recorded the highest mean days to first flower bud opening at 42.10. There is no significant difference between the rates of application (P≤0.05). The interaction between the botanical oils and rates of application indicated that there is no significant difference between the botanical oils and rates of application (P≤0.05).

In 2017 late farming season, the result showed that plots sprayed with Jathropha oil (JEO) and mixed plant oils (JAHEO) recorded the lowest mean days to first flower bud opening at 39.67, this was followed by plots sprayed with *H. suaveolens* oil (HEO) at 39.83, plots sprayed with recorded 34.92 while plots sprayed with Cypermethrin (CYP) and *A. boonei* oil (AEO) recorded the highest mean days to first flower bud opening at 40.00, which didn't differ significantly from each other (P≤0.05). The control rates (0.00/0.00) recorded the lowest mean days to first flower bud initiation at 39.67. This was followed by the medium application rates (4.00/0.40) at 39.73 and the least application rates (2.00/0.20) at 39.93, while the highest application rates (6.00/0.60) recorded the highest mean days to first flower bud opening at 40.00. There is no significant difference between the rates of application ($P \leq 0.05$). The interaction between the botanical oils and rates of application indicated that there is no significant difference between the botanical oils and rates of application ($P \leq 0.05$).

4.12 Effects of botanical oils on days to 50% flowering in 2016 and 2017 early and late farming Seasons

The result on effects of botanical oils on days to 50% flowering revealed that different farming season recorded different mean days to 50% flowering. In 2016 early farming season, it took 49.00 mean days after sowing till 50% of crops produced inflorescences while in late 2016 farming season, mean days to 50% flowering were achieved at 46.00. In 2017 early farming season recorded 47.00 mean days to 50% flowering while late 2017 farming season recorded 44.00 mean days to 50% flowering.

4.13 Effects of botanical oils on Days to 100% maturity in 2016 and 2017 early and late farming Seasons

The result on effects of botanical oils on Days to 100% maturity showed that different farming seasons recorded different mean days to 100% maturity. In 2016 early farming season, it took 97.00 mean days after sowing till 100% of crops to respond to senescence while 2017 early farming season recorded 94.00 mean days to 100% flowering. In late 2016 farming season, mean days to 100% maturity were achieved at 89.00 while late 2017 farming season recorded 84.00 mean days to 100% maturity.

4.14 Effects of botanical oils on plant height at 3 weeks after sowing in 2016 and 2017 early farming Season.

The effects of botanical oils on plant height at 3 weeks after sowing in 2016 and 2017 early farming Season is presented in Table 7. In 2016 early farming season, the result revealed that plots sprayed with mixed plant oils (JAHEO) recorded the highest mean plant height (17.84cm), this was followed by plots sprayed with Cypermethrin (CYP) at 17.83cm, plots sprayed with *Alstonia boonei* oil (AEO) recorded 17.82cm, plots sprayed with *Hyptis suaveolens* oil (HEO) recorded 17.81cm while plots sprayed Jathropha oil (JEO) recorded the lowest mean plant height (17.78cm), which didn't significantly differ from each other ($P \leq 0.05$). The highest application rates (6.00/0.60) and medium application rates (4.00/0.40) recorded the highest mean plant height at 18.61cm. This was followed by least application rates (2.00/0.20) at 17.76cm. The control rates (0.00/0.00) recorded the least mean plant height at 16.29cm. There were significant differences between the rates of application ($P \leq 0.05$). The interaction between the Botanical oils and rates of application indicated that there were no significant differences between the Botanical oils and rates of application ($P \leq 0.05$).

In 2016 late farming season, the result revealed that plots sprayed with Cypermethrin (CYP) recorded the highest mean plant height at 17.95cm, this was followed by plots sprayed with mixed plant oils (JAHEO) at 17.82cm, plots sprayed with *A. boonei* oil (AEO) recorded 17.81cm, plots sprayed with Jathropha oil (JEO) recorded 17.80cm while plots sprayed with *H. suaveolens* oil (HEO) recorded the lowest mean plant height (17.76cm), they didn't differ significantly from each other ($P \leq 0.05$). The highest application rates (6.00/0.60) recorded the highest mean plant height at 18.66cm. This was followed by the medium application rates (4.00/0.40) at 18.43cm and least application rates (2.00/0.20) at 17.79cm. The control rates (0.00/0.00) recorded the least mean plant height at 16.50cm. There were significant differences between the rates of application

(P≤0.05). The interaction between the botanical oils and rates of application indicated that there no were significant difference between the botanical oils and rates of application (P≤0.05).

In 2017 early farming season, the result showed that plots sprayed with *A. boonei* oil (AEO) recorded the highest mean plant height (17.89cm), this was followed by plots sprayed with *H. suaveolens* oil (HEO) at 17.80cm, plots sprayed with Jathropha oil (JEO) recorded 17.79cm and plots sprayed with mixed plant oils (JAHEO) recorded 17.73cm while Cypermethrin (CYP) recorded the lowest mean plant height at 17.63cm, which did not differ significantly from each other (P=0.05). The medium application rates (4.00/0.40) recorded the highest mean plant height at 18.15cm. This was followed by the highest application rates (6.00/0.60) at 18.12cm and least application (2.00/0.20) at 18.05cm. The control rates (0.00/0.00) rates recorded the least mean plant height at 16.75cm. There were significant differences between the rates of application (P≤0.05). The interaction between the Botanical oils and rates of application indicated that there were no significant differences between the Botanical oils and rates of application (P≤0.05).

In 2017 late farming season, the result indicated that plots sprayed with Cypermethrin (CYP) recorded the highest mean plant height (17.84cm), this was followed by plots sprayed with *A. boonei* oil (AEO) at 17.83cm, plots sprayed with *H. suaveolens* oil (HEO) recorded 17.76cm, plots sprayed with mixed plant oils (JAHEO) recorded 17.74cm while plots sprayed with Jathropha oil (JEO) recorded the lowest mean plant height at 17.66cm, which did not differ significantly from each other (P≤0.05). The highest application rates (6.00/0.60) recorded the highest mean plant height 18.61cm, followed by medium application rates (4.00/0.40) at 18.60cm while the least application (2.00/0.20) rates recorded 17.73cm. The control rates (0.00/0.00) recorded the least mean plant height at 16.29cm. There were significant differences between the rates of application (P≤0.05). The interaction between the botanical oils and rates of application indicated that there is no significant difference between the botanical oils and rates of application (P≤0.05)

4.15 Effects of botanical oils on plant height at 4 weeks after sowing in 2016 and 2017 early and late farming Season.

The effects of botanical oils on plant height at 4 weeks after sowing in 2016 and 2017 early and late farming season is presented in Table 8. In 2016 early farming season, the result revealed that plots sprayed with Cypermethrin (CYP) recorded the highest mean plant height (21.44cm), this was followed by plots sprayed with mixed plant oils (JAHEO) at 21.34cm, plots sprayed with *A. boonei* oil (AEO) recorded 21.33cm, plots sprayed with *H. suaveolens* oil (HEO) recorded 21.09cm while plots sprayed Jathropha oil (JEO) recorded the lowest mean plant height (20.77cm), which significantly differed from each other ($P \leq 0.05$). The highest application rates (6.00/0.60) recorded the highest mean plant height at 22.07cm. This was followed by the medium application rates (4.00/0.40) at 21.70cm and least application rates (2.00/0.20) at 21.70cm. The control rates (0.00/0.00) recorded the least mean plant height at 19.80cm. There were significant differences between the rates of application ($P \leq 0.05$). The interaction between the botanical oils and rates of application indicated that there were significant differences between the botanical oils and rates of application ($P \leq 0.05$).

In 2016 late farming season, the result revealed that plots sprayed with Cypermethrin (CYP) recorded the highest mean plant height at 21.44cm, this was followed by plots sprayed with mixed plant oils (JAHEO) at 21.32cm, plots sprayed with *A. boonei* oil (AEO) recorded 21.29cm, plots sprayed with Jathropha oil (JEO) recorded 21.25cm while plots sprayed with *H. suaveolens* oil (HEO) recorded the lowest mean plant height (20.03cm), they didn't differ significantly from each other ($P \leq 0.05$). The medium application rates (4.00/0.40) recorded the highest mean plant height at 22.02cm. This was followed by the highest application rates (6.00/0.60) at 21.97cm and least application rates (2.00/0.20) at 21.04cm. The control rates (0.00/0.00) recorded the least mean plant height at 19.79cm. There were significant difference between the rates of application

(P≤0.05). The interaction between the botanical oils and rates of application indicated that there no were significant difference between the botanical oils and rates of application (P≤0.05).

In 2017 early farming season, the result showed that plots sprayed with Cypermethrin (CYP) recorded the highest mean plant height (21.58cm), this was followed by plots sprayed with mixed plant oils (JAHEO) at 21.17cm, plots sprayed with *A. boonei* oil (AEO) recorded 21.00cm, plots sprayed with *H. suaveolens* oil (HEO) and Jathropha oil (JEO) recorded the lowest mean plant height at 20.99cm, which did not differ significantly from each other (P≤0.05). The highest application rates (6.00/0.60) recorded the highest mean plant height at 21.56cm. This was followed by the medium application rates (4.00/0.40) at 21.49cm and control rates (0.00/0.00) at 20.23cm. The least application (2.00/0.20) rates recorded the least mean plant height at 21.19cm. There were significant differences between the rates of application (P≤0.05). The interaction between the Botanical oils and rates of application indicated that there were no significant differences between the Botanical oils and rates of application (P≤0.05).

In 2017 late farming season, the result indicated that plots sprayed with Cypermethrin (CYP) recorded the highest mean plant height (21.41cm), this was followed by plots sprayed with *A. boonei* oil (AEO) at 21.28cm, plots sprayed with mixed plant oils (JAHEO) recorded 21.27cm, plots sprayed with Jathropha oil (JEO) recorded 21.19cm while plots sprayed with *H. suaveolens* oil (HEO) recorded the lowest mean plant height at 21.01cm, which did not differ significantly from each other (P≤0.05). The highest application rates (6.00/0.60) and medium application rates (4.00/0.40) recorded the highest mean plant height at 21.95cm. This was followed by the least application (2.00/0.20) rates at 21.27cm. The control rates (0.00/0.00) recorded the least mean plant height at 19.75cm. There were significant differences between the rates of application (P≤0.05). The interaction between the botanical oils and rates of application indicated that there is no significant difference between the botanical oils and rates of application (P≤0.05)

4.16 Effects of botanical oils on plant height at 5 weeks after sowing in 2016 and 2017 early farming Season.

The effects of botanical oils on plant height at 5 weeks after sowing in 2016 and 2017 early farming Season is presented in Table 9. In 2016 early farming season, the result revealed that plots sprayed with mixed plant oils (JAHEO) recorded the highest mean plant height (24.35cm), this was followed by plots sprayed with Cypermethrin (CYP) at 23.79cm, plots sprayed with *A. boonei* oil (AEO) and sprayed Jathropha oil (JEO) recorded 23.32cm, while plots plots sprayed with *H. suaveolens* oil (HEO) recorded the lowest mean plant height (23.31cm), which significantly differed from each other ($P \leq 0.05$). The highest application rates (6.00/0.60) recorded the highest mean plant height at 24.59cm. This was followed by the medium application rates (4.00/0.40) at 24.07cm and least application rates (2.00/0.20) at 23.24cm. The control rates (0.00/0.00) recorded the least mean plant height at 21.78cm. There were significant differences between the rates of application ($P \leq 0.05$). The interaction between the botanical oils and rates of application indicated that there were significant differences between the botanical oils and rates of application ($P \leq 0.05$).

In 2016 late farming season, the result revealed that plots sprayed with Cypermethrin (CYP) recorded the highest mean plant height at 23.71cm, this was followed by plots sprayed with *H. suaveolens* oil (HEO) at 23.33cm, plots sprayed with *A. boonei* oil (AEO) recorded 23.32cm, plots sprayed with mixed plant oils (JAHEO) recorded 23.31cm while plots sprayed with Jathropha oil (JEO) recorded the lowest mean plant height (23.24cm), they didn't differ significantly from each other ($P \leq 0.05$). The highest application rates (6.00/0.60) recorded the highest mean plant height at 24.58cm. This was followed by the medium application rates (4.00/0.40) at 24.07cm and least application rates (2.00/0.20) at 23.24cm. The control rates (0.00/0.00) recorded the least mean plant height at 21.67cm. There were significant differences between the rates of application

($P \leq 0.05$). The interaction between the botanical oils and rates of application indicated that there were significant differences between the botanical oils and rates of application ($P \leq 0.05$).

In 2017 early farming season, the result showed that plots sprayed with *H. suaveolens* oil (HEO) recorded the highest mean plant height (23.46cm), this was followed by plots sprayed with Cypermethrin (CYP) at 23.43cm, plots sprayed with *A. boonei* oil (AEO) recorded 23.37cm and plots sprayed with mixed plant oils (JAHEO) recorded 23.21cm, while plots sprayed with Jathropha oil (JEO) recorded the lowest mean plant height at 20.99cm, which did not differ significantly from each other ($P \leq 0.05$). The highest application rates (6.00/0.60) recorded the highest mean plant height at 23.87cm. This was followed by the medium application rates (4.00/0.40) at 23.69cm and least application rates (2.00/0.20) at 23.59cm. The control rates (0.00/0.00) recorded the least mean plant height at 22.25cm. There were significant differences between the rates of application ($P \leq 0.05$). The interaction between the botanical oils and rates of application indicated that there is no significant difference between the botanical oils and rates of application ($P \leq 0.05$).

In 2017 late farming season, the result indicated that plots sprayed with Cypermethrin (CYP) recorded the highest mean plant height (23.77cm), this was followed by plots sprayed with *A. boonei* oil (AEO) at 23.37cm, plots sprayed with Jathropha oil (JEO) recorded 23.35cm, plots sprayed with *H. suaveolens* oil (HEO) recorded 23.33cm while plots sprayed with mixed plant oils (JAHEO) recorded the lowest mean plant height at 23.27cm, they differed significantly from each other ($P \leq 0.05$). The highest application rates (6.00/0.60) recorded the highest mean plant height at 24.65cm. This was followed by the medium application rates (4.00/0.40) at 24.03cm, least application (2.00/0.20) rates at 23.25cm, while control rates (0.00/0.00) recorded the least mean plant height at 21.73cm. There were significant differences between the rates of application ($P \leq 0.05$). The interaction between the botanical oils and rates of application indicated that there is no significant difference between the botanical oils and rates of application ($P \leq 0.05$)

4.17 Effects of botanical oils on damaged leaves at vegetative phase in 2016 and 2017 early and late farming Seasons

The effects of botanical oils on damaged leaves at vegetative phase in 2016 and 2017 early and late farming Season is presented in Table 10. In 2016 early farming season, the result showed that plots sprayed with Cypermethrin (CYP) recorded the lowest mean damaged leaves at 0.71, this was followed by plots sprayed with mixed plant oils (JAHEO) at 0.92, plots sprayed with *A. boonei* extracted oil (AEO) recorded 1.00, plots sprayed with *H. suaveolens* oil (HEO) recorded 1.07 while plots sprayed Jathropha oil (JEO) recorded the highest mean damaged leaves at 1.08, which significantly differed from each other ($P \leq 0.05$). The highest application rates (6.00/0.60) recorded the lowest mean damaged leaves at 0.56. This was followed by the medium application rates (4.00/0.40) at 0.77 and least application rates (2.00/0.20) at 1.08. The control rates (0.00/0.00) recorded the highest mean damaged leaves at 1.43. There were significant differences between the rates of application ($P \leq 0.05$). The interaction between the botanical oils and rate of application indicated that there were significant differences between the botanical oils and rates of application ($P \leq 0.05$).

In 2016 late farming season, the result indicated that plots sprayed with Cypermethrin (CYP) recorded the lowest mean damaged leaves at 0.77, this was followed by plots sprayed with mixed plant oils (JAHEO) at 1.05, plots sprayed with *A. boonei* oil (AEO) recorded 1.11cm, plots sprayed with Jathropha oil (JEO) recorded 1.19 while plots sprayed with *H. suaveolens* oil (HEO) recorded the highest mean damaged leaves at 1.25, which significantly differed from each other ($P \leq 0.05$). The highest application rates (6.00/0.60) recorded the lowest mean damaged leaves at 0.60. This was followed by the medium application rates (4.00/0.40) at 0.74 and least application rates (2.00/0.20) at 1.29. The control rates (0.00/0.00) recorded the highest mean damaged leaves at 1.65. There were significant differences between the rates of application ($P \leq 0.05$). The interaction between the botanical oils and rates of application revealed that there is significant difference between the botanical oils and rates of application (P≤0.05).

In 2017 early farming season, the result showed that plots sprayed with Cypermethrin (CYP) recorded the lowest mean damaged leaves at 0.91, this was followed by plots sprayed with mixed plant oils (JAHEO) at 0.90, plots sprayed with *A. boonei* oil (AEO) and Jathropha oil extract oil (JEO) recorded 1.03, while plots sprayed with *H.suaveolens* oil (HEO) recorded the highest mean damaged leaves at 1.08, which didn't differ significantly from each other (P≤0.05). The highest application rates (6.00/0.60) recorded the lowest mean damaged leaves at 0.82. This was followed by the medium application rates (4.00/0.40) at 0.89 and least application rates (2.00/0.20) at 0.95. The control rates (0.00/0.00) recorded the highest mean damaged leaves at 1.29. There were significant differences between the rates of application (P≤0.05). The interaction between the botanical oils and rates of application revealed that there were no significant differences between the botanical oils and rates of application (P≤0.05).

In 2017 late farming season, the result indicated that plots sprayed with Cypermethrin (CYP) recorded the lowest mean damaged leaves at 0.78, this was followed by plots sprayed with mixed plant oils (JAHEO) at 1.08, plots sprayed with Jathropha oil (JEO) recorded 1.21 and plots sprayed with *H. suaveolens* oil (HEO) recorded 1.26, while *A. boonei* oil (AEO) recorded the highest mean damaged leaves at 1.33, which differed significantly from each other (P≤0.05). The highest application rates (6.00/0.60) recorded the lowest mean damaged leaves at 0.60. This was followed by the medium application rates (4.00/0.40) at 0.75 and least application rates (2.00/0.20) at 1.30. The control rates (0.00/0.00) recorded the highest mean damaged leaves at 1.67. There were significant differences between the rates of application (P≤0.05). The interaction between the botanical oils and rates of application showed that there were significant differences between the botanical oils and rates of application (P≤0.05).

4.18 Effects of botanical oils on damaged leaves at flowering phase in 2016 and 2017 early and late farming Seasons

The effects of botanical oils on damaged leaves at flowering phase in 2016 and 2017 early and late farming Season is presented in Table 11. In 2016 early farming season, the result indicated that plots sprayed with Cypermethrin (CYP) recorded the lowest mean damaged leaves at 0.62, this was followed by plots sprayed with mixed plant oils (JAHEO) at 0.82, plots sprayed with *A. boonei* oil (AEO) recorded 0.93, plots sprayed with Jathropha oil (JEO) recorded 0.95 while plots sprayed with *H. suaveolens* oil (HEO) recorded the highest mean damaged leaves at 0.96, which significantly differed from each other ($P \leq 0.05$). The highest application rates (6.00/0.60) recorded the lowest mean damaged leaves at 0.39. This was followed by the medium application rates (4.00/0.40) at 0.65 and least application rates (2.00/0.20) at 0.74. The control rates (0.00/0.00) recorded the highest mean damaged leaves at 1.28. There were significant differences between the rates of application ($P \leq 0.05$). The interaction between the Botanical oils and rates of application indicated that there were significant differences between the Botanical oils and rates of application ($P \leq 0.05$).

In 2016 late farming season, the result indicated that plots sprayed with Cypermethrin (CYP) recorded the lowest mean damaged leaves at 0.63, this was followed by plots sprayed with mixed plant oils (JAHEO) at 0.83, plots sprayed with *A. boonei* oil (AEO) recorded 0.89cm, plots sprayed with Jathropha oil (JEO) recorded 0.97 while plots sprayed with *H. suaveolens* oil (HEO) recorded the highest mean damaged leaves at 1.00, which significantly differed from each other ($P \leq 0.05$). The highest application rates (6.00/0.60) recorded the lowest mean damaged leaves at 0.43. This was followed by the medium application rates (4.00/0.40) at 0.65 and least application rates (2.00/0.20) at 0.93. The control rates (0.00/0.00) recorded the highest mean damaged leaves at 1.43. There were significant differences between the rates of application ($P \leq 0.05$). The interaction between the botanical oils and rates of application revealed that there were significant differences between the botanical oils and rates of application (P≤0.05).

In 2017 early farming season, the result showed that plots sprayed with Cypermethrin (CYP) recorded the lowest mean damaged leaves at 0.65, this was followed by plots sprayed with mixed plant oils (JAHEO) at 0.83, plots sprayed with *A. boonei* oil (AEO) and Jathropha oil (JEO) recorded 0.95, while plots sprayed with *H.s suaveolens* oil (HEO) recorded the highest mean damaged leaves at 0.99, which didn't differ significantly from each other (P≤0.05). The highest application rates (6.00/0.60) recorded the lowest mean damaged leaves at 0.46. This was followed by the medium application rates (4.00/0.40) at 0.66 and least application rates (2.00/0.20) at 0.85. The control rates (0.00/0.00) recorded the highest mean damaged leaves at 1.54. There were significant differences between the rates of application (P≤0.05). The interaction between the botanical oils and rates of application revealed that there is no significant difference between the botanical oils and rates of application (P≤0.05).

In 2017 late farming season, the result indicated that plots sprayed with Cypermethrin (CYP) recorded the lowest mean damaged leaves at 0.63, this was followed by plots sprayed with mixed plant oils (JAHEO) at 0.86, plots sprayed with *A. boonei* oil (AEO) recorded 0.91 and plots sprayed with *H. suaveolens* oil (HEO) recorded 1.00, while plots sprayed with Jathropha oil (JEO) recorded the highest mean damaged leaves at 1.11, which differed significantly from each other (P≤0.05). The highest application rates (6.00/0.60) recorded the lowest mean damaged leaves at 0.44. This was followed by the medium application rates (4.00/0.40) at 0.75 and least application rates (2.00/0.20) at 0.95. The control rates (0.00/0.00) recorded the highest mean damaged leaves at 1.45. There were significant differences between the rates of application (P≤0.05). The interaction between the botanical oils and rates of application showed that there were significant differences between the botanical oils and rates of application (P≤0.05).

4.19 Effects of botanical oils on damaged leaves at podding phase in 2016 and 2017 early and late farming Seasons

The effects of botanical oils on damaged leaves at podding phase in 2016 and 2017 early and late farming Season is presented in Table 12. In 2016 early farming season, the result indicated that at podding phase, plots sprayed with Cypermethrin (CYP) recorded the lowest mean plant height at 0.37, this was followed by plots sprayed with mixed plant oils (JAHEO) at 0.51, plots sprayed with *A. boonei* oil (AEO) recorded 0.53, plots sprayed with Jathropha oil (JEO) and plots sprayed with *H. suaveolens* oil (HEO) recorded the highest mean damaged leaves at 0.54, which significantly differed from each other (P≤0.05). The highest application rates (6.00/0.60) recorded the lowest mean damaged leaves at 0.25. This was followed by the medium application rates (4.00/0.40) at 0.36 and least application rates (2.00/0.20) at 0.45. The control rates (0.00/0.00) recorded the highest mean damaged leaves at 0.91. There were significant differences between the rates of application (P≤0.05). The interaction between the botanical oils and rates of application indicated that there were significant differences between the botanical oils and rates of application (P≤0.05).

In 2016 late farming season, the result indicated that plots sprayed with Cypermethrin (CYP) recorded the lowest mean damaged leaves at 0.37, this was followed by plots sprayed with mixed plant oils (JAHEO) at 0.51, plots sprayed with *A. boonei* oil (AEO) recorded 0.53, plots sprayed with Jathropha oil (JEO) and plots sprayed with *H. suaveolens* oil (HEO) recorded the highest mean damaged leaves at 0.54, which significantly differed from each other (P≤0.05). The highest application rates (6.00/0.60) recorded the lowest mean damaged leaves at 0.26. This was followed by the medium application rates (4.00/0.40) at 0.43 and least application rates (2.00/0.20) at 0.59. The control rates (0.00/0.00) recorded the highest mean damaged leaves at 0.99. There were significant differences between the rates of application (P≤0.05). The interaction between the botanical oils and rates of application revealed that there were significant differences between the botanical oils and rates of application ($P \leq 0.05$).

In 2017 early farming season, the result showed that plots sprayed with Cypermethrin (CYP) recorded the lowest mean damaged leaves at 0.44, this was followed by plots sprayed with mixed plant oils (JAHEO) at 0.55, plots sprayed with *A. boonei* oil (AEO) recorded 0.56 and plots sprayed with *H. suaveolens* oil (HEO) recorded 0.58, while plots sprayed with Jathropha oil oil (JEO) recorded the highest mean damaged leaves at 0.59, which didn't differ significantly from each other ($P \leq 0.05$). The highest application rates (6.00/0.60) recorded the lowest mean damaged leaves at 0.35. This was followed by the least application rates (2.00/0.20) at 0.50 and medium application rates (4.00/0.40) at 0.51. The control rates (0.00/0.00) recorded the highest mean damaged leaves at 0.91. There were significant differences between the rates of application ($P \leq 0.05$). The interaction between the botanical oils and rates of application revealed that there were no significant differences between the botanical oils and rates of application ($P \leq 0.05$).

In 2017 late farming season, the result indicated that plots sprayed with Cypermethrin (CYP) recorded the lowest mean damaged leaves at 0.57, this was followed by plots sprayed with mixed plant oils (JAHEO) at 0.59, plots sprayed with Jathropha oil (JEO) recorded 0.76 and plots sprayed with *A. boonei* oil (AEO) recorded 0.77, while plots sprayed with *H. suaveolens* oil (HEO) recorded the highest mean damaged leaves at 0.80, which differed significantly from each other ($P \leq 0.05$). The highest application rates (6.00/0.60) recorded the lowest mean damaged leaves at 0.35. This was followed by the medium application rates (4.00/0.40) at 0.52 and least application rates (2.00/0.20) at 0.73. The control rates (0.00/0.00) recorded the highest mean damaged leaves at 1.27. There were significant differences between the rates of application ($P \leq 0.05$). The interaction between the botanical oils and rates of application showed that there is no significant difference between the botanical oils and rates of application ($P \leq 0.05$).

Table 5: Effects of botanical oils on Days to First flower bud initiation in 2016 and 2017 early and late farming Seasons

	Rates of botanical oils ml/100ml water									
Botanical oil	0.00	2.00	4.00	6.00	**Mean**	0.00	2.00	4.00	6.00	**Mean**
	Early 2016 farming season					**Late 2016 farming season**				
CYP	36.00	37.33	37.00	36.33	**36.67**	35.67	35.00	34.67	34.33	**34.92**
AEO	37.00	37.00	37.67	36.00	**36.92**	34.00	34.00	35.00	34.67	**34.42**
HEO	36.33	36.00	37.00	36.33	**36.42**	34.33	35.00	35.67	35.33	**35.08**
JAHEO	37.67	36.67	37.33	36.00	**36.67**	34.33	35.33	35.67	34.00	**34.83**
JEO	36.00	36.00	36.67	37.67	**36.59**	35.67	35.00	34.00	34.00	**34.67**
Mean	**36.60**	**36.60**	**37.13**	**36.47**		**35.67**	**35.00**	**35.00**	**34.00**	
LSD $_{0.05}$ Botanical oils			**NS**					**NS**		
LSD $_{0.05}$ Rates			**NS**					**NS**		
LSD $_{0.05}$ Botanical oils x Rates			**NS**					**NS**		
	Early 2017 farming season					**Late 2017 farming season**				
CYP	37.00	36.67	36.00	0.27	**36.84**	34.67	35.33	34.00	35.67	**34.92**
AEO	36.00	37.00	37.33	0.68	**36.67**	34.33	35.00	35.33	35.67	**35.08**
HEO	37.33	37.67	37.00	0.87	**37.00**	35.67	35.00	34.67	34.67	**35.00**
JAHEO	36.33	37.00	36.00	0.50	**36.42**	35.67	35.67	34.00	34.00	**34.84**
JEO	36.00	37.00	37.33	0.73	**36.92**	34.00	34.67	34.67	35.67	**34.75**
Mean	**36.53**	**37.10**	**37.33**	**37.33**		**34.87**	**35.13**	**34.53**	**35.67**	
LSD $_{0.05}$ Botanical oils			**NS**					**NS**		
LSD $_{0.05}$ Rates			**NS**					**NS**		
LSD $_{0.05}$ Botanical oils x Rates			**NS**					**NS**		

Key: CYP-Cypermethrin 10EC, AEO- Stool wood *Alstonia boonei.* oil, HEO- Bush tea *Hyptis suaveolens* oil, JAHEO- Mixed plant oils from Jathropha, Bush tea and Stool wood, JEO- *Jathropha tanjorensis* oil

Table 6: Effects of botanical oils on days to first flower bud opening in 2016 and 2017 late farming Seasons

	Rates of botanical oils ml/100ml water									
Botanical oils	0.00	2.00	4.00	6.00	**Mean**	0.00	2.00	4.00	6.00	**Mean**
	Early 2016 farming season					**Late 2016 farming season**				
CYP	41.00	42.33	42.00	42.00	**41.83**	39.33	40.00	40.67	39.67	**39.67**
AEO	42.33	42.00	42.67	41.00	**42.17**	39.67	39.00	39.00	40.00	**40.00**
HEO	41.33	41.00	42.00	41.33	**41.42**	40.33	40.00	39.33	40.67	**40.67**
JAHEO	42.67	41.67	42.33	41.00	**41.92**	39.00	40.33	39.33	40.67	**40.67**
JEO	41.00	41.00	41.67	42.67	**41.59**	39.00	40.00	40.67	39.00	**39.00**
Mean	**41.67**	**41.60**	**42.13**	**41.73**		**39.47**	**39.87**	**39.80**	**40.00**	
LSD $_{0.05}$ Botanical oils			**NS**					**NS**		
LSD $_{0.05}$ Rates			**NS**					**NS**		
LSD $_{0.05}$ Botanical oils x Rates			**NS**					**NS**		
	Early 2017 farming season					**Late 2017 farming season**				
CYP	42.00	41.67	41.00	42.67	**41.84**	39.33	40.33	39.67	40.67	**40.00**
AEO	41.00	42.00	42.33	41.33	**41.67**	40.33	40.00	39.33	40.33	**40.00**
HEO	42.33	42.67	42.33	41.00	**42.10**	39.67	40.00	40.33	39.33	**39.83**
JAHEO	41.67	42.00	41.33	41.33	**41.58**	39.33	40.67	40.33	39.00	**39.67**
JEO	41.00	42.00	42.67	42.67	**42.10**	39.67	39.33	39.00	40.67	**39.67**
Mean	**41.60**	**42.10**	**41.93**	**41.80**		**39.67**	**39.93**	**39.73**	**40.00**	
LSD $_{0.05}$ Botanical oils			**NS**					**NS**		
LSD $_{0.05}$ Rates			**NS**					**NS**		
LSD $_{0.05}$ Botanical oils x Rates			**NS**					**NS**		

Key: CYP-Cypermethrin 10EC, AEO- Stool wood *Alstonia boonei.* oil, HEO- Bush tea *Hyptis suaveolens* oil, JAHEO- Mixed plant oils from Jathropha, Bush tea and Stool wood, JEO- *Jathropha tanjorensis* oil

Table 7: Effects of botanical oils on plant height 3 weeks after sowing in 2016 and 2017 Early and late farming Season

	Rates of botanical oils ml/100ml water									
Botanical oils	0.00	2.00	4.00	6.00	**Mean**	0.00	2.00	4.00	6.00	**Mean**
	Early 2016 farming season					**Late 2016 farming season**				
CYP	16.37	18.00	18.57	18.40	**17.83**	16.70	17.83	18.67	18.60	**17.95**
AEO	16.33	17.70	18.60	18.67	**17.82**	16.33	17.70	18.67	18.67	**17.81**
HEO	16.33	17.60	18.50	18.67	**17.81**	16.33	17.70	18.60	18.67	**17.80**
JAHEO	16.30	17.70	18.70	18.67	**17.84**	16.30	18.00	18.83	18.67	**17.82**
JEO	16.13	17.70	18.60	18.67	**17.78**	16.83	17.70	18.00	18.67	**17.76**
Mean	**16.29**	**17.76**	**18.61**	**18.61**		**16.50**	**17.79**	**18.43**	**18.66**	
LSD $_{0.05}$ Botanical oils			**NS**					**NS**		
LSD $_{0.05}$ Rates			**0.154**					**0.154**		
LSD $_{0.05}$ Botanical oils x Rates			**NS**					**NS**		
	Early 2017 farming season					**Late 2017 farming season**				
CYP	17.23	18.20	17.70	17.40	**17.63**	16.37	18.00	18.57	18.40	**17.84**
AEO	16.27	18.33	18.60	18.37	**17.89**	16.33	17.70	18.60	18.67	**17.83**
HEO	16.87	17.43	18.53	18.37	**17.80**	16.30	17.70	18.50	18.60	**17.76**
JAHEO	17.17	18.00	17.63	18.10	**17.73**	16.30	17.00	18.70	18.67	**17.74**
JEO	16.20	18.30	18.30	18.37	**17.79**	16.13	17.30	18.60	18.67	**17.66**
Mean	**16.75**	**18.05**	**18.15**	**18.12**		**16.29**	**17.73**	**18.61**	**18.61**	
LSD $_{0.05}$ Botanical oils			**NS**					**NS**		
LSD $_{0.05}$ Rates			**0.651**					**0.155**		
LSD $_{0.05}$ Botanical oils x Rates			**NS**					**NS**		

Key: CYP-Cypermethrin 10EC, AEO- Stool wood *Alstonia boonei.* oil, HEO- Bush tea *Hyptis suaveolens* oil, JAHEO- Mixed plant oils from Jathropha, Bush tea and Stool wood, JEO- *Jathropha tanjorensis* oil

Table 8: Effects of botanical oils on plant height at 4 weeks after sowing in 2016 and 2017 Early and late farming Season

	Rates of botanical oils ml/100ml water									
Botanical oils	0.00	2.00	4.00	6.00	**Mean**	0.00	2.00	4.00	6.00	**Mean**
	Early 2016 farming season					**Late 2016 farming season**				
CYP	19.77	21.80	21.70	22.50	**21.44**	19.60	21.80	21.70	22.50	**21.44**
AEO	19.87	21.40	22.20	21.83	**21.33**	19.87	21.30	22.07	21.83	**21.29**
HEO	19.87	21.40	21.20	21.87	**21.09**	19.80	21.40	22.00	21.87	**21.03**
JAHEO	19.83	21.20	22.40	21.93	**21.34**	19.83	20.20	22.20	21.83	**21.32**
JEO	19.67	20.40	21.00	22.00	**20.77**	19.57	20.40	22.13	21.83	**21.25**
Mean	**19.80**	**21.24**	**22.70**	**22.07**		**19.79**	**21.04**	**22.02**	**21.97**	
LSD 0.05 Botanical oils			**0.130**					**NS**		
LSD 0.05 Rates			**0.116**					**0.481**		
LSD 0.05 Botanical oils x Rates			**0.259**					**NS**		
	Early 2017 farming season					**Late 2017 farming season**				
CYP	20.70	21.77	21.77	22.07	**21.58**	19.67	21.77	21.70	22.50	**21.41**
AEO	19.83	21.63	21.13	21.40	**21.00**	19.87	21.40	22.03	21.83	**21.28**
HEO	20.53	20.83	20.77	21.50	**20.99**	19.83	20.40	21.97	21.80	**21.01**
JAHEO	20.37	20.57	22.30	21.43	**21.17**	19.77	21.40	22.03	21.83	**21.26**
JEO	19.70	21.37	21.50	21.40	**20.99**	19.63	21.40	22.03	21.70	**21.19**
Mean	**20.23**	**21.19**	**21.49**	**21.56**		**19.75**	**21.27**	**21.95**	**21.94**	
LSD 0.05 Botanical oils			**NS**					**NS**		
LSD 0.05 Rates			**0.718**					**0.475**		
LSD 0.05 Botanical oils x Rates			**NS**					**NS**		

Key: CYP-Cypermethrin 10EC, AEO- Stool wood *Alstonia boonei.* oil, HEO- Bush tea *Hyptis suaveolens* oil, JAHEO- Mixed plant oils from Jathropha, Bush tea and Stool wood, JEO- *Jathropha tanjorensis* oil

Table 9: Effects of botanical oils on plant height 5 weeks after sowing in 2016 and 2017 Early and late farming Season

	Rates of botanical oils ml/100ml water									
Botanical oils	0.00	2.00	4.00	6.00	**Mean**	0.00	2.00	4.00	6.00	**Mean**
	Early 2016 farming season					**Late 2016 farming season**				
CYP	21.77	23.80	24.30	25.30	**23.79**	21.37	23.80	24.30	25.40	**23.71**
AEO	21.80	23.10	24.00	24.40	**23.32**	21.80	23.10	24.00	24.37	**23.32**
HEO	21.80	23.00	24.00	24.40	**23.31**	23.83	23.10	24.00	24.40	**23.33**
JAHEO	21.83	23.20	24.07	24.37	**24.35**	21.73	23.00	24.03	24.37	**23.31**
JEO	21.70	23.10	24.00	24.47	**23.32**	21.60	23.10	23.90	24.37	**23.24**
Mean	**21.78**	**23.24**	**24.07**	**24.59**		**21.67**	**23.24**	**24.07**	**24.58**	
LSD $_{0.05}$ Botanical oils			**0.155**			**0.140**				
LSD $_{0.05}$ Rates			**0.139**			**0.125**				
LSD $_{0.05}$ Botanical oils x Rates			**0.311**			**0.280**				
	Early 2017 farming season					**Late 2017 farming season**				
CYP	22.60	23.97	23.33	23.83	**23.43**	21.70	23.73	24.27	25.37	**23.77**
AEO	21.83	23.70	24.00	23.97	**23.37**	21.80	23.43	23.97	24.30	**23.37**
HEO	22.40	23.00	24.43	24.00	**23.46**	21.77	23.03	23.97	24.57	**23.33**
JAHEO	22.73	23.50	23.00	23.60	**23.21**	21.73	23.00	23.93	24.37	**23.27**
JEO	21.67	23.80	23.70	18.37	**22.00**	21.73	23.00	24.03	24.67	**23.35**
Mean	**22.25**	**23.59**	**23.69**	**23.87**		**21.73**	**23.25**	**24.03**	**24.65**	
LSD $_{0.05}$ Botanical oils			**NS**					**0.230**		
LSD $_{0.05}$ Rates			**0.743**					**0.206**		
LSD $_{0.05}$ Botanical oils x Rates			**NS**					**NS**		

Key: CYP-Cypermethrin 10EC, AEO- Stool wood *Alstonia boonei.* oil, HEO- Bush tea *Hyptis suaveolens* oil, JAHEO- Mixed plant oils from Jathropha, Bush tea and Stool wood, JEO- *Jathropha tanjorensis* oil

Table 10: Effects of botanical oils on damaged leaves at vegetative phase in 2016 and 2017 early and late farming Seasons

	Rates of botanical oils ml/100ml water									
Botanical oil	0.00	2.00	4.00	6.00	**Mean**	0.00	2.00	4.00	6.00	**Mean**
	Early 2016 farming season					**Late 2016 farming season**				
CYP	1.60	0.73	0.30	0.20	**0.71**	1.73	0.77	0.30	0.27	**0.77**
AEO	1.40	1.10	0.90	0.60	**1.00**	1.67	1.40	0.73	0.63	**1.11**
HEO	1.33	1.27	1.00	0.77	**1.07**	1.60	1.50	1.03	0.87	**1.25**
JAHEO	1.30	1.10	0.73	0.53	**0.92**	1.63	1.30	0.77	0.50	**1.05**
JEO	1.50	1.20	0.93	0.70	**1.08**	1.67	1.50	0.87	0.73	**1.19**
Mean	**1.43**	**1.08**	**0.77**	**0.56**		**1.66**	**1.29**	**0.74**	**0.60**	
LSD $_{0.05}$ Botanical oils			**0.080**						**0.060**	
LSD $_{0.05}$ Rates			**0.072**						**0.053**	
LSD $_{0.05}$ Botanical oils x Rates			**0.160**						**0.119**	
	Early 2017 farming season					**Late 2017 farming season**				
CYP	1.37	0.90	0.70	0.66	**0.91**	1.75	0.77	0.35	0.27	**0.78**
AEO	1.43	0.90	0.97	0.80	**1.03**	1.67	1.40	0.77	0.68	**1.33**
HEO	1.10	1.23	0.98	1.00	**1.08**	1.63	1.50	1.03	0.87	**1.26**
JAHEO	1.13	0.70	0.93	0.83	**0.90**	1.67	1.30	0.77	0.50	**1.08**
JEO	1.43	1.00	0.87	0.83	**1.03**	1.67	1.53	0.90	0.73	**1.21**
Mean	**1.29**	**0.95**	**0.89**	**0.82**		**1.67**	**1.30**	**0.75**	**0.60**	
LSD $_{0.05}$ Botanical oils			**NS**						**0.066**	
LSD $_{0.05}$ Rates			**0.283**						**0.059**	
LSD $_{0.05}$ Botanical oils x Rates			**NS**						**0.131**	

Key: CYP-Cypermethrin 10EC, AEO- Stool wood *Alstonia boonei.* oil, HEO- Bush tea *Hyptis suaveolens* oil, JAHEO- Mixed plant oils from Jathropha, Bush tea and Stool wood, JEO- *Jathropha tanjorensis* oil

Table 11: Effects of botanical oils on damaged leaves at flowering phase in 2016 and 2017 early and late farming Seasons

Botanical oils	Rates of botanical oils ml/100ml water									
	0.00	2.00	4.00	6.00	**Mean**	0.00	2.00	4.00	6.00	**Mean**
	Early 2016 farming season					**Late 2016 farming season**				
CYP	1.33	0.56	0.30	0.10	**0.62**	1.57	0.63	0.20	0.11	**0.63**
AEO	1.37	0.80	0.77	0.46	**0.93**	1.40	1.00	0.70	0.47	**0.89**
HEO	1.07	0.91	0.77	0.53	**0.96**	1.40	1.10	0.93	0.57	**1.00**
JAHEO	1.25	0.71	0.67	0.40	**0.82**	1.30	1.00	0.60	0.43	**0.83**
JEO	1.40	0.71	0.77	0.47	**0.95**	1.47	1.00	0.83	0.57	**0.97**
Mean	**1.28**	**0.74**	**0.65**	**0.39**		**1.43**	**0.95**	**0.65**	**0.43**	
LSD $_{0.05}$ Botanical oils			**0.103**					**0.070**		
LSD $_{0.05}$ Rates			**0.092**					**0.063**		
LSD $_{0.05}$ Botanical oils x Rates			**0.160**					**0.140**		
	Early 2017 farming season					**Late 2017 farming season**				
CYP	1.56	0.57	0.32	0.13	**0.65**	1.56	0.63	0.23	0.15	**0.63**
AEO	1.60	0.90	0.77	0.54	**0.95**	1.41	1.00	0.73	0.50	**0.91**
HEO	1.57	1.00	0.78	0.62	**0.99**	1.40	1.11	0.93	0.57	**1.00**
JAHEO	1.40	0.80	0.67	0.44	**0.83**	1.33	1.03	0.63	0.43	**0.86**
JEO	1.57	1.00	0.77	0.54	**0.97**	1.53	1.00	1.20	0.57	**1.11**
Mean	**1.54**	**0.85**	**0.66**	**0.46**		**1.45**	**0.95**	**0.75**	**0.44**	
LSD $_{0.05}$ Botanical oils			**0.108**					**0.212**		
LSD $_{0.05}$ Rates			**0.097**					**0.190**		
LSD $_{0.05}$ Botanical oils x Rates			**NS**					**0.424**		

Key: CYP-Cypermethrin 10EC, AEO- Stool wood *Alstonia boonei.* oil, HEO- Bush tea *Hyptis suaveolens* oil, JAHEO- Mixed plant oils from Jathropha, Bush tea and Stool wood, JEO- *Jathropha tanjorensis* oil

Table 12: Effects of botanical oils on damaged leaves at podding phase in 2016 and 2017 early and late farming Seasons

Botanical oils	Rates of botanical oils ml/100ml water									
	0.00	2.00	4.00	6.00	**Mean**	0.00	2.00	4.00	6.00	**Mean**
	Early 2016 farming season					**Late 2016 farming season**				
CYP	0.87	0.30	0.20	0.11	**0.37**	0.90	0.30	0.37	0.20	**0.44**
AEO	0.90	0.50	0.43	0.30	**0.53**	0.90	0.53	0.40	0.40	**0.56**
HEO	0.93	0.50	0.43	0.30	**0.54**	0.90	0.67	0.61	0.40	**0.58**
JAHEO	0.87	0.47	0.40	0.20	**0.51**	0.83	0.57	0.45	0.37	**0.55**
JEO	0.97	0.47	0.43	0.30	**0.54**	0.97	0.43	0.53	0.40	**0.59**
Mean	**0.91**	**0.45**	**0.38**	**0.25**		**0.90**	**0.50**	**0.52**	**0.35**	
LSD $_{0.05}$ Botanical oils			**0.080**					**0.053**		
LSD $_{0.05}$ Rates			**0.072**					**0.048**		
LSD $_{0.05}$ Botanical oils x Rates			**0.160**					**0.107**		
	Early 2017 farming season					**Late 2017 farming season**				
CYP	0.87	0.40	0.20	0.11	**0.37**	1.21	0.50	0.31	0.23	**0.57**
AEO	1.10	0.63	0.50	0.30	**0.53**	1.36	0.80	0.60	0.35	**0.77**
HEO	0.97	0.77	0.50	0.30	**0.54**	1.24	0.77	0.60	0.57	**0.80**
JAHEO	0.97	0.53	0.47	0.20	**0.51**	0.98	0.77	0.67	0.42	**0.59**
JEO	1.07	0.60	0.47	0.30	**0.54**	1.50	0.88	0.40	0.35	**0.76**
Mean	**0.99**	**0.59**	**0.43**	**0.26**		**1.27**	**0.73**	**0.52**	**0.35**	
LSD $_{0.05}$ Botanical oils			**NS**					**0.151**		
LSD $_{0.05}$ Rates			**0.283**					**0.117**		
LSD $_{0.05}$ Botanical oils x Rates			**NS**					**NS**		

Key: CYP-Cypermethrin 10EC, AEO- Stool wood *Alstonia boonei.* oil, HEO- Bush tea *Hyptis suaveolens* oil, JAHEO- Mixed plant oils from Jathropha, Bush tea and Stool wood, JEO- *Jathropha tanjorensis* oil

4.20 Effect of botanical oils on damaged pods and seeds by discoloration in 2016 and 2017 early and late farming Season

The effect of botanical oils on damaged pods and seeds by discoloration in 2016 and 2017 early and late farming Season is presented in Table 13. In 2016 early farming season, the result indicated that plots sprayed with plots sprayed with *A. boonei* oil (AEO) recorded the lowest mean number of pods and seeds by discoloration at 0.42. This was followed by plots sprayed with Cypermethrin (CYP) at 0.64. Plots sprayed with *H. suaveolens* oil (HEO) at 0.83 and Jathropha oil (JEO) at 0.92, while mixed plant oils (JAHEO) recorded the highest mean number pods and seeds by discoloration at 1.17, there were no significant difference between the botanical oils ($P \leq 0.05$). The medium application rates (4.00/0.40) recorded the lowest mean number of pods and seeds by discoloration at 0.47. This was followed by the highest application rates (6.00/0.60) at 0.60 and control rates (0.00/0.00) at 0.93, while the least application rates (2.00/0.20) recorded the highest mean number of pods and seeds by discoloration at 0.33. There were significant differences between the rates of application ($P \leq 0.05$). The interaction between the acting ingredients and rates of application indicated that there were no significant differences between the acting ingredients and rates of application ($P \leq 0.05$).

In 2016 late farming season, the result indicated that plots sprayed with *A. boonei* oil (AEO) recorded the lowest mean number of pods and seeds by discoloration at 0.42. This was followed by plots sprayed with Cypermethrin (CYP) at 0.67 and Jathropha oil (JEO) at 1.00, while plots sprayed with *H. suaveolens* oil (HEO) and mixed plant oils (JAHEO) recorded the highest mean number pods and seeds by discoloration at 1.08, there were no significant difference between the botanical oils ($P \leq 0.05$). The highest application rates (6.00/0.60) recorded the lowest mean number of Pods and Seeds by discoloration at 0.73. This was followed by the least application rates (2.00/0.20) and medium application rates (4.00/0.40) at 0.80, while the control rates (0.00/0.00) recorded the highest mean number of pods and seeds by discoloration at 1.27. There were no significant difference between the rates of application (P≤0.05). The interaction between the botanical oils and rates of application indicated that there were no significant difference between the botanical oils and rates of application (P≤0.05).

In 2017 early farming season, the result indicated that plots sprayed with *A. boonei* extracted oil (AEO) recorded the lowest mean number of pods and seeds by discoloration at 0.58. This was followed by plots sprayed with Cypermethrin (CYP) and *H. suaveolens* oil (HEO) at 1.17, while plots sprayed with mixed plant oils (JAHEO) and Jathropha oil (JEO) recorded the highest mean number pods and seeds by discoloration at 1.25, there were significant difference between the botanical oils (P≤0.05). The highest application rates (6.00/0.60) at 0.73 recorded the lowest mean number of pods and seeds by discoloration at 0.47. This was followed by the control rates (0.00/0.00) at 0.87 and medium application rates (4.00/0.40) at 1.00, while the least application rates (2.00/0.20) recorded the highest mean number of pods and seeds by discoloration at 1.20. There were no significant difference between the rates of application (P≤0.05). The interaction between the botanical oils and rates of application indicated that there were no significant difference between the botanical oils and rates of application (P≤0.05).

In 2017 late farming season, the result showed that plots sprayed with Cypermethrin (CYP) recorded the lowest mean number pods and seeds by discoloration at 0.42. This was followed by plots sprayed with *A. boonei* oil (AEO) at 0.75. The plots spayed with *H. suaveolens* oil (HEO) and Jathropha oil (JEO) recorded 1.00 each, while plots sprayed with mixed plant oils (JAHEO) recorded the highest mean number of pods and seeds by discoloration at 1.58, there were significant difference between the botanical oils (P≤0.05). The highest application rates (6.00/0.60) recorded the lowest mean number of pods and seeds by discoloration at 0.73. This was followed by the least application rates (2.00/0.20) and medium application rates (4.00/0.40) at 0.80, while the control rates (0.00/0.00) recorded the highest mean number of pods and seeds by discoloration at 1.27. There were no significant difference between the rates of application

(P≤0.05). The interaction between the botanical oils and rates of application indicated that there were no significant difference between the botanical oils and rates of application (P≤0.05).

4.21 Effect of botanical oils on damaged pods and seeds by exist hole in 2016 and 2017 early and late farming Season

The Effect of botanical oils on damaged pods and seeds by exist hole in 2016 and 2017 early and late farming Season is presented in Table 14. In 2016 early farming season, the result indicated that plots sprayed with *A. boonei* oil (AEO) recorded the lowest mean number pods and seeds by exist hole at 0.42. This was followed by plots sprayed with Cypermethrin (CYP) at 0.50. Plots sprayed with and Jathropha oil (JEO) recorded 0.58 and *H. suaveolens* oil (HEO) at 0.67, while plots sprayed with mixed plant extracted oils (JAHEO) recorded the lowest mean number of pods and seeds by exist hole at 0.75, there were no significant difference between the botanical oils (P≤0.05). The medium application rates (4.00/0.40) recorded the lowest mean number of Pods and seeds by exist hole at 0.40. This was followed by the highest application rates (6.00/0.60) at 0.53 and control rates (0.00/0.00) at 0.67, while the least application rates (2.00/0.20) recorded the highest mean number of Pods and Seeds by Exist hole at 0.73. There were no significant difference between the rates of application (P≤0.05). The interaction between the botanical oils and rates of application indicated that there were no significant difference between the botanical oils and rates of application (P≤0.05).

In 2016 late farming season, the result indicated that plots sprayed with mixed plant extracted oils (JAHEO) recorded the lowest mean number pods and seeds by exist hole at 0.42. This was followed by plots sprayed with *A. boonei* oil (AEO) at 0.50. Plots sprayed with Jathropha oil (JEO) recorded 0.67, while plots sprayed Cypermethrin (CYP) and *H. suaveolens* oil (HEO) recorded the lowest mean number of pods and seeds by exist hole at 0.83, there were no significant difference between the botanical oils (P≤0.05). The highest application rates

(6.00/0.60), the least application rates (2.00/0.20) and control rates (0.00/0.00) recorded at 0.67 recorded the lowest mean number of pods and seeds by exist hole at 0.40. This was followed by, while medium application rates (4.00/0.40) recorded the highest mean number of pods and seeds by exist hole at 0.80. There were no significant difference between the rates of application ($P \leq 0.05$). The interaction between the botanical oils and rates of application indicated that there were no significant difference between the botanical oils and rates of application ($P \leq 0.05$).

In 2017 early farming season, the result indicated that plots sprayed with *H. suaveolens* oil (HEO), mixed plant oils (JAHEO) and Jathropha oil (JEO) recorded the lowest mean number pods and seeds by exist hole at 0.58. This was followed by plots sprayed with *A. boonei* extracted oil (AEO) at 0.83, while plots sprayed with Cypermethrin (CYP) recorded the highest mean number of pods and seeds by exist hole at 0.84, there were significant difference between the botanical oils ($P \leq 0.05$). The highest application rates (6.00/0.60) recorded the lowest mean number of pods and seeds by exist hole at 0.40. This was followed by the medium application rates (4.00/0.40) and control rates (0.00/0.00) at 0.67, while the least application rates (2.00/0.20) recorded the highest mean number of pods and seeds by exist hole at 0.80. There were no significant difference between the rates of application ($P \leq 0.05$). The interaction between the botanical oils and rates of application indicated that there were no significant difference between the botanical oils and rates of application ($P \leq 0.05$).

In 2017 late farming season, the result indicated that plots sprayed with Cypermethrin (CYP) the lowest mean number pods and seeds by exist hole at 0.25. This was followed by plots sprayed with Jathropha oil (JEO) at 0.50 and *A. boonei* oil (AEO) at 0.75. Plots sprayed with *H. suaveolens* oil (HEO) recorded 0.83, while plots sprayed with mixed plant oils (JAHEO) recorded the highest mean number of pods and seeds by exist hole at 1.25, there were no significant difference between the botanical oils ($P \leq 0.05$). The medium application rates (4.00/0.40) recorded the lowest mean number of pods and seeds by exist hole at 0.53. This was followed by the least application rates (2.00/0.20) at 0.67 and highest application rates (6.00/0.60) at 0.73, while control rates (0.00/0.00) recorded the highest mean number of pods and seeds by exist hole at 0.93. There were no significant difference between the rates of application (P≤0.05). The interaction between the botanical oils and rates of application indicated that there were no significant difference between the botanical oils and rates of application (P≤0.05).

4.22 Effect of botanical oils on damaged pods and seeds by shriveling in 2016 and 2017 early and late farming Season

The Effect of botanical oils on damaged pods and seeds by shriveling in 2016 and 2017 early and late farming Season is presented in Table 15. In 2016 early farming season, the result indicated that plots sprayed with mixed plant oils (JAHEO) recorded the lowest mean number pods and seeds by shriveling at 0.50. This was followed by plots sprayed with Cypermethrin (CYP) and *H. suaveolens* oil (HEO) at 0.75. Plots sprayed with *A. boonei* oil (AEO) recorded 0.83, while plots sprayed Jathropha oil (JEO) with recorded the highest mean number of Pods and Seeds by Shriveling at 0.92, there were no significant difference between the botanical oils (P≤0.05). The highest application rates (6.00/0.60) and medium application rates (4.00/0.40) recorded the lowest mean number of pods and seeds by shriveling at 0.67. This was followed by control rates (0.00/0.00) at 0.80, while the least application rates (2.00/0.20) recorded the highest mean number of pods and seeds by shriveling at 0.87. There were no significant difference between the rates of application (P≤0.05). The interaction between the botanical oils and rates of application indicated that there were no significant difference between the botanical oils and rates of application (P≤0.05).

In 2016 late farming season, the result indicated that plots sprayed with mixed plant oils (JAHEO) and Cypermethrin (CYP) recorded the lowest mean number pods and seeds by shriveling at 0.67. This was followed by plots sprayed with *A. boonei* oil (AEO) and *H. suaveolens* oil (HEO) at

0.83, while plots sprayed with Jathropha oil (JEO) recorded the highest mean number of pods and seeds by shriveling at 0.92, there were no significant difference between the botanical oils ($P \leq 0.05$). The medium application rates (4.00/0.40) and the least application rates (2.00/0.20) recorded the lowest mean number of pods and seeds by shriveling at 0.67. This was followed by highest application rates (6.00/0.60) at 0.87, while the control rates (0.00/0.00) recorded the highest mean number of pods and seeds by shriveling 0.93. There were no significant difference between the rates of application ($P \leq 0.05$). The interaction between the botanical oils and rates of application indicated that there were no significant difference between the botanical oils and rates of application ($P \leq 0.05$).

In the 2017 early farming season, the result indicated that plots sprayed with mixed plant oils (JAHEO) recorded the lowest mean number of pods and seeds by shriveling at 0.33. This was followed by plots sprayed with Cypermethrin (CYP) at 0.75 and Jathropha oil (JEO) at 0.83, while plots sprayed with *H. suaveolens* oil (HEO) and *A. boonei* oil (AEO) recorded the highest mean number of pods and seeds by shriveling at 1.00. there were no significant difference between the botanical oils ($P \leq 0.05$). The medium application rates (4.00/0.40) recorded the lowest mean number of pods and seeds by shriveling at 0.53. This was followed by the highest application rates (6.00/0.60) at 0.80 and control rates (0.00/0.00) at 0.87, while the least application rates (2.00/0.20) recorded the highest mean number of pods and seeds by shriveling at 0.93. There were no significant difference between the rates of application ($P \leq 0.05$). The interaction between the botanical oils and rates of application indicated that there were no significant difference between the botanical oils and rates of application ($P \leq 0.05$).

In 2017 late farming season, the result showed that plots sprayed with mixed plant oils (JAHEO) and Cypermethrin (CYP) recorded the lowest mean number pods and seeds by shriveling at 0.75. This was followed by plots sprayed with Jathropha extracted oil (JEO) and *A. boonei* extracted oil (AEO) at 0.83, while plots sprayed with *H. suaveolens* extracted oil (HEO) recorded the highest mean number of pods and seeds by shriveling at 0.92, there were no significant difference between the botanical oils (P≤0.05). The medium application rates (4.00/0.40) recorded the lowest mean number of pods and seeds by shriveling at 0.53. This was followed by the least application rates (2.00/0.20) at 0.87 and, while highest application rates (6.00/0.60) and control rates (0.00/0.00) recorded the highest mean number of pods and seeds by shriveling at 0.93. There were no significant difference between the rates of application (P≤0.05). The interaction between the botanical oils and rates of application indicated that there were no significant difference between the botanical oils and rates of application (P≤0.05).

Table 13: Effect of botanical oils on damaged pods and seeds by discoloration in 2016 and 2017 early and late farming Season

	Rates of botanical oils ml/100ml water									
	0.00	2.00	4.00	6.00		0.00	2.00	4.00	6.00	
Acting	0.00	0.20	0.40	0.60	**Mean**	0.00	0.20	0.40	0.60	**Mean**
Early 2016 farming season						**Late 2016 farming season**				
CYP	0.67	1.00	0.00	1.00	**0.67**	1.33	1.33	0.33	0.67	**0.92**
AEO	0.33	1.00	0.33	0.00	**0.42**	0.33	0.33	0.33	0.67	**0.42**
HEO	1.33	1.33	0.33	0.33	**0.83**	1.33	1.00	1.33	0.67	**1.08**
JAHEO	1.33	1.33	1.00	1.00	**1.17**	2.00	0.67	1.33	0.33	**1.08**
JEO	1.00	1.00	0.67	0.67	**0.92**	1.33	0.67	0.67	1.33	**1.00**
Mean	**0.93**	**1.20**	**0.47**	**0.60**		**1.27**	**0.80**	**0.80**	**0.73**	
LSD $_{0.05}$ Botanical oils			**NS**					**NS**		
LSD $_{0.05}$ Rates			**0.503**					**NS**		
LSD $_{0.05}$ Botanical oils x Rates			**NS**					**NS**		
Early 2017 farming season						**Late 2017 farming season**				
CYP	1.00	1.67	1.00	1.00	**1.17**	0.67	1.33	0.33	0.33	**0.42**
AEO	0.33	1.33	0.67	0.00	**0.58**	1.00	0.33	0.67	0.67	**0.75**
HEO	133	1.33	1.33	0.67	**1.17**	0.67	1.00	1.00	1.00	**1.00**
JAHEO	0.33	0.67	0.33	1.00	**0.58**	1.33	2.00	1.33	1.33	**1.58**
JEO	1.33	1.00	1.67	1.00	**1.25**	1.00	1.67	0.67	0.67	**1.00**
Mean	**0.87**	**1.20**	**1.00**	**0.73**		**0.93**	**1.07**	**0.80**	**1.00**	
LSD $_{0.05}$ Botanical oils			**0.575**					**0.553**		
LSD $_{0.05}$ Rates			**NS**					**NS**		
LSD $_{0.05}$ Botanical oils x Rates			**NS**					**NS**		

Key: CYP-Cypermethrin 10EC, AEO- Stool wood *Alstonia boonei.* oil, HEO- Bush tea *Hyptis suaveolens* oil, JAHEO- Mixed plant oils from Jathropha, Bush tea and Stool wood, JEO- *Jathropha tanjorensis* oil

Table 14: Effect of botanical oils on damaged pods and seeds by exist hole in 2016 and 2017 early and late farming Season

	Rates of botanical oils ml/100ml water									
Botanical	0.00	2.00	4.00	6.00		0.00	2.00	4.00	6.00	
oils	0.00	0.20	0.40	0.60	**Mean**	0.00	0.20	0.40	0.60	**Mean**
Early 2016 farming season						**Late 2016 farming season**				
CYP	1.00	0.33	0.00	0.67	**0.50**	0.67	1.00	0.67	1.00	**0.83**
AEO	0.33	1.00	0.33	0.00	**0.42**	0.33	0.33	0.33	1.00	**0.50**
HEO	0.67	1.00	0.33	0.67	**0.67**	0.67	0.67	1.33	0.67	**0.83**
JAHEO	0.67	0.67	0.67	1.00	**0.75**	0.67	0.00	1.00	0.00	**0.42**
JEO	0.67	0.67	0.67	0.33	**0.58**	0.67	1.00	0.67	0.33	**0.67**
Mean	**0.67**	**0.73**	**0.40**	**0.53**		**0.60**	**0.60**	**0.80**	**0.60**	
LSD $_{0.05}$ Botanical oils			**NS**					**NS**		
LSD $_{0.05}$ Rates			**NS**					**NS**		
LSD $_{0.05}$ Botanical oils x Rates			**NS**					**NS**		
Early 2017 farming season						**Late 2017 farming season**				
CYP	1.00	0.67	0.67	1.00	**0.84**	0.67	1.00	0.33	0.00	**0.25**
AEO	0.67	1.67	0.67	0.33	**0.83**	1.67	0.33	0.33	0.67	**0.75**
HEO	0.67	0.33	1.00	0.33	**0.58**	0.67	1.33	0.33	1.00	**0.83**
JAHEO	0.33	0.67	0.33	1.00	**0.58**	1.00	1.33	1.33	1.33	**1.25**
JEO	0.67	0.67	0.67	0.33	**0.58**	0.67	0.33	0.33	0.67	**0.50**
Mean	**0.67**	**0.80**	**0.67**	**0.60**		**0.93**	**0.67**	**0.53**	**0.73**	
LSD $_{0.05}$ Botanical oils			**0.575**					**0.547**		
LSD $_{0.05}$ Rates			**NS**					**NS**		
LSD $_{0.05}$ Botanical oils x Rates			**NS**					**NS**		

Key: CYP-Cypermethrin 10EC, AEO- Stool wood *Alstonia boonei.* oil, HEO- Bush tea *Hyptis suaveolens* oil, JAHEO- Mixed plant oils from Jathropha, Bush tea and Stool wood, JEO- *Jathropha tanjorensis* oil

Table 15: Effect of botanical oils on damaged pods and seeds by shriveling in 2016 and 2017 early and late farming Season

	Rates of botanical oils ml/100ml water									
Botanical	0.00	2.00	4.00	6.00		0.00	2.00	4.00	6.00	
oils	0.00	0.20	0.40	0.60	**Mean**	0.00	0.20	0.40	0.60	**Mean**
Early 2016 farming season						**Late 2016 farming season**				
CYP	1.00	0.67	0.67	0.67	**0.75**	0.67	0.33	0.67	1.00	**0.67**
AEO	1.33	0.67	0.33	1.00	**0.83**	1.33	0.67	0.33	1.00	**0.83**
HEO	0.33	1.00	0.67	1.00	**0.75**	0.67	0.67	1.33	1.00	**0.83**
JAHEO	0.00	0.67	0.67	0.67	**0.50**	0.67	1.00	0.33	0.67	**0.67**
JEO	1.33	1.33	1.00	1.00	**0.92**	1.33	0.67	1.00	0.67	**0.92**
Mean	**0.80**	**0.87**	**0.67**	**0.67**		**0.93**	**0.67**	**0.67**	**0.87**	
LSD $_{0.05}$ Botanical oils				**NS**				**NS**		
LSD $_{0.05}$ Rates				**NS**				**NS**		
LSD $_{0.05}$ Botanical oils x Rates				**NS**				**NS**		
Early 2017 farming season						**Late 2017 farming season**				
CYP	0.67	0.67	0.33	1.33	**0.75**	0.67	1.00	0.67	0.67	**0.75**
AEO	1.33	1.00	0.67	1.00	**1.00**	2.00	0.67	0.33	0.33	**0.83**
HEO	1.00	1.33	1.00	0.67	**1.00**	0.33	1.00	1.00	1.33	**0.92**
JAHEO	0.67	0.33	0.33	0.00	**0.33**	0.33	1.00	0.33	1.33	**0.75**
JEO	0.67	1.33	0.33	1.00	**0.83**	1.33	0.67	0.33	1.00	**0.83**
Mean	**0.87**	**0.93**	**0.53**	**0.80**		**0.93**	**0.87**	**0.53**	**0.93**	
LSD $_{0.05}$ Botanical oils				**NS**				**NS**		
LSD $_{0.05}$ Rates				**NS**				**NS**		
LSD $_{0.05}$ Botanical oils x Rates				**NS**				**NS**		

Key: CYP-Cypermethrin 10EC, AEO- Stool wood *Alstonia boonei.* oil, HEO- Bush tea *Hyptis suaveolens* oil, JAHEO- Mixed plant oils from Jathropha, Bush tea and Stool wood, JEO- *Jathropha tanjorensis* oil

4.23 Effect of botanical oils on 100 pod weight (g) in 2016 and 2017 early and late farming Season

The Effect of botanical oils on 100 pod weight in 2016 and 2017 early and late farming Season is presented in Table 16. In 2016 early farming season, the result showed that plots sprayed with Cypermethrin (CYP) recorded the highest mean 100 pod weight at 103.92g. This was followed by plots sprayed with mixed plant oils (JAHEO) at 100.25g and *A. boonei* d oil (AEO) at 98.25g. Plots sprayed with Jathropha oil (JEO) recorded 97.50g, while plots sprayed with *H. suaveolens* oil (HEO) recorded the least mean 100 Pod weight at 96.75g, there were significant difference between the botanical oils ($P \leq 0.05$). The highest application rates (6.00/0.60) recorded the highest mean 100 pod weight at 104.20g. This was followed by the medium application rates (4.00/0.40) at 101.07g and the least application rates (2.00/0.20) at 99.47g, while the control rates (0.00/0.00) recorded the least mean 100 pod weight at 93.80g. There were significant difference between the rates of application ($P \leq 0.05$). The interaction between the botanical oils and rates of application indicated that there were significant difference between the botanical oils and rates of application ($P \leq 0.05$).

In 2016 late farming season, the result indicated that plots sprayed with Cypermethrin (CYP) recorded the highest mean 100 pod weight at 103.50g. This was followed by plots sprayed with mixed plant oils (JAHEO) at 98.92g and *A. boonei* oil (AEO) at 97.92g. Plots sprayed with Jathropha oil (JEO) recorded 97.17g, while plots sprayed with and *H. suaveolens* oil (HEO) recorded the least mean 100 pod weight at 95.67g, there were significant difference between the botanical oils ($P \leq 0.05$). The highest application rates (6.00/0.60) recorded the highest mean 100 pod weight at 103.20g. This was followed by the medium application rates (4.00/0.40) at 100.67g and the least application rates (2.00/0.20) at 97.20g, while the control rates (0.00/0.00) recorded the least mean 100 pod weight at 93.47g. There were significant difference between the rates of application ($P \leq 0.05$). The interaction between the botanical oils and rates of application indicated that there were significant difference between the botanical oils and rates of application ($P \leq 0.05$).

In 2017 early farming season, the result revealed that plots sprayed with Cypermethrin (CYP) recorded the highest mean 100 pod weight at 103.67g. This was followed by plots sprayed with mixed plant oils (JAHEO) at 99.08g and *A. boonei* oil (AEO) at 98.00g. Plots sprayed with Jathropha oil (JEO) recorded 97.42g, while plots sprayed with and *H. suaveolens* oil (HEO) recorded the least mean 100 pod weight at 96.67g, there were significant difference between the botanical oils ($P \leq 0.05$). The highest application rates (6.00/0.60) recorded the highest mean 100 pod weight at 103.93g. This was followed by the medium application rates (4.00/0.40) at 100.67g and the least application rates (2.00/0.20) at 97.47g, while the control rates (0.00/0.00) recorded the least mean 100 pod weight at 93.80g. There were significant difference between the rates of application ($P \leq 0.05$). The interaction between the botanical oils and rates of application indicated that there were significant difference between the botanical oils and rates of application ($P \leq 0.05$).

In 2017 late farming season, the result showed that plots sprayed with Cypermethrin (CYP) recorded the highest mean 100 pod weight at 101.50g. This was followed by plots sprayed with mixed plant oils (JAHEO) at 99.25g and *A. boonei* oil (AEO) at 97.58g. Plots sprayed with *H. suaveolens* oil (HEO) recorded 97.33g, while plots sprayed with Jathropha oil (JEO) recorded the least mean 100 pod weight at 95.75g, there were significant differences between the botanical oils ($P \leq 0.05$). The highest application rates (6.00/0.60) recorded the highest mean 100 pod weight at 100.53g. This was followed by the least application rates (2.00/0.20) at 99.33g and the medium application rates (4.00/0.40) at 98.73g, while the control rates (0.00/0.00) recorded the least mean 100 pod weight at 94.53g. There were significant difference between the rates of application ($P \leq 0.05$). The interaction between the botanical oils and rates of application indicated that there were significant difference between the botanical oils and rates of application ($P \leq 0.05$).

4.23 Effect of botanical oils on 100 seed weight (g) in 2016 and 2017 early and late farming Season

The Effect of botanical oils on 100 seed weight in 2016 and 2017 early and late farming Season is presented in Table 17. In 2016 early farming season, the result showed that plots sprayed with Cypermethrin (CYP) recorded the highest mean 100 seed weight at 92.42g. This was followed by plots sprayed with mixed plant oils (JAHEO) at 88.12g and *A. boonei* oil (AEO) at 86.25g. Plots sprayed with Jathropha oil (JEO) recorded 85.67g, while plots sprayed with *H. suaveolens* oil (HEO) recorded the least mean 100 seed weight at 85.00g, there were significant difference between the botanical oils ($P \leq 0.05$). The highest application rates (6.00/0.60) recorded highest mean 100 seed weight at 96.60g. This was followed by the medium application rates (4.00/0.40) at 89.13g and the least application rates (2.00/0.20) at 85.40g, while the control rates (0.00/0.00) recorded the least mean 100 seed weight at 81.40g. There were significant difference between the rates of application ($P \leq 0.05$). The interaction between the botanical oils and rates of application indicated that there were significant difference between the botanical oils and rates of application ($P \leq 0.05$).

In 2016 late farming season, the result indicated that plots sprayed with Cypermethrin (CYP) recorded the highest mean 100 seed weight at 92.17g. This was followed by plots sprayed with mixed plant oils (JAHEO) at 90.34g. Plots sprayed with *A. boonei* oil (AEO) and *H. suaveolens* oil (HEO) recorded 85.92g, while plots sprayed with Jathropha oil (JEO) recorded the least mean 100 seed weight at 85.33g, there were significant difference between the botanical oils ($P \leq 0.05$). The highest application rates (6.00/0.60) recorded highest mean 100 seed weight at 93.53g. This was followed by the medium application rates (4.00/0.40) at 89.40g and the least application rates (2.00/0.20) at 86.54g, while the control rates (0.00/0.00) recorded the least mean 100 seed weight at 81.33g. There were significant difference between the rates of application ($P \leq 0.05$). The interaction between the botanical oils and rates of application indicated that there were significant difference between the botanical oils and rates of application ($P \leq 0.05$).

In 2017 early farming season, the result revealed that plots sprayed with Cypermethrin (CYP) recorded the highest mean 100 seed weight at 92.17g. This was followed by plots sprayed with mixed plant oils (JAHEO) at 87.25g and *A. boonei* oil (AEO) at 86.00g. Plots sprayed with Jathropha oil (JEO) recorded 85.58g, while plots sprayed with and *H. suaveolens* oil (HEO) recorded the least mean 100 seed weight at 84.92g, there were significant difference between the botanical oils ($P \leq 0.05$). The highest application rates (6.00/0.60) recorded highest mean 100 seed weight at 93.20g. This was followed by the medium application rates (4.00/0.40) at 88.73g and the least application rates (2.00/0.20) at 85.40g, while the control rates (0.00/0.00) recorded the least mean 100 seed weight at 81.40g. There were significant difference between the rates of application ($P \leq 0.05$). The interaction between the botanical oils and rates of application showed that there were significant difference between the botanical oils and rates of application ($P \leq 0.05$).

In 2017 late farming season, the result indicated that plots sprayed with Cypermethrin (CYP) recorded the highest mean 100 seed weight at 89.83g. This was followed by plots sprayed with mixed plant oils (JAHEO) at 87.58g. Plots sprayed with *H. suaveolens* oil (HEO) recorded 85.50g and *A. boonei* oil (AEO) at 85.42, while plots sprayed with Jathropha oil (JEO) recorded the least mean 100 seed weight at 84.75g, there were significant difference between the botanical oils ($P \leq 0.05$). The highest application rates (6.00/0.60) recorded highest mean 100 seed weight at 89.33g. This was followed by the medium application rates (4.00/0.40) at 87.53g and the least application rates (2.00/0.20) at 87.20g, while the control rates (0.00/0.00) recorded the least mean 100 seed weight at 82.40g. There were significant difference between the rates of application ($P \leq 0.05$). The interaction between the botanical oils and rates of application indicated that there were significant difference between the botanical oils and rates of application ($P \leq 0.05$).

4.24 Effect of botanical oils on pod yield (kg/ha) in 2016 and 2017 early and late farming Season

The Effect of botanical oils on pod yield in 2016 and 2017 early and late farming Season is presented in Table 18. In 2016 early farming season, the result showed that plots sprayed with Cypermethrin (CYP) recorded the highest mean pod yield at 0.71 kg. This was followed by plots sprayed with mixed plant oils (JAHEO) at 0.63 kg and *A. boonei* oil (AEO) at 0.58 kg, while plots sprayed with Jathropha oil (JEO) recorded 0.59 kg and *H. suaveolens* oil (HEO) recorded the least mean pod yield at 0.58 kg, there were variations between the botanical oils ($P \leq 0.05$). The highest application rates (6.00/0.60) recorded highest mean pod yield at 0.70 kg. This was followed by the medium application rates (4.00/0.40) at 0.65 kg and the least application rates (2.00/0.20) at 0.60 kg, while the control rates (0.00/0.00) recorded the least mean pod yield at 0.53 kg. There were variations between the rates of application ($P \leq 0.05$). The interaction between the botanical oils and rates of application indicated that there were variations between the botanical oils and rates of application ($P \leq 0.05$).

In 2016 late farming season, the result showed that plots sprayed with Cypermethrin (CYP) recorded the highest mean pod yield at 0.63 kg. This was followed by plots sprayed with mixed plant oils (JAHEO) 0.56 kg and *A. boonei* oil (AEO) recorded 0.55 kg, while plots sprayed with d with Jathropha oil (JEO) and *H. suaveolens* oil (HEO) recorded the least mean pod yield at 0.53 kg respectively, there were variations between the botanical oils ($P \leq 0.05$). The highest application rates (6.00/0.60) recorded highest mean pod yield at 0.66 kg. This was followed by the medium application rates (4.00/0.40) at 0.59 kg and the least application rates (2.00/0.20) at 0.54 kg, while the control rates (0.00/0.00) recorded the least mean pod yield at 0.45 kg. There were variations between the rates of application ($P \leq 0.05$). The interaction between the botanical oils and rates of application indicated that there were variations between the botanical oils and rates of application ($P \leq 0.05$).

In 2017 early farming season, the result showed that plots sprayed with Cypermethrin (CYP) recorded the highest mean pod yield at 0.69 kg. This was followed by plots sprayed with mixed plant oils (JAHEO) at 0.62 kg and *A. boonei* oil (AEO) at 0.59 kg, while plots sprayed with Jathropha oil (JEO) recorded 0.58 kg and *H. suaveolens* oil (HEO) recorded the least mean pod yield at 0.57 kg, there were variations between the botanical oils ($P \leq 0.05$). The highest application rates (6.00/0.60) recorded highest mean pod yield at 0.69kg. This was followed by the medium application rates (4.00/0.40) at 0.64 kg and the least application rates (2.00/0.20) at 0.59 kg, while the control rates (0.00/0.00) recorded the least mean pod yield at 0.52 kg. There were variations between the rates of application ($P \leq 0.05$). The interaction between the botanical oils and rates of application indicated that there were variations between the botanical oils and rates of application ($P \leq 0.05$).

In 2017 late farming season, the result revealed that plots sprayed with Cypermethrin (CYP) recorded the highest mean pod yield at 0.60 kg. This was followed by plots sprayed with mixed plant oils of (JAHEO) at 0.55 kg. Plots sprayed with *H. suaveolens* oil (HEO) and *A. boonei* botanical oils oil (AEO) recorded 0.52 kg respectively, while plots sprayed with Jathropha oil (JEO) recorded the least mean pod yield at 0.51 kg, there were variations between the botanical oils ($P \leq 0.05$). The highest application rates (6.00/0.60) recorded highest mean pod yield at 0.58 kg. This was followed by the medium application rates (4.00/0.40) and the least application rates (2.00/0.20) at 0.55 kg respectively, while the control rates (0.00/0.00) recorded the least mean pod yield at 0.47 kg. There were variations between the rates of application ($P \leq 0.05$). The interaction between the botanical oils and rates of application indicated that there were variations between the botanical oils and rates of application ($P \leq 0.05$).

4.25 Effect of botanical oils on seed yield (kg/ha) in 2016 and 2017 early and late farming Season

The Effect of botanical oils on seed yield in 2016 and 2017 early and late farming Season is presented in Table 19. In 2016 early farming season, the result showed that plots sprayed with Cypermethrin (CYP) recorded the highest mean seed yield at 0.59kg. This was followed by plots sprayed with mixed plant oils (JAHEO) at 0.51 kg and *A. boonei* oil (AEO) at 0.49 kg. Plots sprayed with Jathropha extracted oil (JEO) recorded 0.47 kg, while plots sprayed with *H. suaveolens* oil (HEO) recorded the least mean seed yield at 0.465kg, there were variations between the botanical oils (P≤0.05). The highest application rates (6.00/0.60) recorded highest mean seed yield at 0.58 kg. This was followed by the medium application rates (4.00/0.40) at 0.52 kg and the least application rates (2.00/0.20) at 0.42 kg, while the control rates (0.00/0.00) recorded the least mean seed yield at 0.42 kg. There were variations between the rates of application (P≤0.05). The interaction between the botanical oils and rates of application indicated that there were variations between the acting ingredients and rates of application (P≤0.05).

In 2016 late farming season, the result revealed that plots sprayed with Cypermethrin (CYP) recorded the highest mean seed yield at 0.53 kg. This was followed by plots sprayed with mixed plant oils (JAHEO) at 0.46 kg and *A. boonei* oil (AEO) and Jathropha oil (JEO) recorded 0.42 kg respectively, while plots sprayed with *H. suaveolens* oil (HEO) recorded the least mean seed yield at 0.39 kg, there were variations between the botanical oils (P≤0.05). The highest application rates (6.00/0.60) recorded highest mean seed yield at 0.52 kg. This was followed by the medium application rates (4.00/0.40) at 0.46 kg and the least application rates (2.00/0.20) at 0.41 kg, while the control rates (0.00/0.00) recorded the least mean seed yield at 0.36 kg. There were variations between the rates of application (P≤0.05). The interaction between the botanical oils and rates of application showed that there were variations between the botanical oils and rates of application (P≤0.05).

In 2017 early farming season, the result showed that plots sprayed with Cypermethrin (CYP) recorded the highest mean seed yield at 0.58 kg. This was followed by plots sprayed with mixed plant oils (JAHEO) at 0.50 kg and *A. boonei* oil (AEO) at 0.47 kg. Plots sprayed with Jathropha oil (JEO) recorded 0.45 kg, while plots sprayed with *H. suaveolens* oil (HEO) recorded the least mean seed yield at 0.44 kg, there were variations between the Acting Ingredients ($P \leq 0.05$). The highest application rates (6.00/0.60) recorded highest mean seed yield at 0.56 kg. This was followed by the medium application rates (4.00/0.40) at 0.51 kg and the least application rates (2.00/0.20) at 0.47 kg, while the control rates (0.00/0.00) recorded the least mean seed yield at 0.40 kg. There were variations between the rates of application ($P \leq 0.05$). The interaction between the botanical oils and rates of application showed that there were variations between the botanical oils and rates of application ($P \leq 0.05$).

In 2017 late farming season, the result indicated that plots sprayed with Cypermethrin (CYP) recorded the highest mean seed yield at 0.48 kg. This was followed by plots sprayed with mixed plant oils (JAHEO) at 0.43 kg. Plots sprayed with *A. boonei* oil (AEO) recorded 0.41 kg and *H. suaveolens* oil (HEO) recorded 0.40 kg, while plots sprayed with Jathropha oil (JEO) recorded the least mean seed yield at 0.37 kg, there variations between the botanical oils ($P \leq 0.05$). The highest application rates (6.00/0.60) recorded highest mean seed yield at 0.45 kg. This was followed by the least application rates (2.00/0.20) at 0.43 kg and the medium application rates (4.00/0.40) at 0.42 kg, while the control rates (0.00/0.00) recorded the least mean seed yield at 0.36 kg. There were variations between the rates of application ($P \leq 0.05$). The interaction between the botanical oils and rates of application showed that there were variations between the botanical oils and rates of application ($P \leq 0.05$).

Table 16: Effect of botanical oils on 100 pod weight (g/plot) in 2016 and 2017 early and late farming Season

	Rates of botanical oils ml/100ml water									
Botanical	0.00	2.00	4.00	6.00		0.00	2.00	4.00	6.00	
oils	0.00	0.20	0.40	0.60	**Mean**	0.00	0.20	0.40	0.60	**Mean**
Early 2016 farming season						**Late 2016 farming season**				
CYP	94.00	105.00	105.00	109.67	**103.92**	93.67	104.67	106.33	109.33	**103.50**
AEO	95.00	95.67	99.33	103.00	**98.25**	94.67	95.33	99.00	102.67	**97.92**
HEO	94.00	95.67	98.00	100.00	**96.75**	93.67	94.67	97.67	96.67	**95.67**
JAHEO	93.00	98.00	102.00	105.00	**99.25**	93.67	97.67	104.00	106.67	**100.60**
JEO	93.00	95.00	99.00	103.00	**97.50**	92.67	94.67	98.67	102.67	**97.17**
Mean	**93.80**	**99.47**	**101.07**	**104.20**		**93.67**	**97.20**	**101.13**	**103.60**	
LSD 0.05 Botanical oils			**0.303**					**1.143**		
LSD 0.05 Rates			**0.271**					**1.022**		
LSD 0.05 Botanical oils x Rates			**0.606**					**2.285**		
Early 2017 farming season						**Late 2017 farming season**				
CYP	94.00	105.00	106.33	109.33	**103.67**	94.00	103.67	105.67	102.67	**101.50**
AEO	95.00	95.67	98.67	102.67	**98.00**	95.67	97.00	98.00	99.67	**97.58**
HEO	94.00	94.67	97.67	100.33	**96.67**	93.33	101.67	95.67	98.67	**97.33**
JAHEO	93.00	97.00	101.67	104.67	**99.08**	96.67	99.00	99.00	102.33	**99.25**
JEO	93.00	95.00	99.00	102.67	**97.42**	93.00	95.33	95.33	99.33	**95.75**
Mean	**93.80**	**97.47**	**100.67**	**103.93**		**94.53**	**99.33**	**98.73**	**100.53**	
LSD 0.05 Botanical oils			**0.409**					**NS**		
LSD 0.05 Rates			**0.366**					**3.131**		
LSD 0.05 Botanical oils x Rates			**0.818**					**7.002**		

Key: CYP-Cypermethrin 10EC, AEO- Stool wood *Alstonia boonei.* oil, HEO- Bush tea *Hyptis suaveolens* oil, JAHEO- Mixed plant oils from Jathropha, Bush tea and Stool wood, JEO- *Jathropha tanjorensis* oil

Table 17: Effect of botanical oils on 100 seed weight (g/plot) in 2016 and 2017 early and late farming Season

	Rates of botanical oils ml/100ml water									
Botanical	0.00	2.00	4.00	6.00		0.00	2.00	4.00	6.00	
oils	0.00	0.20	0.40	0.60	**Mean**	0.00	0.20	0.40	0.60	**Mean**
Early 2016 farming season						**Late 2016 farming season**				
CYP	82.00	94.00	96.00	97.67	**92.42**	82.00	93.67	95.67	97.33	**92.17**
AEO	82.00	83.33	87.00	92.67	**86.25**	81.67	83.00	86.67	92.33	**85.92**
HEO	80.00	82.67	86.00	91.33	**85.00**	79.67	82.67	85.67	91.00	**85.92**
JAHEO	82.00	84.00	90.00	94.67	**88.12**	82.67	90.67	92.67	95.33	**90.34**
JEO	81.00	83.00	86.67	92.00	**85.67**	80.67	82.67	86.33	91.67	**85.33**
Mean	**81.40**	**85.40**	**89.13**	**93.67**		**81.33**	**86.54**	**89.40**	**93.53**	
LSD $_{0.05}$ Botanical oils				**0.280**					**0.306**	
LSD $_{0.05}$ Rates				**0.251**					**0.273**	
LSD $_{0.05}$ Botanical oils x Rates				**0.560**					**0.611**	
Early 2017 farming season						**Late 2017 farming season**				
CYP	82.00	94.00	95.33	97.33	**92.17**	82.00	92.00	94.00	91.33	**89.83**
AEO	82.00	83.33	86.33	92.33	**86.00**	82.67	84.67	85.33	89.00	**85.42**
HEO	80.00	82.67	85.67	91.33	**84.92**	80.67	89.33	83.67	88.33	**85.50**
JAHEO	82.00	84.00	89.67	93.33	**87.25**	86.00	86.67	87.00	90.67	**87.58**
JEO	81.00	83.00	86.67	91.67	**85.58**	80.67	83.33	87.67	87.33	**84.75**
Mean	**81.40**	**85.40**	**88.73**	**93.20**		**82.40**	**87.20**	**87.53**	**89.33**	
LSD $_{0.05}$ Botanical oils				**0.472**					**NS**	
LSD $_{0.05}$ Rates				**0.422**					**3.387**	
LSD $_{0.05}$ Botanical oils x Rates				**0.943**					**NS**	

Key: CYP-Cypermethrin 10EC, AEO- Stool wood *Alstonia boonei.* oil, HEO- Bush tea *Hyptis suaveolens* oil, JAHEO- Mixed plant oils from Jathropha, Bush tea and Stool wood, JEO- *Jathropha tanjorensis* oil

Table 18: Effect of botanical oils on Pod yield (kg/ha) in 2016 and 2017 early and late farming Season

	Rates of botanical oils ml/100ml water									
Botanical	0.00	2.00	4.00	6.00		0.00	2.00	4.00	6.00	
oils	0.00	0.20	0.40	0.60	**Mean**	0.00	0.20	0.40	0.60	**Mean**
Early 2016 farming season						**Late 2016 farming season**				
CYP	0.52	0.72	0.78	0.80	**0.71**	0.40	0.66	0.71	0.74	**0.63**
AEO	0.52	0.58	0.63	0.68	**0.60**	0.46	0.52	0.59	0.62	**0.55**
HEO	0.54	0.55	0.58	0.65	**0.58**	0.48	0.48	0.52	0.65	**0.53**
JAHEO	0.53	0.60	0.67	0.73	**0.63**	0.45	0.52	0.59	0.67	**0.56**
JEO	0.54	0.56	0.59	0.66	**0.59**	0.47	0.50	0.53	0.60	**0.53**
Mean	**0.53**	**0.60**	**0.65**	**0.70**		**0.45**	**0.54**	**0.59**	**0.66**	
LSD $_{0.05}$ Rates				*				*		
LSD $_{0.05}$ Botanical oils				*				*		
LSD $_{0.05}$ Botanical oils x Rates				*				*		
Early 2017 farming season						**Late 2017 farming season**				
CYP	0.51	0.71	0.76	0.78	**0.69**	0.46	0.62	0.67	0.63	**0.60**
AEO	0.51	0.57	0.61	0.67	**0.59**	0.46	0.51	0.53	0.56	**0.52**
HEO	0.53	0.53	0.57	0.63	**0.57**	0.45	0.60	0.48	0.56	**0.52**
JAHEO	0.51	0.60	0.66	0.72	**0.62**	0.52	0.54	0.53	0.61	**0.55**
JEO	0.52	0.55	0.58	0.65	**0.58**	0.45	0.48	0.53	0.56	**0.51**
Mean	**0.52**	**0.59**	**0.64**	**0.69**		**0.47**	**0.55**	**0.55**	**0.58**	
LSD $_{0.05}$ Botanical oils					*				*	
LSD $_{0.05}$ Rates					*				*	
LSD $_{0.05}$ Botanical oils x Rates					*				*	

Key: CYP-Cypermethrin 10EC, AEO- Stool wood *Alstonia boonei.* oil, HEO- Bush tea *Hyptis suaveolens* oil, JAHEO- Mixed plant oils from Jathropha, Bush tea and Stool wood, JEO- *Jathropha tanjorensis* oil

Table 19: Effect of botanical oils on Seed yield (kg/ha) in 2016 and 2017 early and late farming Season

	Rates of botanical oils ml/100ml water									
Botanical	0.00	2.00	4.00	6.00		0.00	2.00	4.00	6.00	
oils	0.00	0.20	0.40	0.60	**Mean**	0.00	0.20	0.40	0.60	**Mean**
Early 2016 farming season						**Late 2016 farming season**				
CYP	0.41	0.59	0.66	0.69	**0.59**	0.37	0.51	0.60	0.65	**0.53**
AEO	0.43	0.47	0.49	0.55	**0.49**	0.36	0.41	0.43	0.49	**0.42**
HEO	0.42	0.44	0.45	0.50	**0.45**	0.36	0.38	0.39	0.42	**0.39**
JAHEO	0.41	0.47	0.54	0.63	**0.51**	0.37	0.41	0.48	0.56	**0.46**
JEO	0.41	0.45	0.48	0.52	**0.47**	0.35	0.38	0.42	0.46	**0.42**
Mean	**0.42**	**0.48**	**0.52**	**0.58**		**0.36**	**0.41**	**0.46**	**0.52**	
LSD $_{0.05}$ Botanical oils				*				*		
LSD $_{0.05}$ Rates				*				*		
LSD $_{0.05}$ Botanical oils x Rates				*				*		
Early 2017 farming season						**Late 2017 farming season**				
CYP	0.40	0.59	0.65	0.67	**0.58**	0.35	0.48	0.56	0.52	**0.48**
AEO	0.41	0.46	0.48	0.54	**0.47**	0.36	0.40	0.40	0.44	**0.41**
HEO	0.41	0.43	0.44	0.49	**0.44**	0.36	0.48	0.35	0.41	**0.40**
JAHEO	0.39	0.46	0.53	0.61	**0.50**	0.40	0.43	0.40	0.50	**0.43**
JEO	0.40	0.43	0.47	0.51	**0.45**	0.33	0.33	0.40	0.40	**0.37**
Mean	**0.40**	**0.47**	**0.51**	**0.56**		**0.36**	**0.43**	**0.42**	**0.45**	
LSD $_{0.05}$ Botanical oils				*				*		
LSD $_{0.05}$ Rates				*				*		
LSD $_{0.05}$ Botanical oils x Rates				*				*		

Key: CYP-Cypermethrin 10EC, AEO- Stool wood *Alstonia boonei.* oil, HEO- Bush tea *Hyptis suaveolens* oil, JAHEO- Mixed plant oils from Jathropha, Bush tea and Stool wood, JEO- *Jathropha tanjorensis* oil

4.2 DISCUSSION

Based on the nutrient status of the soil, it would be taken to be low in fertility and require the addition of nutrients to sustain crop production. The pH of the poultry manure indicated that it could be useful in reducing soil acidity.

The test plant oils from *J. tanjorensis* JL Ellis and Saroja (Euphorbiaceae) (JEO), Bush tea *H. suaveolens*. Poit (Libiatae) (HEO), Stool wood *A. boonei.* De Wild (Apocynaceae) (AEO), Mixed plant oils from Jathropha, Bush tea and Stool wood bark (J+A+HEO) and the standard (Cypermethrin 10 EC (CYP) significantly reduced the population insect pests of Bambara groundnut (Vigna *subterranean* .L). They offered different levels of protection to the leaves, flowers, and pods of the plant against Flea beetles (*P. uniformis* Jacoby: Coleptera *and Podagrica sjostedti* Jacoby: Coleptera) Variegated grasshoppers (*Z. variegatus* L: Orthoptera), Leaf miner (*A. modicella* Devanter: Lepidoptera), and Aphids (*A. crassivora* Glover: Hemiptera). Similar insect pests of Bambara groundnut were also observed in the findings of (Magagula and Maina, 2012; Hillocks *et al*., 2012; Uddun II *et al*., 2017).

4.2.1 Synthetic Pyrethroid Cypermethrin 10EC

Cypermethrin and plant extracts provided effective control of these insect pests. Population of insect pests significantly reduced after each spray, but increased before the next spray. This reduction in insect pest was dose dependent, while insect pest's number increased simultaneous in the control plots. Plots sprayed with Cypermethrin recorded higher plant height and decreasing numbers of damaged leaves at vegetative, flowering and podding phase, also recorded higher pod and seed yield. This is in line with Ekpe (2013) who reported that Cypermethrin at various application rates effectively controlled some insect pests of okra. Ghosh *et al.* (2010) had also reported in their findings that Cypermethrin offered effective control of tomato fruit borer (*Helicoverpa armigera*), a polyphagous insect pest attacking Cotton, Tomato, Okra, Pigeon pea, etc. Degri *et al.* (2012) in their research to determine effect of some insecticides on Cowpea flowering pests reported that Cypermethrin gave the overall best result in the control of Cowpea post flowering pests, *Maruca vitrata F, Clarigralla tomentosicollis* Stal; *Anoplonemis curvipes* L; *Riptortus dentipes* F; *Miirperus jaculus* L and *Nezara viridula* L when compared with plant materials from Balanites (*Balanites aegyptica* Del), *Momordica basamina*; and bitter leaf (*Vernonia amygdalina* L). The performance of Cypermethrin could be as a result of its ability to act on the insect's peripheral nervous system to induce noticeable repetitive activity and production trains of nerve impulses which are permeable to nerve membranes (Siegfried, 1993). This repetitive activity is induced by pyrethroid damage to the voltage- dependent sodium channel, causing sodium channels to stay open much longer than normal (Vijverberg and Vanden Bereke, 1990).

4.2.2 Efficacy of Mixed Plant oil (J+A+HEO)

The plots sprayed with Mixture of Jathropha, Bush tea and Stool wood extracts (J+A+HEO) were the second best in the control of the targeted insect pests. There were no antagonistic reactions from the mixed plant oils rather there were synergism from their actions on the targeted insect pests. The mixed plant oils competed effective with Cypermethrin 10 EC in decreasing numbers of damaged leaves by insect pests at vegetative, flowering and podding phase, thereby increasing pod and seed yield of Bambara groundnut. This agreed with research work of Ebadah *et al*., (2016) who clarified that Lambda and mixture oil (Clove and Bitter orange oils 1:1) were the highest effective against eggs of *Bemisia argentifolii*, that both caused 85.4 and 85.3% reduction in eggs count respectively, while aceptaiprid was the lowest (50.0%). They also indicated that the mortality percentage *B. argentifolii* nymph was ranged from 26.5- 78.0% after 3 days of application, they found out that highest toxic effect was noticed in mix oil (Clove and Bitter orange oils 1:1) treatment followed by Lambda, while the lowest effect was obtained in Bitter orange oil. This Finding is also in line with Mesbah *et al*., (2014) who opined that prepared baits of lone or/ and admixed four botanical oils- Camphor, red basil, menthol oils and rose concentration produced synergistic actions, highest efficient toxicity and an adverse biological performance such as gradual decrease of number of alive immature and adult moths, gradual increase of dead and malformed individuals and adult moths, raised sterile unviable adult moths, gradual decrease of deposited and/ or hatched eggs up to the 4^{th} generation, which ended by complete failure of the development of Greasy cutworm *Agrotis ipsilon* (Hufnagel).

This finding were also supported by the findings of Waliwitiya *et a*l., (2012), they confirmed synergistic effects of insecticidal essential oils (thymol, eugonol, pulegone, terpineol and citronellal) and Piperonyl butoxide (PBO) against four instars of *Aedes eagypti*.L. There work revealed that high concentrations of thymol, eugenol, pulegone and citronellal alone reduced ethoxyresorufin 0-dethylase (EROD) activity by 5-25% in 16 hours post exposure. Terpineol at 10 mg/litre increased EROD activity by 5± 1.8% over controls. The essential oils alone reduced glutathione S-tranferase (GST) activity by 3- 20% but Piperonyl butoxide (PBO) exposure alone did not significantly affect the activity the measured enzymes. All essential oils in combination with PBO reduced GST activity by 3 – 85% at 16 hours post exposure (Waliwitiya *et al*., 2012)

4.2.3 Efficacy of Stool wood *Alstonia boonei* bark oil (AEO)

A. boonei bark extracts were third best after the mixed extracts in control of targeted insect pests. Plots sprayed with *A. boonei* recorded fewer numbers of damaged leaves when compared with plots sprayed with *J. tanjorensis* leaf extract and *H. suavoelense* root extracts and the control plots. This study shows that *A. boonei* bark oil has a very strong negative effect on the insect pest population of Bambara groundnut. This research work is in line the work of Oigiangbe *et al*., (2013) who reported multiple effects of *A. boonei* leaf alkaloid on larval survival, weight, population and adult emergence of *Maruca vitrata* (Fab) and suggested in their work that it is most likely that the significantly lower survival of the larvae of *M. vitrata* in the treatments with the alkaloid was due to the antifeedant or repellent property of the compound.

4.2.4 Efficacy of Jathropha Plant, *Jathropha tanjorensis* oil (JEO)

The plots sprayed with Jathropha Plant, *Jathropha tanjorensis* leaves oil (JEO) were the fourth best in the control of the targeted insect pests. Plots sprayed with *J. tanjorensis* recorded lesser numbers of damaged leaves when compared with the control plots. *J. tanjorensis* exhibited various levels of protection to the leaves and flowers against grass hoppers, leaf hopper, aphids, podagrica spps, leaf rollers and some other minor insect pests that visited Bambara field throughout the field experimentations. This efficacy of *J. tanjorensis* could be as a result of its chemical constituents. This research finding is in line with works of Ilondu and Enwa, (2013) who revealed the presence of saponins, cardiac glycosides, flavonoids, terpenoids and tannins in the leaf extract of *J. tanjorensis*.

4.2.5 Efficacy of Bush tea *Hyptis suaveolens* oil (HEO)

Bush tea *H. suaveolens* leaves oil (HEO) was fifth best after Jathropha Plant in control of targeted insect pests. *H. suaveolen* exerted various levels of protection to the leaves and flowers against grass hoppers, aphids, podagrica spps, leaf miner and some other minor insect pests that visited Bambara field throughout the field experimentations. This findings is in line with the work of Peer *et al*., (2018) opined that *H. suaveolens* was found to be toxic to the third, fourth and fifth larvae of Rice moth, *Corcyra cephalonica.* This work is also supported by the findings of Pavunraj *et al*., (2016) who reported that the crude ethyl acetate extract of *H. suaveolens* and *M. corchorifolia* at 1% concentration possess very active feeding deterrent against larvae of *H. armigera.*

4.2.6 Phyto constituents

The tested plant oils from *J. tanjorensis* JL Ellis and Saroja (Euphorbiaceae) (JEO), Bush tea *H. suaveolens*. Poit (Libiatae) (HEO), Stool wood *A. boonei.* De Wild (Apocynaceae) (AEO) were effective in the control of insect pests of Bambara groundnut, their effectiveness could be attributed to presence of Alkaloids, Flavonoids, Glycocides, Saponins, Tannins and Terpenoids.

This research indicated that presence of alkaloids could be responsible for effectiveness of the flant oils from *J. tanjorensis* JL Ellis and Saroja (Euphorbiaceae) (JEO), Bush tea *H. suaveolens*. Poit (Libiatae) (HEO), Stool wood *A. boonei.* De Wild (Apocynaceae) (AEO). This findings corresponded with work of Oigiangbe *et al*., (2010) who revealed that *Alstonia boonei* stem back alkaloid possesed very high level of insecticidal property against *Sesemia calamistis.* Hikal *et al*., (2017) confirmed that alkaloids are the the most important group of natural product playing an important role in insecticidal. Wachira *et al*., (2014) observed that pyridine alkaloids extracted from Ricinus communis against the malaria vector Anopheles gambiae.

Presence of flavonoids could be one of the reasons why the plant oils from *J. tanjorensis* JL Ellis and Saroja (Euphorbiaceae) (JEO), Bush tea *H. suaveolens*. Poit (Libiatae) (HEO), Stool wood *A. boonei.* De Wild (Apocynaceae) (AEO) became effective in the control of targeted insect pests. This finding is in line with finding of Santos *et al*., (2016) who concluded in their work that *Tagetes erecta* and *Tagetes patula* have phytotoxic flavonoids that can promote and expand its use as a natural insecticide.

Glycoside presence in plant oils from *J. tanjorensis* JL Ellis and Saroja (Euphorbiaceae) (JEO), Bush tea *H. suaveolens*. Poit (Libiatae) (HEO), Stool wood *A. boonei.* De Wild (Apocynaceae) (AEO) could be of one of the reasons they proved effective against insect pest. This agreed with the work of Nobsathian *et al*., (2019) who indicated that efficiency and effectiveness of *Holothuria atra* extractions and triterpene glycoside compounds against *Spodoptera litura* shows their potential use in intergrated pest management programs and sources of insecticidal compounds.

Tannin found in the plant oils from *J. tanjorensis* JL Ellis and Saroja (Euphorbiaceae) (JEO), Bush tea *H. suaveolens*. Poit (Libiatae) (HEO), Stool wood *A. boonei.* De Wild (Apocynaceae) (AEO) could be responsible for reduction in attacks by insect pestds. This finding are in line with Jin *et al*., (2015) who reported that insecticidal activity was enhanced when *Bacillus thuringengiensis* subsp. Kurstaki KB100 strain containing insecticital activity against *Spodoptera exigua* was mixed with tannic acid, a protease inhibitor.

Presence of saponins in the plant oils from Bush tea *H. suaveolens*. Poit (Libiatae) (HEO) and Stool wood *A. boonei.* De Wild (Apocynaceae) (AEO) could have contributed to protect bambara grounut from attack by insect pest in the field, According to Hussein *et al*., (2005): De geyter *et al*., (2007) Saponins give rise to increased mortality levels, lowered food intake by making food less attractive by repellent or deterrent activity, weight reduction, retardation in development, disturbances in development and decreased reproduction in insect pests.

Presence of terpenoids in the plant oils from *J. tanjorensis* JL Ellis and Saroja (Euphorbiaceae) (JEO), Bush tea *H. suaveolens*. Poit (Libiatae) (HEO), Stool wood *A. boonei.* De Wild (Apocynaceae) (AEO) could be responsible for their efficacy in controlling the targeted insect pests. This finding corresponds with the finding of Scalerandi *et al*., (2018) who reported the synergetic combination of terpenes from 1,8-Cineole, citronellol, citronellic acid, linalool, (R)-limonene, (R)-a-pinene, (S)-β-pinene, (R)-pulegone, α-terpinenene, γ-terpinene, thymol and PBO in unequal proportions to avoid metabolization of most toxic compound increased toxicity by 2-31 times compared to the corresponding individual terpenes against *Musca domestica.*

4.2.7 Plant height of Bambara groundnut in 2016 and 2017 early and late farming Season as influenced by botanical oils

The botanical oils demonstrated significant effects on Plant height at in 2016 early farming Season the result revealed that plots sprayed with mixed plant oils (JAHEO) recorded the highest mean plant height (24.35cm), this was followed by plots sprayed with Cypermethrin (CYP) at 23.79cm, plots sprayed with *A. boonei* oil (AEO) and sprayed Jathropha oil (JEO) recorded 23.32cm, while plots plots sprayed with *H. suaveolens* oil (HEO) recorded the lowest mean plant height (23.31cm).In 2016 late farming season, plots sprayed with Cypermethrin (CYP) recorded the highest mean plant height at 23.71cm, this was followed by plots sprayed with *H. suaveolens* oil (HEO) at 23.33cm, plots sprayed with *A. boonei* oil (AEO) recorded 23.32cm, plots sprayed with mixed plant oils (JAHEO) recorded 23.31cm while plots sprayed with Jathropha oil (JEO) recorded the lowest mean plant height (23.24cm. In 2017 early farming season, plots sprayed with *H. suaveolens* oil (HEO) recorded the highest mean plant height (23.46cm), this was followed by plots sprayed with Cypermethrin (CYP) at 23.43cm, plots sprayed with *A. boonei* oil (AEO) recorded 23.37cm and plots sprayed with mixed plant oils (JAHEO) recorded 23.21cm, while plots sprayed with Jathropha oil (JEO) recorded the lowest mean plant height at 20.99cm, while in 2017 late farming season, the result indicated that plots sprayed with Cypermethrin (CYP) recorded the highest mean plant height (23.77cm), this was followed by plots sprayed with *A. boonei* oil (AEO) at 23.37cm, plots sprayed with Jathropha oil (JEO) recorded 23.35cm, plots sprayed with *H. suaveolens* oil (HEO) recorded 23.33cm while plots sprayed with mixed plant oils (JAHEO) recorded the lowest mean plant height at 23.27cm.

4.2.8 Damaged leaves at Vegetative, Flowering and Podding phase in 2016 and 2017 early and late farming Seasons as influenced by Botanical oils

The effects of botanical oils on damaged leaves at vegetative phase in early 2016 farming Season showed that plots sprayed with CYP recorded the lowest mean damaged leaves at 0.71, this was followed by plots sprayed with JAHEO at 0.92, plots sprayed with AEO recorded 1.00, plots sprayed with HEO recorded 1.07 while plots sprayed JEO recorded the highest mean damaged leaves at 1.08. Among the rates of application, the control rates (0.00/0.00) recorded the highest mean damaged leaves at 1.43. In 2016 late farming season, the result indicated that plots sprayed with CYP recorded the lowest mean damaged leaves at 0.77, this was followed by plots sprayed with JAHEO at 1.05, plots sprayed with AEO recorded 1.11, plots sprayed with JEO recorded 1.19 while plots sprayed with HE) recorded the highest mean damaged leaves at 1.25. Among the rates of application, the control rates (0.00/0.00) recorded the highest mean damaged leaves at 1.65. In 2017 early farming season, the result showed that plots sprayed with CYP recorded the lowest mean damaged leaves at 0.91, this was followed by plots sprayed with JAHEO at 0.90, plots sprayed with AEO and JEO recorded 1.03, while plots sprayed with HEO recorded the highest mean damaged leaves at 1.08. Among the rates of application, the control rates (0.00/0.00) recorded the highest mean damaged leaves at 1.29. In 2017 late farming season, the result indicated that plots sprayed with CYP recorded the lowest mean damaged leaves at 0.78, this was followed by plots sprayed with JAHEO at 1.08, plots sprayed with JEO recorded 1.21 and plots sprayed with HEO recorded 1.26, while AEO recorded the highest mean damaged leaves at 1.33. Among the rates of application, the control rates (0.00/0.00) recorded the highest mean damaged leaves at 1.67

The effects of botanical oils on damaged leaves at flowering phase in 2016 early farming Season indicated that plots sprayed with CYP recorded the lowest mean damaged leaves at 0.62, this was followed by plots sprayed with JAHEO at 0.82, plots sprayed with AEO recorded 0.93, plots sprayed with JEO recorded 0.95 while plots sprayed with HEO recorded the highest mean damaged leaves at 0.96. Among the rates of application, the control rates (0.00/0.00) recorded the highest mean damaged leaves at 1.28.

In 2016 late farming season, the result indicated that plots sprayed with CYP recorded the lowest mean damaged leaves at 0.63, this was followed by plots sprayed with JAHEO at 0.83, plots sprayed with AEO recorded 0.89, and plots sprayed with JEO recorded 0.97 while plots sprayed with HEO recorded the highest mean damaged leaves at 1.00. Among the rates of application, the control rates (0.00/0.00) recorded the highest mean damaged leaves at 1.43. In 2017 early farming season, the result showed that plots sprayed with CYP recorded the lowest mean damaged leaves at 0.65, this was followed by plots sprayed with JAHEO at 0.83, plots sprayed with AEO and JEO recorded 0.95, while plots sprayed with HEO recorded the highest mean damaged leaves at 0.99, Among the rates of application, the control rates (0.00/0.00) recorded the highest mean damaged leaves at 1.54. In 2017 late farming season, the result indicated that plots sprayed with CYP recorded the lowest mean damaged leaves at 0.63, this was followed by plots sprayed with JAHEO at 0.86, plots sprayed with AEO recorded 0.91 and plots sprayed with HEO recorded 1.00, while plots sprayed with JEO recorded the highest mean damaged leaves at 1.11. Among the rates of application, the control rates (0.00/0.00) recorded the highest mean damaged leaves at 1.45.

The effects of botanical oils on damaged leaves at podding phase in 2016 early farming season indicated that CYP recorded the lowest mean plant height at 0.37, this was followed by plots sprayed with JAHEO at 0.51, plots sprayed with AEO recorded 0.53, plots sprayed with JEO and plots sprayed with HEO recorded the highest mean damaged leaves at 0.54. Among the rates of application, the control rates (0.00/0.00) recorded the highest mean damaged leaves at 0.91. In 2016 late farming season, the result indicated that plots sprayed with CYP recorded the lowest mean damaged leaves at 0.37, this was followed by plots sprayed with JAHEO at 0.51, plots sprayed with AEO recorded 0.53, plots sprayed with JEO and plots sprayed with HEO recorded the highest mean damaged leaves at 0.54. Among the rates of application, the control rates (0.00/0.00) recorded the highest mean damaged leaves at 0.99. In 2017 early farming season, the result showed that plots sprayed with CYP recorded the lowest mean damaged leaves at 0.44, this was followed by plots sprayed with JAHEO at 0.55, plots sprayed with AEO recorded 0.56 and plots sprayed with HEO recorded 0.58, while plots sprayed with JEO recorded the highest mean damaged leaves at 0.59. Among the rates of application, the control rates (0.00/0.00) recorded the highest mean damaged leaves at 0.91. In 2017 late farming season, the result indicated that plots sprayed with CYP recorded the lowest mean damaged leaves at 0.57, this was followed by plots sprayed with JAHEO at 0.59, plots sprayed with JEO recorded 0.76 and plots sprayed with AEO recorded 0.77, while plots sprayed with HEO recorded the highest mean damaged leaves at 0.80. Among the rates of application, the control rates (0.00/0.00) recorded the highest mean damaged leaves at 1.27.

4.2.9 Population dynamics of Grass hopper (*Zonocerus variegatus*) as influenced by Botanical oils in 2016 and 2017 early and late season Bambara groundnut cultivation

Population of grass hopper (*Z. variegatus*) exhibited a unique pattern of infestation in Bambara groundnut production in early and late season of 2016 and 2017 farming season. They insect pests were present throughout the production, and occurred in various instars ranging from larva to adult stage. Each of the instars stage caused damages such as defoliation at the vegetative, flowering and podding phase of Bambara groundnut. Their population started increasing from the vegetative phase, but recorded the highest population index at the flowering phase while there was a decline in their population at the podding phase. This significant increase from the vegetative phase to the flowering phase could be as a result of abundant food resources of succulent leaves, while the significant population decline from the flowering phase to the podding phase could be as a result of leaves scenesensing. The control plots recorded highest number of *Z. variegatus* while the treated plots recorded fewer numbers of *Z. variegatus*. These significant reductions in population of the insect pests were dose dependent because highest dose (6.00/0.60ml) recorded the least number of *Z. variegatus* while least dose (2.00/0.20ml) recorded higher number of *Z. variegatus*. The populations of Grass hopper were higher in early farming season of 2017 than in early farming season of 2016 and late farming season of 2017 recorded higher number of *Z. variegatus* than late season of 2016. This finding on fluctuation in population and availability of grass hopper throughout the cropping season at various instars conformed to findings of Kekeunou *et al.,* (2014) who reported that *Z. variegatus* is present throughout in two univoltine populations which have unequal abundance and duration with higher attack during the dry season

4.2.10 Population dynamics of *Podagrica uniforma* and *Podagrica sjostedti* as influenced by Botanical oils in 2016 and 2017 early and late season Bambara groundnut cultivation

Population of *P. uniforma* and *P. sjostedti* took different dimensions at various phases in Bambara groundnut production in 2016 and 2017 early and late season. There were co-existence of *P. uniforma* and *P. sjostedti* in Bambara groundnut, their populations were abundance in all the farming seasons. Similar trend were observed by Onayemi *et al*., (2016); Uddin and Odebiyi, (2011) and Echezona *et al*., (2010). *P. uniforma* visited the Bambara field at the early vegetative phase while *P. sjostedti* appeared in the field at the ending of the vegetative phase and unset of the flowering phase. *P. uniforma* recorded the highest population index at the Vegetative phase and started declining from the flowering phase while *P. sjostedti* recorded its highest population index at the flowering phase but declined in population at the podding phase. The control plots recorded the highest number of *P. uniforma* and *P. sjostedti* while the treated plots recorded fewer numbers of *Podagrica spps* which were dose related. Higher numbers of Podagrica spps were recorded in early 2017 than the early 2016 while late 2017 season recorded higher number of *Podagrica spps* than late 2016. This variation in population dynamics of the *Podagrica spps* were in line with the findings of Echezona *et al.*, (2010), they reported variations in population of two major *Podagrica spps* at different stages of Okra plat development. According to their findings, *P. sjostedti* infestation on Okra plant occurred one week later than the *P. uniforma.* They also confirmed that flea beetle count was relatively low at the vegetative stage of Okra, but increased progressively through the flower, fruit set and fruit harvest stage. This finding is also in line with findings of Venkanna (2014) who reported that On *kharif* Okra crop, the incidence of *Podagrica spps* were maximum (0.9/plant) at 9^{th} WAS and minimum (0.1/plant) at both 4^{th} and 16^{th} WAS on okra genotype Arka Anamika, while in case of genotype No-55, the population of flea beetles varied from 0.2 to 1.8 per plant, the incidence was maximum (1.8/plant) at 10^{th} WAS and minimum (0.2/plant) at both 15 and 17^{th} WAS.

4.2.11 Population Dynamics of Aphids (*Aphis crassivora* Glover) as influenced by Botanical oils in 2016 and 2017 late season Bambara groundnut cultivation

Aphids (*A. crassivora*) visited the Bambara field only in the late farming season of 2016 and 2017 farming season. They were present from the vegetative to the podding phase, but the Flowering recorded the highest population index of the *A. crassivora*. The Control plots recorded the highest number of *A. crassivora* while fewer numbers of *A. crassivora* were recorded from the treated plots. The treated plots were dose dependent as the highest dose (6.00/0.60ml) recorded fewer numbers of *A. crassivora* while the least application rate (2.00/0.20ml) recorded higher number of *A. crassivora*. Higher numbers of *A. crassivora* were recorded in late in late 2017 farming season while 2016 late season recorded lesser number of *A. crassivora*. This study conforms with the findings of Venkanna (2014) who reported that *A. crassivora* were harbored in all the stages of Okra production, he also indicated that incidence of *A. crassivora* on *rabi* crop on genotype Arka

Anamika started from 3rd WAS (1.2 aphids/3 leaves) and reached its peak incidence during 11th WAS (6.2 aphids/3 leaves). From 11th week onwards there was decline in the population and reached to a lowest population of 3.00 aphids/3 leaves at 17th WAS.

4.2.12 Population Dynamics of Leaf miner (*Aproaerema modicella*) as influenced by botanical oils in 2017 late season Bambara groundnut cultivation

Leaf miner (*A. modicella*) only visited Bambara field in the 2017 early farming season, although they were present from the vegetative phase to the podding phase, but the flowering phase recorded the highest population with a decline in population at the podding phase. The control plots had the highest numbers of *A. modicella* while fewer numbers were recorded in the treated plots and were dose related. The leaf miner larvae caused short blister like mines, while the older larvae folded the leaflets and fed within. This resulted to a shrivel and dry up which later turned to burnt brown appearance. This study is in line with Ajeigbe *et al.*, (2014) who reported that groundnut growth and yield were affected by young larvae of leaf miner (*A. modicella*) that mined the leaves and later instars exit the mine to web together several leaflets thereby causing early defoliation of groundnut leaves. This is supported by the research findings of Arunachalam and Kavitha, (2012) who revealed that among the leaf feeders screened, the leaf miner was found to be affecting the groundnut crop. They also found out that leaf miner incidence was maximum at 45 DAS in rainy season and 60 DAS in post rainy season.

4.2.13 Number of days to flower bud initiation, number of days to flower bud opening, 50% flowering and 100% maturity as influenced by botanical oils.

Number of days to flower bud initiation, number of day to flower bud opening, 50% flowering and 100% maturity showed that late seasons of 2016 and 2017 recorded lower number of days to flower bud initiation, number of days to flower bud opening, 50% flowering and 100% maturity than 2016 and 2017 early seasons. The effects of botanical oils on Days to First flower bud initiation in 2016 early farming season showed that plots sprayed with HEO recorded the lowest mean days to first flower bud initiation at 36.42 while plots sprayed with AEO recorded the highest mean days to first flower bud initiation at 36.92. In 2017 early farming season, the result indicated that plots sprayed with JAHEO recorded the lowest mean days to first flower bud initiation at 36.42 while plots sprayed with HEO recorded the highest mean days to first flower bud initiation at 37.00. But in 2016 late farming season, the result revealed that plots sprayed with AEO recorded the lowest mean days to first flower bud initiation at 34.42 while plots sprayed with HEO recorded the highest mean days to first flower bud initiation at 35.08. In 2017 late farming season, the result revealed that plots sprayed with JEO recorded the lowest mean days to first flower bud initiation at 34.75 while plots sprayed with AEO recorded the highest mean days to first flower bud initiation at 35.08.

The highest mean days to first flower bud was recorded in 2016 early farming season, plots sprayed with AEO recorded the highest mean days to first flower bud opening at 42.10 while plots sprayed with HEO recorded the lowest mean days to first flower bud opening at 41.42. In 2017 early season while plots sprayed with JEO and HEO recorded the lowest mean days to first flower bud opening at 41.10. In 2016 late season, plots sprayed with HEO and JAHEO recorded the highest mean days to first flower bud initiation at 40.67 while plots sprayed with JEO recorded the lowest mean days to first flower bud opening at 39.00. In 2017 late season, plots sprayed with CYP and AEO recorded the highest mean days to first flower bud opening at 40.00 while plots sprayed with JEO JAHEO recorded the lowest mean days to first flower bud opening at 39.67. This finding corresponded with the research findings of Bamishaiye, (2011) and Adikuru et al., (2017) who reported that Bambara groundnut started flowering from 30- 55 days after sowing.

The result on Days to 50% flowering revealed that different farming season recorded different mean days to 50% flowering. In 2016 early farming season, it took 49.00 mean days after sowing till 50% of crops produced inflorescences while 2017 early farming season recorded 47.00 mean days to 50% flowering. In late 2016 farming season, mean days to 50% flowering were achieved at 46.00 while late 2017 farming season recorded the least mean days to 50% flowering at 44.00. These reproductive parameters were not influenced by the botanical oils as there were no significant differences recorded, rather the number of days to flower bud initiation, number of day to flower bud opening, 50% flowering and 100% maturity differed between the early season and late seasons. These influences might be induced by the changes in the weather and moisture stress. The metrological data of the study area indicated a serious reduction in the moisture level from the flowering phase in the late plating seasons. The lower number in number of days to flower bud initiation, number of day to flower bud opening, 50% flowering and 100% maturity in the late seasons of Bambara groundnut cultivation could be as a result of moisture stress and drought escape strategy exhibited by crops as the dry season approached. This research finding corresponded with the results of Mabhaudhi and Modi, (2013) who reported that Bambara groundnut was observed to have drought escape mechanism where, under drought stress, it had a shortened vegetative stage and early maturity in order minimize the adverse effect of drought on plant development,

4.2.14 Pod/seed damage assessment as influenced by botanical oils in 2016 and 2017 early and late Bambara groundnut cultivation.

Pod damage (a measure of efficacy of insecticides against insect pest infestation on pods) was assessed at maturity by counting 100 pods/seeds produced per plot. Pod/seed damage were determined by assessment on Pod/seed discoloration, shriveling, stunting, and presence of entry/exit holes of pod borers on pods. The Plant oils were able to reduce the population of insects which resulted in an increase in the number of undamaged pods. But there no significant difference from the control plots. This report is in line with the work of Uddun II *et al.*, (2017) who reported that Jatropha leaf extract had the lowest mean number of damaged pods of Bambara groundnut and it was not significantly different to the value of cypermethrin while Aqueous leaf extract of lemon grass had a high mean number of damaged pods and it was not significantly different from the control.

4.2.15 Yield parameters; 100 Pod weight (g), Seed weight (g), Pod yield (kg/ha) and Pod yield (kg/ha) as influenced by botanical oils.

Hundred (100) Pod weight (g) as influenced by botanical oils in 2016 and 2017 early and late farming Season indicated that there were significant difference between the botanical oils, application rates and also in interactions between the botanical oils and rates of applications (P=0.05) on 100 Pod weight in 2016 and 2017 early and late farming Season. The result showed that plots sprayed with CYP recorded the highest mean 100 Pod weight at 103.92g, 103.50g, 103.67g and 101.50 in 2016 and 2017 early and late season respectively, while plots sprayed with JAHEO competed favorably at 99.25, 100.60g, 99.08g, and 99.25g. Plots sprayed with AEO recorded 98.25g, 97.92g, 98.00g and 97.58g and plots sprayed with JEO recorded 97.50g, 97.17g, 97.42g and 95.75g respectively, while plots sprayed with HEO recorded 96.75g, 95.67g, 96.67g, and 97.33g respectively. Plots sprayed with JEO recorded the least means 100 Pod Weight at 95.75g in 2017 late season. The highest application rates (6.00/0.60) recorded the highest mean 100 Pod weight at 104.20g, 103.60, 103.93g, and 100.53g respectively This was followed by the medium application rates (4.00/0.40) at 101.07g, 101.13g, 100.67g, and 98.73g respectively and the least application rates (2.00/0.20) at 99.47g, 97.20g, 97.47g and 99.33g respectively while the control rates (0.00/0.00) recorded the least mean 100 Pod weight at 93.80g, 93.67g, 93.80g, and 94.53g in 2016 and 2017 early and late farming Season respectively.

Hundred (100) Seed weight (g) in 2016 and 2017 early and late farming Season showed that there were significant difference between the botanical oils, application rates and also among the interactions between the botanical oils and rates of applications (P=0.05). Plots sprayed with CYP recorded the highest mean 100 Seed weight at 92.42g, 92.17g, 92.17g and 89.83g in 2016 and

2017 early and late farming Season respectively. Plots sprayed with JAHEO competed favorably at 88.12g, 87.25g, 90.34g, and 87.58g respectively. AEO recorded 86.25g, 86.00g, 97.92g and 85.42 respectively and plots sprayed with JEO recorded 97.50g, 85.58g and 84.75g respectively, while plots sprayed with HEO recorded the least means 100 Seed weight at 85.00g, 84.92g, 85.92g and 85.50g respectively, Plots sprayed with JEO recorded the least means 100 Seed weight at 85.33g in 2016 late season. The highest application rates (6.00/0.60) recorded the highest mean 100 Seed weight at 96.60g, 93.20g, 93.53g, and 89.33g respectively. This was followed by the medium application rates (4.00/0.40) at 89.13g, 88.73g, 89.40g and 87.53g respectively and the least application rates (2.00/0.20) at 85.40g, 85.40g, 86.54g and 87.20g respectively while the control rates (0.00/0.00) recorded the least mean 100 Seed weight at 81.40g, 81.40g, 81.33g and 82.40g in 2016 and 2017 early and late farming Season respectively.

Pod yield (kg/ha) in 2016 and 2017 early and late farming Season as influenced by botanical oils showed that there were no significant difference between the botanical oils, application rates and also among the interactions between the acting ingredients and rates of applications (P=0.05) on Pod yield (kg/ha) in 2016 early season, 2017 early, 2016 late 2017 late farming Season the result indicated that plots sprayed with CYP recorded the highest mean Pod yield at 2.12 kg, 1.88 kg, 2.07 kg and 1.79 kg in 2016 and 2017 early and late farming Season respectively. This was followed by plots sprayed with JAHEO at 2.00 kg, 1.67 kg, 1.87 kg and 1.65 kg. Plots sprayed with AEO recorded 1.81 kg, 1.64 kg, 1.77 kg and 1.55 kg respectively. JEO recorded 1.74 kg, 1.73 kg, 1.58 kg while plots sprayed with and HEO recorded the least mean Pod yield at 1.74 kg, 1.55 kg, 1.70 kg, and1.55 kg. Plots sprayed with JEO recorded 1.76 kg, 1.58 kg, 1.73 kg and 1.50 kg in 2016 and 2017 early and late season. The highest application rates (6.00/0.60) recorded highest mean Pod yield at 2.11 kg, 1.96 kg, 2.07 kg and 1.73 kg. This was followed by the medium application rates (4.00/0.40) at 1.95 kg, 1.77 kg, 1.91 kg and 1.65 kg, and the least application rates (2.00/0.20) at 1.81 kg, 1.61 kg, 1.78 kg and 1.65 kg while the control rates

(0.00/0.00) recorded the least mean Pod yield at 1.59 kg, 1.35 kg 1.55 kg and 1.40 kg in 2016 and 2017 early and late farming Season respectively.

Seed yield (kg/ha) in 2016 and 2017 early and late farming Season as influenced by botanical oils revealed that there were no significant difference between the botanical oils, application rates and also in the interactions between the botanical oils and rates of applications (P=0.05) on Seed yield (kg/ha) in 2016 and 2017 early and late farming Season the result indicated that plots sprayed with CYP recorded the highest mean Seed yield at 1.76 kg, 1.60 kg, 1.73 kg, and 1.43 kg in 2016 and 2017 early and late farming Season respectively. This was followed by plots sprayed with JAHEO at 1.54 kg, 1.37 kg, 1.50 kg and 1.30 kg. Plots sprayed with AEO recorded 1.46 kg, 1.27 kg, 1.42 kg and 1.20 kg respectively. JEO recorded 1.40 kg, 1.21 kg, 1.36 kg and 1.14 kg while plots sprayed with HEO recorded 1.36 kg, 1.16 kg, 1.33 kg and 1.20 kg. Plots sprayed with JEO recorded the least means Seed Yield at 1.14 kg in 2017 late season. The highest application rates (6.00/0.60) recorded highest mean Seed yield at 1.74 kg, 1.55 kg 1.69 kg and 1.36 kg. This was followed by the medium application rates (4.00/0.40) at 1.57 kg, 1.39 kg, 1.54 kg and 1.27 kg, and the least application rates (2.00/0.20) at 1.45 kg, 1.25 kg, 1.42 kg and 1.30 kg while the control rates (0.00/0.00) recorded the least mean Seed yield at 1.24 kg, 1.08 kg, 1.21 kg and 1.07 kg in 2016 and 2017 early and late farming Season respectively.

This study revealed that botanical oils were able to reduce the population of insects which resulted in an increase in the 100 Seed and Pod weight (g) which differed significantly, while Seed and Pod Yield (kg/ha) were not significantly different (P>0.05) but plots treated with botanical oils recorded higher yields than the untreated plots. This study agreed with the finding of Uddun II *et al.*, (2017) who insisted that Bambara can produce higher yield if protected from insect pests hence aqueous leaf extract of lemon grass increase in yield (35.4g) when compared to the untreated crops (14g).

The higher yields of Bambara groundnut was dose dependent as the highest application rates (6.00/0.60ml) recorded the highest yield while the untreated plots (0.00/0.00ml) recorded the lowest yeild. This research finding is in line with the study of Nwankpa *et al*., (2019) who observed that seed extracts of *Moringa oliefera* and *Artemisia annua* reduced insect infestation of okra and the reduction were dose- dependent hence increase in treatment material concentrations decreased insect infestations and enhanced okra yield.

CHAPTER FIVE

5.0 SUMMARY, CONCUSION AND RECOMMENDATION

5.1 Summary

In summary, the botanical oils from *J. tanjorensis* JL Ellis and Saroja (Euphorbiaceae) (JEO), Bush tea *H. suaveolens*. Poit (Libiatae) (HEO), Stool wood *A. boonei.* De Wild (Apocynaceae) (AEO) and Synthentic insecticide (Cypermethrin 10 EC (CYP) significantly reduced the population of insect pests of Bambara groundnut (Vigna *subterranean* .L). They offered different levels of protection to the leaves, flowers, and pods of the plant against Flea beetles (*P.uniformis* Jacoby: Coleptera *and P. sjostedti* Jacoby: Coleptera) Variegated grasshoppers (*Z. variegatus* L: Orthoptera), Leaf miner (*A. modicella* Devanter: Lepidoptera), and Aphids (*A. crassivora* Glover: Homoptera). The Mixed plant oil from Jathropha, Bush tea and Stool wood bark (J+A+HEO) competed favorably with Cypermethrin 10 EC at various levels and afforded the crop the highest protection and resulted in the highest yield of Bambara groundnut, they performed reasonable well.

The insect pest population dynamics showed that Variegated grasshoppers (*Z. variegatus*), Flea beetles (*P. uniforma and P. sjostedti*) were available at the vegetative phase, flowering phase and podding phase throught out the 2016 and 2017 ealy and late seasons. *P. uniforma* arrived in the Bambara field at the early stage of the vegetative phase while *P. sjostedti* came to the Bambara field at the later stage of the vegetative phase, also it recorded higher population at later stage of the flowering phase than the *P. uniforma.* Aphids (*A. crassivora*) visited the bambara field only in the late farming season of 2016 and 2017 farming season and were present from the vegetative to the podding phase, while Leaf miner (*A. modicella*) only visited bambara field in the 2017 early farming season, although they were present from the vegetative phase to the podding phase.

The treated plots recorded higher yields of Bambara groundnut than the untreated plots (0.00/0.00ml), the higher yields of Bambara groundnut was dose dependent as the highiest application rates (6.00/0.60ml) recorded the highest yield.

5.2 Conclusions

Field evaluation of these plant oils proved successful in the control of the field insect pests of Bambara groundnut, they can be commercialized to substitute some costly synthetic insecticides. They are convenient, easy to apply, not lethal to beneficial and non target organisms and could increase consumers' confidence towards consumption of farm products. The plots sprayed with mixture of Jathropha, Bush tea and Stool wood extracts (J+A+HEO) were very effective in the control of the targeted insect pests. There were synergetic actions from the mixed plant oils on the targeted insect pests. The mixed plant oils competed effectively with Cypermethrin 10 EC in decreasing numbers of damaged leaves by insect pests at vegetative, flowering and podding phase, thereby increasing pod and seed yield of Bambara groundnut.

5.3 Recommendations

This research study recommends the need to continue studies on the potentials of these plants products as insecticides (Plant oils). Cultivation of Jathropha, *J. tanjorensis*, Stool wood, *A. boonei* and Bush tea *H. suaveolens* should be the focus of ministries of Agriculture, Agricultural Institutes, Departments and Faculties in tertiary institutions in Nigeria. The availability of these plant materials could help their commercialization and production for insect pest control. Hence Bambara can be cultivated effectively in all the seasons under control measures against insect pests, farmers in owerri are adviced to incoperate bambara groundnut into the number of crops they cultivate.

Farmers are therefore advised to use these plant oils at the highest rate (6.00 ml), which proved to be effective in the control of field insect pests and enhanced yield of Bambara groundnut.

5.4 Contribution to Knowledge

i. This research work extensively revealed the potentials of the test plant oils from *Jatropha tanjorensis*, Stool wood, *A. boonei* and Bush tea, *H. suaveolens* against field insect pests of Bambara groundnut.

ii. This work established that Bambara groundnut can be cultivated in both early and late farming seasons under control measures with plant oils from *Jatropha tanjorensis*, Stool wood *A. boonei* and Bush tea *H. suaveolens* in Owerri rain forest zone.

iii. This research clearly identified major field insect pests that caused damages to Bambara groundnut at the early and late farming season in 2016 and 2017.

iv. This research work also brought to our present knowledge population dynamics of insect pests of Bambara groundnut under control measures with plant oils. It showed population of insect pests at vegetative, flowering and podding phase of Bambara groundnut.

v. Bambara groundnut is an underutilized crop that plays significant role in food security despite the fact that they receive little scientific research. This research then assessed yield parameters and damage of Bambara groundnut caused by insect pests.

vi. This research study indicated that mixed plant oils from *Jatropha tanjorensis,* Stool wood *A. boonei* and Bush tea *H. suaveolens* (JAHEO) could be alternative to synthetic insecticides, hence it competed favourably well with Cypermethrin 10EC in protecting bambara groundnut against field insect pests.

vii. This research also confirmed that reduction in insect pest infestation was dose dependent, insect pests number increased simultaneous in the control plots while plots sprayed with highest, medium and lowest application rates recorded higher plant height and decreasing numbers of damaged leaves at vegetative, flowering and podding phase, also recorded higher pod and seed yield respectively.

viii. This research work went ahead to reveal qualitative phytoconstituents of the plant oils, the tested plant oils from *J. tanjorensis* JL Ellis and Saroja (Euphorbiaceae) (JEO), Bush tea *H. suaveolens*. Poit (Libiatae) (HEO), Stool wood *A. boonei.* De Wild (Apocynaceae) (AEO) recorded presence of Alkaloids, Flavonoids, Glycocides, Saponins, Tannins and Terpenoids which could be responsible for the efficacy of the plant oils against insect pests of Bambara groundnut.

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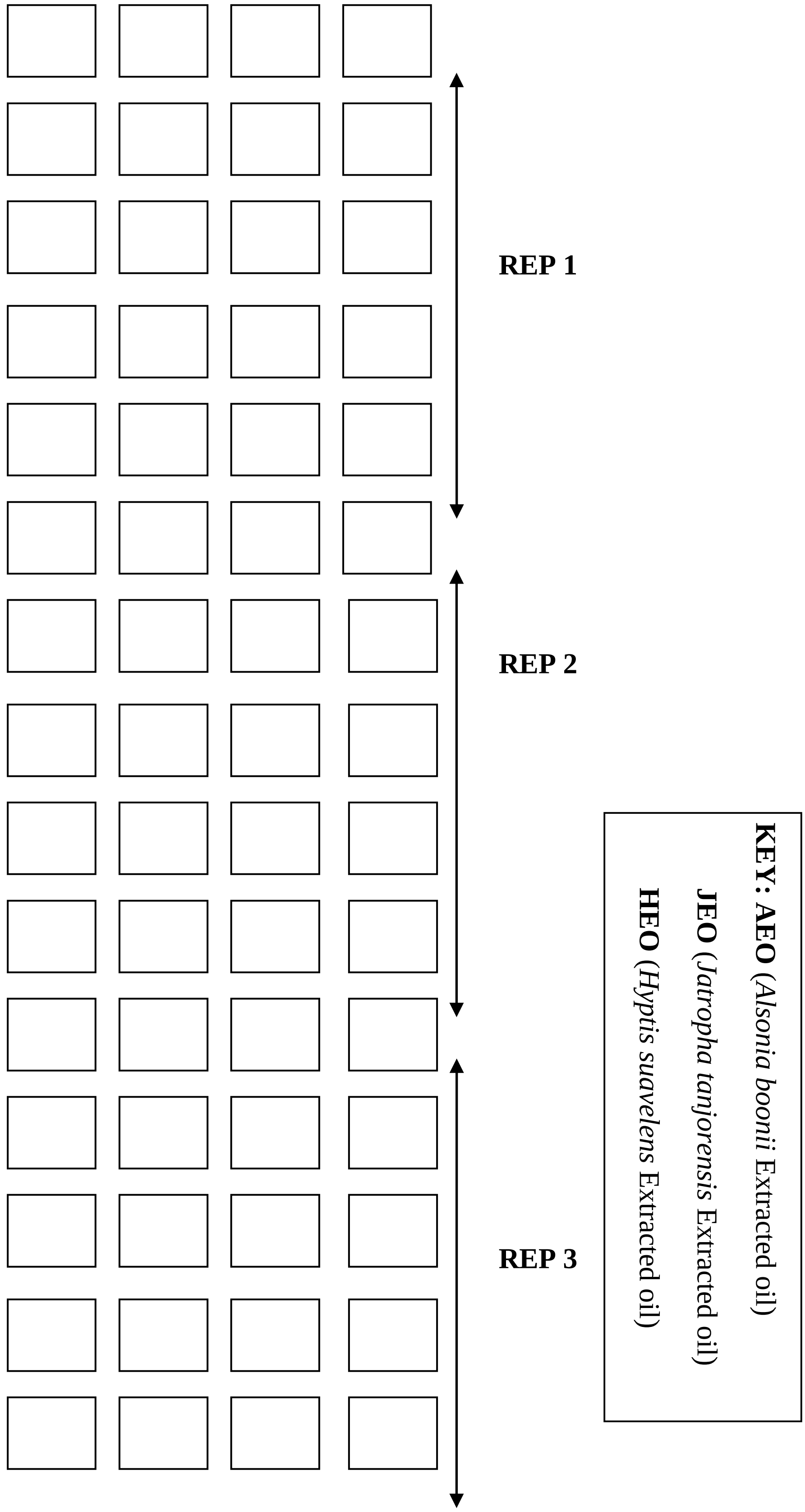
APENDIX I

FIELD LAYOUT



APENDIX II

	Treatment	Rate/ 100 ml of H_2O	Replication
1	JOE	0.00ml	111
2	JOE	2.00ml	111
3	JOE	4.00ml	111
4	JOE	6.00ml	111
5	HEO	0.00ml	111
5	HEO	2.00ml	111
6	HEO	4.00ml	111
7	HEO	6.00ml	111
9	AEO	0.00ml	111
10	AEO	2.00ml	111
11	AEO	4.00ml	111
12	AEO	6.00ml	111
13	(J+A+HEO)	0.00ml	111
14	(J+A+HEO)	2.00ml	111
15	(J+A+HEO)	4.00ml	111
16	(J+A+HEO)	6.00ml	111
17	ACT	0.00ml	111
18	ACT	0.20ml	111
19	ACT	0.40ml	111
20	ACT	0.60ml	111

APPENDIX III

Factorial arrangement with three replications fitted into Randomized Complete Block Design (RCBD)

Treatments		**Blocks**				
A	**B**	**I**	**II**	**III**	**Treatment Total**	**Treatment Combination**
1	1	1	1	1	3	A_1B_1
	2	1	1	1	3	A_1B_2
	3	1	1	1	3	A_1B_3
	4	1	1	1	3	A_1B_4
2	1	1	1	1	3	A_2B_1
	2	1	1	1	3	A_2B_2
	3	1	1	1	3	A_2B_3
	4	1	1	1	3	A_2B_4
3	1	1	1	1	3	A_3B_1
	2	1	1	1	3	A_3B_2
	3	1	1	1	3	A_3B_3
	4	1	1	1	3	A_3B_4
4	1	1	1	1	3	A_4B_1
	2	1	1	1	3	A_4B_2
	3	1	1	1	3	A_4B_3
	4	1	1	1	3	A_4B_4
5	1	1	1	1	3	A_5B_1
	2	1	1	1	3	A_5B_2
	3	1	1	1	3	A_5B_3
	4	1	1	1	3	A_5B_4
Block Total		20	20	20	60	

A = Essential oils and Cypermethrin 10EC
B = Rates of the oils

APENDIX IV

Analysis of Variance Table (ANOVA)

FACTORIAL IN RCBD ANOVA TABLE

Source of variation	**d.f.**	**s.s.**	**m.s.**	**v.r.**	**fpr.**
Block	2				
Treatments (A)	4				
Rates (B)	3				
Treatment Rates (AB	12				
Error	30				
Total	**59**				

Plate 9(a): Podagrica (*Podagrica jostdeti*) feeding on Bambara groundnut

Plate 9(b): Podagrica (*Podagrica uniforma*) feeding on Bambara groundnut

Plate 10(a): Aphids (*Aphids crassivora*)

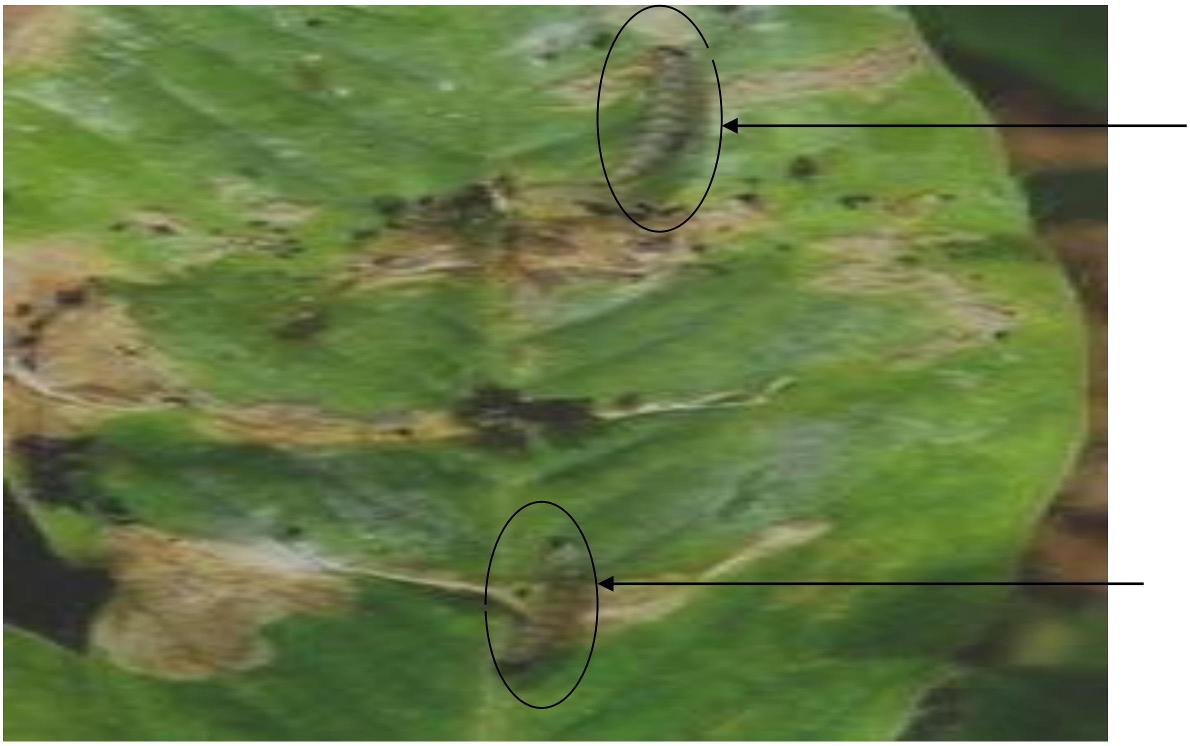


Plate 10(b): Leaf miner (*Aproaerema modicella*)

Plate 11(a): Beneficial Lady bird beetle *Cheilomenes spp* (Coleoptera: Coccinellidae)

Plate 11(b): Lady bird beetle (*Cheilomenes sulphurea*) Natural enemy of Aphids on Bambara groundnut

Plate 12(a): Bambara groundnut Plant

Plate 12(b): Bambara groundnut Plant at maturity and Harvested Bambara pods