

**RESPONSES OF SELECTED FRUIT VEGETABLES TO
INTERCROPPING WITH JUVENILE OIL PALM AND WEED
DIVERSITY**

BY

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**BEING A THESIS SUBMITTED IN PARTIAL FULFILLMENT
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AUGUST, 2018

CERTIFICATION

I certify that the study reported in this thesis was conducted under the supervision of Dr. K. S. Olorunmaiye, in the Department of Plant Biology of the University of Ilorin. The thesis has been read and accepted as meeting the requirement of the Department of Plant Biology and the University for the award of Ph.D. degree in Plant Biology (Plant Physiology).

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DEDICATION

This research work is dedicated to the glory of God and the use of mankind.

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I give all glory and adoration to Almighty God, the author and finisher of our faith, for his mercy, grace, favour, provision and compassion throughout my period of this study. He has indeed been my strength and my sustainer without which I would not have achieved anything. He has been ever faithful to me and I will forever be grateful.

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ABSTRACT

The wide spacing used for oil palm plantation has led to serious weed infestation from transplanting to canopy closure stages when the oil palm becomes productive. The study was conducted to investigate the responses of some fruit vegetables to intercropping with juvenile oil palm of two years old. The objectives of the study were to: (i) evaluate the growth and yield of the fruit vegetables to three spacing regimes in juvenile oil palm/fruit vegetable intercrop; (ii) determine the effects of intercropping on growth of the juvenile oil palms; (iii) determine the biological and economic efficiencies of oil palm/fruit vegetable intercrop; (iv) investigate weed species diversity in the experimental plots; and (v) establish the effect of the intercrops on weed smothering efficiency, density and biomass.

Four fruit vegetables: (i) tomato (accessions NGB 01665 and NG/AA/SEP/09/053); (ii) pepper (NGB 01312 and NGB 01641); (iii) okra (NGB 01184); and (iv) egg plant (NGB 01737), were intercropped within alley of juvenile oil palms (240 m²) during rainy season of 2016 and 2017 at oil palm plantation in Ala, Akure-North Local Government Area, Ondo State. Each vegetable was intercropped at a distance of 1, 2 or 3 m from the juvenile oil palm and control plot (non-intercropped) at 1 X 1 m spacing. Intercropped and non-intercropped juvenile oil palm growths were compared. Weed species distribution and diversity were evaluated. Data were subjected to analysis of variance using Statistical Package for Social Sciences and means were separated using Duncan Multiple Range Test at P<0.05.

The findings of the study were that:

- i. tomato (NGB 01665) and okra (NGB 01184) intercropped recorded highest yield at 3 m from the juvenile oil palm (3.893 and 0.321 tonha⁻¹ respectively); and tomato (NG/AA/SEP/09/053), pepper (NGB 01312 and NGB 01641) and eggplant (NGB 01737)

intercropped at 3 m from the juvenile oil palms were higher in yield (3.704, 0.614, 0.570 and 2.063 tonha⁻¹, respectively) than other spacing regimes and control;

- ii. juvenile oil palms did not show any adverse effects when intercropped with the fruit vegetables during second (2016) and third year (2017) of establishment (canopy spread, 218.20 cm and 433.80 cm, respectively);
- iii. pepper (NGB 01641)-, okra (NGB 01184)- and eggplant (NGB 01737)-intercrops recorded land equivalency ratio of 1.404, 1.447 and 1.097 respectively, while tomato (NGB 01665 and NG/AA/SEP/09/053) recorded intercropping advantages at 3 m from juvenile oil palm;
- iv. twenty-eight and 20 different weed species were found at 3 weeks after intercrop and harvesting of the fruit vegetables, respectively. Members of Asteraceae and Poaceae were the most abundant weeds at 3 weeks after intercrop (17.86%) and after harvesting (20.0%), respectively. Pepper control plot had the highest weed species diversity; and
- v. tomato (NG/AA/SEP/09/053) and eggplant (NGB 01737) exhibited greatest smothering effect on weeds at 3 m from juvenile oil palm (46.64% and 58.414%, respectively).

The study concluded that tomato (NG/AA/SEP/09/053) and eggplant (NGB 01737) have highest yield and weed smothering effect respectively. It is therefore recommended that they should be intercropped within the alley of juvenile oil palm.

CHAPTER ONE

INTRODUCTION

1.0 Background of Study

Oil palm is a tropical tree crop which is majorly grown for the industrial production of vegetable oil (Verheye, 2010). The oil palm (*Elaeis guineensis* Jacq.) is regarded as one of the most vital economic crops in the tropics (Anyanwu *et al.*, 1982; Ibitoye *et al.*, 2011). Oil palm is a very versatile tree crop that has useful parts that are of great economic value. The primary product obtained from oil palm is the palm fruit, which is processed to produce three commercial products. These include palm oil, palm kernel oil and palm kernel cake. There are many uses of oil palm with various uses (Adegbola *et al.*, 1979). This was not unconnected with its economic value as a very important source of edible and technical oils of a huge National revenue earning potentials (Ibitoye *et al.*, 2011). Industrial oil palm plantations require the clearance of large areas hence they often need the confiscation of land and the cutting of large pristine forest areas. Hence, the development of this kind of plantations is usually associated with land tenure conflicts and problems of local land ownership (Verheye, 2010).

Increase in population in developing countries has led to reduced arable land and increase in the demand for agriculture products (Seran and Brintha, 2009). Currently, oil palm sector in Nigeria is undergoing reactivation following its downturn during the discovery of crude oil. Other factors that gave rise to the decline of Nigeria oil palm industry include civil war (1967 – 1970), inavailability of modern farm mechanization, over dependency on smallholder/traditional processors, land tenure problem, inadequate infrastructure, poor funding, campaign by environmentalist for environmental protection etc. However, Soyebó *et al.* (2005) asserted that

the main factor limiting oil palm cultivation is land. Reports indicated that majority of the farmers in Nigeria (81%) are faced with land problem, 34.2% with problem of fund while 53.2% complained of inadequate information and cultivation knowledge about oil palm. Small-holding farms cover a range of 1-5 hectares and are sometimes characterized by mixed cropping obviously to maximize the usage of the land (Thompson and Eshalomi, 2010).

Triangular spacing of 9 X 9 m triangular spacing used in the cultivation of oil palm provides wide space between juvenile oil palms (Okigbo, 1979). This results in considerable waste of solar radiation and serious weed problem from transplanting to canopy closure which takes between three to five years (Chee *et al.*, 2000), when the oil palms become productive. To achieve production at this age, the plantation has to be properly maintained by prompt weeding and fertilizer application. More so, due to the long period of juvenility of oil palm, farmers often make use of the large fallow spacing land to intercrop other food crops especially shade tolerant types to generate income until steady production of fruits by the oil palm trees is achieved. At the stage when the oil palm has started producing fruits, the canopy size of the palm tree would have increased significantly to prevent much intercropping due to heavy shading (Okigbo, 1979).

The only way to increase agricultural production in the small or marginal units of farming is to raise the productivity per unit time and area (Chatterjee *et al.*, 1993). Intercropping is one of the farming systems identified in West Africa that deals specifically with the ways farmers employ land resources in agribusiness (Opeke, 2006). Growing a number of other food crops in association with juvenile oil palm trees is a widespread practice in most oil palm growing areas in the country. Intercropping vegetables with different architecture and nutritional value such as beet and okra, pepper and onion with juvenile oil palm has been practised in tropical Asia (Okigbo, 1979). Vegetables such as cabbage, cucumber, radish, snap bean, and broccoli are

intercropped into rows of other field crops that are planted on plain field or raised soil beds. The rationale for this form of intercropping practice is that these food crops can profitably be grown between and under the oil palm during the juvenile stage and thus contribute to the overall productivity of the land during this long juvenility of 4-5 years (Liyanage, 1976).

One of the purposes for intercropping is that two or more crops are together in a place, during their growing season or at least in a time frame. Therefore it is possible that the plants are different in terms of planting time (Ofori and Stern, 1987; Mazaheri *et al.*, 2006). For example, in an oil palm plantation, the oil palms are first planted at the recommended planting spacing of 9 X 9 m triangular arrangement with a wide space of 7.62 m existing between the oil palm rows. This wide inter-row space may then be utilized for growing other crops particularly food crops. Such crop as plantains, cocoyam, maize, cowpea, pineapple, groundnut, rice, cassava, yam and melon may be economically cultivated with the oil palm by applying adequate spacing for the food crops up till the fifth year. More so, crops that are shade tolerant such as pineapple, tomato, cocoyam and pepper can still be grown with the inter-row space beyond the five years limit. The advantages of intercropping with juvenile oil palms in the field include adding value to the oil palm when the food crops are harvested and sold, and particularly so in the early years when the oil palm has not started to yield fruit bunches. In addition, the planting of the food crops between inter-rows of the oil palm facilitates field maintenance of the plantations, as the field is kept clean of competing vegetation through weeding of the food crops and ultimately overall maintenance cost is reduced since labour cost for weeding the intercropped area was also applicable to the oil palm hence the double cost of maintenance is avoided (NIFOR, 2008).

Vegetable production has been asserted as one of the numerous approaches which will successfully transform Nigeria's subsistence vegetable farming into a high value vegetable

production (Nnaemeka, 2013). Vegetables are rich and efficient source of essential vitamins A and C. It serves as a source of healthy delicacy as the leafy is combined with fruit vegetables and other ingredients in the preparation of soups used in eating different kinds of foods. Some common vegetables found in our region are: pumpkin, water leaf, pepper, amaranthus, okra, tomatoes, lettuce, egg plant, cabbage etc. (Nnaemeka, 2013).

Nuertey *et al.* (2000) identified a number of crops that the farmers intercrop with oil palm and the basis of their selection. Farmers may seem justified then by growing food and or cash crops at different intercropping distances from the juvenile oil palm trees until canopy closure. However, there are two distinct parameters that should be considered in the evaluation of intercropping advantages (Willey, 1985): a biological objective to determine the increased biological efficiency of intercropping; and a practical objective to determine tangible advantages that are likely to be obtained by a farmer. These dynamics need a thorough understanding before compromising on an ideal system performance of intercrops for recommendation to the farmers, since a biologically efficient system may not necessarily be economically viable (Ghulam *et al.*, 2003).

It is very difficult to do away with intercropping oil palm with food crops especially among the small scale oil palm farmers. Nuertey *et al.* (2000) suggested that it is profitable to intercrop oil palm with food crops especially for the first three to four years when the palms are not fruiting as compared to sole cropping. This makes it important to educate farmers on the proper way to carryout intercropping and the suitability of the various food crops. Farmers would be able to raise some money from the intercrop to sustain their family and also to maintain the farm. Researchers have also pointed out that there is no adverse effect of early intercropping oil palm with maize, cassava and plantain.

Oil palm can successfully be intercropped with food crops. It was also reported that yields differences obtained from oil palm intercropped with food crops compared to oil palm monocrop were not significant. However, it is advisable to follow the proper intercropping system in order to gain the full benefit of the oil palm-food crops intercrop (Okyere *et al.*, 2014). The relative advantage of intercropping oil palm with food crops, suggests that intercropping systems may be most suitable for small-scale producers with limited resources to purchase large land to develop oil palm and food crops separately (Okyere *et al.*, 2014). Intercropping helps smallholder farmers who face labour constraints because it has the potential to reduce weeding frequency. Farmers in the tropics face serious weed challenge than any part of the world and spend 75% of their time battling weeds in their fields. These farmers also experience great labour constraints; they invariably weed large portions of crop late when it has already suffered significant yield damage (Mashingaidze *et al.*, 2004).

The agronomic impact of weeds differs with different crops and location as many of them have been reported to be crop and location specific. Weeds exhibit diversity in their level of occurrence and distribution at various locations and during different seasons; however, it is perceived to have adverse ecological and economic impact on agricultural and natural systems (Olorunmaiye *et al.*, 2013). Weed species distribution in terms of species richness is measured as the number of species in a community. Distribution could be within or between communities; two communities with the same number of species can differ in terms of evenness, and hence it is useful to know the proportion or relative abundance of species within the community (Karaye *et al.*, 2007).

Many researchers have reported the reductive effect of weeds on crop production and it has been indicated that a 51% reduction in cowpea yield can occur due to weed infestation, 65% in

cassava, 73% in yam and 80% in maize (Olorunmaiye *et al.*, 2013). Weed suppression and management in intercropping system through more efficient use of environmental resources by component crops has also been reported by researchers (Liebman and Dyck, 1993; Mashingaizde *et al.*, 2000; Mashingaizde, 2004; Poggio, 2005; and Eskandari and Kazemi, 2011). The complementary effect of companion crops is believed to be reduction in weed pressure (Orluchukwu and Udensi, 2013). Furthermore, an ideal spatial pattern should be used with minimum influence on companion crops' yield while it's able to suppress weeds. Common intercrop spatial patterns used worldwide are intra-row (within the same row), inter-row (alternating rows) and random (mixed). Planting pattern affects interaction between intercrop companion crops, their use of environmental resources, and thus influence the outcome of intercrop compared to sole cropping system (Lithourgidis *et al.*, 2011).

For a farmer, higher income may be more essential than higher crop yields (Joshi and Prabhakarasetty, 2005). Evaluating cropping systems is important to select superior ones over the existing system adapted by the farmers or researchers in terms of biological productivity and economic potential for particular area (Seran and Brintha, 2009). In general, a biological efficient system is also economically superior; however, the economic efficiency of superior system depends on the cost of input and price of produce (Sivaraman and Palaniappan, 1996). Economic value is pertinent only to the location and time for which computation was based. Its real value changes greatly over time and for different locations. However, selected cropping system is good for a particular area until a new system would be developed and subsequently prove to be more superior (Seran and Brintha, 2009 and Chumba *et al.*, 2013).

1.1 Statement of problem

The wide field spacing (6 – 9 m between palm stands) used in oil palm cultivation allows for waste of solar radiation and has consequently led to serious weed infestation from transplanting to canopy closure stages when the oil palm becomes productive. Oil palm has a long juvenility period of about 4 years during which the palm is not productive. During this period, farmers spend on a lot of money on labour for weeding the plantation every year without any monetary returns. Vegetables intercropped with juvenile oil palm have good potential in our climate; however, none of them has been systematically tested in agroforestry system or under natural shade condition to see their production ability under partial shade condition (Nahid, 2006). For this purpose, the best way of experimentation is to grow different crops at different spacing from the tree. So, if we know the suitability of different crops in terms of growth and yield, and appropriate spacing, it would be very useful information for selecting the best tree-crop combination at specific spacing. This can be achieved by experimenting under different oil palm-vegetable combinations at different spacing for screening of different crops in terms of their growth and yield performance.

The wide empty spaces among the rows of young oil palms have resulted in ineffective or inefficient utilization of environmental resources, such as land, growing space, sunlight and CO₂ (Rezig *et al*, 2012). Thus, the introduction of annual crops, such as soybean and groundnut in young oil palm plantation areas, has provided the opportunity to improve the efficiency and effective uses of environmental resources (Aynehband *et al*, 2010; Rezig *et al*, 2012; Abera and Feyisa, 2009; Amanullah *et al*, 2006).

Regardless of the cropping systems practiced, the weed problem remains a major cause of yield loss in crops and detailed knowledge and understanding of their distribution, biology, survival

mechanism and life cycle would help in further research to reduce devastating effects of weeds on agricultural farms and ultimately food security.

1.2 Justification of Study

The enrichment model of the components of young oil palm ecosystem, through the introduction of annual food crops, is a method that can be used to improve the effectiveness and efficiency of the use of environmental resources (Rezig *et al*, 2012). However, this requires strategies, so that the introduction of the annual food crops will not interfere with the growth and development of the young oil palms which are the main crop. The introduction of annual crops was informed by the availability of resources in the environment of young oil palms (aged 1-4 years), which are otherwise utilized by weeds (Celette *et al*, 2009; Ghosh *et al*, 2006). It is worthy to note that the right type of the annual crop(s) will not interfere negatively with the growth and development of oil palms; on the contrary, a positive interaction between young oil palms and the annual food crops would actually has a good chance to promote the growth and development of the main crop. More so, the selection of appropriate annual crops will also optimize food production because those crops have optimal growth, development and yield (Szumigalski and Akcer, 2006).

Nonetheless, the type and the appropriate seasonal crops are allegedly different in oil palm plantations aged 1 to 5 years since the composition of the environmental resources vary between the phases of oil palm development. Evaluating the effects of different intercropping system and component crop combinations on weed distribution is important in selecting more efficient intercropping patterns and crop combinations that will help to reduce weed infestation greatly, develop better weed management systems, increase yield; and hence promote food security.

1.3 Aim of the study

It is to intercrop six accessions of fruit vegetables at varying spacing regimes with juvenile oil palm; examine their biological and economic efficiencies and the effect of fruit vegetables-juvenile oil palm intercrop on weed flora and species diversity in the study area.

1.4 Objectives of the study

The objectives were to evaluate the;

1. physiological responses in terms of growth and yield of the fruit vegetables to three spacing regimes in juvenile oil palm-vegetables intercrop;
2. effect of intercropping on the growth of juvenile oil palms;
3. effect of intercropping on physicochemical properties of the soil;
4. biological and economic efficiencies of oil palm-vegetables intercrop;
5. weed flora and species composition in the intercropped alleys of the oil palm plantation;
6. diversity of weed species in the experimental plots;
7. effect of intercropping of different fruit vegetables with juvenile oil palm on the smothering efficiency of the intercrops, weed density and biomass.

CHAPTER TWO

LITERATURE REVIEW

2.1 Intercropping

Intercropping is a planting strategy employed by farmers to cultivate at least two crops at the same time on the same plot of land (Leigh *et al.*, 2013). It is also regarded to as the cultivation of two or more crops at the same time in the same field. Its advantages are risk minimization, increased income and food security, reduction of soil erosion, and pest and improved disease control (George and Jeruto, 2010). Intercropping has been practised in the developing countries of Central America, Asia and Africa (Allen and Obura, 1983; Altier and Liebman, 1994; Bekunda and Woomer., 1996; Bekunda, 1999; Grossman and Quales, 1993; Jodha, 1979; Prabhakar *et al.*, 1983). Intercropping is a common practice in Africa. In East Africa, fruit crops are usually intercropped with annual crops. For example, banana is intercropped with food and or fodder crops to increase land use efficiency for smallholder farms (Clark and Francis, 1985). In Kenya, intercropping of fruit trees with all kinds of short term crops such as beans, millet, peas, potatoes, maize, exotic and indigenous vegetables when they are still young as a way of attaining food security and income before the trees mature (George and Jeruto, 2010).

When two or more crops are cultivated together on the same field, the possibility of crop failure is spread over the different crops as the different crops have diverse periods and growing patterns, and are affected by different types of diseases. If one of the crops fails (due to drought, pests and or diseases), there could still be a harvest from the other crops (Adebowale and Amusat, 2005). This increases food security. In good years, the yield of two crops grown on the same field as an intercrop is often higher than the yield of the same crops grown separately. Pest and disease often are less abundant in intercrops (Ibeawuchi, 2007). There are different ways to

explain this. If pest or disease has a specific host, it does not spread as easily through an intercrop as it does in a monocrop. Insects and pests can also be misled by the canopy of an intercrop and not recognize the specific crop they use as a host. Substances that other crops produce may drive insects away from the main crop or natural enemies of insects may be attracted by one of the crops in the intercrop. In some cases, diseases and pests may also be stimulated by the intercrop, for example diseases or pests that prosper in shady conditions (Martine, 2007).

Intercropping is a method to increase the diversity of the farming system. More diversity in the farming system generally means better stability, which result in risk spreading and reduced pest and disease incidence. When two or more crops that have different systems of rooting, different demand for nutrient and water patterns and different above-ground habit are intercropped together, sunlight and nutrients are more efficiently utilized. As a result, the combined yields of two crops cultivated together as intercrops can be greater than the yield of the same crops grown as pure stand (Ozobia, 2014). Intercropping is important because it helps to improve and maintain soil fertility. This is achieved when a cereal crop (such as maize or sorghum) or a tuber crop (such as cassava) is grown in association with a pulse (beans, peas, etc.); deep rooting crops, such as pigeon pea, also take up nutrients from deeper soil layer thereby recycling nutrient leached from the surface. After the intercrop is harvested, roots that have decayed and fallen leaves provide nitrogen and other nutrients for the next crop. The residual effect of the pulse crop on the next crop is greatest when the leftovers of the crops are left on the field and ploughed under the soil after harvesting. However when a large quantity of nitrogen is taken away in the grain harvest, more nitrogen is taken away from the field than fixed by the pulse crop. Thus soil

fertility reduction can still take place in intercrop of grain and pulse when the nutrient taken up by the crops are not replaced with manure or fertilizer (Martine, 2007).

The component crops of intercropping system do not only provide a source of nitrogen and other nutrients to the associated crops, but also increase the amount of humus in the soil, due to decaying crop remains. This results in an improved soil structure, reducing the necessity for soil tillage. Water losses, erosion of soil and leaching of nutrients are also depleted in intercropping systems, as a result of the improved structure of the soil and because of a better soil cover, especially when creeping pulse crops are used. With a good soil cover, the impact of rain drops on disruption of the soil is reduced. In relay-intercropping, the pulse crop is planted sometime after the main crop and continues to grow after harvest of the main crop. This result in a more efficient use of soil water and prevents leaching and erosion, as the soil is still covered after harvest of the main crop (Martine, 2007).

Depending on the crops intercropped, competition for water, light and nutrients may give rise to lower yields. Changes in the spatial arrangement of the crops will reduce competition (Reddy and Willey, 1981). A larger distance between plants reduces competition for water. Other problems that could arise from intercropping are difficulties in mechanization and increased labour requirements. When machines are used for weeding or harvesting, intercropping can be difficult. However, strip intercropping is a useful alternative to mixed or row intercropping (Martine, 2007).

When two or more crops are growing on the same piece of land at a particular time, each of them should have enough space to maximize interactive cooperation and decrease competition between them. This is achieved by the following factors outlined: spatial arrangement; plant

density; dates of maturity of the crops grown; and plant architecture (Okigbo, 1979). The spatial arrangements are:

1. Row intercropping – cultivating two or more crops together at the same time with at least one crop cultivated in rows.
2. Strip intercropping – Growing two or more crops together in strips wide enough to separate crop production using machines, but close enough to interact.
3. Mixed cropping – Cultivating two or more plants together without any distinct row arrangement.
4. Relay intercropping – Planting a second crop into a standing crop at a period when the initial standing plant is at its reproductive stage however before harvesting (Okigbo, 1979).

In order to optimize density of plant, the rate of seedling of each crop on the intercrop is adjusted below the maximum rate to decrease competition and overcrowding (Hiesbick, 1980; Magaguda *et al.* 1979; Prabhakar *et al.*, 1983). Intercrop with staggered maturity periods or periods of development utilize variations in maximum resource requirements for nutrients, water and sunlight (George and Jeruto, 2010). Plant architecture gives room for one intercrop to capture sunlight that would not otherwise be accessible to others (Reddy and Wiley, 1981; Gardiner and Craker, 1981).

However, depending on the plants intercropped, competition for water, light and nutrients may result in depleted yields (George and Jeruto, 2010). Farmers intercrop to maximize returns from their land by planting multiple crops on the same piece of land at the same time. It was reported that farmers may choose to intercrop as a way to reduce the risk of single crop failure (Lithourgidis *et al.*, 2011). Potential advantages of intercropping may include higher yields,

decreased production constraints coming from weeds or pests, and increased crop diversity per unit of land (Leigh *et al.*, 2013). Other benefits of intercropping are risk minimization, effective utilization of available resources, efficient use of labour, increased productivity of crop, control of erosion and food security. It has been reported that in intercropping systems, weed population density and biomass production in the intercrop was lower in many cases than in all of the component sole crops (Bekunda and Woomer, 1996; Bekunda, 1999; Jodha, 1979; Owuor *et al.*, 2002). It has also been revealed that tree crops intercropping systems may contribute to the welfare and livelihoods of farmers (Eshchanov *et al.*, 2008).

Stability is can be achieved in a community through intercropping. Stability is achieved by a community when it has attained a great level of diversity. Diverse communities possess lower fluctuations in numbers of a particular species and are stable. The practices which facilitate stability and diversity on the farm are diversification of enterprise, rotation of crop, use of wind breaks, availability of more habitats for microorganisms, intercropping and integration of crop farming with lproduction of livestock (Reddy and Wiley., 1981; Reddy *et al.*, 1992). Farmers prioritized production of fruit over woody species. Gardeners out to use their diverse knowledge, generated and obtained over many years, to plan the diversity of potential plants and decide what and when to crop, while putting in place social and economic areas of land utilization. Such decisions show the values and priorities of users of land in the selection and management of trees and crops in tree intercropping systems (Eshchanov *et al.*, 2008). However, Chamshama *et al.* (1998) asserted that intercropping with fruit trees gives rise to a reduction in yields of annual crop over time as a result of competition for moisture and nutrient in the soil.

There is decrease in population of insect/mite pest as a result of the diversity of crops cultivated and decrease in plant diseases due to the distance between plants that belong to the same species

is occupied or higher as a result of the planting of other crops between them, alteration of more advantageous insects particularly when crops that are flowering are included in the cropping system, increase in total production of the farm and profitability and decline of weed population via allelopathy and efficient production of crop (Maguguda *et al.*, 1979). In addition, when the intercrop generates a great soil cover, temperature of soil will remain relatively low. This disallows burning of the organic matter in the soil and loss of nutrients. More so, it give rise to a microclimate that can be favourable for associated crops. In a maize-bean intercrop, for example, climbing beans can use the maize stalks for support (Maguguda *et al.*, 1979).

The distinct areas of intercropping are: detailed planning, appropriate and timely planting of each crop, adequate fertilization at optimal dosage and times, proper weed, pest and disease control, and efficient harvesting (George and Jeruto, 2010).

Planning should include selection of crop species, cultivars at are appropriate, availability of water, spacing, population of plant and labour requirements throughout the season, tillage requirements and predicted profitability of intercrops, planting time, appropriate fertilization, pest and disease control (Prabhakar *et al.*, 1983, Reddy and Willey, 1981). Some factors will influence whether or not two crops can be successfully intercropped, these include plant height, ability to tolerate shade, root system etc. (Spiejer *et al.*, 1999), the size of the leaves and the orientation and distribution of these leaves in the plant canopy (Sogbedji *et al.*, 2006). These variables influence the amount of sunlight that goes through the canopies (Grossman and Quales, 1993), which could affect the photosynthetic rates of the leaves under the shade. In intercropping systems with different canopy heights the crop in the understorey needs to be shade tolerant for the plant to be productive (Sogbedji *et al.*, 2006).

The decision to intercrop annual crops with fruit trees may be distinct from the decision to intercrop a variety of annual crops. Intercropping annual crops alongside with fruit trees can be a strategy to promote food security and income before the maturity of trees, or to maximize the efficiency of resources on smallholder plots (Ouma and Jeruto, 2010). Farmers may seem justified then by growing food and /or cash crops between oil palm trees until canopy closure. To explain the performance of intercrop components, the idea of Land Equivalent Ratio (L. E. R.) is put to use. It quantifies the merits of utilizing intercropping systems on combined yields of both crops (Okigbo, 1979). Land Equivalent Ratio (L. E. R.) is a method used to ascertain the efficiency of intercropping systems. It is the most widely used index for measuring the advantages of intercropping systems on combined yield of both crops (Mandal and Roy, 1986). It is defined as the relative land area under sole crops required producing yields achieved in intercropping (Trenbath, 1976). It supplies a standardized ground for comparing systems under different circumstances and combinations of crop (Mead and Willey, 1980). Monetary advantage was calculated to find out the extent of monetary advantage derived due to intercropping (Trenbath, 1976).

2.2 Oil palm (*Elaeis guineensis* Jacq.)

The oil palm (*Elaeis guineensis*) is regarded as one of the important economic crops found in the tropics (Anyanwu and Anyanwu, 1982). Oil palm is a tropical tree crop which is grown industrially for production of vegetable oil (Verheye, 2011). It belong to the family *Palmae* (with over 2600 species and 225 genera), and the subfamily *Cocoideae* among which it is the most vital member (Opeke, 1987). The genus contains two main species: *E. guineensis* or African oil palm, and *E. melanococca* or American oil palm; the latter is only of importance for hybridization purpose. Male and female flower inflorescences takes place on the same tree in

interchanged cycles of the same sex, and are only separated after approximately two years. This process is controlled by fertilization, moisture and temperature conditions and other secondary ecological factors (Verheye, 2010).

There is a consensus that the oil palm (*Elaeis guineensis* Jacq.) is a native of West Africa. Many reports cited Nigeria among the most probable place where the fruit was first domesticated before the 14th century (Thompson and Eshalomi, 2010). Palm tree is found predominantly in southern Nigeria especially in the wet rain forests and savanna belt. It also exists in the wet parts of North central Nigeria, in areas like Southern Kaduna, Kogi, Kwara, Benue, Niger, Plateau, Taraba and Nasarawa States as well as the Federal Capital Territory (FCT) (Thompson and Eshalomi, 2010).

Oil palm is a wide spaced perennial crop with a long juvenile period of 4-5 years. Inter and intra row space can be used to generate income during the juvenile phase of the crop. Juvenility is a stage in the development of the plant in which it is regarded as young plant. A plant usually develops into mature stage from the juvenile stage. There is a time period during which a plant can be categorized to be juvenile and this varies from plant to plant. Some plants have short period of juvenility e.g. pepper while others may have long juvenility period e.g. oil palm, coffee, kola, etc. Certain features characterize this stage of development in plant, these may include leaf shape, phylotaxis, stem habit, ability of stem cuttings to root, ability of plant to produce flower, ability of plant to accept graft union, etc. Juvenile stage in oil palm is characterized by small canopy size and absence or inability to flower or to produce fruits. This stage could last for about 3 and half to 5 years depending on variety and maintenance practice in the oil palm plantation (Rees, 1961).

The oil palm (*Elaeis guineensis* Jacq.) is one of the main sources of vegetable oil. Two distinct oil types- the palm oil (mesocarp oil) and the kernel oil (the seed oil) - are obtained from the oil palm tree. The oil palm belongs to the subfamily Cocoideae of which it is the most important member. The origin of the oil palm is in dispute. Reports suggested an American origin of the oil palm, because palms grow spontaneously and freely in the coastal areas of Brazil and because the American palm (*Coroza oleifera*) has its centre of origin in Latin America. However, a number of authorities (Zeven, 1967) provided fossil, historical and linguistic evidence to confirm the African origin of *Elaeis guineensis*. While some maintain a reserve position on the centre of origin of oil palm, most authorities accept the tropical rain forest region of West Africa as the centre of origin of oil palm.

Oil palm with various cultivars grows freely and spontaneously in West Africa. Recent studies have shown that the oil palm spreads from 16°N latitude in Senegal to 15°S latitude in Angola and eastward to Zanzibar and the Malagasy Republic. However, the main oil palm belt of West Africa runs through the southern latitudes of Sierra Leone, Liberia, Cote d'Ivoire, Ghana, Togo, Benin, Nigeria, Cameroun and into the equatorial region of Zaire and Angola between latitude 10°N and 10°S. Oil palm occurs naturally in the Semiliki Valley of the Zaire-Uganda border, on the Ruzizi plains between Lake Kivu and Tanzania, on the eastern shores of Lake Tanganyika and the western shores of Lake Nyasa. Oil palm accompanied the slave trade to the New World (the Americas). Oil palm plantations have been developed in a number of places in Latin America since 1960 (Purseglove, 1975). However, Malaysia is one of the major producers of the oil palm; the crop was introduced to that part of the world from West Africa, especially Nigeria.

2.2.1 Botany of oil palm

Elaeis guineensis grows to height of 9 m or more, with a stout stem, covered with semi-persistent leaf bases on which epiphytes often grow. It is monocotyledonous and monoecious plant. The stem may be 30-38 cm in diameter, with progressive thickening towards the base on older palms, the stem is punctuated with conspicuous and regularly arranged leaf scars and the stem terminates in a handsome growth of leaves (fronds). The crown may contain up to 40 or more leaves (Olagunju, 2008). The palm leaf is compound and is known as the palm frond. The leaf is paripinnate with a prominent petiole (0.9 to 1.5 m long). The petiole often broadens at the base to form a clasper round the stem. Each palm frond bears from 20 to over 150 pairs of leaflets arranged in more or less two rows along each side of the flattened rachis with the longer pinnae varying up to 120 cm; the pinnae are parallel veined.

Unimproved palms flower at the age of four to five years while selected and bred palms flower in about three years. When in full bearing, a palm may bear up to 12 bunches of fruits per year. An average mature tree may produce up to 24 fronds per year with an axillary flower cluster for each frond. The succession of production of male and female flowers is unpredictable. The inflorescence is enclosed in a spathe, the whole structure is the spadix. When fully grown, the spadix splits into two or more parts longitudinally to expose the flowers (the florets).

The inflorescence is composed of a main axis and up to 40 or more side branches with florets. The male flowers are borne on side branches; they are numerous, small, each with six perianth segments arranged in two alternating whorls and an aborted ovary. The stamens consist of stout filaments each carrying a two-celled anther lobe. The anther lobe splits longitudinally to release powdery pollen grains. The female flower is composed essentially of six perianth segments which are thick and tightly folded over the pistil when young; the ovary with trifid stigmatic

surfaces, and aborted stamens. Both male and female flowers are borne on thick peduncles. There are three basic types (varieties) of the oil palm (Basiron and Weng, 2004).

These are as follows:

1. The Dura type: this is characterized by thin mesocarp, thick endocarp (shell) with generally large kernels: the Dura type is genotypically denoted by *DD*.
2. The Tenera type: this possesses thick mesocarp, thin endocarp with reasonably sized kernel. This is a dual purpose palm for the production of mesocarp oil and kernel. It is genotypically heterozygous and denoted by *Dd*.
3. The Pisifera type: this possesses thick mesocarp (with very little oil content), no endocarp (shell-less) with small kernel. The female flowers are often sterile, this resulting in bunch failure. It is genotypically homozygous and recessive for shell. It is denoted as *dd*.

There occurred in the early days a type of palm known as the Deli palm. Deli palm was common in the Far East in the olden days. It has been assumed that it was a selection from the Tenera, which was introduced into the Far East around 1840. The Deli palm has now been replaced by improved Tenera types, especially in Malaya (Omoti, 2004).

The oil palm is naturally cross-pollinated. Cross-pollination is ensured by the production of two types of inflorescence- male and female- separately although occurring on the same plant; male and female flowers opening and being receptive at different times. Rarely do the terminal female flowers of an inflorescence remain receptive when the male flowers of the next upper ring of the inflorescence commence discharging pollen grains. The main agencies of pollination are wind and insects, especially those of the Diptera (Owolarafe and Arumughan, 2007).

Immediately after fertilization, fruit development commences with rapid expansion of the husk, enlargement of the cavity followed by the development of the endosperm and the embryo. The embryo is embedded in the endosperm just below the eye. Initially the embryo is thin and jelly-like, but later thickens to fill the cavity and hardens. The inflorescence develops into the fruit bunch (Purse-glove, 1975).

2.2.2 Climatic and edaphic conditions for oil palm cultivation

The oil palm belongs to the warm, high rainfall, tropical forest areas. It grows best where rainfall is not less than 1500 mm, evenly distributed throughout the year. Ideal temperatures are 27°C to 35°C, while the nights should be frost-free. Oil palms will tolerate even higher temperatures provided there is adequate moisture. Oil palms require plenty of sunshine, productivity being reduced in areas with excessive humidity; yields are adversely influenced when the crop is exposed to dry harmattan winds. Oil palm is a lowland crop although it can grow well up to an altitude of 900 m. It has a fibrous root system and benefits from deep soils which are fertile, free from iron concretions and well drained. It could also tolerate a fair range of soil pH although neutral soil is most favourable (Orewa, 1998).

2.2.3 Global palm oil production

Global palm oil production has increased from 15.2 million tons in 1995 to 62.6 million tons in 2015. This is the highest production volume of all vegetable oils, exceeding the second biggest oil seed crop by more than 10 million tons. This volume is mainly produced by Indonesia (53 percent) and Malaysia (32 percent). There has also been a marked increase in palm oil production in other parts of the world. Most of the additional volume is generated in South and Central America (3.4 million tons), Thailand (1.8 million tons) and Western Africa (2.4 million

tons). Among major oilseed crops, oil palm amount for the smallest percentage (5.5 percent) of all the cultivated land for oils and fats globally, but produces the largest percentage (32 percent) of total output. It uses less than half the land required by other crops (such as sunflower, soybeans or rapeseed oil) to produce the same amount of oil. Production and use of sustainable palm will help to maintain or enhance biological, ecological and social values in the countries of origin (EPOA, 2016).

Oil palm accounts for 34 percent of the world's annual production of vegetable oil and 63 percent of the global exports of vegetable oils (USDA, 2010). It is produced in tropical climates and in 42 countries across the world. Palm fruit from which palm oil is extracted is of immense value. Some African nations are currently producing palm oil on a commercial scale (Soyebo *et al.*, 2005). Uganda is currently developing oil palm plantations as tool to eradicate poverty. Nigeria is currently the third largest producer of palm oil in the world after Indonesia and Malaysia; however it remains a net importer (Pleanjai *et al.*, 2007). The Nigerian experience of oil palm development provides a clear example of how oil palm, as a result of its high yield and low production costs, is a highly effective means of alleviating poverty (Thompson and Eshalomi, 2010).

Oil palm intercrop

While growing intercrops in mature oil palm gardens of 8-12 years of age or palms that have attained a height of 3 m, intercrops should be able to grow under partially shaded conditions and should not compete with oil palm for water, sunlight and nutrients (e.g. cocoa, pepper, heliconia and ginger lilly) (Prasad *et al.*, 2011). The spacing habit and growth pattern (9 X 9 m triangular spacing) of oil palm plantation permit a number of annual and perennial crops to be grown with and under its canopy during the juvenile stage of the oil palm.

It has been reported that large number of compatible crops- both annuals and perennial- are grown under coconuts in different geographical and eco-climatic regions (Hettiarachchi, 1974; Karunaratne *et al.*, 1978; Liyanage, 1976; Nair, 1979; Nelliath and Bhat, 1979).

Meanwhile, the components of the young oil palm ecosystem are also more diverse with the introduction of the annual crops within the empty spaces among the rows of main crop. The increasing diversity of the ecosystem components has given impacts on the improvement of land capability to save water and CO₂, and solar radiation harvesting (Chianeh *et al*, 2011; Prasad and Brook, 2005). Therefore, the introduction of annual crops has caused the ecosystem health in young oil palm areas to become better. In the long term, the young oil palm areas will be enriched with annual crops and have a chance to address global warming due to the increased capacity in the amount of CO₂ harvested by the ecosystem (Rezig *et al*, 2012). Other opportunities that can be captured through the introduction of the annual crops were to make young oil palm plantation areas as a buffer of food production. Food production is derived from the introduction of the annual crops (Igene *et al.*, 2015).

2.3 Vegetable Crops

All societies and ethnic groups eat vegetables because they are essential for maintaining human health. In simple terms, modern vegetable science deals with growing herbaceous plants for human consumption to meet basic nutritional needs. As the world's population grows, the demand for vegetables will continue to grow as well. Vegetable science, sometimes called olericulture, is one of the most dynamic and important fields of the agricultural sciences. The importance of vegetables has never been greater. Vegetable is an herbaceous plant or portion of a plant that is eaten whole or in part, raw or cooked, generally with an entree or in a salad but not as a dessert. Of course there are exceptions to this definition. Rhubarb, watermelon and

cantaloupes are all considered vegetables but commonly used as desserts. Mushrooms are fungi and not plants however they are in general regarded to as vegetables.

Since “vegetable” is not a botanical term, some vegetables in botany terms are also referred to as fruits. In a botanical sense, a fruit describes a ripened ovary containing seeds together with adjacent parts that are eaten at maturity. For example, cantaloupe, pepper, tomato and beans botanically speaking meet the definition of fruit, but because of the way they are traditionally used and produced they are considered to be vegetables. Therefore, since there are essentially two classification systems, some commodities may be classified as a vegetable based on their usage while at the same time they are botanically fruits.

Vegetables are a horticultural food crop. Other food crops that are horticultural include tree fruits and small fruits, which are often grown as perennials. Vegetable crops may be either annuals or perennials. From a production standpoint, a vegetable crop may be defined as a high-value crop that is intensively managed and requires special care after harvest. Agriculturalists often segregate agronomic or “field” crops into a separate category as crops that are extensively grown and less intensively managed in comparison to vegetable and the other horticultural crops. Wheat, cotton, soybean, sugarcane and rice are all examples of agronomic crops. Many agronomic crops are grains that are planted and destructively mechanically harvested at full physiological maturity at the end of their life cycles. In contrast, many vegetable crops are harvested in an immature state, while still fragile, so great care must be taken to preserve their quality from the field to the consumer (Ndereyimana *et al.*, 2013).

Irish potato is regarded to be a vegetable by many but as crop that is agronomic to others depending on the region, type and scale of production. Soybeans and corn can either be regarded as vegetable or agronomic crops depending on the cultivated cultivars, their stage of maturity at

harvest and their end use. While these definitions are not perfect, they do have value in allowing us to group different crops and types of production to understand better the more unique aspects of vegetable production, management and handling compared to other crops. So in summary, “vegetable” is a term used based on the herbaceous plants or portions of plants used that are eaten whole or in part, raw or cooked, generally with an entree or in a salad but not as a dessert, that are intensively managed and may require special care after harvest to maintain quality.

There is a wide variety of indigenous vegetables and fruits found in Africa, which are chief sources of nutrients, vitamins, antioxidants, minerals, and proteins (Odhav *et al.*, 2007). Eifediyi *et al.* (2008) pointed out that the use of indigenous vegetables and fruits are part of African cultural heritage, and they play important role in the tradition and food culture of the African households. Vegetables play very important role as a source of nutrients to the human body and their consumption ensures intake of various essential vitamins and mineral elements thus avoiding the problem of malnutrition (Yamaguchi, 1983).

2.3.1 The Evolution of Vegetable Production

Over the years, world vegetable production has increased. For example, there was over a four-fold increase in world vegetable production from 1970 until 2009 (FAO, 2005). The long-term increase has largely been the result of a series of technological advances. The first were labor-saving technologies such as the moldboard plow, and power equipment such as trucks, tractors and harvesting equipment. Subsurface drainage systems were developed to improve productivity of chronically waterlogged soils. During the first half of the 20th century, low-cost commercial fertilizers were mass-produced, leading to dramatic improvements in fertility management and productivity. In the 1930s, new plant-breeding techniques led to development of more productive cultivars.

Many view the period after World War II as the chemical era of agriculture as many synthetic pesticides, e.g. fungicides, insecticides and herbicides, became readily available. Chemicals were intended to more easily control crop pests to enable a large-scale, single-crop production system called monoculture where only a single crop is grown in a field and all other vegetation is excluded. The monoculture system and the related technologies like chemical pest control and concentrated synthetic-fertilizer usage were designed in part to reduce the amount of labor needed in agriculture so that one person could effectively manage more crop-production acreage and increase productivity. During the 1970s and 1980s, concerns about human health issues led to interest in and the development of more sustainable and low-input approaches to vegetable production. Also in the past 50 years, conservation tillage practices have been developed to reduce soil erosion, decreasing the number of passes made over a field to decrease soil compaction. Plastic mulches were developed to modify soil temperatures, control weeds, reduce leaching and use less water to produce vegetables. Trickle-irrigation systems were developed to precisely apply water and nutrients to vegetable crops throughout the season. Raised-bed production systems improved drainage, encouraged better root development and reduced disease. During this same time frame, computer technology also impacted both production and management issues, increasing production efficiency.

Despite these advances, there seems to be declining interest in vegetable science as a discipline in the academic circles of many developed countries. Government sponsorship of research on applied aspects of vegetable science in many developed countries has declined in recent years as funding has been diverted to more basic research in plant science. There is a perception that research on vegetable crop production is no longer a high priority in countries with developed

agriculture industries because most of the production-related questions have already been answered or are being addressed by the private sector (Nafiu *et al.*, 2011).

2.3.2 Vegetable Diversity

The diversity of vegetables consumed by humans varies widely with both geography and culture. It is difficult to estimate the diversity of vegetables grown around the world, but the number of unique vegetables is likely in the thousands. Vegetables crops are increasingly traded internationally (Murphy *et al.*, 2007). Transportation and post-harvest handling and preservation are some of the problems limiting distribution of fresh vegetables. The diversity of vegetables available to consumers has also been increased through new introductions and cultivar development.

Scientific evidence shows that the vegetables of today did not suddenly appear on earth, but have evolved over a very long period of time thanks to natural selection, human selection, and more recently plant breeding and other forms of genetic improvement. Ethnobotany is the scientific study of the relationships that exist between people and plants. From the studies of anthropologists and ethnobotanists, we know that ancient humans were not farmers.

Many vegetables familiar to us today were unknown to Europeans before Columbus discovered the New World. Indigenous peoples of the Western Hemisphere domesticated many of our most important world vegetables long before the Europeans were aware of their existence. When vegetables were taken from their original habitat in the New World and introduced to Europe, some were initially very successful because there were fewer diseases and insects and lack of competition.

Of the hundreds of thousands of plants known in the world, only several hundred are used as vegetables. However, in order to manage information about plants, some system of classification, preferably having universal applicability, is beneficial.

2.3.3 Botanical classification system

The botanical classification system is the most precise, universal, and useful. Botanical classification is largely based on the variability among plants with regard to flower type, morphology, and sexual compatibility.

Vegetables are primarily seed bearing plants, but by general agreement mushrooms, a fungus, are included (Bailey, 1949). The sub-groupings most useful to the discussion of vegetables are family, genus, species, and cultivars.

Although the botanical classification system has stood the test of time relatively well, modern genetic tools have shown certain classifications based on plant morphology to be incorrect. For example, the Latin binomial for tomato has been changed from the long-standing *Lycopersicon esculentum* to *Solanum lycopersicon* based on molecular phylogenetic analyses (Bohs, 2005). More changes in the botanical system of vegetables can be anticipated in the years ahead as additional molecular phylogenetic studies are conducted.

Most agriculturalists would agree that research has played an important role in advancing vegetable science to its current state. Innovative new research will be necessary in the future to meet the needs of a growing global population for safe, nutritious and sustainably produced vegetables. The need for primary information about vegetable production for the developing world remains great. Both now and in the future, research and education programs will be needed to address food safety and security issues. In many developed countries, only a very small percentage of people are involved in food production. This has led to misconceptions and

uncertainty about where vegetables come from, the effect production has on the environment, and whether or not vegetables are safe to eat (Mohammad and Ramdane, 2003).

Vegetable science is truly fundamental to our very existence because it is a discipline that deals with the basic needs of the human race rather than its wants. The following is a partial list of challenges that face commercial vegetable growers in many areas of the world; novel research approaches will be required to solve them. Understanding and controlling the causes of biological contamination on vegetable crops is a major challenge. Developing highly productive and efficient sustainable vegetable production systems is another. Improving the quality and nutritional value of commercial vegetables is an ongoing challenge.

2.4 Tomato (*Solanum lycopersicon* L.)

Tomato (*Solanum lycopersicon* L.) is one of the most important vegetables worldwide. World tomato production in 2001 was about 105 million tons of fresh fruit from an estimated 3.9 million ha. As it is a relatively short duration crop and gives a high yield, it is economically attractive and the area under cultivation is increasing daily. Tomato belongs to the *Solanaceae* family. This family also includes other well-known species, such as potato, tobacco, peppers and eggplant (Grubben and Denton 2004).

Tomato has its origin in the South American Andes. The cultivated tomato was brought to Europe by the Spanish conquistadors in the sixteenth century and later introduced from Europe to southern and eastern Asia, Africa and the Middle East. More recently, wild tomato has been distributed into other parts of South America and Mexico. Common names for the tomato are: tomate (Spain, France), tomat (Indonesia), faan ke'e (China), tomati (West Africa), tomatl (Nahuatl), jitomate (Mexico), pomodoro (Italy), nyanya (Swahili). Tomatoes contribute to a healthy, well-balanced diet. They are rich in minerals, vitamins, essential amino acids, sugars

and dietary fibres (Law-Ogbomo and Egharevba, 2009). Tomato contains much vitamin B and C, iron and phosphorus. Tomato fruits are consumed fresh in salads or cooked in sauces, soup and meat or fish dishes. They can be processed into purées, juices and ketchup. Canned and dried tomatoes are economically important processed products (George 1999).

Tomato is an annual plant, which can reach a height of over 2 m. In South America, however, the same plants can be harvested for several years in succession. The first harvest is possible 45-55 days after flowering, or 90-120 days after sowing. The shape of the fruit differs per cultivar. The colour ranges from yellow to red (Youdeowei, 2004).

2.4.1 Botanical description of tomato plant

Root: Tomato has vigorous tap root system that can grow to a depth of 50 cm or more. The main root produces dense lateral and adventitious roots.

Stem: The growth habit ranges between erect and prostrate. It grows to a height of 2-4 m and the stem may be solid, coarse, hairy or glandular.

Leaf: They are arranged in spirals, 15-50 cm long and 10-30 cm wide. The leaflets are ovate to oblong and covered with glandular hairs. Small pinnates appear between larger leaflets. Inflorescence is clustered and produces 6-12 flowers. Petiole is 3-6 cm.

Flower: They are bisexual, regular and 1.5-2 cm in diameter. They grow opposite or between leaves. Calyx tube is short and hairy, while the sepals are persistent. Usually 6 petals up to 1 cm in length; yellow when mature. Anthers are bright yellow in colour surrounding the style with an elongated sterile tip. Ovary is superior and with 2-9 compartments. Mostly self- but also partly cross-pollinated. Bees and bumblebees are the most important pollinators of tomato.

Fruit: Fleshy berry, globular to oblate in shape and 2-15 cm in diameter. The immature fruit is green and hairy. Ripe fruits range from yellow, orange to red. It is usually round, smooth or furrowed.

Seeds: Numerous, kidney or pear shaped. They are hairy, light brown 3-5 mm long and 2-4 mm wide. The embryo is coiled up in the endosperm and an approximate weight of 1000 seeds is 2.5 – 3.5 g (Green *et al.* 1989).

2.4.2 Requirements for successful cultivation

Climate and soil, Temperature and light:

Tomato requires a relatively cool, dry climate for high yield and premium quality. However, it is adapted to a wide range of climatic conditions from temperate to hot and humid tropical. The optimum temperature for most varieties ranges between 21 and 24 °C. The plants can survive a range of temperatures, but the plant tissues are damaged below 10 °C and above 38 °C.

Tomato plants react to temperature variation during the growth cycle; for seed germination, seedling growth, flower and fruit set and fruit quality. If cool or hot weather spells persist during flowering, pollen production will be low. This will influence fruit formation. Frost will kill the plants. To avoid frost damage, it is best to wait until the winter is definitely over before sowing. It is possible to sow indoors earlier (in pots or trays). Light intensity can affect the colour of the leaves, fruit set and fruit colour. In tropical lowlands, the minimum temperature at night is also important. Temperatures below 21 °C can cause fruit abortion (Stoll, 2000).

Water stress and long dry periods will cause buds and flowers to drop off, and the fruits to split. However, if rains are too heavy flowers may become washed off; and if humidity is too high, this will increase the growth of mould and the fruit will rot. Tomato grows well on most mineral soils that have proper water holding capacity and aeration, and are free of salt. It prefers deep, well

drained, sandy loam soils. Soil depth of 15 to 20 cm required to grow a healthy tomato. In heavy clay soils, deep ploughing allows better root penetration. Tomato is moderately tolerant to a wide range of pH (level of acidity), but grows well in soils with a pH of 5.5 – 6.8 that have adequate nutrient supply and availability. Addition of organic matter is generally favourable for good growth. Soils that have very high organic matter content, like peat soils, are less suitable due to their high water holding capacity and nutrient deficiencies (Varela *et al.*, 2003).

Tomatoes are normally transplanted because much better results are gained when seedlings are raised in a nursery. Two methods of raising seedling in nurseries can be used: sowing in seedbed; and sowing in seedling tray. The seedlings can be selected for growth and health before planting in the field. It also helps the plantlets to be well protected and the planting distance to be more regular than sowing directly in the field. The seedbed should be 60-120 cm wide and 20-25 cm high. Seedbeds should be watered twice daily to ensure sufficient moisture for germination (Stoll, 2000).

Weeds compete with the tomato plants for light, water and nutrients. Sometimes they provide shelter for organisms that cause tomato diseases, such as Tomato Yellow Leaf Curl Virus (TYLCV), and reduce the yield. Effective non-chemical weed management begins with deep ploughing, diverse crop rotations and competitive cover crops. It is important to keep the field weed free for 4-5 weeks after transplanting. It is during this period that weed competition must be suppressed to avoid reduction in yield (Green *et al.*, 1989).

Tomato can be grown in monoculture or as an intercrop. Intercropping is advantageous because it reduces the incidence of diseases and pests. Smallholders will gain the most from the advantages of mixed cropping. Shade halls are essential in a dry sunny climate or in the dry

season of a monsoon climate ensure protection of the crop against the blazing sun (Dubose, 1985).

2.5 Pepper (*Capsicum annuum* L.)

Peppers (hot and sweet) belong to the Solanaceae family, genus *Capsicum* (Greenleaf, 1986). This genus originated from Central and South America (Grubben and El Tahir, 2004) and comprises about 30 species, of which, five domesticated that comprise *Capsicum annuum* L. (hot and sweet peppers), *Capsicum frutescens* L. or bird pepper, *Capsicum chinense* Jacq. or aromatic chili pepper, *Capsicum baccatum* L. (aji), and *Capsicum pubescens* Ruiz and Pav. (rocoto). The first three species are the most cultivated in both tropical and temperate zones. *C. annuum* often forms a complex with *C. frutescens* and *C. chinense*. In Africa, they are generally considered together as *C. annuum* L (Grubben and El Tahir, 2004). The majority of pepper and other vegetable fields in most West African countries (Mali, Burkina Faso, Chad, Guinea, Niger and Senegal) are located in rural areas and exploited mainly by smallholder farmers (AVRDC, 2008). The crop may be produced in monoculture or intercropped with staple crops or other vegetables, sometimes even with other crops of the Solanaceae family (Adekola and Oluleye, 2012). In urban, peppers and other vegetables are produced to provide nearby city dwellers with fresh produces and growers and marketers with cash income. Farm labour is provided mostly by family members in rural environments and family members in addition to paid personnel in urban settings (Hamma *et al.*, 2012).

2.5.1 General Description

The initial growth form is herbaceous, but it later hardens and becomes woody. The wood is brittle. Older plants are multi-stemmed and very branchy, with a thick, leafy crown. The leaves are dark green, ovate to lanciolate, 4 to 15 cm long, with petioles 0.5 to 3 cm long. The twigs are

stiff and straight between nodes (Liogier, 1995). The flowers are mostly solitary or in pairs. The corolla is greenish-white or yellowish-white, 1 to 2 cm broad, with blue, violate, or yellow anthers. The fruits, which are ellipsoidal berries with thin flesh, are 0.4 to 3 cm long (usually about 0.8 cm in wild plants) and red or orange-red. The seeds are cream to yellow in color (Howard 1989; Liogier, 1995).

2.5.2 Growth and Management

Because the species name “*annuum*” means annual and because cultivated forms are also annual, or are treated as annuals, pepper has been assumed to be an annual crop (Liogier, 1995). In its wild state, it is, in fact, a short-lived perennial, living 3 or 4 years, if conditions are favorable (Floridata, 2001). Plants may occasionally reach 5 m in height (Howard, 1989).

Sweet pepper (*Capsicum annum* L.) belongs to the family Solanaceae under the genus *Capsicum* (Russo, 1996). The crop is a native of Tropical South America especially Brazil which is thought to be the original home of peppers (Islam *et al.*, 2010). It is now widely cultivated in Central and South America, Peru, Bolivia, Costa Rica, Mexico, and in almost all the European countries, Hong Kong and India. Most of the peppers cultivated in temperate and tropical areas belong to the botanical species *Capsicum annum*, thought to have originated in Mexico and Central America (Islam *et al.*, 2011; Andrew, 1984).

2.5.3 Popular varieties and crop profile

There are many local cultivars grown in West Africa. Nigeria alone has more than 200 selections of pepper (Idowu-Agida *et al.*, 2012). However, the literature available regarding other countries is limited. It is generally recognized that the species *C. annum* is popular in other West African countries, while almost unknown to Malian consumers who by far preferred the bird pepper *C. frutescens* and the aromatic pepper *C. chinense*. However, since 2008, Malian stakeholders are

gaining more interest in *C. annuum* consequent of the efforts of the Vegetable Breeding and Seed Systems for the sub-Saharan Africa Project (VBSS) and partners in introducing, testing, promoting, and disseminating this type of pepper (Afari-Sefa *et al.*, 2012).

The genus *Capsicum* contains about 20 species but the popularly cultivated species are sweet pepper (*Capsicum annuum*) and hot pepper (*Capsicum frutescens*) both serving as a food and cash crops in Nigeria and other countries. Much foreign exchange is earned from exportation of this crop to other countries of the world (Verroens *et al.*, 2006).

There are more than 200 common names in use for this species (Zhigila *et al.*, 2014). The most common include chilli pepper, paprika (sweet varieties); bell pepper, cayenne, jalapenos, chiltepin (hot varieties); Christmas peppers (ornamental) (Lathan, 2009; Zhang *et al.*, 2002).

The sweet pepper may either be used green or red and may be eaten as cooked or raw, as well as in salad (Andrews, 1984). The sweet pepper is relatively non-pungent with thick flesh and is the world's second most important vegetable after tomato (Anonymous, 1989). It is also used for pickling in brine, baking and stuffing. The leaves are also consumed as salad, soup, or eaten with rice. It was found to be a good source of medicinal preparation against vomiting and paralysis (Islam *et al.*, 2010). Pepper has little energy value but higher nutritive value of protein, vitamins A, C and calcium.

Capsicum annuum L. is an important versatile spice as well as a vegetable crop. India is the largest producer and consumer of chilli in the world. Chillies constitute about 20 per cent of Indian spice exports in quantity and about 14 per cent in value (Sujay and Giraddi, 2014).

2.5.4 Main biotic constraints

Peppers are usually considered a robust crop compared with tomatoes and chili pepper is more robust than sweet pepper. However, both peppers are susceptible to a number of pests and

pathogens causing considerable economic losses. The most economically important pests to peppers in West Africa are thrips (*Frankliniella* sp.) feeding on the leaves, flowers or fruits; aphids (*Myzus persicae* Sulzer, *Aphis* sp, and *Macrosiphum euphorbiae* Thomas) feeding on young leaves and shoots; whitefly (*Bemisia tabaci* Gennadius) feeding on the leaves, root knot nematodes (*Meloidogyne* spp) feeding on the roots, the Mediterranean fruit fly (*Ceratitis capitata*) feeding on the fruit flesh, red spider mites (*Tetranychus* spp.) feeding on the leaves, and fruit borers (*Lepidopterae* spp). In addition to damages caused to the plants by direct feeding, some pests such as nematodes, whiteflies, aphids and thrips are vectors of viruses.

2.5.6 Yield potential of exotic and local varieties

Chili pepper may yield up to 18 tons/ha and sweet pepper up to 30 tons/ha in open-fields (Grubben and El Tahir, 2004). Yields greater than 20 ton/ha have been reported for introduced *C. annuum* chili varieties grown on-station in Mali. Identifying varieties with high yield potential is important to breeders, growers, and seed producers in the sub-region. From 2005 to 2010, multi-location experimentations involving 39 entries of exotic and local varieties were conducted jointly by the National Agricultural Research Systems of 6 West African countries (Benin, Burkina Faso, Chad, Gambia, Niger, and Togo) and the AVRDC. The World Vegetable Center's sub-regional office in Mali, hence, brings up to seven the number of test countries. Results indicated country yield range of 0.14 to 21.91 tons/ha and a mean sub-regional yield of 6.78 t/ha, the highest yield of 14 tons/ha being observed in Niger. In the FAOStat (2012) estimates, the highest pepper yield of the sub-region was also observed in Niger (9.25 tons/ha), followed closely by Nigeria (8.33 t/ha). Compared to the mean chili and green pepper yield of the world (14.82 t/ha) (FAOSTAT, 2012) and the yield potentials reported by Grubben and El Tahir (2004), this regional mean yield is low, suggesting that further improvement of pepper yield in

West Africa is needed. Improvement of pepper yield in West Africa can be achieved by introducing and evaluating more exotic varieties in multi-location experimentations. Since yield is dependent on the genetic background of the plant and the environment, focus should be on varieties with moderate to high tolerance to the prevailing environmental conditions such as high temperatures, viruses, bacterial wilt and *Phytophthora* spp., etc. Also needed for reducing the pepper yield gap in West Africa is promotion and adoption of best cultural practices.

The world fresh chili and sweet pepper production was 27.6 million tons in 2010, to which West Africa contributed 888,400 tons or 3.2%. The biggest West African contributors are Nigeria and Ghana that ranked 8th and 13th, respectively (FAOStat, 2012). The vast majority of West Africa's pepper is sold in local or regional (Senegal, Gambia, Liberia, Sierra Leone and Mali), and international markets (Europe and North America). The crop therefore constitutes a major source of income for resource poor households in rural and urban areas. Women are the main processors, traders, buyers, and users in West African cuisines. There are some *C. annuum* chili varieties that have high fruit yield, many fruits/plants, and attractive fruit color and shape, and that are easy to grow and harvest. They are suitable for use in poverty reduction programs targeting resource poor households, including women in developing countries.

2.6 Okra (*Abelmoschus esculentus* L. Moench)

Abelmoschus esculentus L. (Moench) is an economically important vegetable crop grown in tropical and sub-tropical parts of the world. This crop is suitable for cultivation as a garden crop as well as on large commercial farms. It is grown commercially in India, Turkey, Iran, Western Africa, Yugoslavia, Bangladesh, Afghanistan, Pakistan, Burma, Japan, Malayasia, Brazil, Ghana, Ethiopia, Cyprus and the Southern United States. India ranks first in the world with 3.5 million

tonnes (70% of the total world production) of okra produced from over 0.35 million hectare land (FAOSTAT, 2012).

Okra was earlier included in the genus *Hibiscus*, section *Abelmoschus* in the family *Malvaceae*. The section *Abelmoschus* was subsequently proposed to be raised to the rank of distinct genus by Medikus (1787). The wider use of *Abelmoschus* was subsequently accepted in the taxonomic and contemporary literature.

About 50 species have been described by taxonomists in the genus *Abelmoschus*. The taxonomical revision carried out by Borssum Waalkes (1966) and its continuation by Bates (1968) constitutes the most fully documented studies of the genus *Abelmoschus*. *A. esculentus* is found all around the world from Mediterranean to equatorial areas.

Okra is cultivated for its green non-fibrous fruits or pods containing round seeds. The fruits are harvested when immature and eaten as a vegetable. Okra is regarded as an important diet in the tropics which is considered rich in minerals and vitamins. It was reported to have anticarcinogenic, human immunity promoting and age prevention properties (Olubode *et al.*, 2012). Vegetables such as okra and pepper have been reported to occupy a valuable ecological niche in tropical agriculture and play a significant role in the eco-physiology of mixed systems (Olasantan, 2001).

It is generally an annual crop. Its stem is robust, erect, variable in branching and varying from 0.5 to 4 m in height. The leaves are alternate and usually palmate with five lobes, whereas the flower is axillary and solitary.

Okra plants exhibit indeterminate growth. Flowering is continuous but highly dependent upon biotic and abiotic stress. The plant usually bears its first flower one to two months after sowing.

The fruit is a capsule and grows quickly after flowering. The greatest increase in fruit length, height and diameter occurs during 4th to 6th day after pollination. It is at this stage that fruit is most often plucked for consumption. The okra pods are harvested when immature and high in mucilage, but before becoming highly fibrous. Generally the fiber production in the fruit starts from 6th day onwards of fruit formation and a sudden increase in fibre content from 9th day is observed. Okra plants continue to flower and to fruit for an indefinite time, depending upon the variety, the season and soil moisture and fertility. In fact, the regular harvesting promotes continuous fruiting, so much that it may be necessary to harvest every day in climates where growth is vigorous (Kumar *et al.*, 2013).

The okra flowers are 4-8 cm in diameter, with five white to yellow petals, often with a red or purple spot at the base of each petal and the flower withers within one day. The flower structure combines hermaphroditism and self compatibility. Flower bud appears in the axil of each leaf, above 6th to 8th leaf depending on the cultivar. The crown of the stem at this time bears 3-4 underdeveloped flowers but later during the period of profuse flowering of the plant there may be as many as 10 undeveloped flowers on a single crown. As the stem elongates more, the lower flower buds open into flowers. There may be a period of 2, 3 or more days between the time of development of each flower but never does more than one flower appear on a single stem. A flower bud takes about 22-26 days from initiation to full bloom. The style is surrounded by a staminal column which may bear more than 100 anthers. The pollen may come in contact with the stigmas through a lengthening of the staminal column or through insect foraging. Thus the flowers of okra are self fertile. The pollen grain is large with many pores, and every pore is a potential tube source; therefore, many tubes can develop from one pollen grain.

Okra has perfect flowers (male and female reproductive parts in the same flower) and is self-pollinating. If okra flowers are bagged to exclude pollinators, 100% of the flowers will set seed. It has been found experimentally that there is no significant difference in fruit set under open-pollinated, self-pollinated (by bagging alone) and self-pollinated (hand pollination of bagged flowers), indicating that it is potentially a self-pollinated crop. Although insects are unnecessary for pollination and fertilization in case of okra, the flowers are very attractive to bees and the plants are cross-pollinated.

Okra requires a long, warm and humid growing period. It can be successfully grown in hot humid areas. It is sensitive to frost and extremely low temperatures. For normal growth and development a temperature between 24°C and 28°C is preferred. At 24°C the first flower bud may appear in the third leaf axil while at 28°C it may appear in sixth leaf axil. This higher position is not necessarily accompanied with a delay in time because at higher temperatures the plants grow faster and the higher position is reached earlier. For faster plant growth, higher temperature helps though it delays fruiting. But at higher temperatures beyond 40°– 42°C, flowers may desiccate and drop, causing yield losses (Olubode *et al.*, 2012).

For seed germination, optimum soil moisture and a temperature between 25°C and 35°C is needed with fastest germination observed at 35°C. Beyond this range the germination will be delayed and weak seeds may not germinate. It is grown on sandy to clay soils but due to its well-developed tap root system, relatively light, well-drained, rich soils are ideal. As such, loose, friable, well-manured loam soils are desirable. A pH of 6.0–6.8 is ideally-suited. However, all soils need to be pulverized, moistened and enriched with organic matter before sowing (Olasantan, 2001).

2.7 Eggplant (*Solanum melongena* L.)

Eggplant, *Solanum melongena* L., is a popular vegetable crop grown in the subtropics and tropics. It is called brinjal in India and aubergine in Europe. The name eggplant derives from the shape of the fruit of some varieties, which look like chicken eggs (Kantharajah and Golegaonkar, 2004).

Eggplant (*Solanum melongena* L.) is a short-lived Perennial herb that belongs to the family Solanaceae. It is grown as an annual plant and is one of the most consumed fruit vegetables in tropical Africa; probably the third after tomato and onion, and before okra (Grubben and Denton, 2004). Although excessive rainfall affects both vegetative growth and flower formation, the plant is well adapted to both wet and dry season cultivation. In West Africa, the eggfruits are eaten raw, cooked or fried with spices in stews, or dried and pound as condiments (Fayemi, 1999; AVRDC, 2008).

It is a versatile crop adapted to different agro-climatic regions and can be grown throughout the year. It is perennial crop but grown commercially as an annual crop. A number of cultivars are grown in Nigeria, consumer preference being dependent upon fruit color, size and shape.

The varieties of *Solanum melongena* L. display a wide range of fruit shapes and colours, ranging from oval or egg-shaped to long club-shaped; and from white, yellow, green through different degrees of purple pigmentation to almost black. Eggplant fruit (unripe) is primarily consumed as cooked vegetable in various ways and dried shoots are used as fuel in rural areas. It is low in calories and fats, contains mostly water, some protein, fibre and carbohydrates. It is a good source of minerals and vitamins and is rich in total water soluble sugars, free reducing sugars, amide proteins among other nutrients. It has been reported that on an average, the oblong-fruited eggplant cultivars are rich in total soluble sugars, whereas the long-fruited cultivars contain a

higher content of free reducing sugars, anthocyanin, phenols, glycoalkaloids (such as solasodine), dry matter, and amide proteins (Bajaj *et al.*, 1979).

For processing purposes, the fruit should have a high dry matter content and a low level of phenolics. Bitterness in eggplant is due to the presence of glycoalkaloids which are of wide occurrence in plants of *Solanaceae* family. The glycoalkaloid contents in the commercial cultivars vary from 0.37 mg/100 g fresh weight to 4.83 mg) (Bajaj *et al.*, 1981). Generally, the high content of glycoalkaloids (20mg/100 g fresh weight); produce a bitter taste and off flavor. The discoloration in eggplant fruit is attributed to high polyphenol oxidase activity. The cultivars which are least susceptible to discoloration are considered suitable for processing purposes. Eggplant is known to have ayurvedic medicinal properties and is good for diabetic patients. It has also been recommended as an excellent remedy for those suffering from liver complaints (Shukla and Naik 1993).

Eggplant has been cultivated for many years in Nigeria, although it is often thought of as a Mediterranean or mid-Eastern vegetable. The global area under eggplant cultivation has been estimated at 1.85 million ha with total production of brinjal fruit of about 32 million MTs. Eggplant is also exported in the fresh or frozen form (FAO data, 2005).

2.7.1 Taxonomy

Brinjal belongs to the family *Solanaceae* and is known under the botanical name *Solanum melongena* L. The family contains 75 genera and over 2000 species, out of which, about 150-200 are tuber bearing and belong to section *Tuberarium*. The majority of species (about 1800) are non tuber bearing. Cytological studies have indicated that basic chromosomal number $2n = 24$ are same in almost all the varieties and species. There are 3 main botanical varieties under the

species *melongena* (Choudhury, 1976a). The common eggplant, to which large, round or egg-shaped fruited forms belong, are grouped under var. *esculentum*. The long, slender types are included under var. *serpentinum* and the dwarf eggplants are put under var. *depressum*.

2.7.2 Geographic origin and distribution

Brinjal is considered a native to India where the major domestication of large fruited cultivars occurred. In “Origin of cultivated plants” published in 1886 De Candolle, stated that the species *S. melongena* has been known in India from ancient times and regarded it as a native of Asia. Vavilov (1928) was of the opinion that its centre of origin was in the Indo-Burma region. Various forms, colours and shapes of brinjal are found throughout South-East Asia, suggesting that this area is an important centre of variation. A centre of diversity is believed to be in the region of Bangladesh and Myanmar (Former India-Burma border). Evidence to this was given by Isshiki *et al.* (1994) based on the isoenzyme and morphological variation noticed in large germplasm collection from India. According to Zeven and Zhukovsky (1975), it originated in India but spread eastward and by the 5th century B.C. was in China, which became a secondary centre of variation. Thus, it has been known for the last 1500 years in China. Arabic traders were responsible for subsequent movement to Africa and Spain. Brinjal cultivation in the Mediterranean region is relatively recent. Portuguese colonies took it to Brazil. It is now widely cultivated for its fruits in the tropical, subtropical and warm temperate zones, especially in Southern Europe and the Southern United States. Sampson (1936) suggested the African origin of this crop, but there is no evidence that *S. melongena* is native there though there are spiny African brinjal plants.

2.7.3 Seedling production

No treatment is needed if you are sowing fresh, vigorous seed in sterilized soil. Otherwise, soak seeds in warm water (50 °C) for 30 minutes, rinse them in cold water, and dry them before sowing. Seeds may be further treated to prevent seedling rot. The optimum temperature for germination is at 24 to 29 °C. At this temperature, seedlings should emerge in six to eight days. Transplants are usually used to establish a uniform and complete stand of plants. Transplants grown in cells or containers are ideal because they allow field planting without disturbing the root system. Seeds may also be sown in seedling beds. The seedbeds should be fertile and well drained. Thin seedlings at the first true leaf stage will be ready for transplanting in five to six weeks after sowing.

2.7.4 Growth and development

The ideal transplant is a seedling with three to four true leaves, stocky and disease-free, and without flower buds. Begin hardening plants six to nine days before transplanting to reduce transplanting shock. Slightly withhold water. Expose seedlings to stronger sunlight by removing the netting. Transplanting should be done in the late afternoon or on a cloudy day in order to minimize transplanting shock.

Seedlings should be transplanted by digging a hole deep enough to bury a plant so that its first true leaf is just above the soil surface. Press the soil firmly around the root. Irrigate furrows immediately after transplanting.

Transplanting can be done manually or by machine. If transplanting is done by machine, the plug seedling trays must be compatible with the transplanter. The field should be irrigated immediately after transplanting to establish a good root-to-soil contact.

Depending on whether the sowing period corresponds to more or less favourable agro climatic conditions, the first flower appears one and a half to three months after sowing. Growth and

flowering are continuous throughout the life of the plant. Taking into account the competition between the vegetative growth and fruit production, eggplant is capable of indefinite production. Weeds are controlled either by physical methods or chemical control. Physical methods, such as hand weeding, cultivation, and mulching are quite common in small vegetable farms. Chemical weed control is especially popular in places where labor is expensive. Suitable herbicides include Lasso, Enide 50WP, and Sencor 70WP. The best chemical, rate, and method of application will vary depending on the weed species present, soil type, and temperature at time of application.

2.7.6 Floral biology

Eggplant flowers are large, violet coloured and solitary or in clusters of two or more. The flower consists of calyx: sepals 5, united, persistent; corolla: petals 5, united, usually cup shaped; androecium: stamens 5, alternate with corolla; gynoecium: carpels are united, ovary superior. In most varieties the perfect flowers are borne singly and opposite the leaves. Four types of flowers have been reported depending on the length of styles, viz. (i) long-styled with large ovary, (ii) medium-styled with medium size ovary, (iii) pseudo short-styled with rudimentary ovary and (iv) true short-styled with very rudimentary ovary (Krishnamurthi and Subramaniam, 1954).

It has been reported that long and medium-styled flowers produce fruits whereas pseudo-short and short-styled flowers do not set any fruits. Further, chances of cross pollination are more in long style flowers. The percentage of long and medium styled flowers is a varietal character. Fruit setting of long styled flowers varies from 70% to 86.7% in different varieties. In medium styled flowers, fruit set ranges from 12.5% to 55.6%. All varieties have flowers with different style length. In short-styled flowers the androecium is fertile but the stigma is smaller with underdeveloped papillae and lower sugar content than that in long-styled flowers. There is no

pollen germination on the stigma or penetration of pollen tube into short styles (Rylski *et. al.* 1984).

2.7.7 Pollination

Eggplant is usually self-pollinated, but the extent of cross-pollination has been reported as high as 48% and hence it is classified as cross-pollinated crop. The cone-like formation of anthers favors self-pollination; but since the stigma ultimately projects beyond the anthers, there is an ample opportunity for cross-pollination. The rates of natural cross-pollination may vary depending on genotype, location, and insect activity.

Flowers generally emerge 40-45 days after transplanting. The anthesis and dehiscence in eggplant are mainly influenced by the daylight, temperature and humidity and therefore the exact timing for every area should be determined by observation and experience. Usually anthesis starts from 6.00 to 7.30 AM and continues up to 11.00 AM. Peak time for anthesis is 8.30 to 10.30 AM. The pollen dehiscence starts from 9.30 to 10.00 AM. Stigma receptivity is highest during anthesis. The receptivity of the stigma could be observed from the plump and sticky appearance which gradually turns brown with the loss of receptivity. The stamens dehisce at the same time stigma is receptive so that self pollination is a rule, although there is some cross pollination by insects also. The period of effective receptivity ranges from a day prior to flower opening. Pollen is most fertile immediately after the anther dehiscence. Pollen remains viable for a day. Opening of anthers is mostly by pore or slit at or near the apex. Repeated pollination and pollen from different plants increases both fruit and seed set. There is also variation in the size of pollen grains (Prasad *et. al.* 1968). Popova (1958) reported that pollen remained viable for 7-10 days and stigma remained receptive for 6-8 days. Maximum fruit set was observed when stigma received pollen from many different plants.

2.7.8 Seeds and fruit

The seeds are borne on the fleshy placenta and the placenta and the seeds fill the locular cavity. The number of seeds per fruit varies; the seed color is white, light yellow, brownish yellow, brown to black brown for different varieties. The fruit is pendent and is a fleshy berry borne singly or in clusters. The shape of fruit varies from ovoid, oblong, ovoid, or long cylindrical. The colour of the mature fruit varies from single coloured like purple with different shades such as purple black, yellowish, white, green; and variegated types of purple with white stripes, green with light green / white stripes or even combination of three colours. The fruit is rich in essential vitamins and minerals. It contains 89.0g water, 1.4g protein, 1.0g fat, 8.0g carbohydrate, 1.5g cellulose, 130mg calcium, 105mg vitamin c and 1.6 mg Iron (Romain, 2001). In particular, eggplant is a good source of Calcium, Phosphorus and Iron salts for bone and blood cell formation in the body, as well as a reasonable source of vitamin A (Carotene), Vitamin B-complex and vitamin C, all essential for good health (Fayemi, 1999; Schippers, 2000; Romain, 2001).

2.8 Weed and weed species distribution

By producing a limited number of crop plants and animals, human kind has substantially decreased the level of biological diversity over much of the earth. There is more cooperation in nature than competition. Cooperation is exemplified by mutually beneficial relationships that occur between species within particular communities (Olorunmaiye, 2008). If left undistributed and unplanted an abandoned crop field will at first be colonized by just a few species of organisms but after several years a complex community made up of many wild species emerges. Stability is attained by a community when it has reached a high level of diversity. Diverse

communities have fewer fluctuations in numbers of a given species and are stable (Olorunmaiye, 2010).

Stability is reached by a community when it has reached a high level of diversity (George and Jeruto, 2010). Diverse communities have fewer fluctuations in numbers of a given species and are stable (George and Jeruto, 2010). The practices which promote diversity and stability on the farm are enterprise diversification, crop rotation, use of wind breaks, provision of more habitats for microorganisms, intercropping and integration of crop farming with livestock production (Reddy and Willey, 1981; Reddy *et al.*, 1992).

Due to increased emphasis on long-term management of weed populations in cropping systems with a reduced dependence on the use of herbicides, the production of seeds by weeds that emerge after the critical period for weed control is increasingly important. It was hypothesized that increased soil cover and light interception by a crop canopy would shorten the critical period for weed control and reduce growth and fecundity of late-emerging weeds. Because labour-intensive methods of weed control are not sustainable, better preventive tactics, decision-making procedures, and control technology are required (Kropff *et al.*, 1996). Intercropping is one option for reducing weed problems through non-chemical methods (Vandermeer, 1989).

According to Egbe (2010), Intercropping helped to reduce the number of weeds in intercropped plots. Baumann *et al.* (2000) suggested that leek could be intercropped with celery to improve weed suppression relative to a leek monoculture, whose open canopy structure permits weeds to proliferate.

Intercropping has been attributed to high efficiency of weed elimination, which consequently reduced the competitive ability of weeds against crop plants (Karkanis *et al.*, 2011).

Eskandari and Kazemi (2011) reported that intercropping promotes weed suppression and more efficient use of resources by component crops.

Lithourgidis *et al.* (2011) also reported that planting pattern affects interaction between intercrop companion crops and weed, and their use of environmental resources. Similarly intercropping has been reported to help suppress weeds and control erosion (Olaoye and Adekanye, 2011).

Companion crops have complementary effect of suppressing weeds (Orluchukwu and Udensi, 2013). According to Olorunmaiye *et al.* (2013), proper planting density in an intercropping system has been reported to adequately help reduce incidence of weeds.

Intercropping helps to maximize beneficial interactions and minimize competition between companion crops (Poodineh *et al.*, 2014). It was reported by Oluwatobi and Olorunmaiye (2014) that intercropping reduces weed species distribution. Chipomho *et al.* (2015) also reported that intercrop spatial patterns have potential to reduce weed density and biomass.

The intercropping of component crops is practiced with the singular aim of maximizing plant cooperation for maximum crop yield (Sullivan 2001). Olsantan and Lucas (1992) noted that canopy height is one of the important features that determine competition ability of plants for light. Palaniappan (1985) observed that when one component is taller than the other in an intercropping system, the taller component intercepts the larger share of the light such that growth rates of the two components will be proportional to the quality of the photosynthetically active radiation intercepted. Muoneke *et al.* (1997) opined that the taller okra plants obtained by intercropping with maize were an adaptation to maximize interception of solar radiation. More so, Njoku *et al.* (2007) asserted that intercropping generally increased okra plant height.

2.8.1 Evaluating Intercropping System

To identifying the compatible tree- crop combination, particularly understory species i.e. different crops should be screened out in terms of their adaptability, growth and yield in association with the early stage of tree crop development. Intercrop selected should be compatible with the main crop and should have little competition with oil palm for light, water and nutrients (Mazaheri *et al.*, 2006). Any remunerative crop can be grown, but the most suitable crops are vegetables, banana, flowers, tobacco, chillies, turmeric, ginger, pineapple etc. Though, the aforementioned vegetable crops are very common to all and have good potential in our climate; none of them was systematically tested in agroforestry system or in natural shade condition to see their performance in terms of growth and yield (Liegh *et al.*, 2013).

For this purpose, the best way of experimentation is to grow different crops at different spacing from the tree crop. So, if we know the suitability of different crops in terms of their biological and economic productivities, it would be very useful information for selecting the best tree-crop combination. It was suggested that it is wise to conduct experiments under different tree crop or vegetable combination at different spacing for screening of different crops in terms of their growth and yield performance (Nahid, 2006).

For a farmer, higher income may be more essential than higher crop yields. Evaluating cropping system is crucial to select superiority over the existing system adapted by the farmers or researchers in terms of biological productivity and economic potential for particular area (Seran and Brintha, 2009). Several concepts and/or indices have been employed over the years by diverse scholars to evaluate component crop interactions for competition and potential benefits, losses or efficiency of various intercropping systems (Chumba *et al.*, 2013).

No single index is capable of evaluating cropping system. Agronomist decides biological efficiency based on indices such as land equivalent ratio, area-time equivalency ratio, cropping

intensity index, while economists decide the economic worthiness of the system using economic indices (Sivaraman and Palaniappan, 1996). In general, a biological efficient system is also economically superior; however, the economic efficiency of superior system would be determined by the cost of input and price of produce (Sivaraman and Palaniappan, 1996). Economic value is relevant only to the location and time for which the computation was based. Its real value changes greatly over time and for different locations. However, selected cropping system is good for a particular area until new system would prove to be more superior (Seran and Brintha, 2009).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Description of study area

The field experiment was conducted within an established juvenile oil palm plantation located at Ala in Akure-North Local Government Area of Ondo State. The oil palm plantation is located at a coordinate of 7.093⁰ N, 5.354⁰ E in the tropical rain forest region of Nigeria. It is located in the equatorial zone and has predominant climatic characteristics of warm and humid with little seasonal variation (Ibitoye *et al.*, 2011). It has two distinct seasons namely: dry and wet seasons. Wet season is between April and November and dry season is between November and March. Annual rainfall varies from 1150 mm to 2550mm. Temperature is moderately high year round and range between 22⁰ C and 34⁰ C with daily average of 30⁰ C (Ogunrayi *et al.*, 2016).

The field experiment started in May, 2016 at the onset of rainy season with the establishment of a nursery. The pepper and eggplant accessions were raised in the nursery for 6 weeks while those of the tomato were raised for 4 weeks (Opeke, 2006). The okra seeds were planted directly on the field.

The oil palm plantation has a plant spacing of 6m X 6m and has attained the age of about 2 years at the commencement of the study.

3.2 Experimental Design

The field experiment was carried out twice; first trial season when the juvenile oil palms were 2 years old and second trial season when they were 3 years old so that they will be able to offer different sizes of canopy spread and levels of interaction with the intercropped fruit vegetables.

3.2.1 Pre-planting operations

3.2.1.1 Land selection

Six different plots within the alleys of the juvenile oil palm plantation were selected for each of the fruit vegetable crops covering an area of 16 m². Another open plots (without juvenile oil palms), covering an area of 144 m² was also selected as control plot for of the vegetable crops to be planted.

3.2.1.2 Land preparation

Land preparation started after more than five consecutive rainfalls at the beginning of rainy season.

- Land clearing: This was carried out manually with the use of cutlass and hoe.
- Soil Tillage: Tilling of the soil was also carried out manually by using hoe immediately after land clearing.

3.2.2 Soil test

Top soils (0-15 cm) were collected from the six different plots of alleys selected for each fruit vegetable crop and the control plot (without juvenile oil palms) for soil test. Soil samples were randomly collected in 10 locations within each plot and made into composite samples. The soil test carried out was to determine the physicochemical properties of the soil. These properties include: soil pH, total carbon, organic matter, electrical conductivity, exchangeable cations (Na⁺, Mg²⁺, K⁺, Ca²⁺ and titratable acidity or acid value), cation exchange capacity (C.E.C.), nitrate content, phosphorus content, particle size (clay, sand and silt) and soil type (Olabisi *et al.*, 2009). These tests were carried out at the Department of Chemistry, Faculty of Physical Sciences, University of Ilorin.

3.2.2.1 pH determination

The pH of the soil was determined by using a pH meter on 1:2.5 (w/v) soil water mixture (Olabisi *et al.*, 2009). The pH meter used was PHS-3C SEARCHTECH INSTRUMENT. Five gram (5 g) of air dried soil was weighed out and sieved through 2 mm sieve into 50 ml beaker. Then 12.5 ml distilled water was added and stirred for 10 minutes. The suspension was allowed to stand for about 15 minutes and the electrode of the pH meter was inserted into partly settled suspension. The pH of the suspension was then taken and recorded.

3.2.2.2 Electrical conductivity (EC)

This was done with EC meter. Twenty grams (20 g) of soil was added into 40 ml distilled water. The suspension was stirred intermittently for half an hour and kept for 30 minutes without any disturbance for complete dissolution of soluble salts. The soil was allowed to settle down and then EC ($\mu\text{S}/\text{cm}$) was determined (Wagh *et al.*, 2013). The EC was determined using Hanna Instruments 214 Conductivity Meter.

3.2.2.3 Estimation of Total Organic Carbon (TOC) and Total Organic matter (TOM)

Loss-on-ignition (LOI) method of Wagh *et al.* (2013) was adopted. Five grams (5 g) of soil samples were placed in a crucible and heated at 105 °C for 12 hours to remove soil moisture. The soil samples were then combusted in a muffle furnace (Carbolite ELF 11/148) at 375 °C for 17 hours. Total organic matter was calculated as the weight loss between 105 °C and 375 °C:

$$\text{TOM (g/ kg)} = \frac{(\text{weight } 105\text{ }^{\circ}\text{C} - \text{weight } 375\text{ }^{\circ}\text{C})}{\text{weight } 105\text{ }^{\circ}\text{C}} \times 100$$

TOC is 58% of TOM.

3.2.2.4 Exchangeable cations (Na^+ , Mg^{2+} , K^+ , Ca^{2+})

Neutral (pH 7.00) 1.00 M ammonium acetate (NH₄OAc) extraction method was used to estimate the exchangeable cation according to Reeuwijk (2002). The soil sample was extracted with a 1 M NH₄OAc solution at pH =7.00. The soil-solution slurry was shaken for 2 hours, and the solution was separated from the solid by centrifugation. The addition of NH₄⁺ in excess to the soil displaces the rapid exchangeable alkali and alkaline cations from the exchange sites of the soil particles. The concentrations of Na, K, Ca and Mg were subsequently analyzed by inductively coupled plasma optical emission spectroscopy (ICP-OES).

3.2.2.5 Titratable acidity or acid value

The hydrolytic acidity values were determined according to Kappen (1929). The samples were treated with 0.5 M/dm³ Ca-acetate solution adjusted to pH 8.2 in the ratio of 1:2.5). The suspensions were shaken at room temperature for one hour then filtrated. The filtrates were titrated with 0.1 M/dm³ NaOH solution in the presence of phenolphthalein indicator and the hydrolytic acidity values were calculated from the amount of alkali consumed (0.1 M/dm³ NaOH cm³ for 50 g soil). The pH-stat titrations were carried out in 0.01 M/dm³ CaCl₂ solution with the titration equipment designed for this purpose (Czinkota *et al.* 2002). The titrations themselves were performed in a 1:25 ratio 0.01 M/dm³ CaCl₂ solution suspensions. The fixed limit value of the titration was pH = 6.5.

3.2.2.6 Cation exchange capacity (C.E.C.)

From the values of Ca, Mg and K obtained from exchangeable cation using the formula:

$$\text{CEC (cmol/kg)} = (\text{ppm Ca} / 200) + (\text{ppm Mg} / 120) + (\text{ppm K} / 390) \quad (\text{Thomas, 1982}).$$

3.2.2.7 Nitrate content

Soil sample (10 g) was dried and sieved into 100 ml flask. Fifty (50 ml) of Morgan's solution was added to the flask horizontally in the reciprocal shaker and shaken for 15 minutes on low speed (9180 oscillation per minute). The extract was filtered through filter paper (Whatmanv2V) into a test tube. The test tube containing the extract was placed in the rack. The extract was analyzed using EasyChem Discrete Analyzer and nitrate content calculated as follows: $\text{mg/kg of NO}_3\text{+NO}_2\text{-N} = \text{NO}_3\text{+NO}_2\text{-N in extract mg/L} \times 50 / \text{sample weight}$. (Ahmed, 2009).

3.2.2.8 Phosphate content

Soil sample (2.5 gram) and 50 milliliters of 0.5 M sodium bicarbonate (pH 8.5) solution were shaken for 30 minutes. The mixture was then filtered through Whatman filter paper and the phosphate in the filtered extract was determined colorimetrically (at 630 nm in Technicon AutoAnalyzer II) by reacting it with ammonium molybdate using ascorbic acid as the reducing agent. Results are reported as parts per million (ppm) Phosphorus (P) in the soil (Mussa *et al.*, 2009).

3.2.2.9 Particle size (clay, sand and silt)

Rapid method was used to determine the particle size. Fifteen gram (15 g) of soil was used for this analysis. 0.053 mm sieve is used to collect the sand fraction. The silt and clay particles were rinsed into 600 ml beaker, then stirred thoroughly to suspend all particles, then allowed to settle undisturbed at room temperature (18 -24 °C) for a sedimentation period of 90 minutes. After the sedimentation period, the suspended clay fraction was decanted from the settled silt particles and discarded. The settled silt fraction was then dried in the beaker at 105 °C to constant weight.

The soil sand % and silt % were calculated based on their fraction of the original sample mass as follows:

$$\text{sand \%} = \frac{(\text{oven dry sand mass})}{(\text{original sample mass})} \times 100$$

$$\text{silt \%} = \frac{(\text{oven dry silt mass})}{(\text{original sample mass})} \times 100$$

The clay was determined by calculating the difference of 100% minus the sum of the sand% and silt % (Kettler *et al.*, 2001).

3.2.3 Nursery preparation

Vegetable seeds of tomato, pepper, okra and eggplant with the following accession numbers were used for the research work:

Tomato (*Solanum lycopersicum* L.) NGB 01665

Tomato (*Solanum lycopersicum* L.) NG/AA/SEP/09/053

Pepper (*Capsicum annuum* var. abbreviatum Fingh.) NGB 01312

Pepper (*Capsicum annuum* var. abbreviatum Fingh.) NGB 01641

Okra (*Abelmoschus esculentus* Moench) NGB 01184

Eggplant (*Solanum melongena* L.) NGB 01737

The vegetables were raised in prepared nursery for six weeks before transplanting to the field to enhance stand establishment except okra that was planted directly on the field.

3.2.4 Experimental layout

The juvenile oil palm trees in the plantation were planted at a plant spacing of 6m X 6m. The experimental plots within the alleys were mapped out and pegged at 1, 2 and 3m distances from the juvenile oil palm trees in a completely randomized block design.

A pre-emergent herbicide (Atrazine) was sprayed on the prepared land before planting to suppress weeds from germinating early in the experimental plot before transplanting of seedlings of the fruit vegetables.

3.2.5 Planting and transplanting

Planting and transplanting was done at recommended spacing of (1m X 1m) and at seeding rate of 2 seeds per stand (for okra) and 2 seedlings per stand (for transplanted vegetable crops) within the alleys. The seeds were planted at a depth of 3cm in the soil (Opeke, 2006).

Four replicates for each of the treatment distances (1, 2, 3 m and control) from each vegetable crop – juvenile oil palm intercrop plots were selected randomly and tagged with marked pegs (plastic spoons).

Seeds planted were obtained at the National Centre for Genetic Resources and Biotechnology (NACGRAB) research institute, Ibadan, Oyo State. Germination test was carried out on the seeds and germination indices were computed according to Khamassi *et al.*, 2013.

3.2.6 Germination Test

One hundred seeds (50 seeds per petri dish) of each accession of the vegetable crops were sown in Petri dishes between the layers of moist paper towel at 25°C in an incubator.

Germination was performed in a vacuum oven (VO, Memmert, WI, USA) in which 50 seeds were placed between two layers of soaked Whatman filter paper in 15-cm-diameter glass Petri

dishes at 25°C. Distilled water was regularly added to each Petri dish to replace any evaporated water. The seeds were first observed after three days and subsequently every two days until number of germinated seeds was constant. The seeds were considered to have germinated when the radicle emerges (Maynard and Hochmuth, 2007; AOSA, 1990; Farooq *et al.*, 2005; Khamassi *et al.*, 2013 and Samimy *et al.*, 1987).

3.2.6.1 Germination indices

Six germination indices calculated include; Germination capacity (GC), 50% germination (T50), Mean germination time (M-days), Coefficient of the velocity or rate of germination (CRG), Speed of germination (S) and the Accumulated germination speed (AS), average germinated seed per day (AGSD). Data were statistically analyzed using Excel 2010 software to calculate indices (Khamassi *et al.*, 2013).

Germination indices tested in this study

Germination capacity (G.C.): $\frac{NT \times 100}{N}$

T₅₀: Days required for 50% germination of the total number of seeds.

Average number of seeds germinated per day (AGSD): $\frac{NT}{T}$

Mean germination time in days (M-days): $\frac{(N1 \times T1) + \dots + (Nn \times Tn)}{(N1 + N2 + N3 + \dots + Nn)}$

Speed of germination (S): $(N1 \times 1) + (N2 - N1) \times \frac{1}{2} + (N3 - N2) \times \frac{1}{3} + \dots + (Nn - Nn - 1)$

Speed of Accumulated germination (A.S.): $\frac{N1}{1} + \frac{N2}{2} + \frac{N3}{3} + \dots + \frac{Nn}{n}$

Coefficient of the velocity or rate of germination (CRG): $100 \times \frac{(N1 + N2 + N3 + \dots + Nn)}{(N1 \times T1) + \dots + (Nn \times Tn)}$

Germination index (G.I.) was calculated as described in the Association of Official Seed Analysts (1983) and Farooq *et al.* (2005) as the following formulae:

Germination Index (G.I.) = $\frac{\text{Number of germinated seeds}}{\text{Days of first count}} + \dots + \frac{\text{Number of germinated seeds}}{\text{Days of final count}}$

3.3 Physiological Parameters

3.3.1 Growth parameters of vegetable crops

Growth parameters taken include:

1. Plant height (cm) measured using meter rule.
2. Leaf number determined by direct counting of the number of leaves.
3. Leaf area (cm²) was measured using Easy leaf Area software for android devices (Hsien and Arnold, 2014).
4. Chlorophyll index was determined using handheld chlorophyll meter (atLEAF).
5. Total chlorophyll content was calculated by converting chlorophyll index values obtained from the handheld chlorophyll meter (atLEAF) at www.atleaf.com/conversion (Zhu *et al*, 2012).
6. Dry matter: Fresh vegetable crops for each of the treatments were uprooted, washed, air dried, oven dried at 80°C for 2 hours and weighed to determine the dry matter (Ogunkunle *et al.*, 2013).

These parameters were taken until flowering was observed.

3.3.2 Reproductive parameters of vegetable crops

Number of days to flowering: This was determined by noting the number of days from planting or transplanting till flowering is observed in the vegetable crop.

Number of days to 50% flowering: This was determined by noting number of days from planting or transplanting till 50% of the vegetable crops flowered.

During harvesting of each of the vegetable crops, progressive harvesting was employed by harvesting every week and the following parameters were collected:

- Number of fruits harvested per plant: by counting the number of fruits collected every week progressively.
- Weight of fruit per plant: by weighing the fruits collected from each vegetable under the different treatments every week using a weighing scale.
- Weight of 100 fruits: This was determined by weighing 100 fruits of each of the vegetable crops.
- Fruit girth: This was determined by measuring the girth of the fruits of the vegetable crops under each treatment using a caliper.
- Fruit length: This was determined by measuring the length of the fruits of the vegetable crops under each treatment using a caliper.
- Yield (tonnes/hectare): This was determined by computing total weight of fruit per treatment in tonnage per hectare.

3.3.3 Juvenile oil palm growth parameters

Readings were taken from sole and intercropped juvenile oil palms every 4 weeks (4 weeks, 8 weeks and 16 weeks after intercropping).

Growth parameters collected on the juvenile oil palm include:

- Number of fronds: This was determined by counting the number of fronds on each juvenile oil palm tree.

- Average length of fronds: This was obtained by measuring with a meter rule the length of the fronds and finding the average.
- Average number of leaflets: This was obtained by counting the number of leaflets on fronds and finding the average.
- Average canopy spread determination: Canopy spread of the juvenile oil palms was measured according to Spoke Method (Blozan, 2004) with the use of graduated coloured plank or wooden rod (tar rod). Ten measurements were taken from the midpoint of the trunk to the outer extremities of the crown. These were averaged to get the result of the average canopy or crown spread. Canopy spread measurements were taken every 4 weeks (4, 8, 12 weeks and until final harvesting).
- Trunk height: This was measured with the use of graduated coloured plank (tar rod) (Blozan, 2004).
- Canopy height: It was also measured with the use of graduated coloured plank (tar rod) (Blozan, 2004).

3.3.4 Biological indices

3.3.4.1 Partial Land Equivalent Ratio (LER) of the vegetable crops

This was evaluated by dividing the intercrop yield of the vegetable crop by the sole yield (control).

$$\text{Partial LER} = \frac{\text{yield of intercrop of vegetable crop}}{\text{yield of sole vegetable crop}}$$

3.3.4.2 Area-Time Equivalency Ratio (ATER) of the vegetable crops

Since Land Equivalent Ratio does not take into account the time for which the land was occupied by the component crops of the intercropping system, area-time equivalency ratio (ATER) was determined as follows:

$$ATER = \frac{L_a \times t_a}{T}$$

Where, L_a = Partial Land Equivalent ratio of the vegetable crop, t_a = duration (days) of vegetable crop and T = duration (days) of the intercropping system.

3.3.4.3 Economic Indices of the vegetable crops

Gross Return: This was determined by multiplying the yield by the prevalent market price per unit weight (kg).

$$\text{Gross Return} = \text{Yield (kg)} \times \text{Market price (₹) per unit kg}$$

Cost of Cultivation: This was calculated by summing all the fixed cost and variable cost (cost of seeds, herbicide, labour, transport, etc.).

Net Return: This was calculated by subtracting cost of cultivation from gross return.

$$\text{Net Return} = \text{Gross Return} - \text{Cost of Cultivation}$$

Cost-Benefit Ratio: this was calculated as:

$$\text{Cost-Benefit ratio} = \frac{\text{Gross Return}}{\text{Total (variable) cost of cultivation}}$$

(Sivaraman and Palaniappan, 1996, Seran and Brintha, 2009).

These indices were calculated for each of the vegetable crops using four replicates from each of the intercropping distances (total of twelve replicates) against twelve replicates from the control.

3.4 Weed species distribution

Weed survey was carried out according to the method of Thomas, 1985 and Olorunmaiye *et al.*, 2011. An 'M' pattern was systematically identified and mapped out in each plot from the edge and 0.5m X 0.5m quadrat (0.25m^2) was used for sampling 5 times per plot (for area less than 5 hectares).

Weeds found within each quadrat were uprooted, sorted into species, identified, counted and recorded. Data collected were subjected to ecological analysis according to Oluwatobi and Olorunmaiye, 2014.

Weeds found within each quadrat in each plot were identified using a standard manual by Akobundu and Agyakwa (1998). They were counted and recorded to compute the frequency, density, relative frequency (RF), relative density (RD) and relative importance value (RIV), abundance, dominance, and relative dominance of each species according to Das (2011) and Oluwatobi and Olorunmaiye (2014).

Prior to each weeding at 3 and 6 WAI, weed species were collected to determine weed density (counts m^{-2}) and biomass (grams m^{-2}). Sampling was also done after harvesting of fruits from the intercropped vegetables.

Weeds were cut at ground level, packed in papers bags, oven dried at 80°C for 2 hours and weighed to determine their biomass (Ogunkunle *et al.*, 2013 and Chipomho *et al.*, 2015).

3.4.1 Weed species parameters

Data collected were computed to determine quantitative analysis such as frequency, density, relative frequency, relative density, importance value, abundance, dominance and relative dominance. These parameter were determined according to Olorunmaiye *et al.* (2013) and Oluwatobi and Olorunmaiye, (2014).

Frequency: This was calculated as number of quadrats where weed species was found.

Density: This was calculated as number of species per area of quadrat (0.25 m²).

Other parameters were determined as follows:

$$\text{Relative frequency} = \frac{\text{frequency of species}}{\text{total frequency of all species}} \times 100$$

$$\text{Relative density} = \frac{\text{density of species}}{\text{total density of all species}} \times 100$$

Relative importance value (RIV) = relative frequency + relative density

$$\text{Abundance} = \frac{\text{relative frequency} + \text{relative density}}{2}$$

$$\text{Dominance} = \frac{\text{absolute density of species}}{\text{number of quadrates where species are found}} \times 100$$

$$\text{Relative Dominance} = \frac{\text{dominance of species}}{\text{total dominance of all species}} \times 100$$

Simpson's Diversity Index (D): This measures the probability that two individual weed species randomly selected from a sample will belong to the same species. This index was calculated as follows:

$$\text{Simpson's diversity index (D)} = \frac{\sum n(n-1)}{N(N-1)}$$

Where n = total number of a particular weed species; N = total number of all weed species

Simpson's index of diversity (1 – D): This is the probability that two individual weed species randomly selected from a sample will belong to different species. This was calculated by subtracting Simpson's diversity index (D) from 1.

Simpson's reciprocal index (1/D): The value of this index starts with 1 as the lowest possible figure. The figure would represent a community containing only one species. It was calculated by finding the inverse of Simpson's index of diversity (D).

(Ali and Bibi, 2013; Oluwatobi and Olorunmaiye, 2014).

Weed smothering efficiency: This was determined using the mathematical formula below:

$$\text{Weed smothering efficiency (WSE)} = \frac{\text{WDwt in monocrop} - \text{WDwt in intercrop}}{\text{WDwt in monocrops}} \times 100$$

WD_{wt} = weed dry weight.

(Chipomho *et al.*, 2015).

3.4 Statistical Analysis

The data collected from the study were analyzed statistically using statistical package for social sciences (SPSS: version 16.0) by subjecting the data to analysis of variance (ANOVA). The mean values of the data were separated using Duncan Multiple Range Test (DMRT) at 5% probability level. Interaction analysis was carried out using SPSS. Data collected on growth

parameters of oil palms were analyzed using T-test. The results were presented in tables and charts. Graphs were plotted using Origin (version 7.0) software.



Plate 1: A view of the experimental area



Plate 2: Preparation for transplanting



Plate 3: Weeding tomato (NGB 01665) intercrop plot



Plate 4: Okra (NGB 01184) at 2 weeks after intercropping (WAI)



Plate 5: Eggplant (NGB 01737) intercropped at 3 m from juvenile oil palm



Plate 6: Taking readings from pepper (NGB 01312)-juvenile oil palm intercrop plot

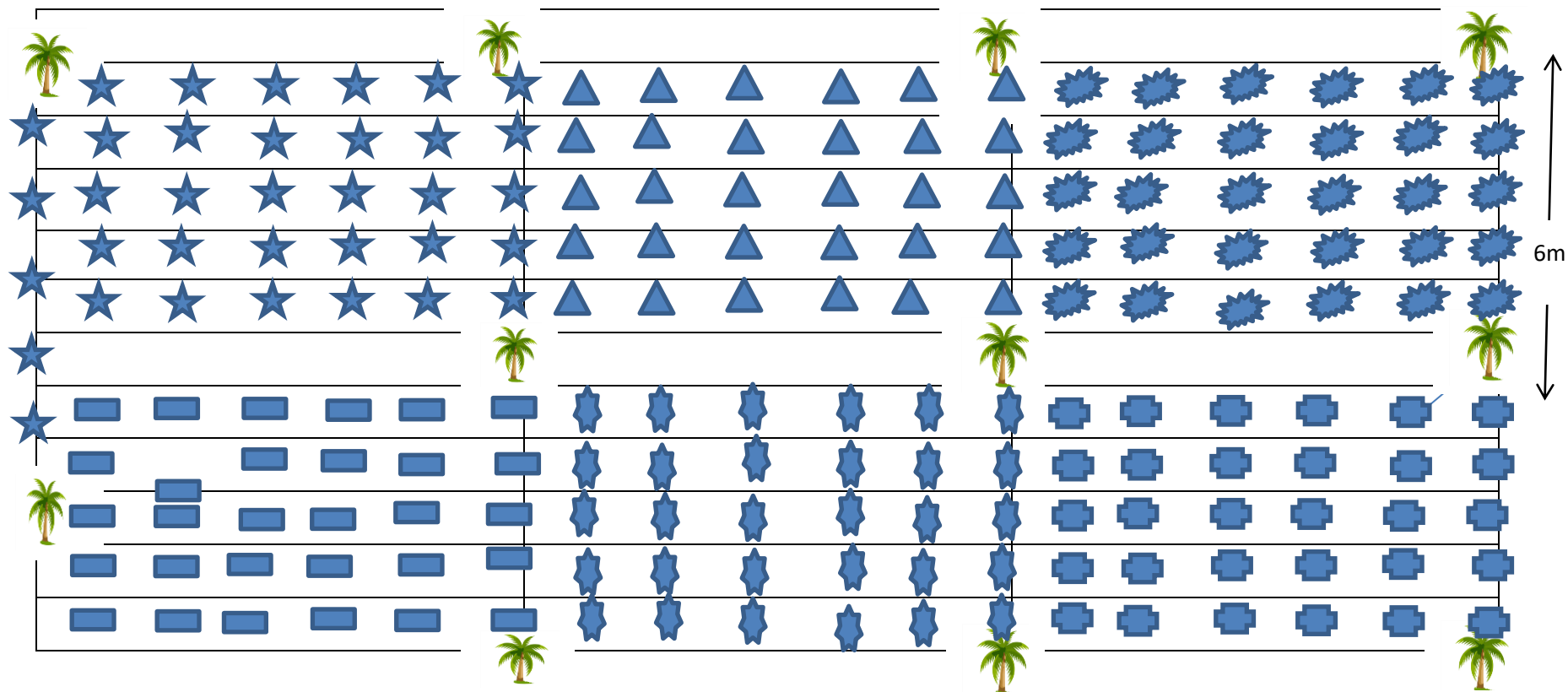


Figure	Key
	<i>Solanum lycopersicum</i> L. (NGB 01665)
	<i>Capsicum annum</i> L. (NGB 01312)
	<i>Abelmoschuus esculentum</i> Moench (NGB 01184)
	<i>Solanum lycopersicum</i> L. (NG/AA/SEP/09/053)
	<i>Solanum melongena</i> L. (NGB 01737)
	<i>Capsicum annum</i> L. (NGB 01641)
	<i>Elaeis guineensis</i> Jacq.

Plate 7: Experimental layout

CHAPTER FOUR

RESULTS AND OBSERVATIONS

4.1 Growth and yield responses of fruit vegetables to intercropping with 2 years old juvenile oil palm

4.1.1 Growth responses of tomato (NGB 01665) to intercropping with juvenile oil palm

At 2 weeks after intercropping (WAI), control plot recorded the highest leaf number (91.3) which was not statistically different from other treatments. Tomato planted at 1 m from juvenile oil palm recorded the lowest leaf number (51.5). There was increase in leaf number from 1, 2, 3 m and control. Similarly at 4 WAI, the control recorded the highest leaf number (141.0) which was also not statistically different from other treatments. However, the tomato planted at 2 m recorded the lowest leaf number (69.8) as shown in Fig. 1.

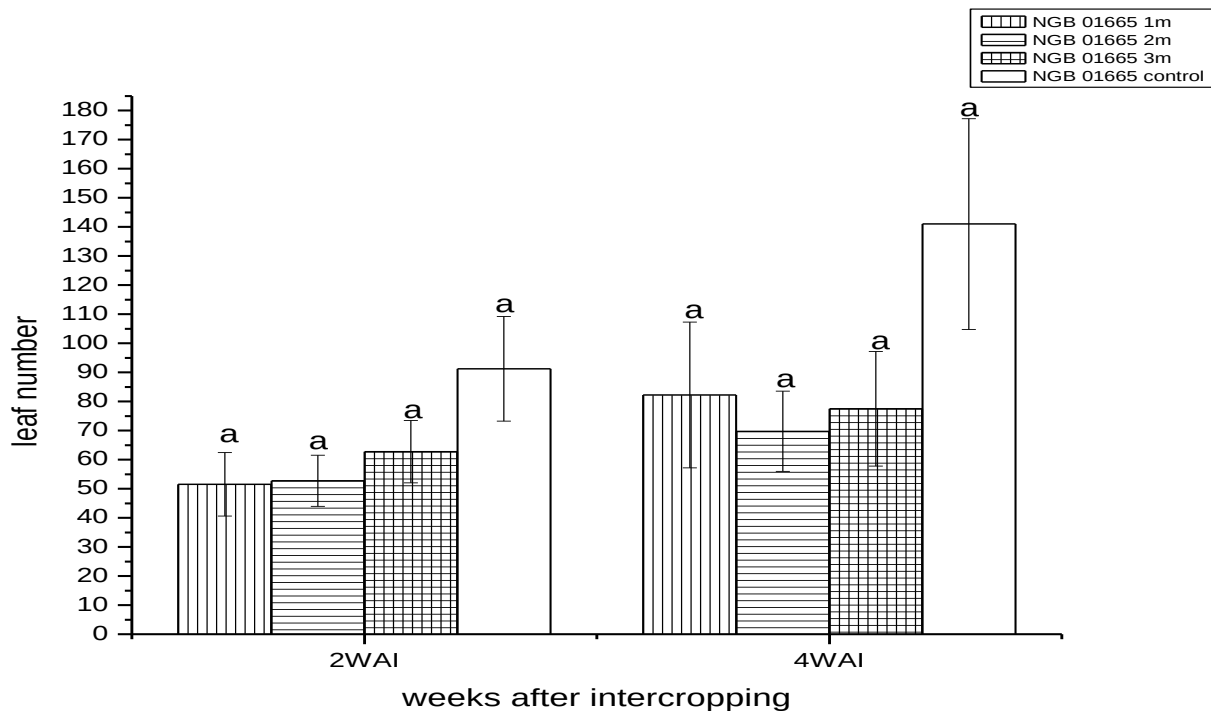


Fig. 1: Effects of intercropping on the number of leaves of tomato (NGB 01665) at 2 and 4 WAI

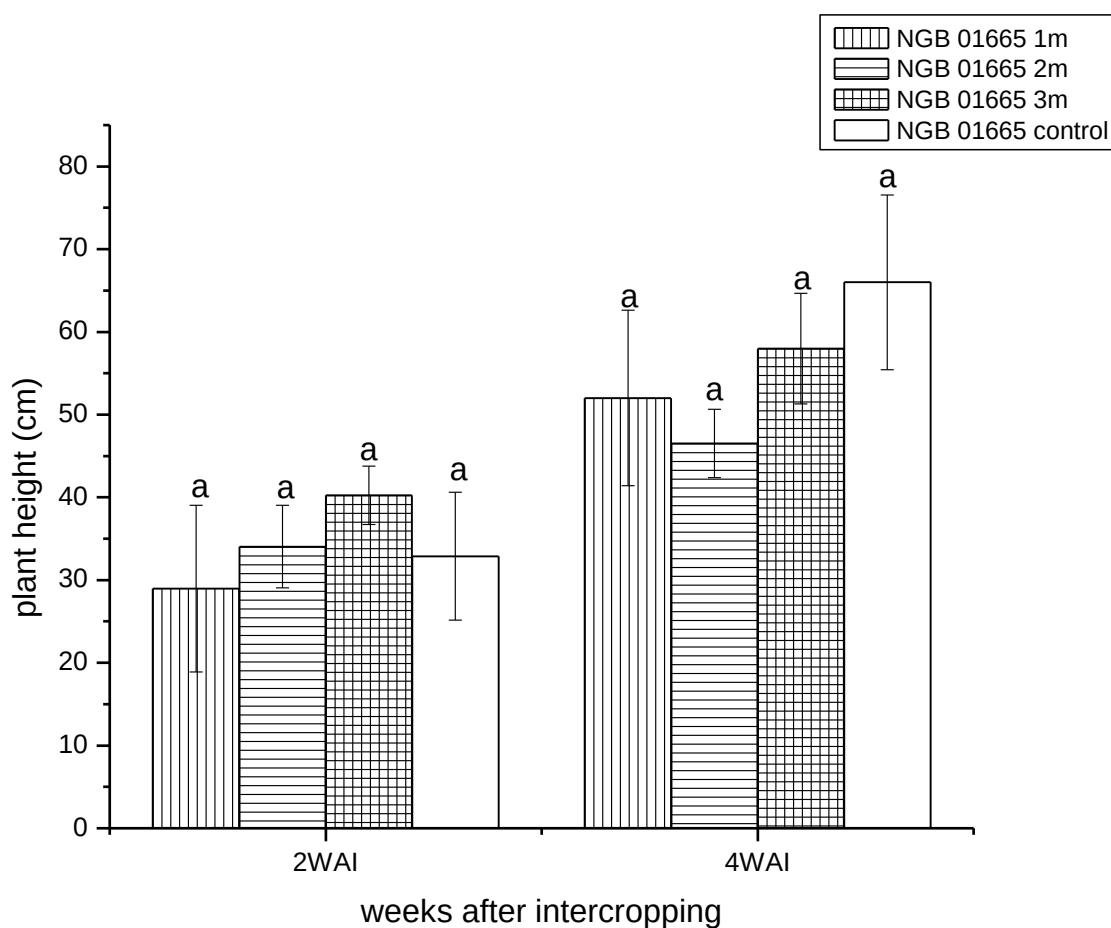


Fig. 2: Effects of intercropping on the plant height of tomato (NGB 01665) at 2 and 4 WAI

The value of plant height of tomato planted at 3 m from the juvenile oil palm was highest (40.25 cm) at 2 WAI, 2 m (34.05 cm), control (32.88 cm) and 1 m (28.98 cm). However, there was no statistical difference among the treatments. Similarly at 4 WAI, there was statistical difference however those of the control plot recorded the highest plant height (66.00 cm). This was followed by 3 m (58.0 cm), 1 m (52.0 cm) and 2 m (46.5 cm) as shown in Fig. 2.

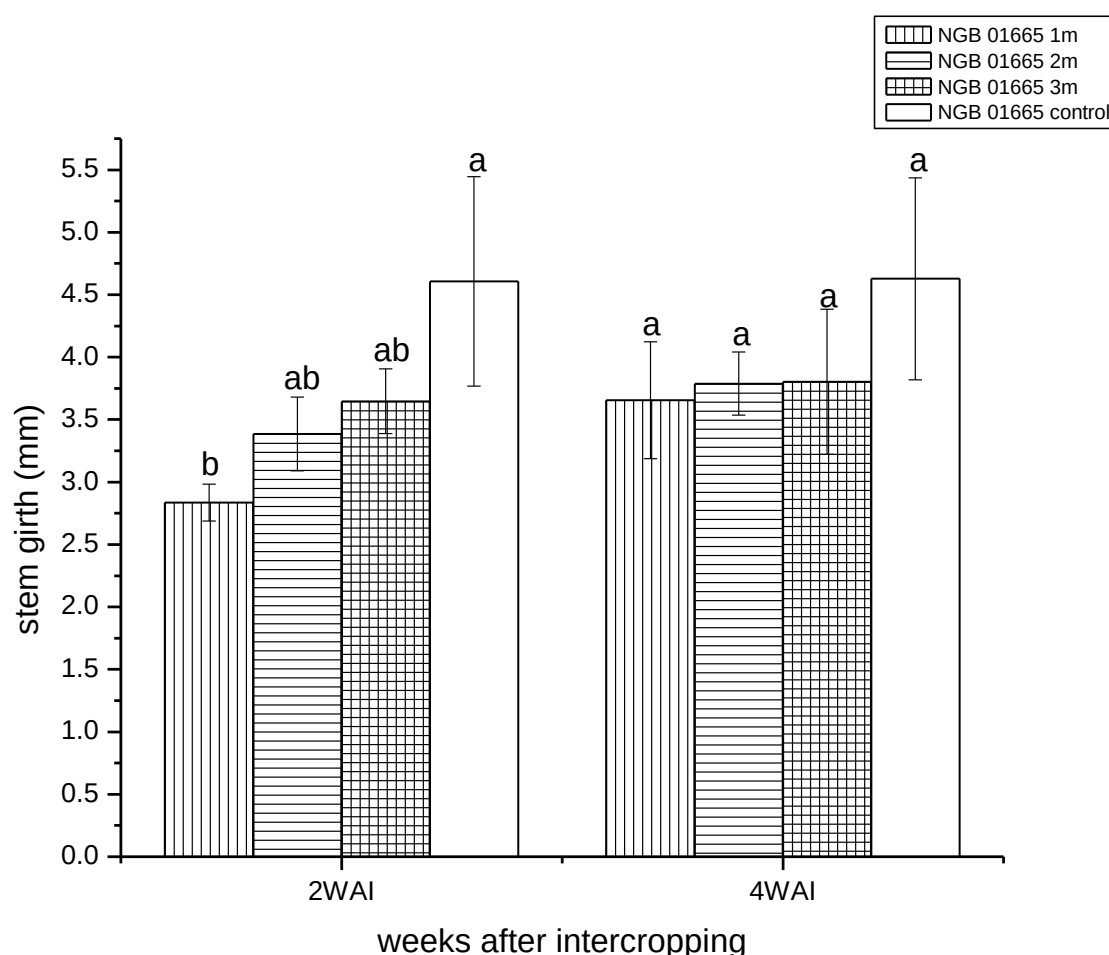


Fig. 3: Effects of intercropping on the stem girth of tomato (NGB 01665) at 2 and 4 WAI

Fig. 3 shows that the highest stem girth was recorded by tomato of the control plot, which was not statistically different from those planted at 2 m (3.385 mm) and 3 m (3.648 mm) from the juvenile oil palm at 2 WAI. However, it was statistically different from those at 1 m (2.835 mm) that recorded the lowest stem girth. At 4 WAI, there was no statistical difference across the treatments with tomatoes of the control plot recording the highest stem girth (4.628 mm), followed by 3 m (3.803 mm), 2 m (3.788 mm) and 1 m (3.655 mm) as shown in Fig. 3.

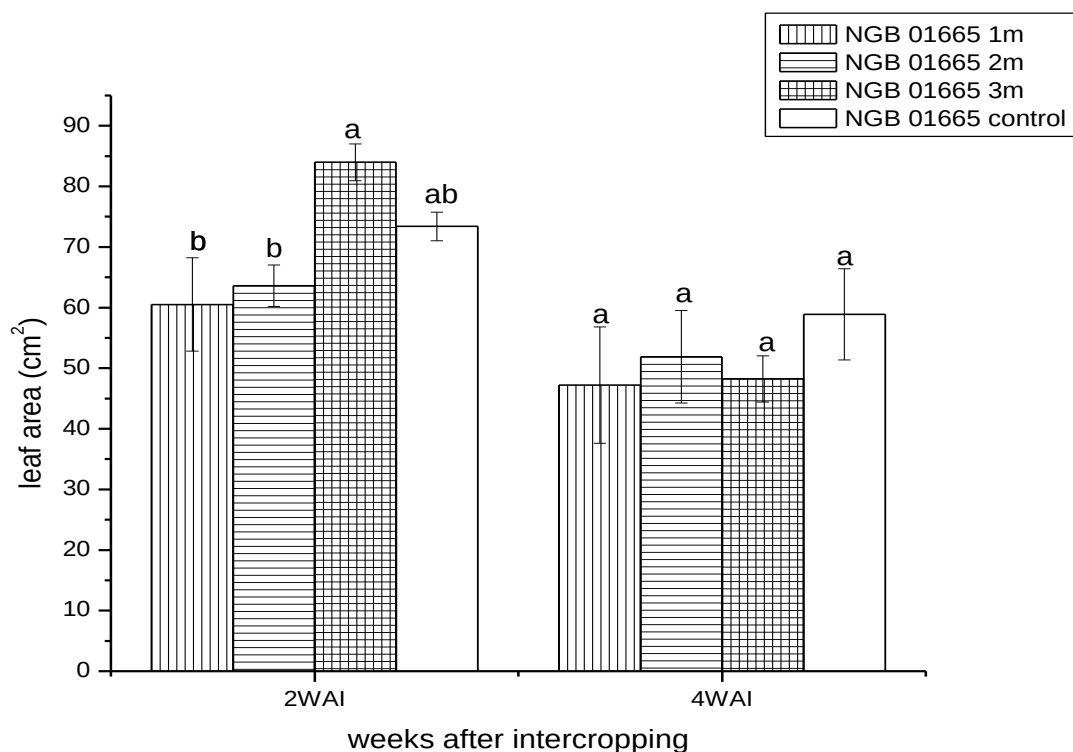


Fig. 4: Effects of intercropping on the leaf area of tomato (NGB 01665) at 2 and 4 WAI

At 2 WAI, tomato plants at 3 m from juvenile oil palm recorded the highest leaf area (83.98 cm²) which was not statistically different from those of the control plot (73.393 cm²). The value of leaf area of the control plot (73.393 cm²) was followed by 2 m (63.62 cm²) and 1 m (60.508 cm²); which recorded the lowest leaf area. However, the values of leaf area of tomato of the control plot, 1 and 2 m were not statistically different. There was no statistical difference across the treatments at 4 WAI with highest leaf area recorded by those of the control plot. This was followed by 2 m (51.896 cm²), 3 m (48.235 cm²) and 1 m (47.233 cm²) as shown in Fig. 4.

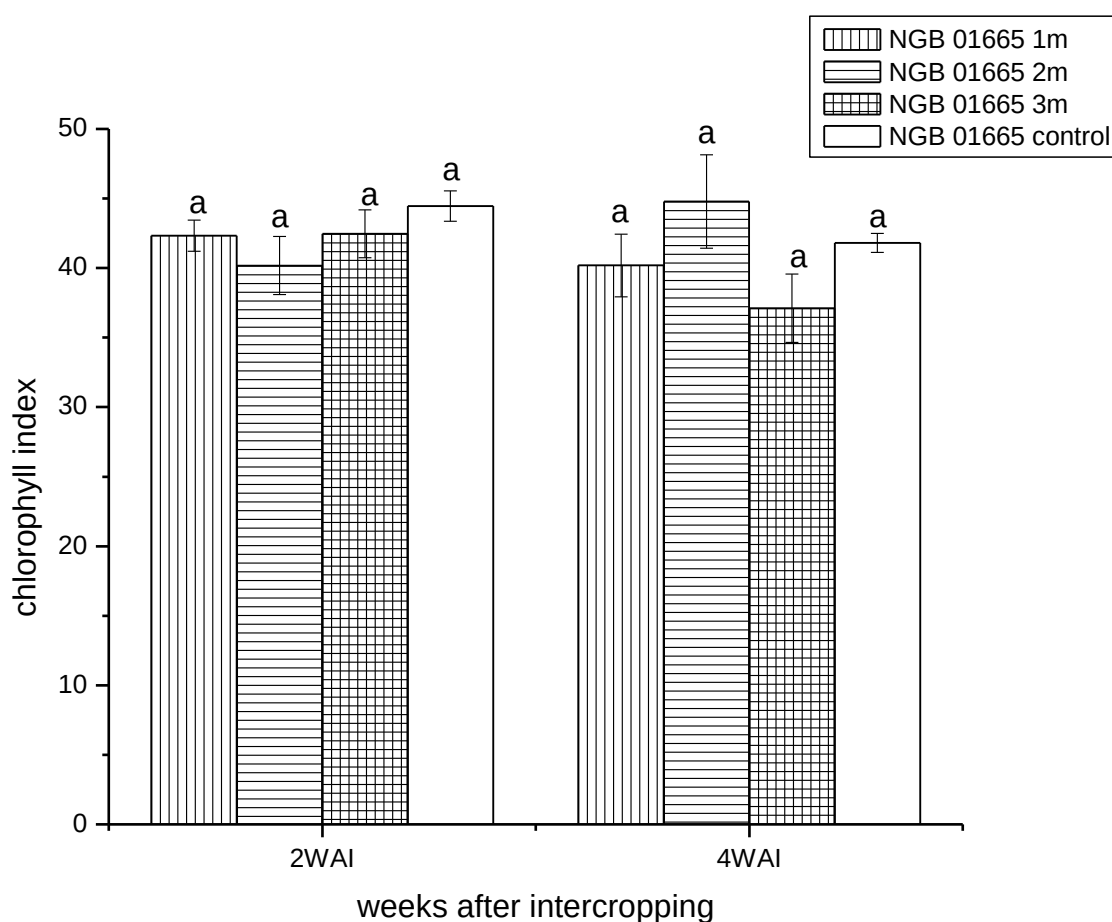


Fig. 5: Effects of intercropping on the chlorophyll index of tomato (NGB 01665) at 2 and 4 WAI

Effects of intercropping on the chlorophyll index of tomato (NGB 01665) at 2 and 4 WAI are shown in Fig. 5. At 2 WAI and 4 WAI, the chlorophyll index across the treatments were not statistically different however at 4 WAI the highest and lowest were obtained from tomato plants at 2 m (44.78) and 3 m from the juvenile oil palm (37.113).

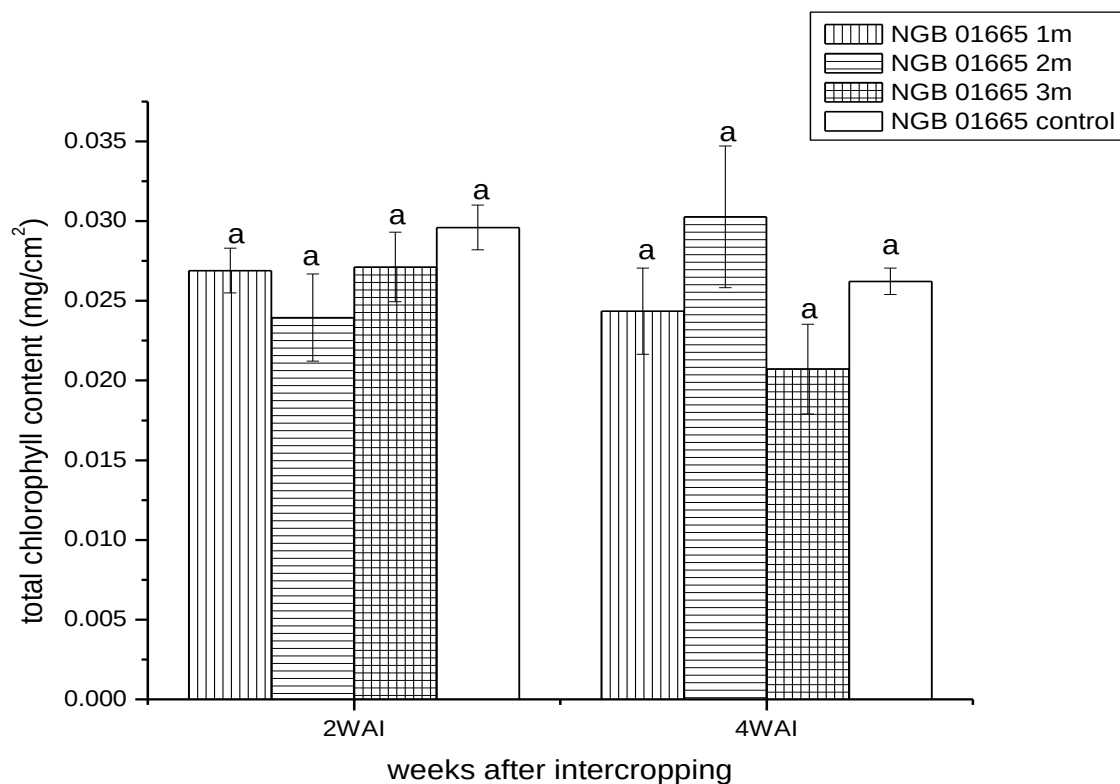


Fig. 6: Effects of intercropping on total chlorophyll content of tomato (NGB 01665) at 2 and 4 WAI

Fig. 6 shows the effects of intercropping on total chlorophyll content of tomato (NGB 01665) at 2 and 4 WAI. Similar results to chlorophyll index were obtained for the total chlorophyll content with highest and lowest recorded by those of control plot and 2 m from the juvenile oil palm (0.0296 mg/cm² and 0.0239 mg/cm² respectively) at 2 WAI. At 4 WAI, tomato at 2 m from the juvenile oil palm recorded the highest value of total chlorophyll content (0.030 mg/cm²), followed by control (0.026 mg/cm²), 1 m (0.024 mg/cm²) and 3 m from the juvenile oil palm (0.021 mg/cm²).

4.1.2 Growth responses of tomato (NG/AA/SEP/09/053) to intercropping with juvenile oil palm

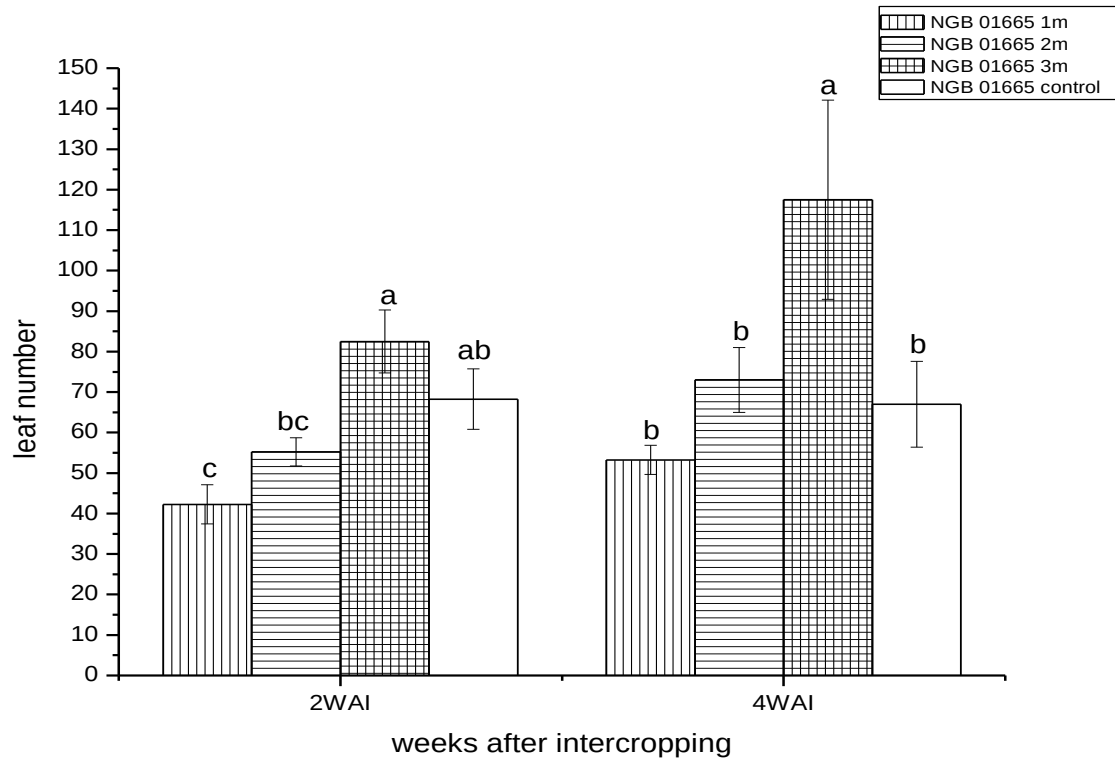


Fig. 7: Effects of intercropping on number of leaves of tomato (NG/AA/SEP/09/053) at 2 and 4 WAI

Tomato at 3 m from the juvenile oil palm recorded the highest number of leaves (82.5); however, this was statistically different from other treatments except those of the control plot (68.3) at 2 WAI. Leaf number values of tomato at 2 m from the juvenile oil palm (55.3) were not statistically different from those at the control plot (68.3) and at 1 m from the juvenile oil palm (42.3). At 4 WAI, leaf number of tomato at 3 m from the juvenile oil palm was the highest, followed by 2 m (73.0), control, (67.0) and 1 m (53.3). However, there was statistical different between those at 3 m from juvenile oil palm and other treatments as shown in Fig. 7.

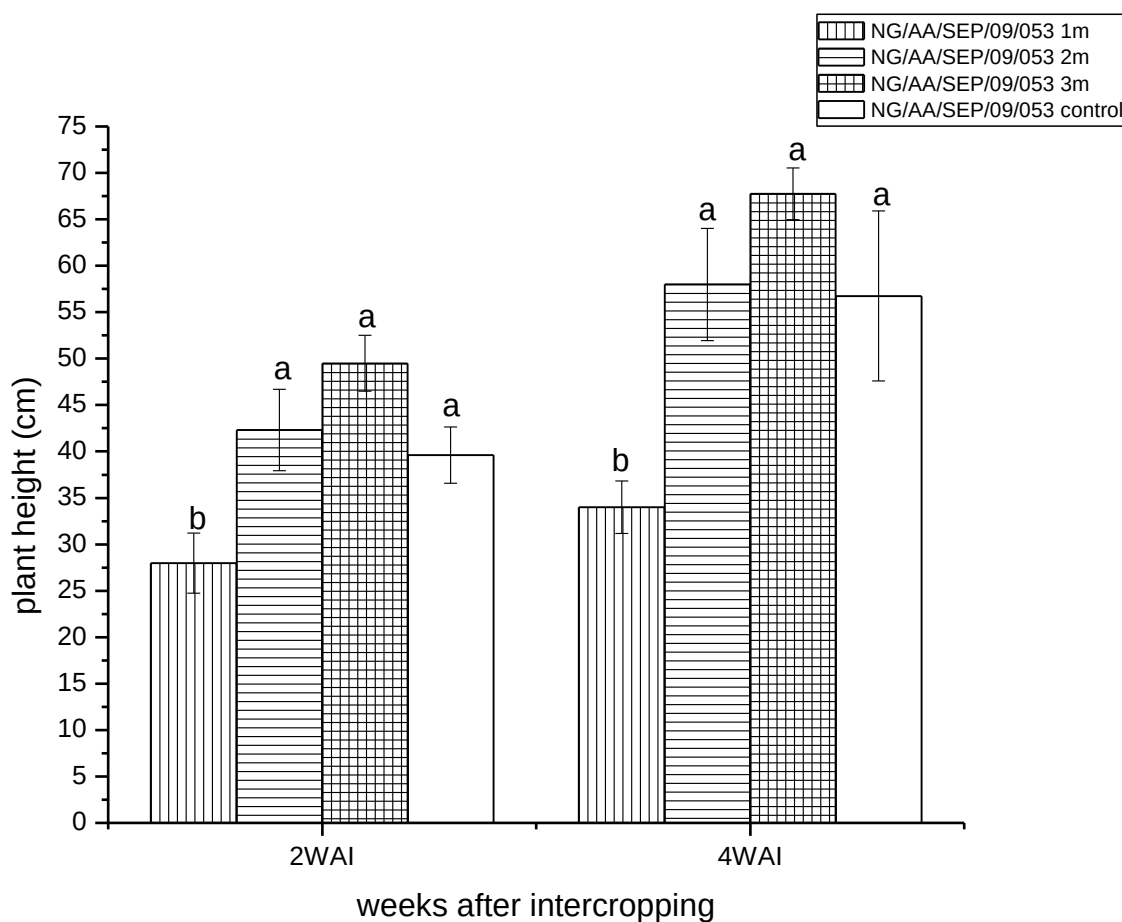


Fig. 8: Effects of intercropping on plant height of tomato (NG/AA/SEP/09/053) at 2 and 4 WAI

Fig. 8 shows the effects of intercropping on plant height of tomato (NG/AA/SEP/09/053) at 2 and 4 WAI. The plant height value recorded by tomato at 3 m from the juvenile oil palm (49.50 cm) was the highest though it was only statistically different from those at 1 m from the juvenile oil palm (27.98 cm) at 2 WAI. Plant height value of tomato at 2 m from the juvenile oil palm (42.33 cm) was higher than those of the control plot (39.63 cm); however, they were not statistically different. Similar result was obtained at 4 WAI with those at 1 and 3m from the juvenile oil palm recording the least and highest plant height values (34. 00 and 67.75 cm).

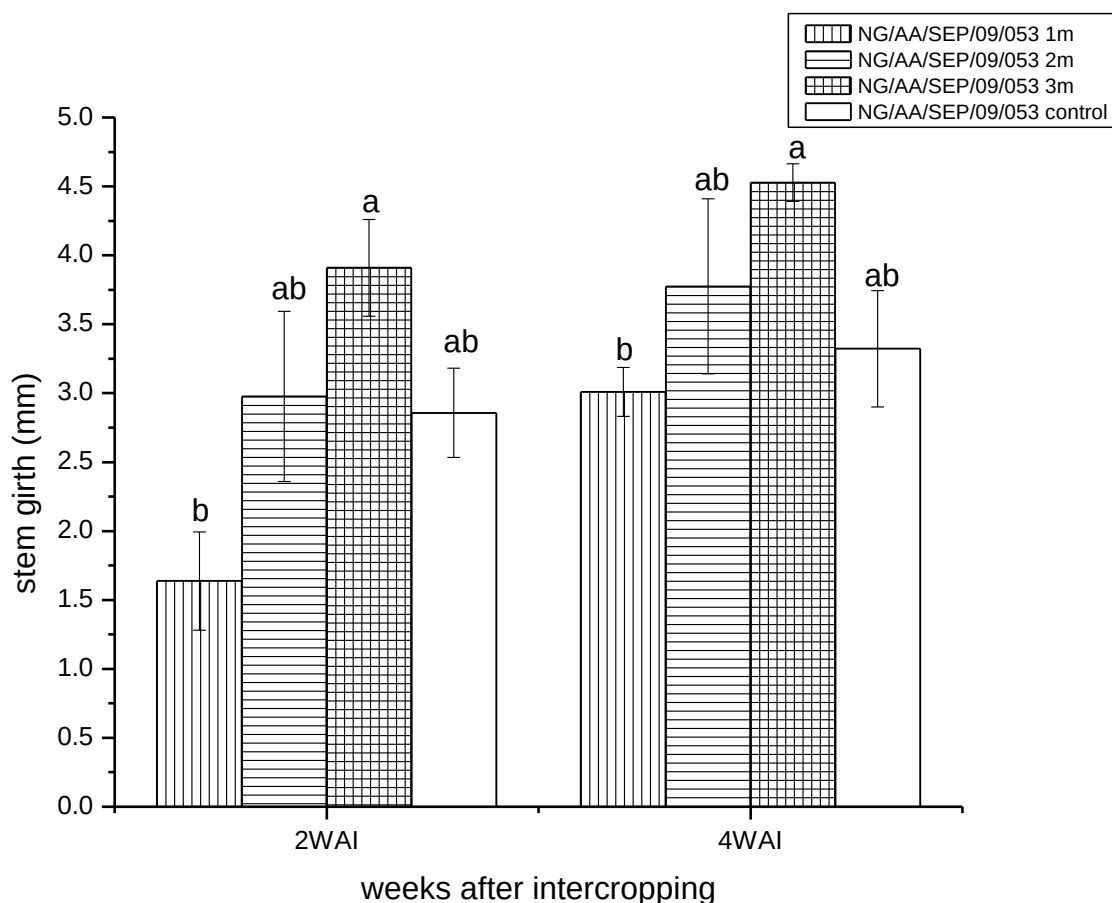


Fig. 9: Effects of intercropping on stem girth of tomato (NG/AA/SEP/09/053) at 2 and 4 WAI

At 2 WAI, tomato plants at 3 m from the juvenile oil palm recorded the highest stem girth value (3.910 mm), followed by 2 m (2.978 mm), control (2.856 mm) and control (1.638 mm). However, stem girth values of tomato at 3 m from juvenile oil palm was not statistically different from those of the control plot (2.858 mm) and those planted at 2 m from the juvenile oil palm (2.978 mm). Similarly at 4 WAI, tomato plants at 3 m from the juvenile oil palm recorded the highest stem girth value (4.528 mm) which was only statistically different from those at 1 m from the juvenile oil palm (3.01 mm) as shown in Fig. 9.

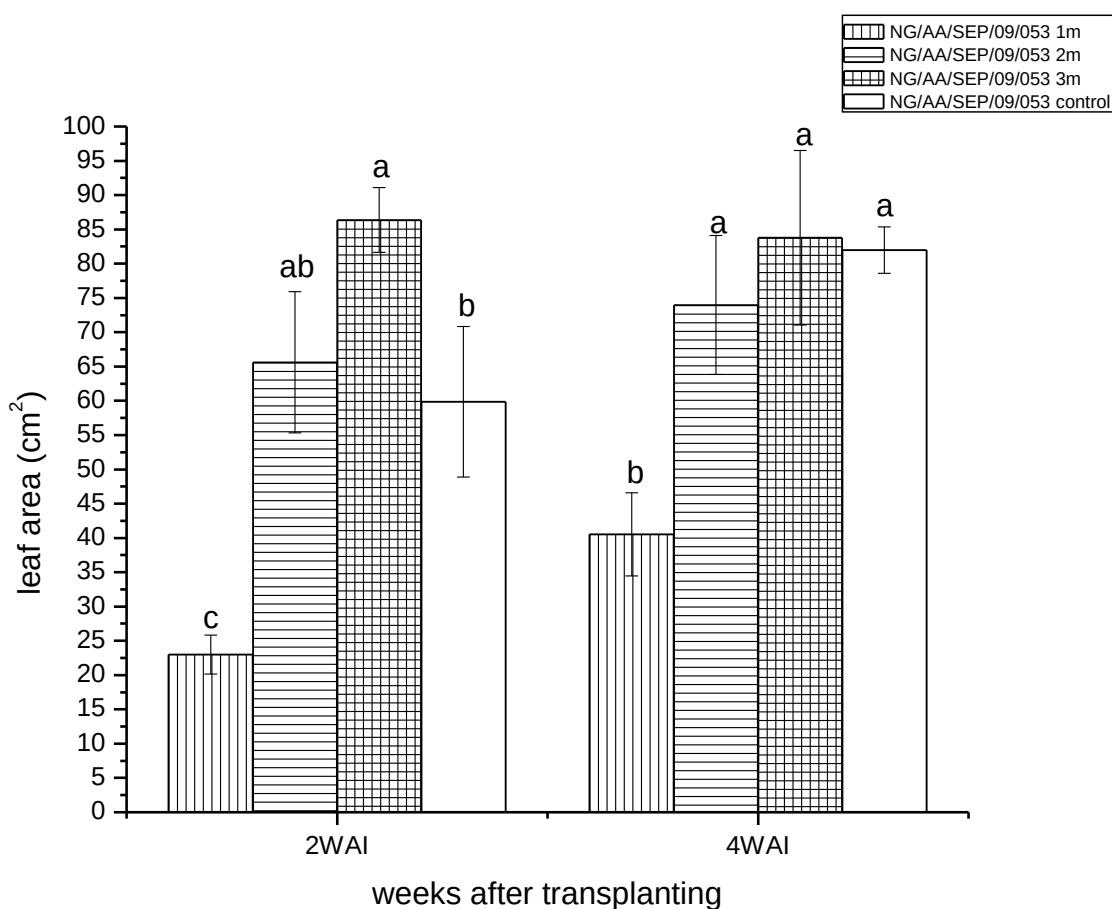


Fig. 10: Effects of intercropping on leaf area of tomato (NG/AA/SEP/09/053) at 2 and 4 WAI

The effects of intercropping on leaf area of tomato (NG/AA/SEP/09/053) at 2 and 4 WAI are shown in Fig. 10. The highest and lowest leaf area were obtained from those planted at 3 m and 1 m from the juvenile oil palm (86.372 cm² and 22.967 cm² respectively) at 2 WAI. However, leaf area values of tomato at 2 and 3 m from juvenile oil palm were not statistically different. At 4 WAI, the leaf area value of tomato at 3 m (83.77 cm²) was the highest, followed by those of the control plot, 2 m (73.962 cm²) and 1 m (40.517 cm²). There was statistical different between leaf area values of 1 m from the juvenile oil palm and other treatments.

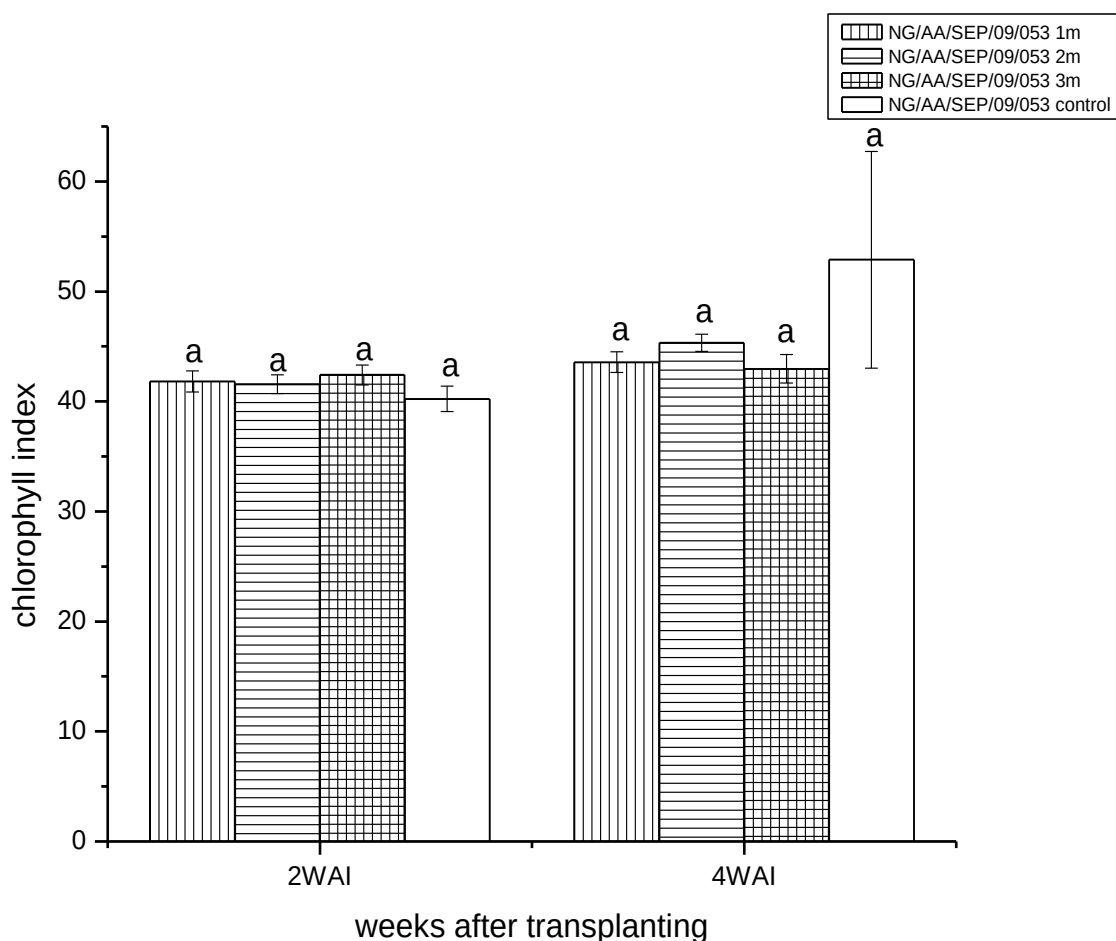


Fig. 11: Effects of intercropping on index of tomato (NG/AA/SEP/09/053) at 2 and 4 WAI

The chlorophyll index values across the treatments were not statistically different at 2 WAI; however, the highest and lowest values were obtained from tomato plants at 3 m and 1 m from the juvenile oil palm (42.412 and 41.825 respectively) at 2 WAI. At 4 WAI, the control plot recorded the highest chlorophyll index (52.887), followed by 2 m (45.337), 1 m (43.575) and 3 m (42.962). However, they were not statistically different as shown in Fig. 11.

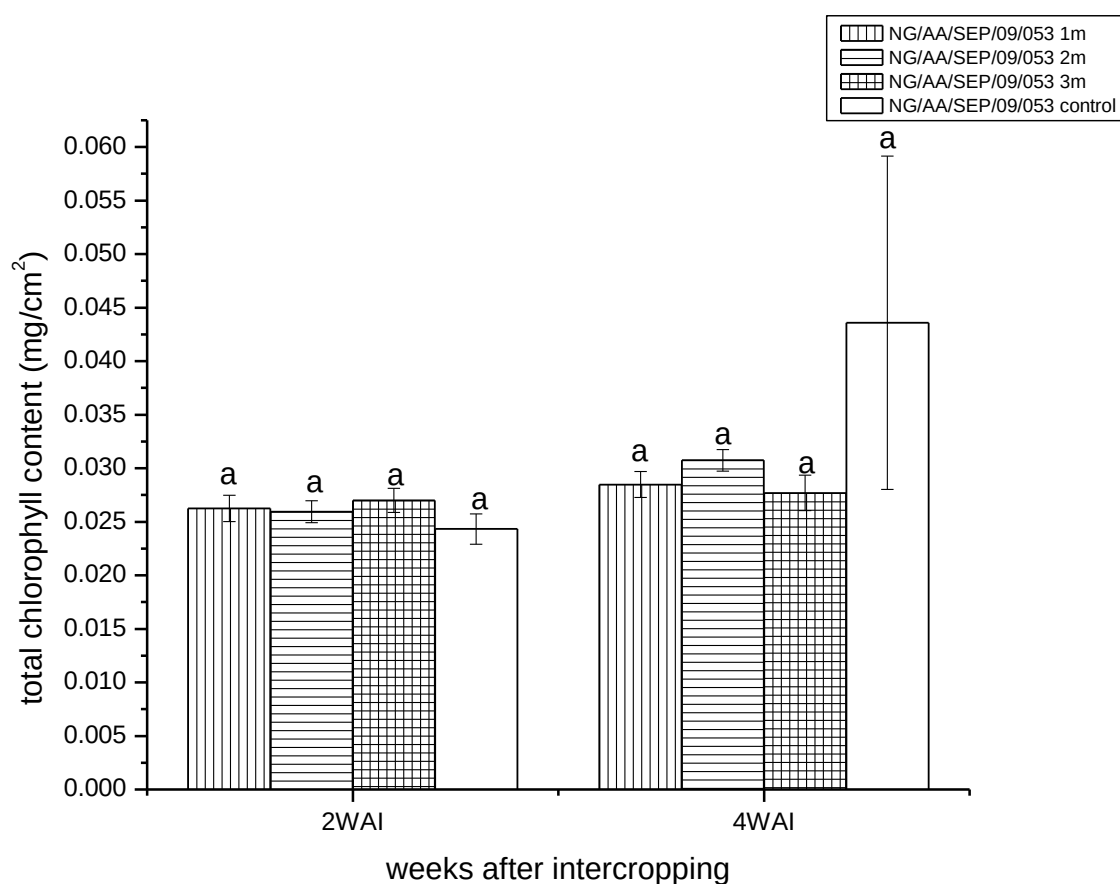


Fig. 12: Effects of intercropping on total chlorophyll content of tomato (NG/AA/SEP/09/053) at 2 and 4 WAI

Fig. 12 shows the effects of intercropping on the total chlorophyll content of tomato (NG/AA/SEP/09/053). Similar results to the chlorophyll index were obtained at 2 WAI and 4 WAI with the highest total chlorophyll content recorded from tomato plants at 3 m from the juvenile oil palm and the control plot at 2 WAI and 4 WAI (0.027 mg/cm² and 0.044 mg/cm² respectively). The lowest total chlorophyll content values at 2 and 4 WAI were obtained from tomatoes of the control plot and 1 m from the juvenile oil palms (0.024 and 0.029 mg/cm²) respectively as shown in Fig. 12.

4.1.3 Growth responses of pepper (NGB 01312) to intercropping with juvenile oil palm

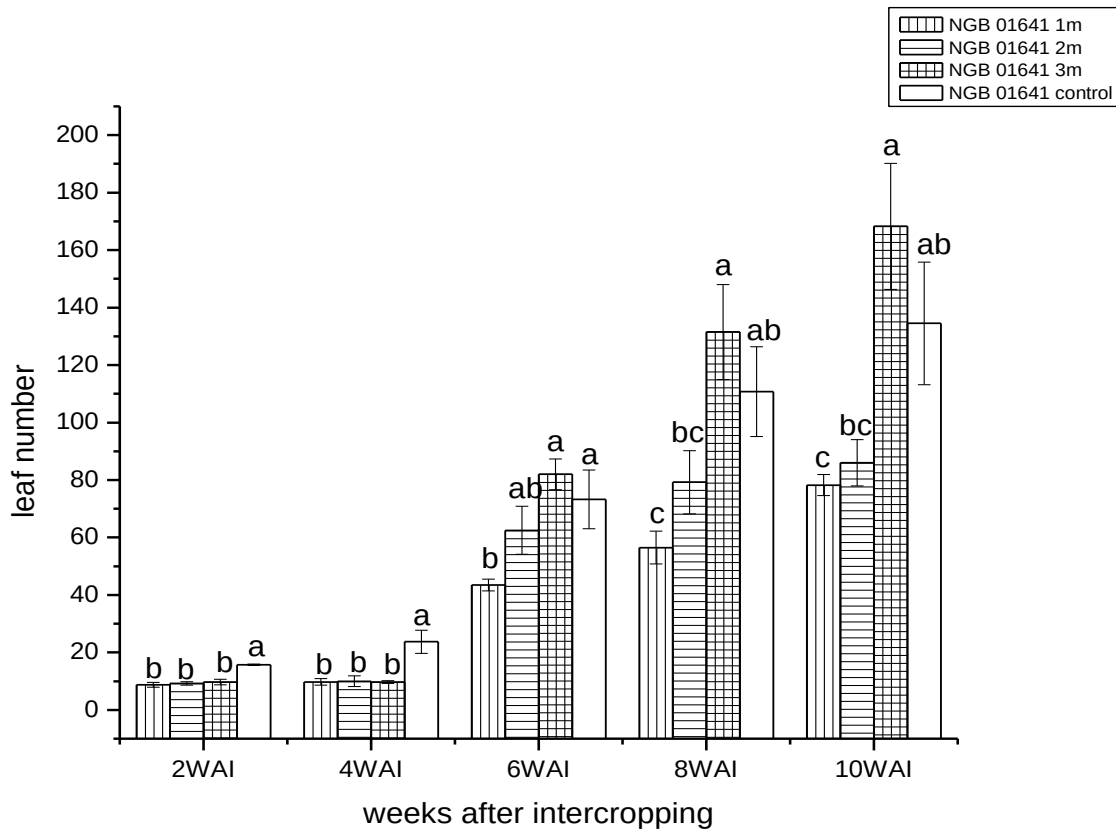


Fig. 13: Effects of intercropping on number of leaves of pepper (NGB 01312) at 2, 4, 6, 8 and 10 WAI

At 2 WAI, pepper of the control plot recorded the highest leaf number (15.8) which was statistically different from other treatments. At 4 WAI, similar trend was obtained with the control plot recording the highest leaf number (23.8). At 6 WAI, 3 m recorded the highest leaf number (82.0) which was only statistically different from those planted at 1 m from the juvenile oil palm. Similar trends were obtained at 8 WAI and 10 WAI (131.5 and 168.3) with those planted at 1 m from the juvenile oil palm recording the lowest values (43.5 and 78.3) respectively as shown in Fig. 13.

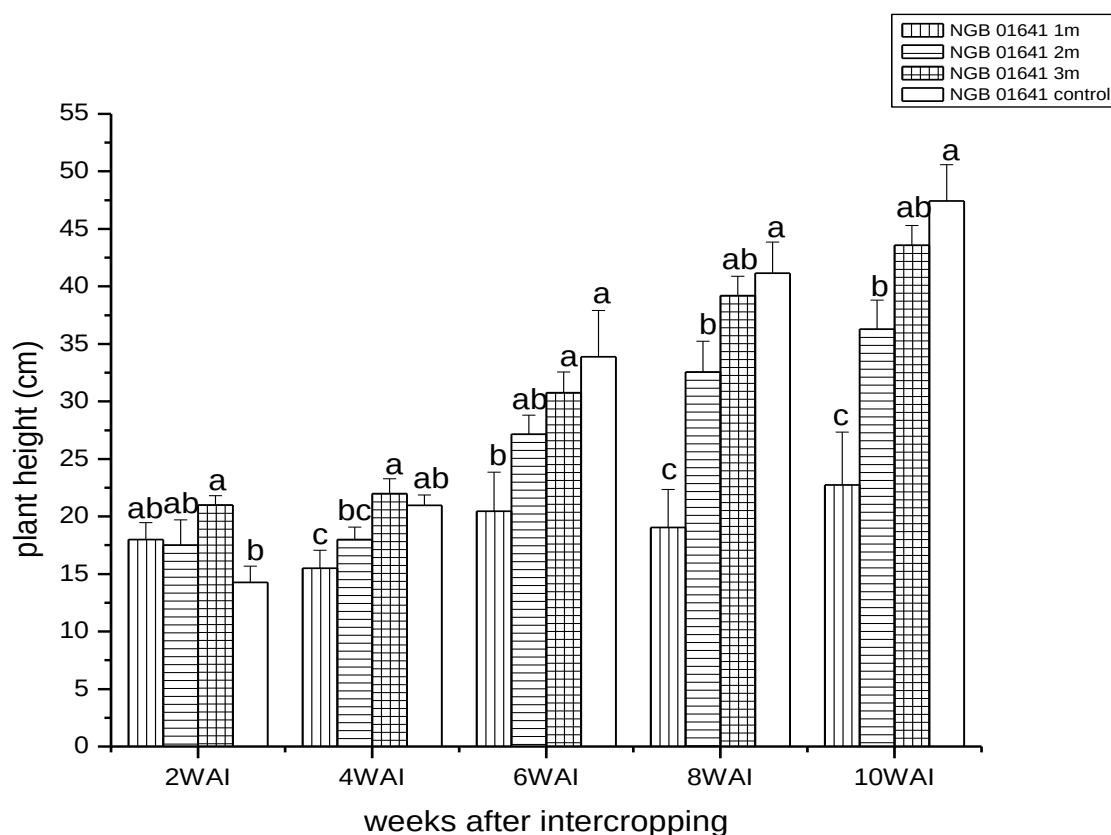


Fig. 14: Effects of intercropping on plant height of pepper (NGB 01312) at 2, 4, 6, 8 and 10 WAI

Highest plant height was recorded in pepper plants at 3 m from the juvenile oil palm (21.00 cm) and was only statistically different from those of the control (14.275) at 2 WAI. At 4 WAI, the stem height of pepper at 3m from the juvenile oil palm produced the highest plant height (22.00 cm) while those at 1 m from the juvenile oil palm produced the least (15.50 cm). Similarly at 6 WAI, the highest and lowest plant heights were obtained from those at 3 m (30.75 cm) and 1 m (20.45 cm) from the juvenile oil palm. At 8 WAI and 10 WAI, the control plot produced the highest plant height (41.15 cm and 47.43 cm), and were statistically different from those at 1 m from the juvenile oil palm as shown in Fig. 14.

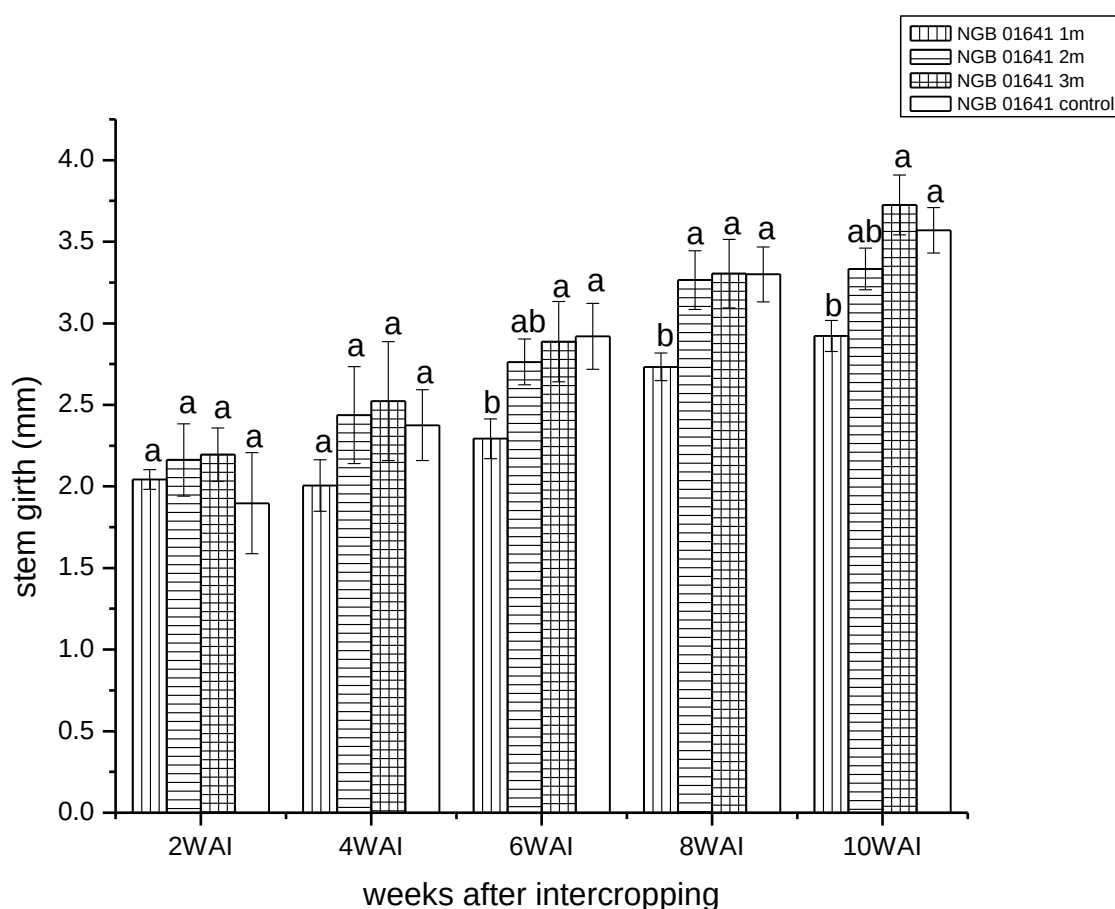


Fig. 15: Effects of intercropping on stem girth of pepper (NGB 01312) at 2, 4, 6, 8 and 10 WAI

Fig. 15 shows the effects of intercropping on stem girth of pepper (NGB 01312) at 2, 4, 6, 8 and 10 WAI. At 2 WAI and 4 WAI, the stem girths across the treatments were not statistically different. However, the highest was recorded in pepper at 3 m from the juvenile oil palm during both periods (2.20 mm and 2.53 mm respectively). The control plot recorded the highest stem girth (2.92 mm) at 6 WAI and was only statistically different from those at 1 m from the juvenile oil palm (2.30 mm). At 8 WAI and 10 WAI, those planted at 3 m from juvenile oil palm recorded the highest stem girth (3.31 mm and 3.73 mm respectively). The lowest were obtained from those at 1 m from the juvenile oil palm.

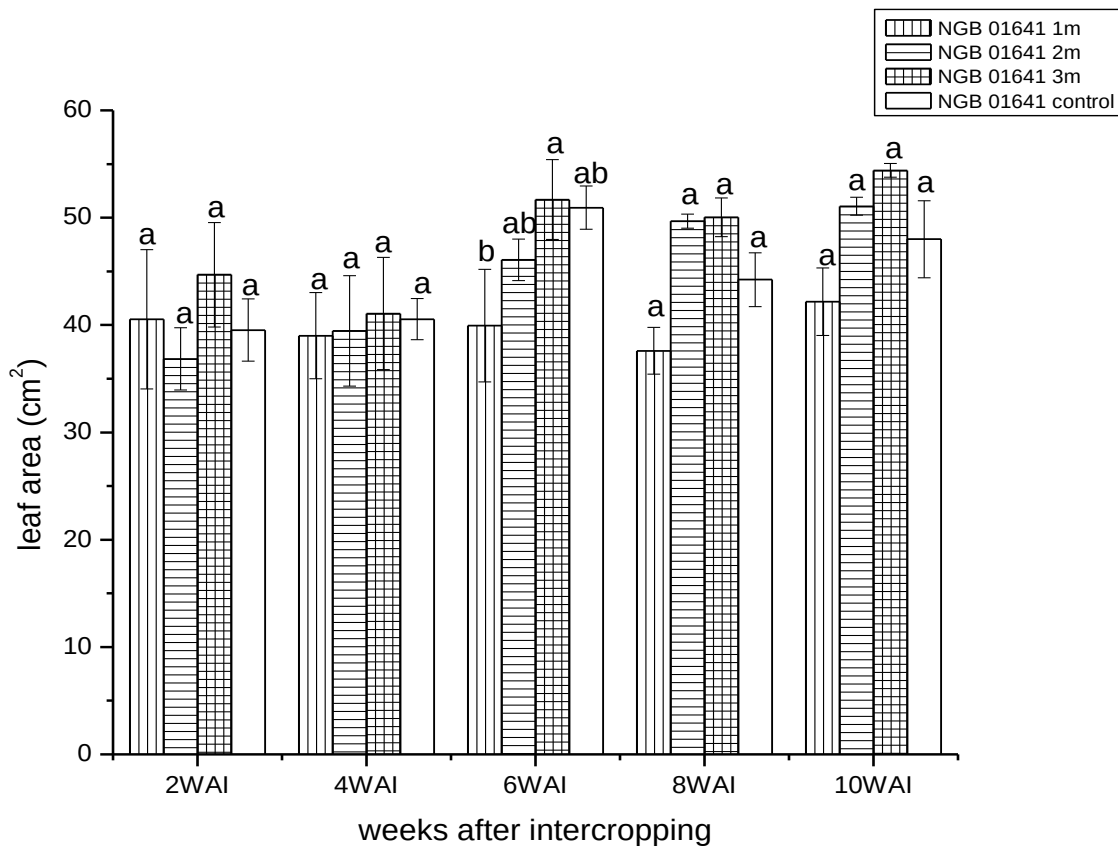


Fig. 16: Effects of intercropping on leaf area of pepper (NGB 01312) at 2, 4, 6, 8 and 10 WAI

The leaf area across the treatments were not statistically different at 2 WAI and 4 WAI, however, highest values were recorded in pepper at 3 m from the juvenile oil palm (44.69 cm² and 41.08 cm² respectively). At 6 WAI, those at 3 m from the juvenile oil palm recorded the highest leaf area (51.69 cm²) however it was only statistically different from those planted at 1 m from the juvenile oil palm. Similar trends were obtained at 8 WAI and 10 WAI with the least value recorded by those at 1 m from the juvenile oil palm (37.6 cm² and 42.18 cm²) respectively as shown in Fig. 16.

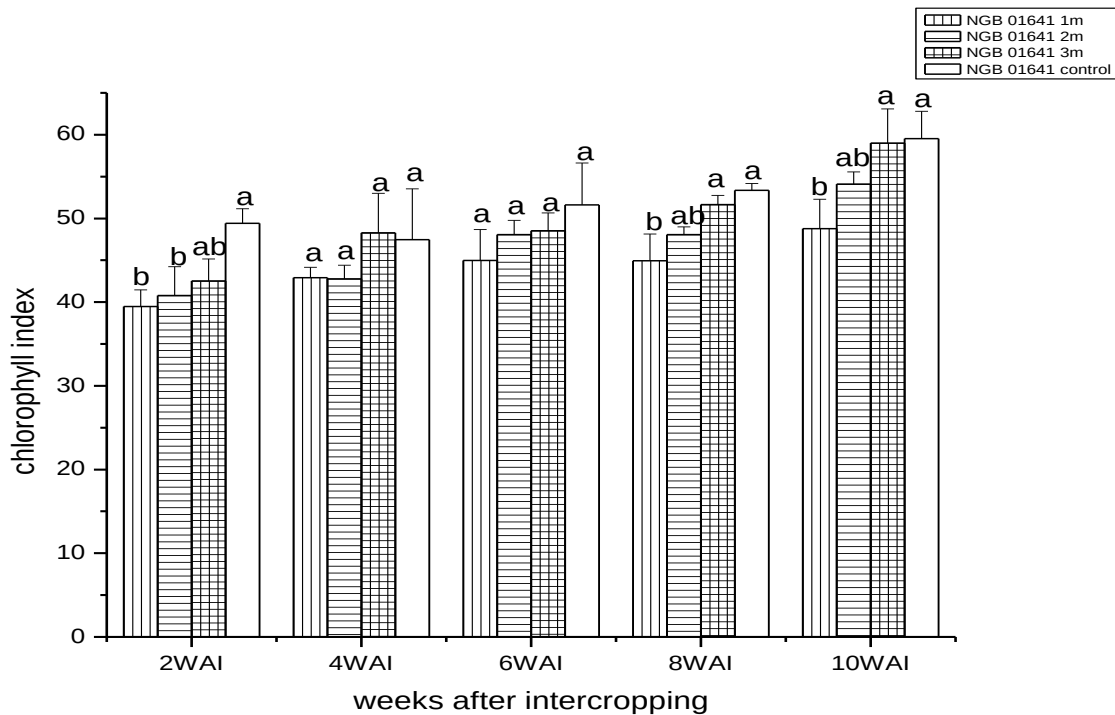


Fig. 17: Effects of intercropping on chlorophyll index of pepper (NGB 01312) at 2, 4, 6, 8 and 10 WAI

The pepper of the control plot recorded the highest chlorophyll index at 2 WAI (49.4). However, it was not statistically different from those at 3 m from the juvenile oil palm (42.52). At 4 WAI, those at 3 m from the juvenile oil palm recorded the highest chlorophyll index (48.26) though this was not statistically different from other treatments. At 6 WAI, the chlorophyll index was not statistically different across the treatments though those of control recorded the highest chlorophyll index (51.60). At 8 WAI and 10 WAI, those at control plot recorded the highest chlorophyll indices (53.36 and 59.54) respectively, which were only statistically different from those at 1 m from the juvenile oil palm as shown in Fig. 17.

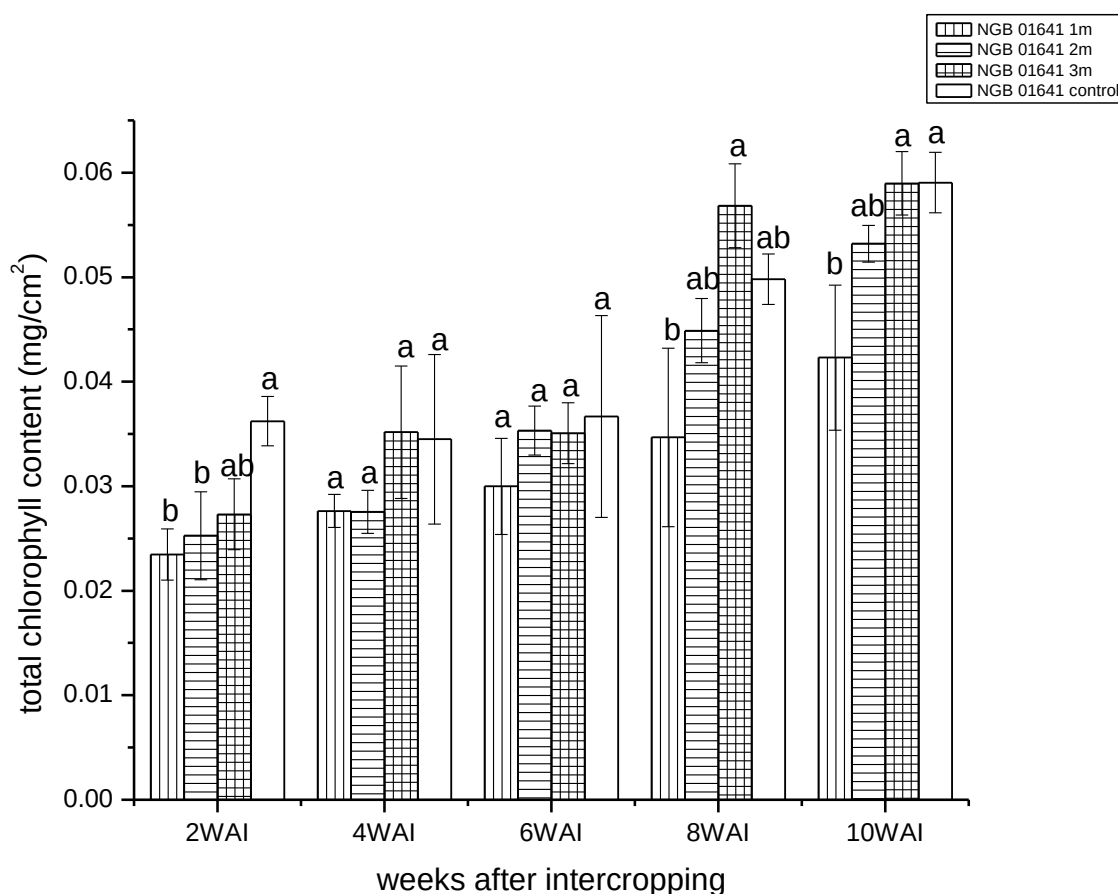


Fig. 18: Effects of intercropping on total chlorophyll content of pepper (NGB 01312) at 2, 4, 6, 8 and 10 WAI

Fig. 18 shows the effects of intercropping on total chlorophyll content of pepper (NGB 01312) at 2, 4, 6, 8 and 10 WAI. Similar results to chlorophyll index were obtained and total chlorophyll content value of pepper of the control plot was the highest at 2 WAI, 4 WAI, 8 WAI and 10 WAI (0.0362 mg/cm², 0.0367 mg/cm², 0.057 mg/cm² and 0.059 mg/cm²) respectively. Also, the total chlorophyll content value of pepper planted at 1 m from the juvenile oil palm was the lowest at 2, 6, 8 and 10 WAI (0.0235 mg/cm², 0.0230 mg/cm², 0.0350 mg/cm² and 0.0423 mg/cm²) respectively.

4.1.4 Growth responses of pepper (NGB 01641) to intercropping with juvenile oil palm

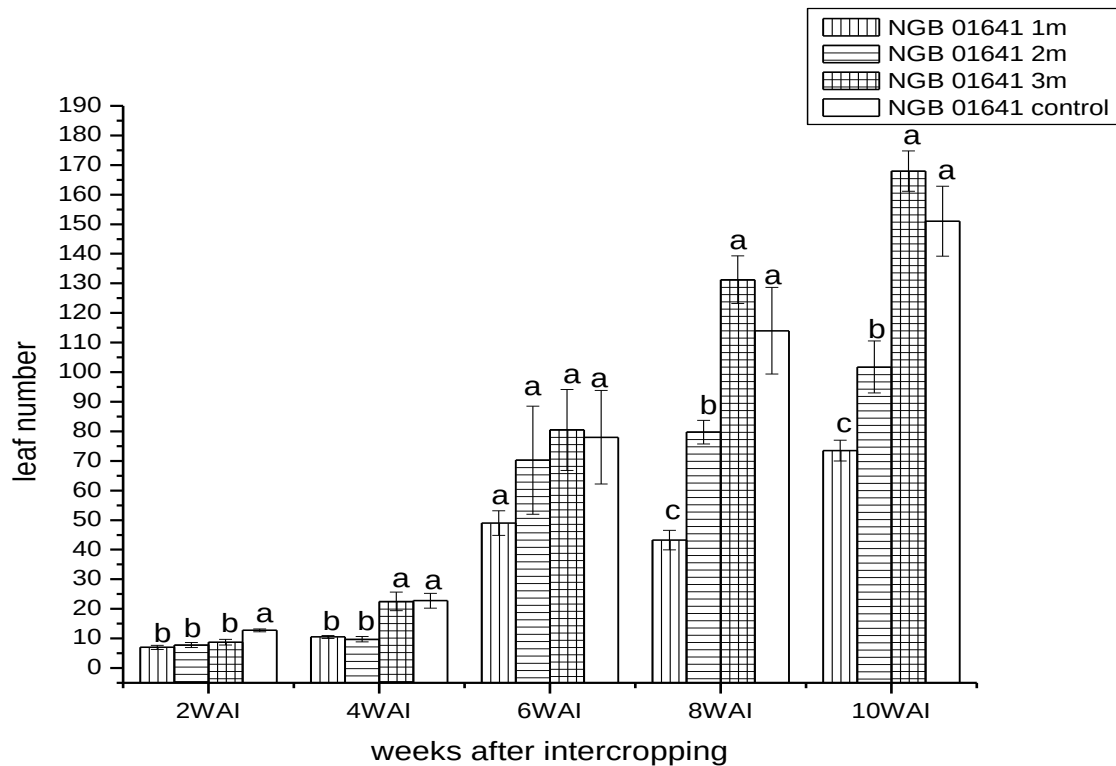


Fig. 19: Effects of intercropping on number of leaves of pepper (NGB 01641) at 2, 4, 6, 8 and 10 WAI

Fig. 19 shows the effects of intercropping on leaf number of pepper (NGB 01641) at 2, 4, 6, 8 and 10 WAI. Pepper of control plot recorded the highest leaf number at 2 WAI (12.75) and was statistically different from other treatments. At 4 WAI, the control also recorded the highest leaf number while the lowest was obtained from those at 1 m from the juvenile oil palm. At 6 WAI, 8 WAI and 10 WAI, highest number of leaves were recorded in pepper planted at 3 m from the juvenile oil palm (80.50, 131.25 and 168.00 respectively). Similarly, those at 1 m from the juvenile oil palm also recorded the lowest number of leaves (49.00, 43.25 and 73.50 respectively).

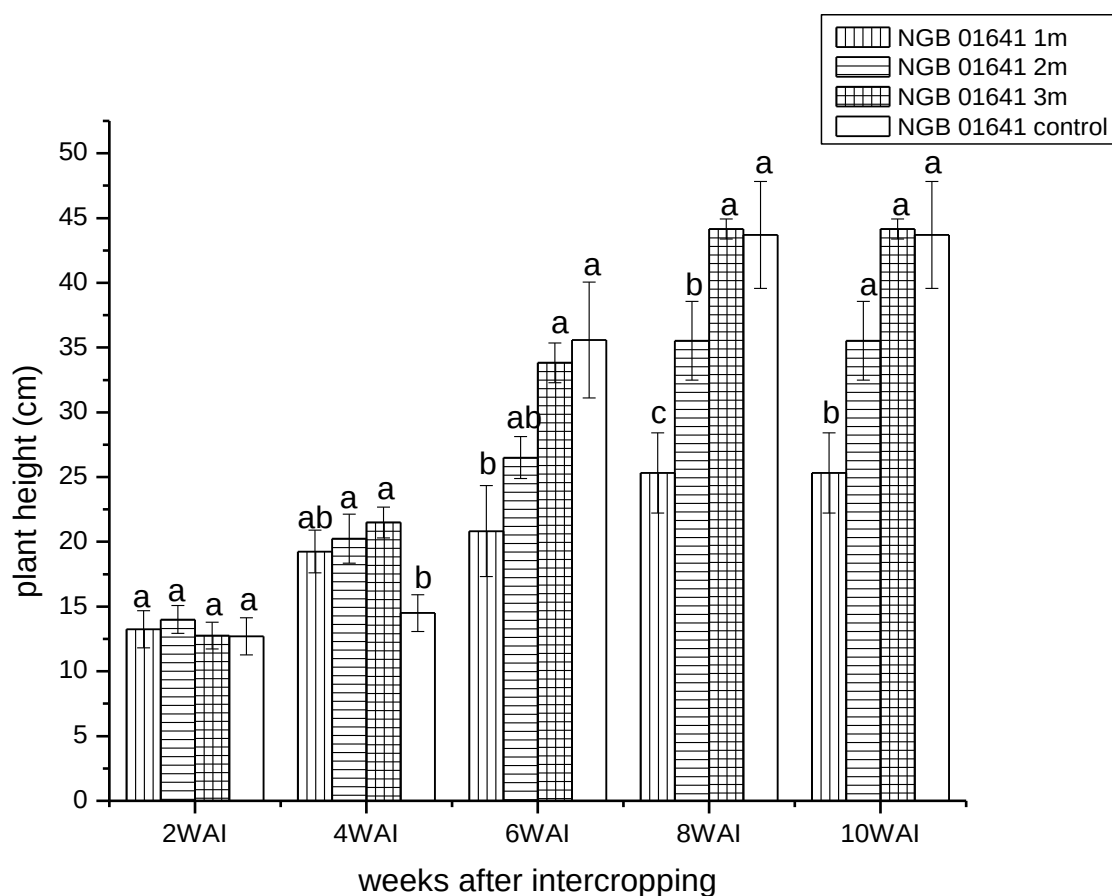


Fig. 20: Effects of intercropping on plant height of pepper (NGB 01641) at 2, 4, 6, 8 and 10 WAI

The effects of intercropping on plant height of pepper (NGB 01641) at 2, 4, 6, 8 and 10 WAI are shown in Fig. 20. At 2 WAI, the plant heights recorded across the treatments were not statistically different though those at 2 m from the juvenile oil palm recorded the highest value (14.00 cm). At 4 WAI, 6 WAI, 8 WAI and 10 WAI, those at 3 m from the juvenile oil palm recorded the highest plant height (21.50 cm, 33.83 cm, 38.55 cm and 44.15 cm) respectively. The least plant height at 6 WAI, 8 WAI and 10 WAI were recorded by those planted at 1 m from the juvenile oil palm (49.00 cm, 43.25 cm and 25.33 cm) respectively.

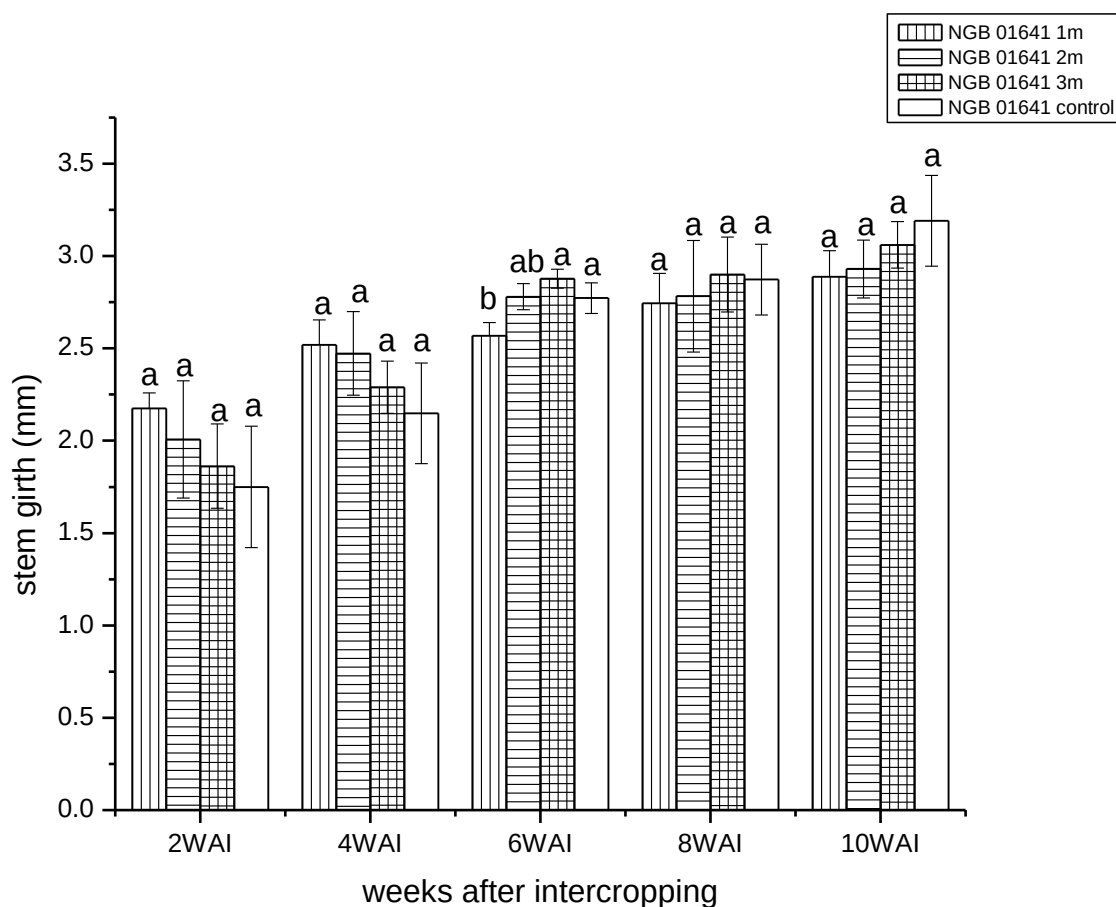


Fig. 21: Effects of intercropping on stem girth of pepper (NGB 01641) at 2, 4, 6, 8 and 10 WAI

At 2 WAI and 4 WAI, the stem girths across the treatments were not statistically different though the highest values were recorded by those at 1 m from the juvenile oil palm. At 6 WAI, 8 WAI and 10 WAI, pepper at 3 m from the juvenile oil palm recorded the highest stem girth (2.88 mm, 2.90 mm and 3.06 mm respectively). The value at 6 WAI was only statistically different from those at 1 m from the juvenile oil palm. At 8 WAI and 10 WAI, the values of stem girth recorded from all the treatments were not statistically different as shown in Fig. 21.

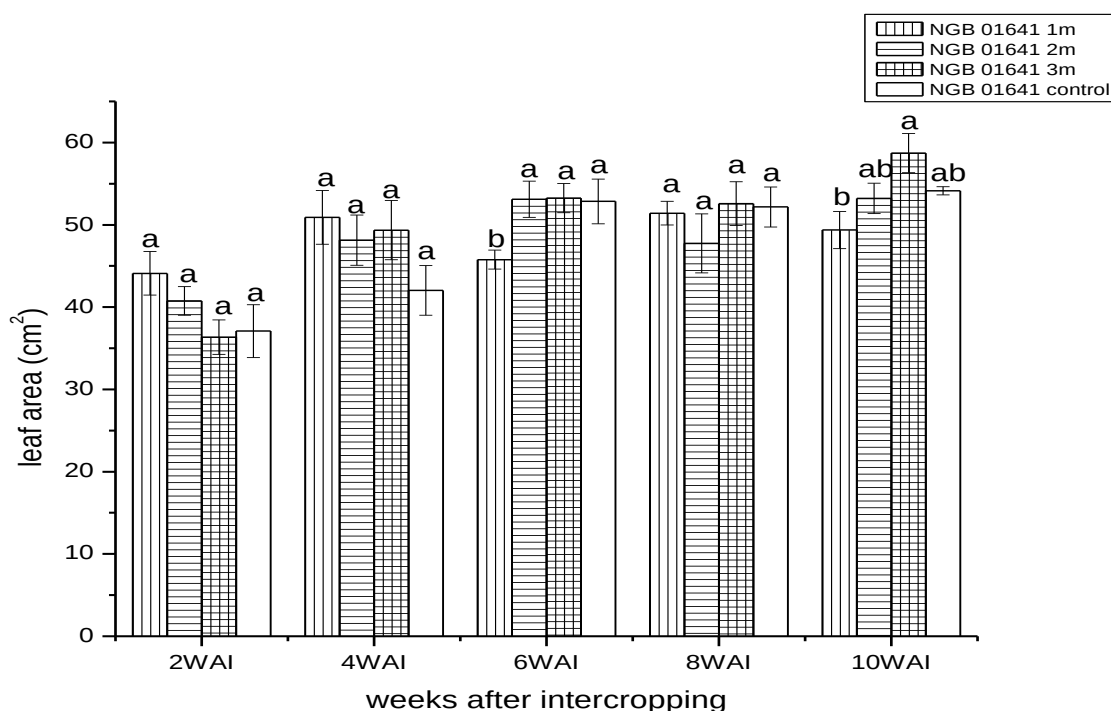


Fig. 22: Effects of intercropping on leaf area of pepper (NGB 01641) at 2, 4, 6, 8 and 10 WAI

The leaf area at 2 WAI and 4 WAI were not statistically different however those at 1 m from juvenile oil palm recorded the highest values (44.10 cm² and 50.91 cm² respectively). At 6 WAI, highest leaf area was recorded in pepper at 2 m from the juvenile oil palm (53.10 cm²), followed by 3 m and control (both 52.90 cm²). Lowest leaf area value was obtained from pepper at 1 m from juvenile oil palms (45.77 cm²) at 6 WAI. At 8 WAI, the leaf areas recorded across the treatments were not statistically different though those at 3 m from juvenile oil palm recorded the highest leaf area (58.73 cm²), followed by control (52.18 cm²), 1 m (51.42 cm²) and 2 m (47.75 cm²). There was no statistical difference at 8 WAI. At 10 WAI, leaf area of pepper at 3 m from the juvenile oil palm was the highest (58.73 cm²), followed by control (54.15 cm²), 2 m (53.23 cm²) and 1 m (49.37 cm²). Leaf area of pepper at 3 m from juvenile oil palm was statistically different from those at 1 m from the juvenile oil palm at 10 WAI as shown in Fig. 22.

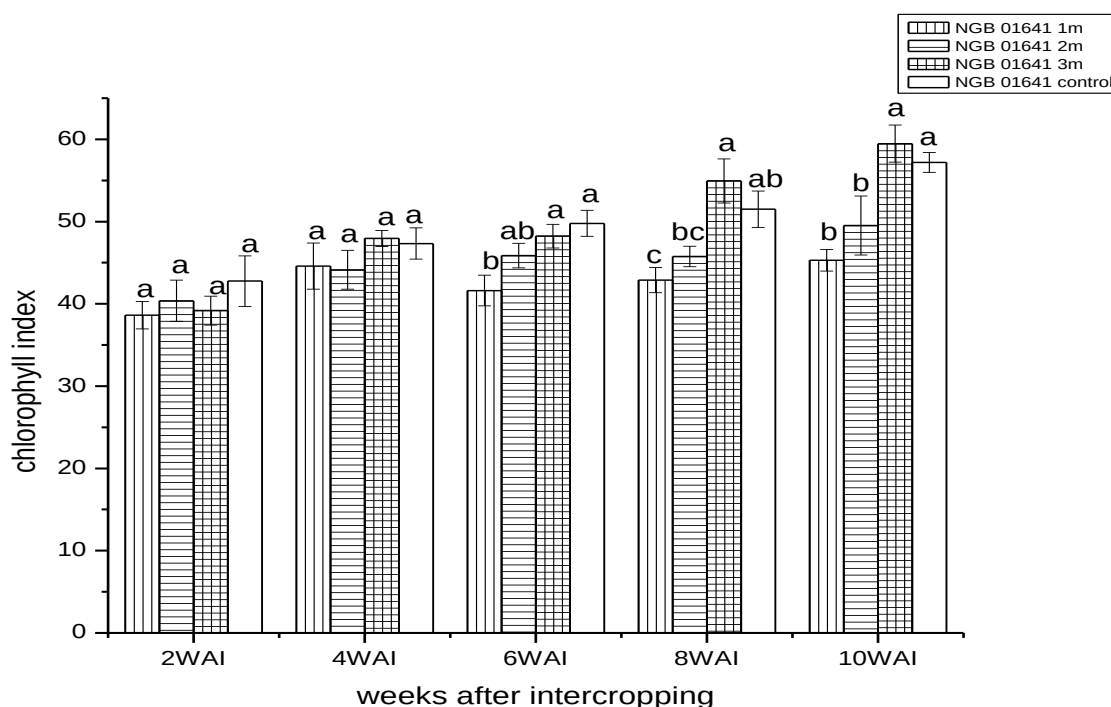


Fig. 23: Effects of intercropping on chlorophyll index of pepper (NGB 01641) at 2, 4, 6, 8 and 10 WAI

The effects of intercropping on chlorophyll index of pepper (NGB 01641) at 2, 4, 6, 8 and 10 WAI are shown in Fig. 23. At 2 WAI and 4 WAI, the chlorophyll indices were not statistically different across the treatments. However, pepper at control plot and at 3 m from the juvenile oil palm recorded the highest values (942.78 and 47.95) respectively at 2 and 4 WAI. At 6 WAI, chlorophyll index value in the control plot was the highest (49.80), followed by 3 m (48.20), 2 m (45.90) and 1 m (41.60). chlorophyll indices at control and 3 m were statistically different from those at 1 m from the juvenile oil palms. At 8 WAI and 10 WAI, chlorophyll indices at 3 m from the juvenile oil palm produced the highest values (54.94 and 59.48) respectively; followed by pepper at the control plot (51.49 and 57.19) respectively. The lowest values of chlorophyll index were obtained from pepper planted at 1 m from the juvenile oil palm (42.88 and 45.30) respectively during both periods.

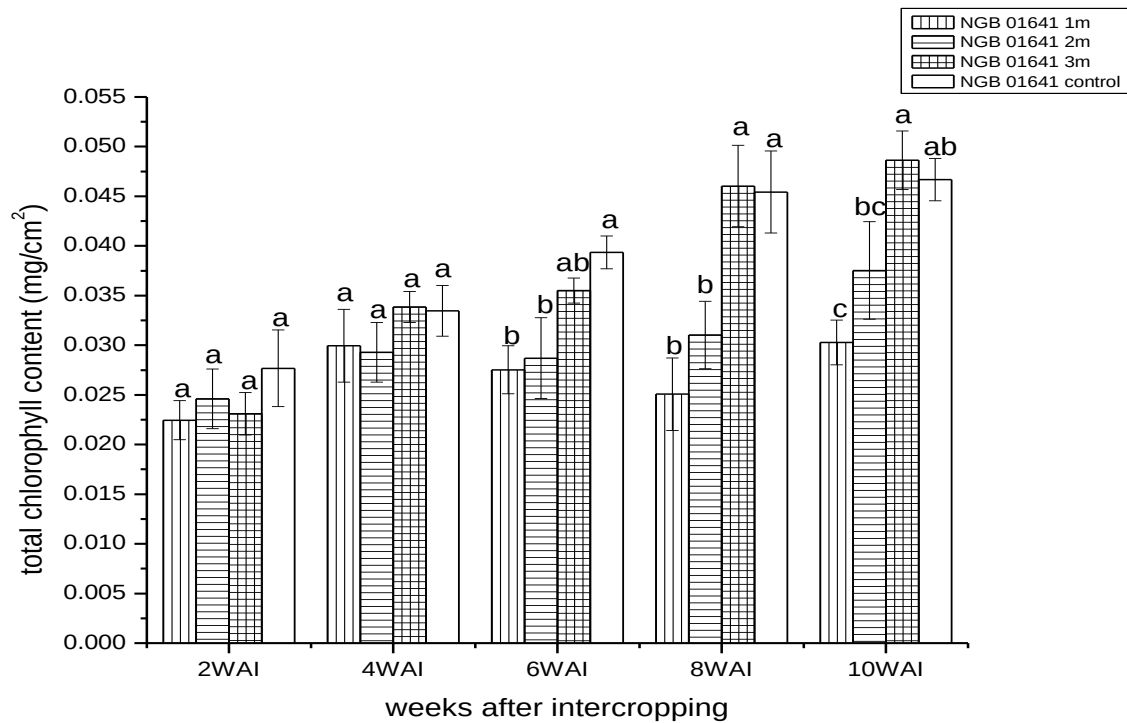


Fig. 24: Effects of intercropping on total chlorophyll content of pepper (NGB 01641) at 2, 4, 6, 8 and 10 WAI

Fig. 24 shows the effects of intercropping on total chlorophyll content of pepper (NGB 01641) at 2, 4, 6, 8 and 10 WAI. Values of the total chlorophyll content followed similar trend with results for chlorophyll index with no statistical difference obtained at 2 WAI and 4 WAI. However, there were statistical differences at 6, 8 and 10 WAI. Highest values of total chlorophyll content at 2 and 4 WAI were obtained in pepper planted at 3 m from the juvenile oil palm (0.046 mg/cm² and 0.0486 mg/cm²) respectively. At 6 WAI, total chlorophyll content of pepper in the control plot was the highest followed by 3 m (0.036 mg/cm²), 2 m (0.029 mg/cm²) and 1 m from the juvenile oil palms (0.028 mg/cm²). Pepper planted at 3 m from juvenile oil palms produced the highest total chlorophyll contents (0.046 mg/cm² and 0.0486 mg/cm²) respectively at 8 and 10 WAI.

4.1.5 Growth responses of okra (NGB 01184) to intercropping with juvenile oil palm

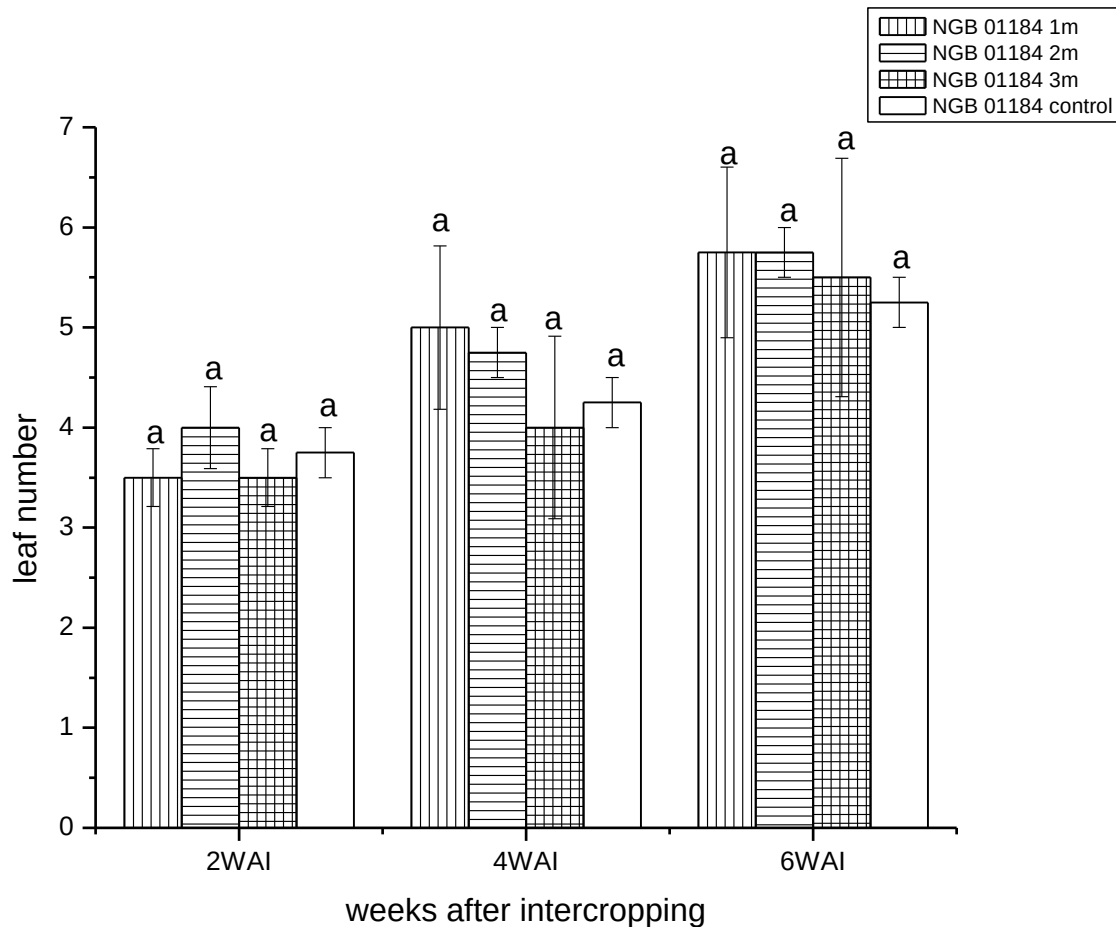


Fig. 25: Effects of intercropping on number of leaves of okra (NGB 01184) at 2, 4 and 6 WAI

The leaf number at 2 WAI was not statistically different though okra at 2 m from juvenile oil palm recorded the highest value (4.0), followed by control (3.8) and 1 m and 3 m. Similarly at 4 WAI and 6 WAI, the numbers of leaves across the treatments were not statistically different. However, at 4 WAI, those at 1 m from the juvenile oil palm recorded the highest leaf number (5.0); followed by 2 m (4.8), control (4.3) and 3 m (4.0). At 6 WAI, okra planted at 1 m and 2 m from the juvenile oil palm have the highest number of leaves (5.8) as shown in Fig. 25.

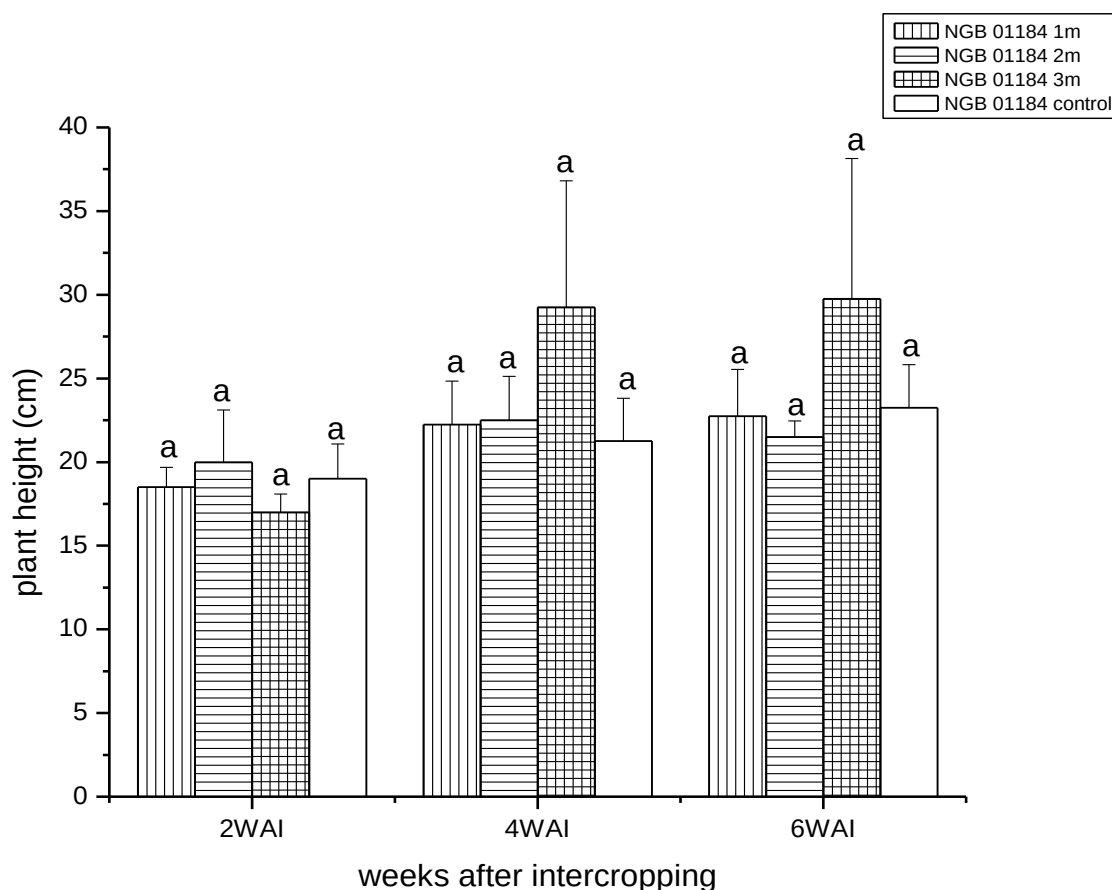


Fig. 26: Effects of intercropping on plant height of okra (NGB 01184) at 2, 4 and 6 WAI

Fig. 26 shows the effects of intercropping on plant height of okra (NGB 01184) at 2, 4 and 6 WAI. The plant heights from the treatments were not statistically different from other treatments at 2 WAI, 4 WAI and 6 WAI. However those at 2 m from juvenile oil palm (20.0 cm) produced the highest plant height value, followed by control (19.0 cm), 1 m (18.5 cm) and 3 m (17.0 cm) at 2 WAI. At 4 WAI and 6 WAI, okra planted at 3 m from juvenile oil palm produced the highest height (29.3 cm and 29.8 cm) respectively.

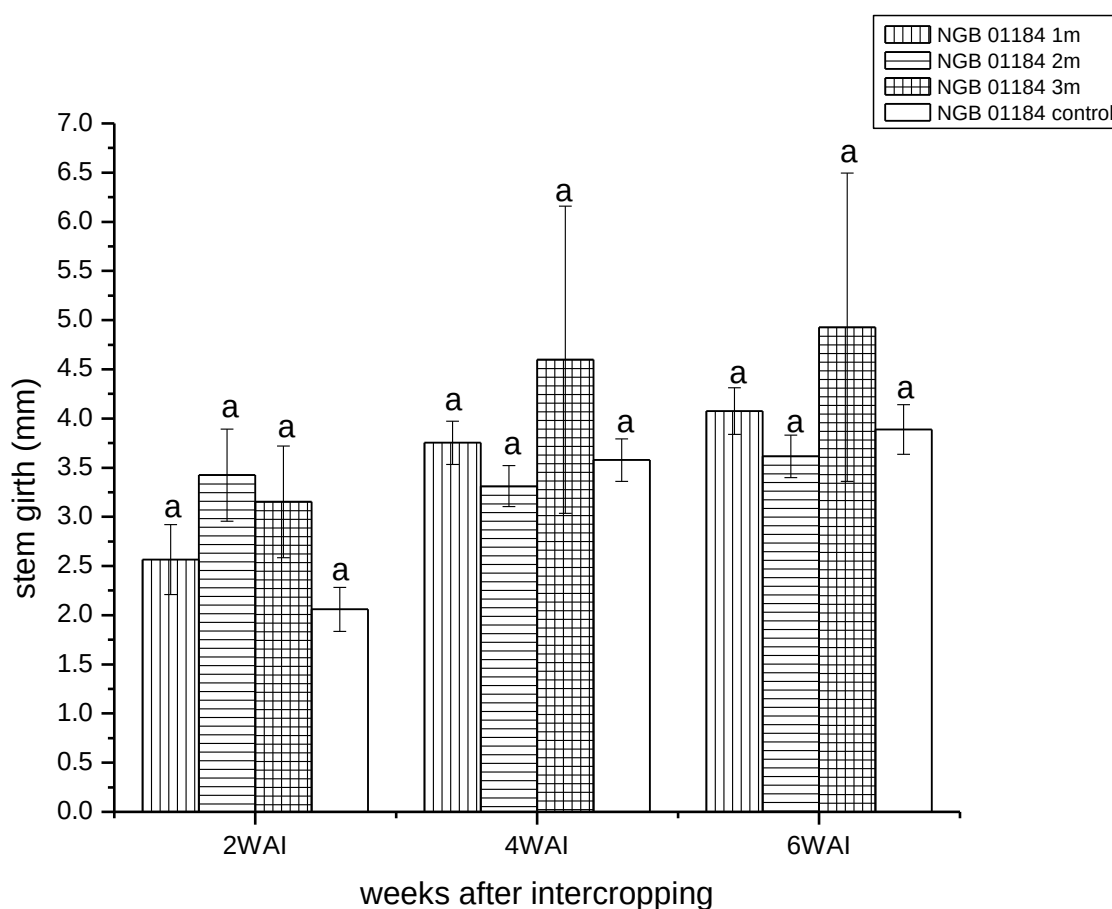


Fig. 27: Effects of intercropping on stem girth of okra (NGB 01184) at 2, 4 and 6 WAI

The effects of intercropping on stem girth of okra (NGB 01184) at 2, 4 and 6 WAI are shown in Fig. 27. There was no statistical difference among the stem girth across the treatments at 2 WAI, 4 WAI and 6 WAI. However, those at 3 m from the juvenile oil palm recorded the highest stem girth at 4 and 6 WAI (4.60 and 4.93 mm) respectively. Stem girth of okra planted at 2 m from juvenile oil palms produced the highest stem girth value (3.43 mm), followed by 3 m (3.15 mm), 1 m (2.57 mm) and control (2.06 mm) at 2 WAI. Stem girth values of okra planted at 2 m from the juvenile oil palms were the lowest at 4 WAI and 6 WAI (3.31 and 3.62 mm) respectively.

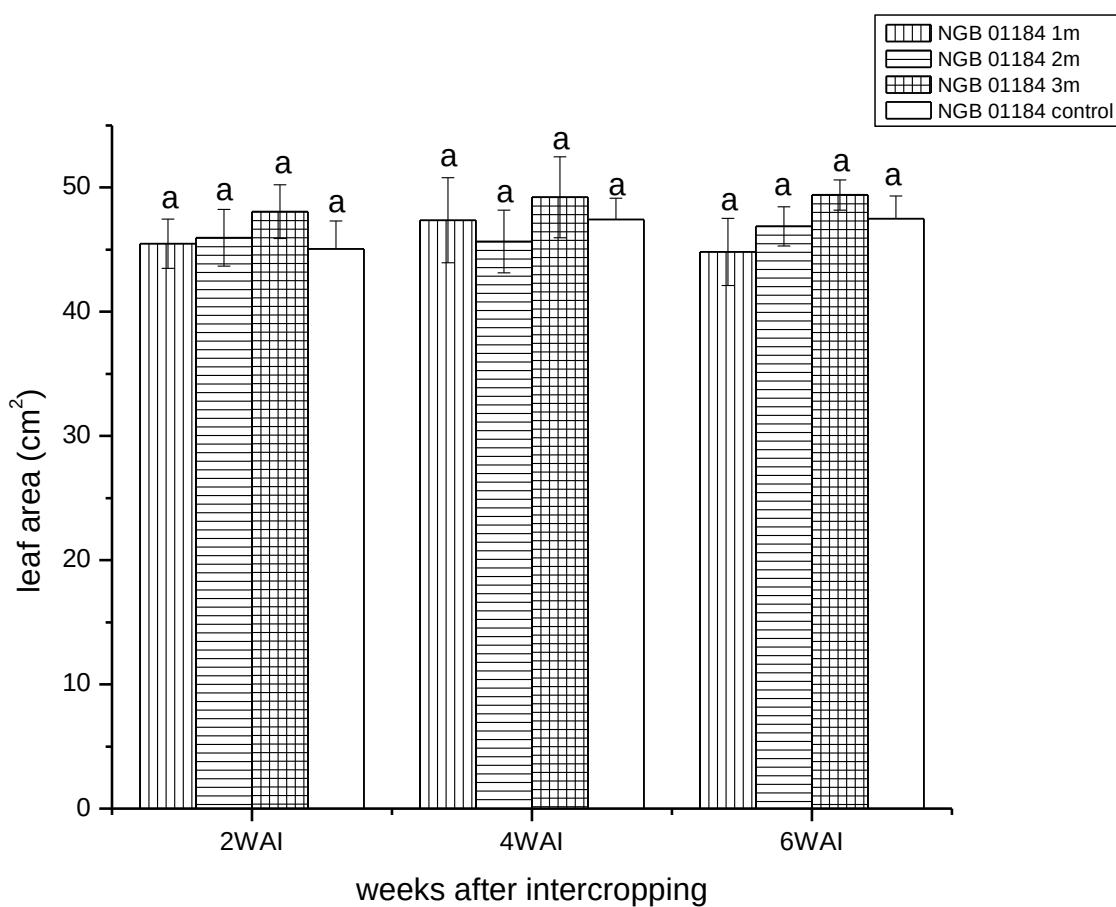


Fig. 28: Effects of intercropping on leaf area of okra (NGB 01184) at 2, 4 and 6 WAI

Leaf areas across the treatments were not statistically different at 2 WAI, 4 WAI and 6 WAI.

Okra planted at 3 m from the juvenile oil palm recorded the highest leaf area at 2 WAI, 4 WAI and 6 WAI (48.05, 49.23 and 49.40 cm²) respectively. At 6 WAI, the least leaf area was recorded by okra plants at 1 m from the juvenile oil palm (44.83 cm²).

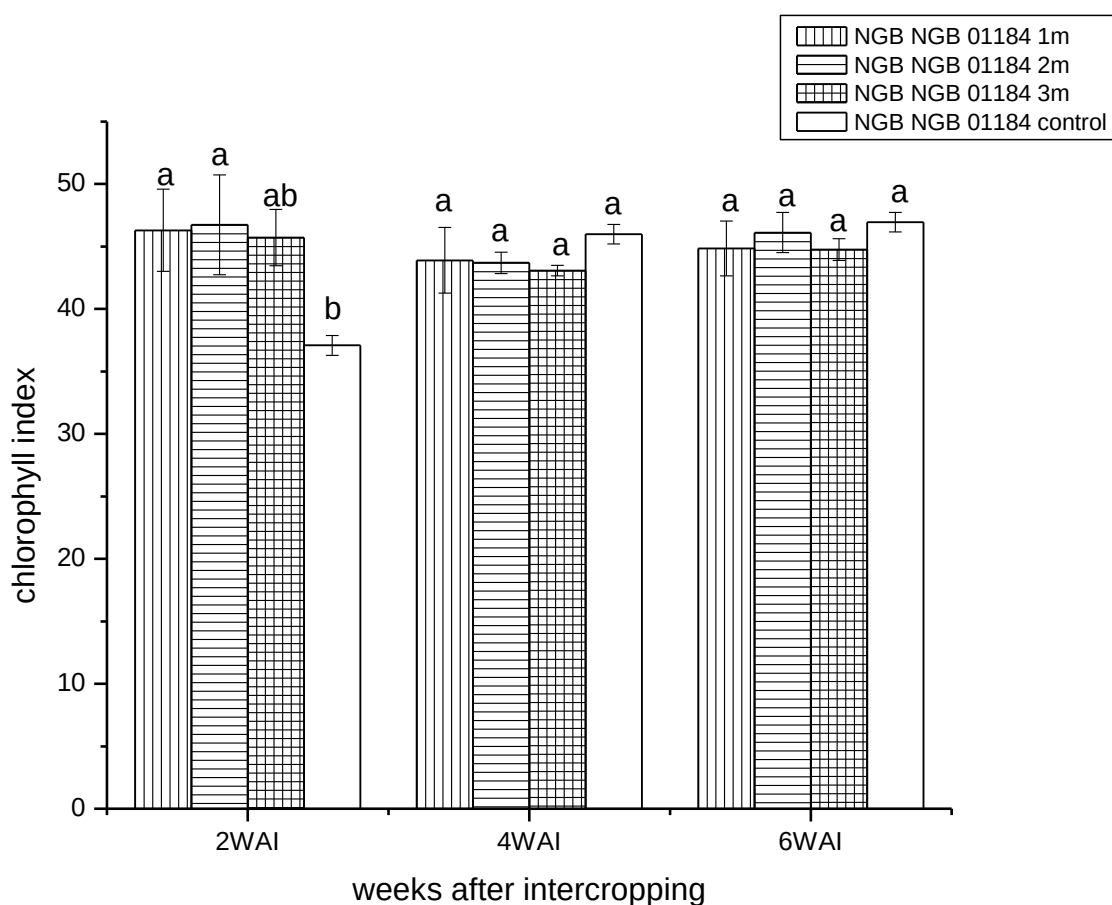


Fig. 29: Effects of intercropping on chlorophyll index of okra (NGB 01184) at 2, 4 and 6 WAI

At 2 WAI, okra at 2m from the juvenile oil palm recorded the highest chlorophyll index (46.74) which was statistically different from those of the control plot (37.09). At 4 WAI and 6 WAI, there was no statistical difference among the treatments. However, the control plot recorded the highest chlorophyll index at 4 WAI and 6 WAI (45.98 and 46.95) respectively.

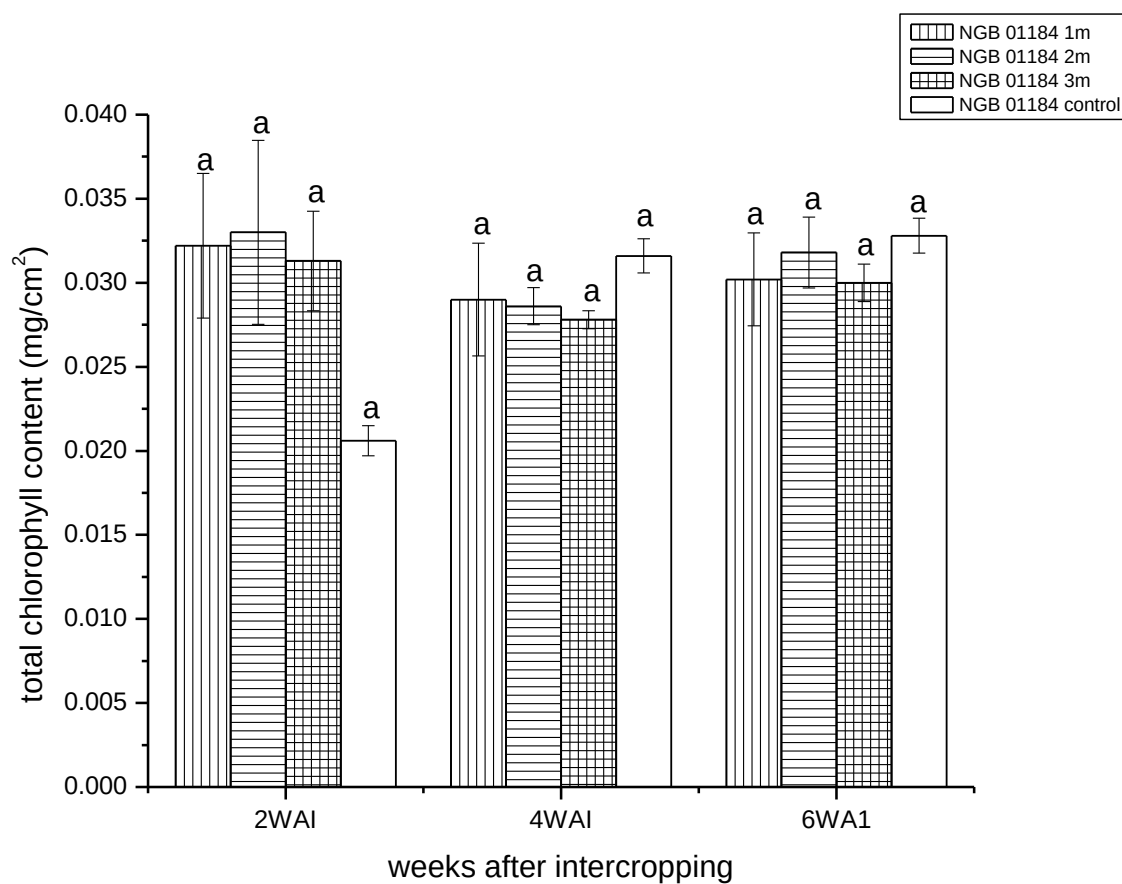


Fig. 30: Effects of intercropping on total chlorophyll content of okra (NGB 01184) at 2, 4 and 6 WAI

The total chlorophyll content showed no statistical difference across the treatments at 2 WAI, 4 WAI and 6 WAI. At 2 WAI, okra plants at 2 m from the juvenile oil palm recorded the highest total chlorophyll content (0.033 mg/cm²); at 4 WAI and 6 WAI, those of the control plot recorded the highest values of total chlorophyll content (0.032 mg/ cm² and 0.033 mg/cm²) respectively.

4.1.6 Growth responses of eggplant (NGB 01737) to intercropping with juvenile oil palm

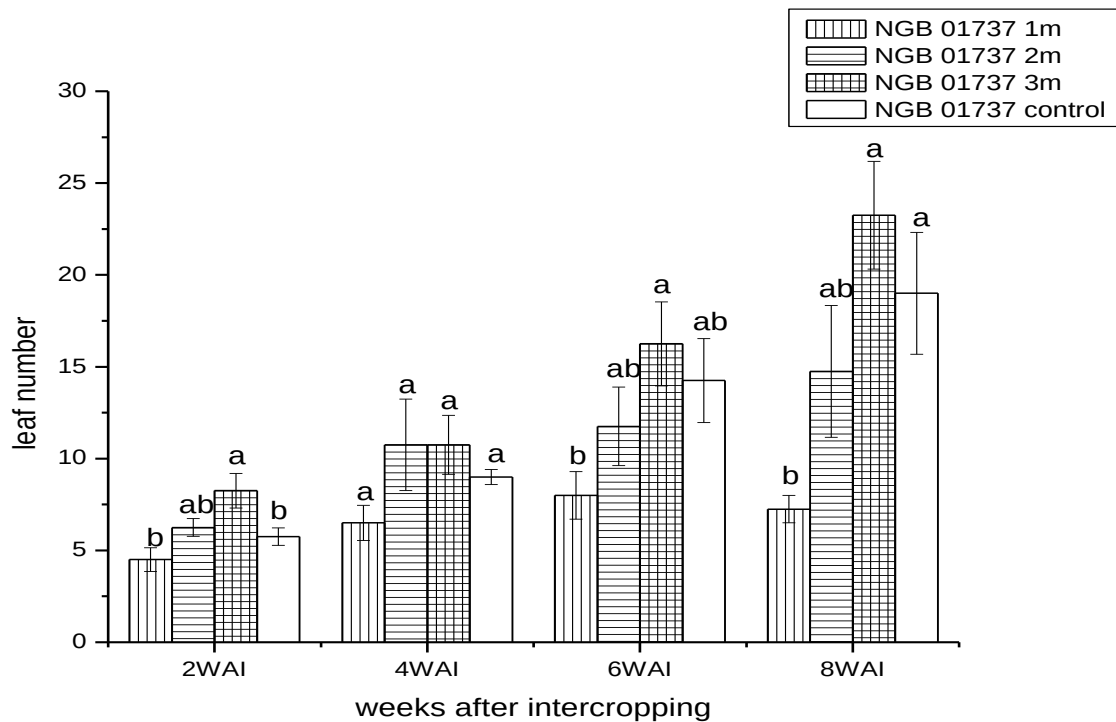


Fig. 31: Effects of intercropping on number of leaves in eggplant (NGB 01737) at 2, 4, 6 and 8 WAI

At 2 WAI, eggplant at 3 m from the juvenile oil palm recorded the highest number of leaves (8.25) and this value was statistically different from those at 1 m from the juvenile oil palm (4.50) and those at the control plot (5.75). There was no statistical difference among the treatments at 4 WAI; however, those eggplants at 2 m and 3 m from the juvenile oil palm both recorded the highest number of leaves each (10.75). At 6 WAI and 8 WAI, eggplants at 3 m from the juvenile oil palm recorded the highest number of leaves (16.25 and 32.25) respectively. At 6 WAI and 8 WAI, highest values (8.00 and 7.25) of number of leaves were recorded in eggplants at 1 m from the juvenile oil palm and was only statistically different from values obtained at 3 m from the juvenile oil palm (16.25 and 32.25).

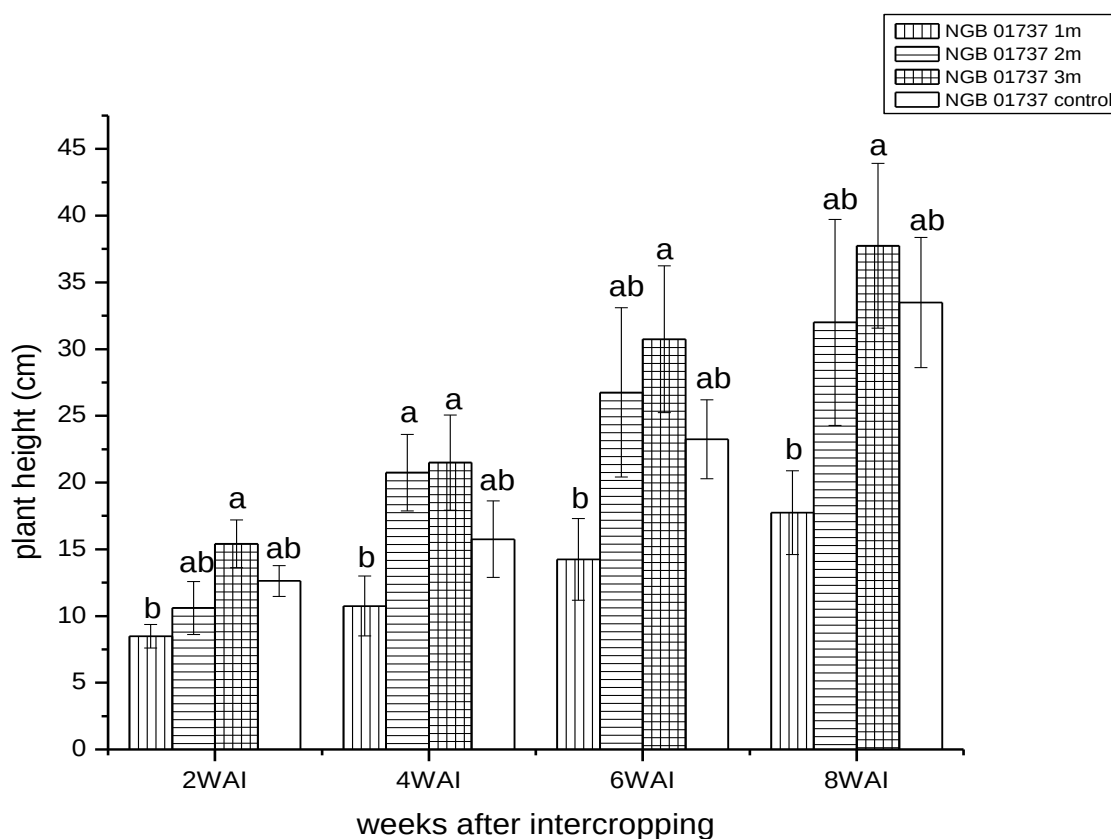


Fig. 32: Effects of intercropping on plant height of eggplant (NGB 01737) at 2, 4, 6 and 8 WAI

At 2, 4, 6 and 8 WAI, eggplants at 3 m from the juvenile oil palm recorded the highest plant height values (15.40, 21.50, 30.75 and 37.75 cm) respectively which were only statistically different from those planted at 1 m from the juvenile oil palm (8.48, 10.75, 14.25 and 17.75 cm) respectively.

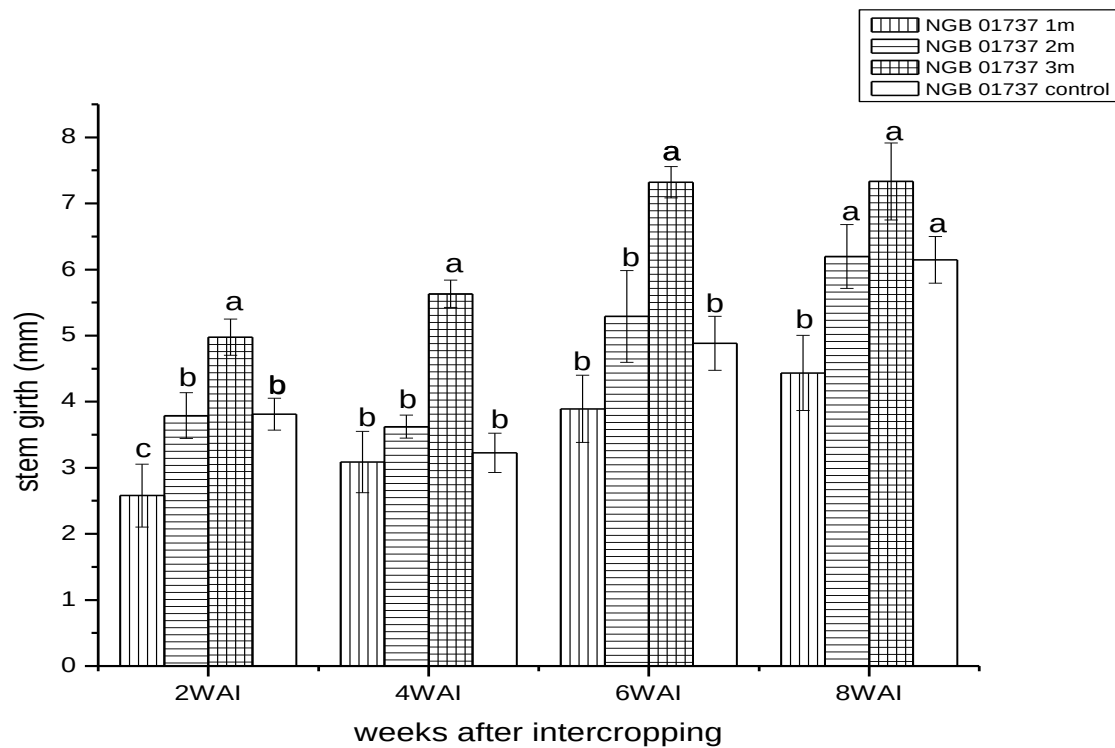


Fig. 33: Effects of intercropping on stem girth of eggplant (NGB 01737) at 2, 4, 6 and 8 WAI

The highest stem girth at 2 WAI was recorded by those planted at 3m from the juvenile oil palm and this was statistically different from other treatments. The lowest stem girth was recorded by those planted at 1m from the juvenile oil palm (2.58 mm). At 4 WAI and 6 WAI, eggplant at 3 m from the juvenile oil palm also recorded the highest stem girth (5.63 mm and 7.32 mm respectively) which was statistically different from other treatments. At these periods (4 WAI and 6 WAI), eggplants at 1 m from the juvenile oil palm recorded the lowest stem girth (3.09 mm and 3.89 mm) respectively. At 8 WAI, those at 3 m from the juvenile oil palm also recorded the highest stem girth (7.33 mm); however, it was only statistically different from those at 1 m from the juvenile oil palm (4.44 mm).

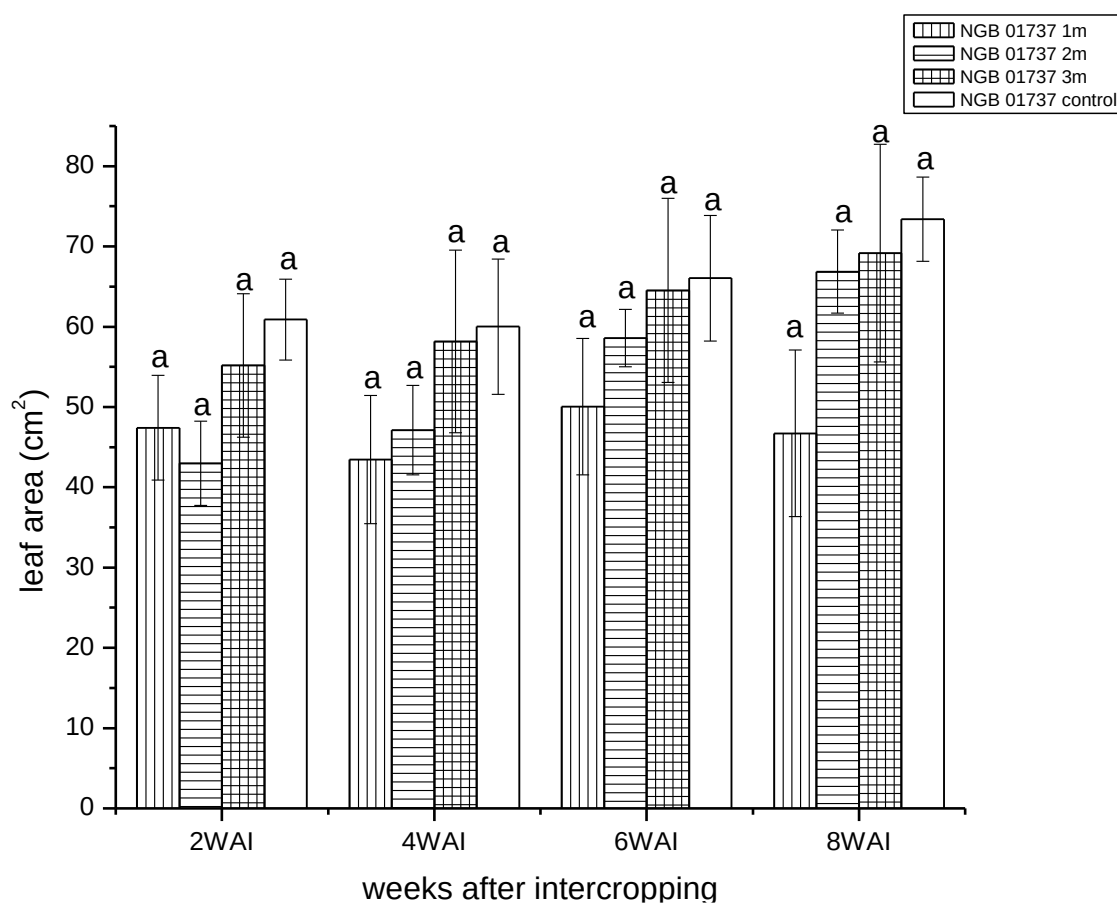


Fig. 34: Effects of intercropping on leaf area of eggplant (NGB 01737) at 2, 4, 6 and 8 WAI

The leaf areas were not statistically different across all the treatments at 2, 4, 6 and 8 WAI and those of the control recorded the highest leaf area (60.89, 60.00, 66.05 and 73.41 cm²) respectively, while lowest leaf areas were recorded from eggplants at 1m from the juvenile oil palm except at 2 WAI where those at 2 m from the juvenile oil palm recorded the lowest leaf area (42.98 cm²).

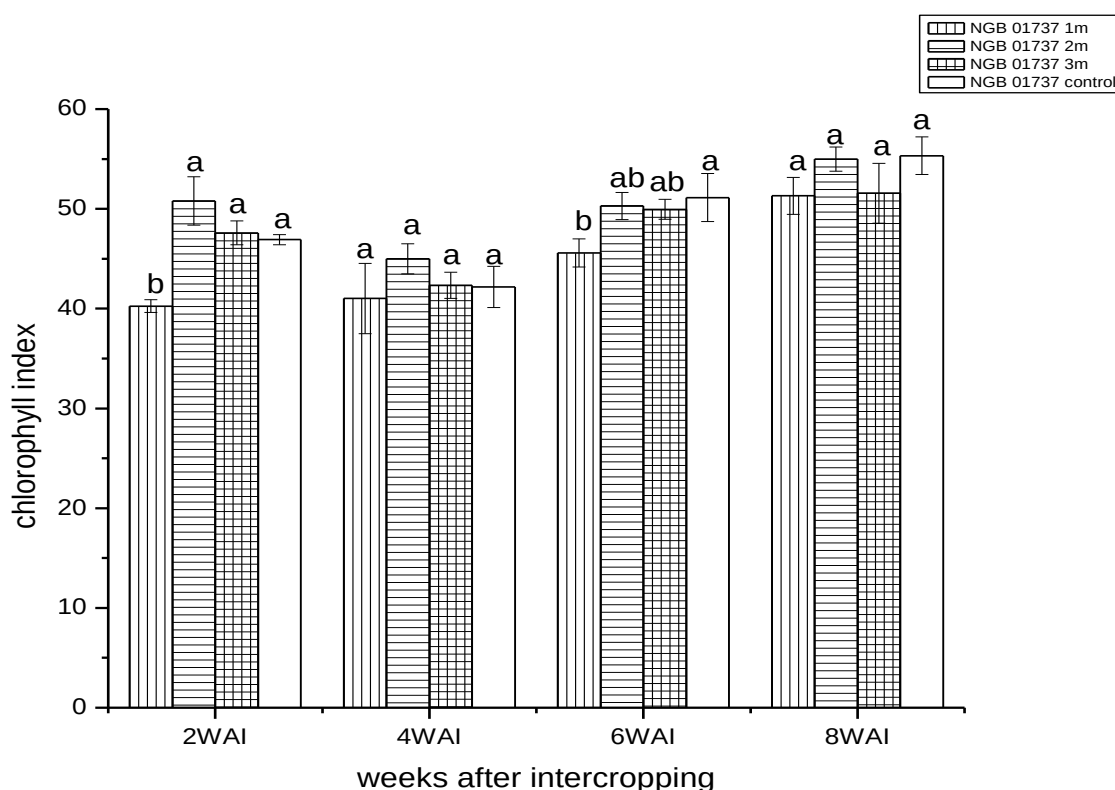


Fig. 35: Effects of intercropping on chlorophyll index of eggplant (NGB 01737) at 2, 4, 6 and 8 WAI

Eggplants at 2 m from juvenile oil palm recorded the highest chlorophyll index (50.79) at 2 WAI and were statistically different from those at 1 m from the juvenile oil palm (40.25). at 4 WAI, there was no statistical difference across all the treatments. However, eggplant at 2 m and 1 m from the juvenile oil palm recorded the highest and lowest chlorophyll index (44.99 and 41.01) respectively. At 6 WAI, the control plot recorded the highest chlorophyll index (51.13) which was statistically different from only those at 1 m from the juvenile oil palm (45.59). At 8 WAI, the chlorophyll indices across the treatments were not statistically different though those at the control plots and 1 m from the juvenile oil palm recorded the highest and lowest chlorophyll index.

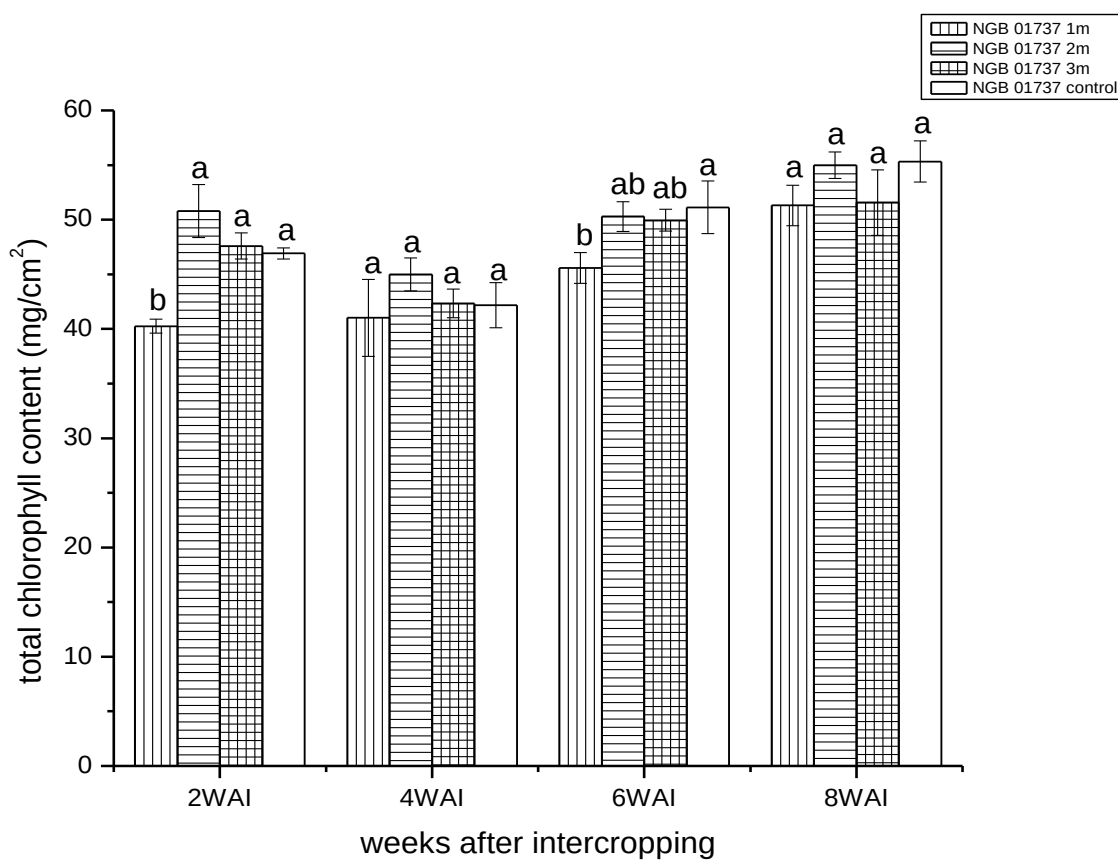


Fig. 36: Effects of intercropping on total chlorophyll content of eggplant (NGB 01737) at 2, 4, 6 and 8 WAI

Total chlorophyll contents were similar to chlorophyll index at 2, 4, 6 and 8 WAI, and there was no statistical difference at 4 and 8 WAI with the control recording the highest total chlorophyll content.

4.2 Effect of intercropping on reproductive parameters of fruit vegetable crops intercropped with juvenile oil palm

4.2.1 Effect of intercropping on flowering of fruit vegetable crops intercropped with 2 years old juvenile oil palm

Table 1: Effects of intercropping on number of days to flowering and days to fifty percent flowering of vegetable crops intercropped with 2 years old oil palm

Accession	Parameter	1 m	2 m	3 m	Control
Tomato	NDF	45.50 ^a	43.25 ^b	39.25 ^c	38.75 ^c
	NDFP	52.50 ^a	50.25 ^b	42.25 ^c	40.75 ^d
Tomato	NDF	46.50 ^a	41.00 ^b	38.25 ^c	38.00 ^c
	NDFP	51.75 ^a	48.25 ^b	40.75 ^c	40.00 ^c
Pepper	NDF	107.25 ^a	103.25 ^b	99.50 ^c	96.00 ^d
	NDFP	113.50 ^a	109.50 ^{ab}	108.00 ^b	102.50 ^c
Pepper	NDF	106.50 ^a	102.75 ^{ab}	98.50 ^{bc}	97.00 ^c
	NDFP	113.25 ^a	112.50 ^a	108.50 ^{ab}	104.25 ^b
Okra	NDF	42.50 ^a	41.00 ^b	38.00 ^c	38.00 ^c
	NDFP	46.00 ^a	44.50 ^b	40.00 ^c	40.00 ^c
Eggplant	NDF	48.00 ^a	46.50 ^b	42.50 ^c	43.00 ^c
	NDFP	55.75 ^a	53.50 ^a	45.00 ^b	45.50 ^b

NDF: Number of days to flowering

NDFP: Number of days to fifty percent flowering

Means with the same letter(s) along the same row are not significantly different at (P<0.05) level of significance.

Tomato (NGB 01665)-juvenile oil palm:

Number of days to flowering: shortest day to flowering was recorded by tomato plants at control plot (38.50 days). However, it was not statistically different from those at 3 m from juvenile oil palm (39.50 days).

Number of days to 50% flowering: Similarly, tomatoes of the control plots recorded the shortest number of days to flowering (41.00 days). It was also not statistically different from those at 1 m from the juvenile oil palm (42.75 days).

Tomato (NG/AA/SEP/09/053)-juvenile oil palm:

Number of days to flowering: Tomato plants at 3 m from the juvenile oil palm and those of the control plots recorded the shortest number of days to flowering (38.00 days) which was statistically different from those at 1 m and 2 m from juvenile oil palm.

Number of days to 50% flowering: tomatoes at 3 m from the juvenile oil palm recorded the lowest number of days to 50 % flowering and it was statistically different from others except those of the control plot (40.50 days).

Pepper (NGB 01312)-juvenile oil palm:

Number of days to flowering: pepper plants of the control plots recorded the shortest number of days to flowering (98.00 days) however this was not statistically different from those at 3 m from the juvenile oil palm (40.50 days).

Number of days to 50 % flowering: Similarly, pepper plants at the control plot recorded the shortest number of days to 50 % flowering (104.00 days). It was not statistically different from those at 3 m from the juvenile oil palm (109.00 days).

Pepper (NGB 01641)-juvenile oil palm:

Number of days to flowering: pepper plants of the control plot recorded the shortest number of days to flowering (97.50 days) which was statistically different form only those at 1 m from the juvenile oil palm (106.20 days).

Number of days to 50 % flowering: Similar result was obtained for number of days to 50% flowering with those of the control plot recording the shortest number of days to 50% flowering (104.75 days).

Okra (NGB 01184)-juvenile oil palm:

Number of days to flowering: Okra plants at 3 m from the juvenile oil palm and those of the control recorded the shortest number of days to flowering (38.50 days) and were statistically different from those at 1 m and 2 m from juvenile oil palm (41.50 days and 40.50 days respectively).

Number of days to 50% flowering: Okra plants of the control plot recorded the shortest number of days to 50% flowering (40.50 days) though it was not statistically different from those at 3 m from the juvenile oil palm.

Eggplant (NGB 01737)-juvenile oil palm:

Number of days to flowering: The shortest number of days to flowering was recorded by eggplants of the control plot (43.50 days). However, it was not statistically different from those at 3 m from the juvenile oil palm.

Number of days to 50% flowering: Similarly those at control plot recorded the shortest number of days to 50% flowering which was however not statistically different from those at 3 m from the juvenile oil palm.

4.2.2 Effect of intercropping on yield and yield components of fruit vegetable crops intercropped with 2 years old juvenile oil palm

Table 2: Effects of intercropping on yield components of tomato (NGB 01665)-juvenile oil palm intercrop

Treatment	Number of fruits/ plant	Fruit weight/ plant (g)	Weight of 100 fruits (g)	Fruit girth (mm)	Fruit length (mm)	Yield (tonha ⁻¹)
1 m	12.25 ^b	882.38 ^c	6431.60 ^a	40.23 ^b	39.83 ^b	2.68 ^b
2 m	18.75 ^b	2033 ^b	7179.40 ^b	42.59 ^b	48.90 ^a	3.08 ^{ab}
3 m	39.50 ^a	2265.8 ^b	8847.80 ^{ab}	52.23 ^a	54.73 ^a	3.74 ^{ab}
Control	42.50 ^a	3172.8 ^a	10625.00 ^a	52.97 ^a	54.15 ^a	4.35 ^a

Means with the same letter(s) along the same column are not significantly different at (P<0.05) level of significance.

Tomato (NGB 01665) plants at the control plot recorded the highest number of fruits/ plant (42.50/ plant) which was not statistically different from those at 3 m from juvenile oil palm (39.50/ plant). Tomato (NGB 01665) at 1m from the juvenile oil palm recorded lowest number of fruits (12.25). Similarly the tomato accession NGB 01665 at 1 m from juvenile oil palm recorded the lowest values in fruit weight/ plant (882.38 g), weight of 100 fruits (6431.6 g), fruit girth (40.23 mm), fruit length (39.83 mm) and yield (2.68 tonnes/ha). Highest values of fruit weight/ plant, weight of 100 fruits, fruit girth, fruit length and yield were obtained from tomato accession NGB 01665 at control plot.

Table 3: Effect of intercropping on yield components of tomato (NG/AA/SEP/09/053)- juvenile oil palm

Treatment	Number of fruits/ plant	Fruit weight/ plant (g)	Weight of 100 fruits (g)	Fruit girth (mm)	Fruit length (mm)	Yield (tonha ⁻¹)
1 m	17.00 ^b	1108.00 ^b	5992.50 ^a	42.17 ^a	41.60 ^a	2.48 ^b
2 m	24.50 ^b	1685.30 ^b	6616.90 ^a	55.06 ^a	44.56 ^a	2.80 ^{ab}
3 m	37.00 ^a	2732.00 ^a	9844.50 ^a	49.56 ^a	40.39 ^a	3.76 ^{ab}
Control	42.00 ^a	2859.70 ^a	7696.20 ^a	50.02 ^a	54.16 ^a	3.99 ^a

Means with the same letter(s) along the same column are not significantly different at (P<0.05) level of significance.

Tomato (NG/AA/SEP/09/053) planted at the control plot recorded highest values in all the yield components except weight of 100 fruits (1492.10 g) however these values were not statistically different from values obtained from those planted at the remaining planting distance regimes from juvenile oil palm. In all the yield components examined, tomato (NG/AA/SEP/09/053) planted at 1 m from juvenile oil palm recorded the lowest values except for fruit length (41.60 mm) in which those at 3 m recorded the least value (40.39 mm). However, the difference was not statistically significant.

Table 4: Effect of intercropping on yield components of pepper (NGB 01312)-juvenile oil palm

Treatment	Number of fruits/ plant	Fruit weight/ plant (g)	Weight of 100 fruits (g)	Fruit girth (mm)	Fruit length (mm)	Yield (tonha ⁻¹)
1 m	34.25 ^c	277.34 ^c	883.83 ^a	17.98 ^b	24.94 ^b	0.31 ^b
2 m	53.50 ^b	489.88 ^b	3177.40 ^a	20.03 ^b	25.01 ^b	0.45 ^b
3 m	74.00 ^a	752.06 ^a	1397.30 ^a	35.77 ^a	31.12 ^a	0.62 ^a
Control	62.00 ^{ab}	764.78 ^a	1492.10 ^a	30.99 ^a	32.70 ^a	0.64 ^a

Means with the same letter(s) along the same column are not significantly different at (P<0.05) level of significance.

Pepper (NGB 01312) planted at 3 m recorded highest number of fruits per plant (74.00/ plant), fruit girth (35.77 mm) which was not statistically different from those at the control plot. The control plot recorded highest values of fruit weight/ plant (764.78 g), weight of 100 fruits (1492.1 g) fruit length (32.7 mm) and yield (0.641 tonnes/ha). However these values were not statistically different from values obtained from those planted 3 m from the juvenile oil palm. Pepper (NGB 01312) planted at 1 m from the juvenile oil palm recorded the lowest values in all the yield components examined.

Table 5: Effect of intercropping on yield components of pepper (NGB 01641)-juvenile oil palm

Treatment	Number of fruits/ plant	Fruit weight/ plant (g)	Weight of 100 fruits (g)	Fruit girth (mm)	Fruit length (mm)	Yield (tonha ⁻¹)
1 m	29.25 ^c	246.41 ^c	809.86 ^b	18.20 ^a	25.28 ^b	0.30 ^b
2 m	54.25 ^{bc}	468.34 ^{bc}	1217.4 ^{ab}	20.49 ^a	27.53 ^b	0.48 ^b
3 m	94.25 ^a	946.47 ^a	1455.70 ^a	29.86 ^a	35.35 ^a	0.69 ^a
Control	73.00 ^{ab}	742.41 ^{ab}	1329.30 ^{ab}	30.34 ^a	35.28 ^a	0.70 ^a

Means with the same letter(s) along the same column are not significantly different at (P<0.05) level of significance.

Pepper (NGB 01641) planted at 3 m from juvenile oil palm recorded the highest number of fruits per plant (94.25/ plant), weight of 100 fruits (1455.70 g) and fruit length (35.35 mm), however these values were not statistically different from those at the control plot. Highest values of fruit girth (30.34 mm) and yield (0.70 tonnes/ha) were obtained from those planted in the control plot. Similarly, they were not statistically different from those planted at 3 m from the juvenile oil palm.

Table 6: Effect of intercropping on yield components of okra (NGB 01184)-juvenile oil palm

Treatment	Number of fruits/ plant	Fruit weight/ plant (g)	Weight of 100 fruits (g)	Fruit girth (mm)	Fruit length (mm)	Yield (tonha ⁻¹)
1 m	13.50 ^c	63.08 ^c	479.83 ^c	16.05 ^{ab}	43.80 ^b	0.19 ^b
2 m	21.25 ^b	102.97 ^{bc}	520.56 ^{bc}	15.10 ^b	45.62 ^b	0.22 ^b
3 m	28.25 ^a	219.53 ^a	889.47 ^a	18.17 ^a	64.22 ^a	0.37 ^a
Control	29.00 ^a	162.74 ^{ab}	737.77 ^{ab}	17.28 ^{ab}	64.24 ^a	0.32 ^a

Means with the same letter(s) along the same column are not significantly different at (P<0.05) level of significance.

Okra (NGB 01184) planted at control plot recorded the highest number of fruits per plant (29.00/ plant) and fruit length (64.24 mm) but was not statistically different from those at 3 m from the juvenile oil palm (28.25 and 64.22 mm) respectively. Okra (NGB 01184) planted at 3 m from juvenile oil palm recorded highest values of fruit weight per plant (219.53 g/ plant), weight of 100 fruits (889.47 g), fruit girth (18.17 mm) and yield (0.369 tonnes/ha). However those values were not statistically different from those planted in the control plot. Okra (NGB 01184) plants at 1 m from juvenile oil palm recorded lowest values for all the yield components examined except fruit girth where those at 2 m recorded the lowest value (15.10 mm). However the difference was not statistically significant.

Table 7: Effect of intercropping on yield components of eggplant (NGB 01737)-juvenile oil palm

Treatment	Number of fruits/ plant	Fruit weight/ plant (g)	Weight of 100 fruits (g)	Fruit girth (mm)	Fruit length (mm)	Yield (tonha ⁻¹)
1 m	5.25 ^c	173.65 ^b	2594.70 ^c	48.550 ^b	31.58 ^b	12.20 ^c
2 m	6.75 ^b	194.31 ^b	4006.20 ^b	53.50 ^{ab}	35.68 ^a	16.79 ^b
3 m	10.25 ^a	332.85 ^a	5689.10 ^a	56.80 ^a	38.16 ^a	21.51 ^a
Control	9.25 ^a	303.18 ^a	4868.40 ^{ab}	57.83 ^a	38.48 ^a	20.54 ^{ab}

Means with the same letter(s) along the same column are not significantly different at (P<0.05) level of significance.

Eggplant (NGB 01737) at 3 m from the juvenile oil palm recorded the highest number of fruits (10.25). However this was not statistically different from those of control (9.25). The lowest number of fruits per plant was recorded for those planted at 1 m from the juvenile oil palm. Similarly, eggplant (NGB 01737) at 1 m also recorded the lowest fruit weight per plant (173.65 g), weight of 100 fruits (2594.70 g), fruit girth (48.55 mm), fruit length (31.58 mm) and yield (12.20 tonnes/ha). Eggplant (NGB 01737) planted at 3 m from juvenile oil palm recorded the highest fruit weight per plant (332.85 g/ plant), weight of 100 fruits (5689.10 g) and yield (21.50 tonnes /ha). However they were not statistically different from those planted at the control plot.

Table 8: Interaction of Tomato accessions and intercropping distances on growth parameters and yield components of tomato accessions NGB 01665 and NG/AA/SEP/09/053 during first experimental trial

Factors		Number of leaves	Plant height (cm)	Stem girth (mm)	Leaf area (cm ²)	Dry matter (g)	Chlorophyll index	Total chlorophyll content (mg/cm ²)	Fruit number/ plant	Fruit weight / plant (g)	Weight of 100 fruits (g)	Fruit circumference (mm)	Fruit length (mm)	Yield/hectare (tonnes/ha)
Accessions	Tomato NGB 01665	78.594	44.832	3.793	60.97	2.318	41.662	0.026	28.25	2089	8271	47.005	49.718	3.448
	Tomato NG/AA/SEP/09/053	69.875	46.991	3.252	64.378	2.513	43.852	0.029	30.125	2096	7538	49.201	45.177	3.256
Standard error		5.804	2.798	0.167	2.975	0.199	1.087	0.02	1.728	145.317	608.653	2.159	3.135	0.218
Distance	1 m	57.312 ^c	35.738 ^b	2.784 ^b	42.806 ^b	2.149 ^a	41.978 ^a	0.026 ^a	14.625 ^b	99.174 ^c	6212 ^b	41.201 ^b	40.718 ^b	2.578 ^c
	2 m	62.688 ^{bc}	45.219 ^{ab}	3.481 ^a	63.774 ^a	2.257 ^a	42.967 ^a	0.028 ^a	21.625 ^b	1859 ^b	6898 ^{ab}	48.825 ^{ab}	46.731 ^{ab}	2.911 ^{bc}
	3 m	85.062 ^{ab}	53.875 ^a	3.972 ^a	75.589 ^a	2.643 ^a	41.238 ^a	0.026 ^a	38.250 ^a	2499 ^a	9346 ^a	50.895 ^a	47.559 ^{ab}	3.745 ^{ab}
	Control	91.875 ^a	48.812 ^a	3.854 ^a	68.527 ^a	2.612 ^a	44.844 ^a	0.031 ^a	42.250 ^a	3016 ^a	9161 ^a	51.491 ^a	54.154 ^a	4.173 ^a
Standard error		8.208	3.957	0.237	4.208	0.282	1.537	0.02	2.444	205.509	860.765	3.053	3.135	0.309
Interaction	Accession X Distance	*	NS	*	*	NS	NS	NS	NS	NS	NS	NS	NS	NS

Where “*” means interaction was significant and “NS” means interaction was not significant for the respective growth and reproductive parameter.

Table 8 shows the interaction analysis between tomato accessions (NGB 01665 and NG/AA/SEP/09/053) during the first trial. There were significant interactions in the number of leaves, stem girth and leaf area of the 2 tomato accessions. However the interaction was not significant between the 2 tomato accessions for plant height, dry matter, chlorophyll index, total chlorophyll content, fruit number and weight per plant, weight of 100 fruits, fruit circumference, fruit length and yield per hectare.

Tomato accession NGB 01665 recorded higher number of leaves (78.60), stem girth (3.79), weight of 100 fruits (8271 g), fruit length (49.72 mm) and yield per hectare (3.45 tonnes/hectare).

Based on the intercropping distances, tomato intercropped at 3 m from the juvenile oil palm recorded highest values for plant height, stem girth, leaf area, dry matter and weight of 100 fruits (53.88 cm, 3.97 mm, 75.59 cm², 2.64 g and 9346 g respectively).

Table 9: Interaction of Pepper accessions and intercropping distances on growth parameters and yield components of pepper accessions NGB 01312 and NGB 01641 during first experimental trial

Factors		Number of leaves	Plant height (cm)	Stem girth (mm)	Leaf area (cm ²)	Dry matter (g)	Chlorophyll index	Total chlorophyll content (mg/cm ²)	Fruit number	Fruit weight (g)	Weight of 100 fruits (g)	Fruit circumference (mm)	Fruit length (mm)	Yield/hectare (tonnes/ha)
Accessions	Pepper NGB 01312	60.15	27.075	2.733	44.375	2.086	48.314	0.039	55.938	571.012	1213.00	26.19	28.44	0.51
	Pepper NGB 01641	50.375	23.089	2.468	47.013	2.141	45.923	0.032	62.688	600.91	1203.00	24.73	30.86	0.54
Standard error		5.719	1.178	0.068	0.866	0.212	0.768	0.001	3.306	41.79	83.130	1.579	0.903	0.030
Distance	1m	34.075 ^c	19.332 ^b	2.484 ^a	44.600 ^a	1.152 ^c	43.241 ^b	0.029 ^b	31.750 ^c	261.87 ^c	846.84 ^b	18.11 ^b	25.11 ^b	0.31 ^c
	2m	45.425 ^{bc}	24.492 ^a	2.626 ^a	45.833 ^a	1.855 ^{bc}	45.368 ^b	0.033 ^b	53.875 ^b	479.11 ^b	1149.00 ^{ab}	20.26 ^b	26.27 ^b	0.46 ^b
	3m	74.125 ^a	28.575 ^a	2.699 ^a	47.523 ^a	2.638 ^{ab}	48.994 ^a	0.039 ^a	84.125 ^a	849.27 ^a	1426.00 ^a	32.81 ^a	33.236 ^a	0.66 ^a
	Control	67.425 ^{ab}	27.928 ^a	2.592 ^a	44.821 ^a	2.808 ^a	50.871 ^a	0.040 ^a	67.500 ^b	753.59 ^a	1411.00 ^a	30.66 ^a	33.99 ^a	0.67 ^a
Standard error		8.088	1.666	0.096	1.225	0.300	1.086	0.002	4.675	59.103	117.563	1.276	1.276	0.042
Interaction	Accession X Distance	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS

Where “*” means interaction was significant and “NS” means interaction was not significant for the respective growth and reproductive parameter.

Interaction analysis of the 2 pepper accessions (NGB 01312 and NGB 01641) was not significant for all the growth and reproductive parameters except in leaf area where the interaction was significant as shown in Table 9 during the first trial of the experiment.

Pepper NGB 01312 recorded higher number of leaves, plant height, stem girth, chlorophyll index, total chlorophyll content, weight of 100 fruits and fruit circumference (60.15, 27.08 cm, 2.73 mm, 48.31, 0.039 g/cm², 1213 g and 26.19 mm respectively).

Regardless of the accession of pepper, pepper plants at 3 m from the juvenile oil palm recorded highest values for number of leaves, plant height, stem girth, leaf area, fruit number, fruit weight, weight of 100 fruits and fruit circumference (74.13, 28.57 cm, 26.70 mm, 47.52 cm², 84.13, 849.27 g, 1426.00 g and 32.81 mm respectively).

Table 10: Partial land equivalency ratios (LER) of fruit vegetable crops-juvenile oil palm intercrop during 2nd year of plantation establishment

Vegetable crop accession	Intercrop distance (m)	Partial LER
Tomato (NGB 01665)	1	0.278
	2	0.641
	3	0.714
Tomato (NG/AA/SEP/09/053)	1	0.388
	2	0.589
	3	0.955
Pepper (NGB 01312)	1	0.369
	2	0.641
	3	0.983
Pepper (NGB 01641)	1	0.332
	2	0.631
	3	1.275
Okra (NGB 01184)	1	0.388
	2	0.633
	3	1.349
Eggplant (NGB 01737)	1	0.573
	2	0.641
	3	1.098

Table 9 shows the partial Land Equivalency Ratio (LER) of the intercropped vegetable accessions at 1, 2 and 3 m from the juvenile oil palm. Vegetable crops intercropped at 3 m from the juvenile oil palm recorded the highest partial LER values among the intercropping regimes. Pepper (NGB 01312), okra (NGB 01184) and eggplant (NGB 01737) recorded partial LER values higher than unity (that is, 1) at 3 m from juvenile oil palm.

4.3 Growth and yield responses of fruit vegetables to intercropping with 3 years old juvenile oil palm

4.3.1 Growth responses of tomato (NGB 01665) to intercropping with juvenile oil palm

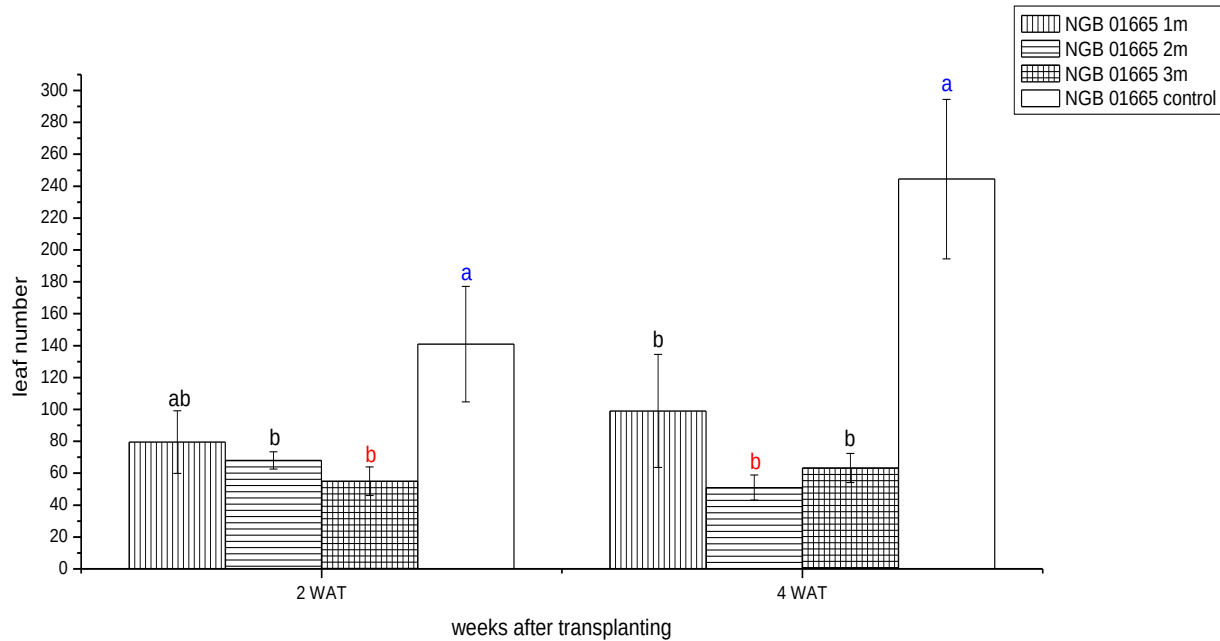


Fig. 37: Effects of intercropping on number of leaves of tomato (NGB 01665) at 2 and 4 WAT

At 2 weeks after transplanting (WAT), tomato plants of the control plot recorded the highest leaf number while those planted at 3 m from the juvenile oil palm recorded the lowest value and this value was statistically different. Similarly, at 4 WAT, the tomato plants of the control plot also recorded the highest leaf number which was statistically different from those at 2 m from the juvenile oil palm of 3 years old.

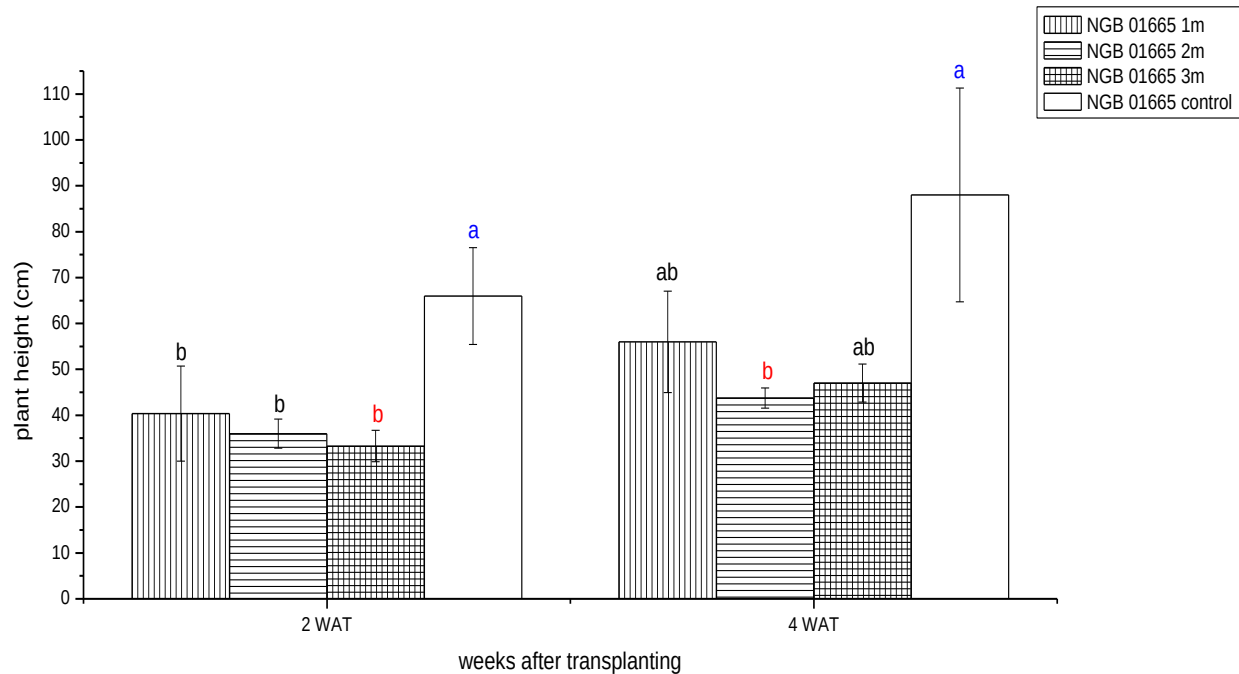


Fig. 38: Effects of intercropping on plant height of tomato (NGB 01665) at 2 and 4 WAT

The plant height of tomatoes of the control plot recorded the highest plant height which was statistically different from those at 3 m from the juvenile oil palm. Those at 3 m from the juvenile oil palm also recorded the lowest plant height at 2 WAT. Similar result was also recorded at 4 WAT with those at the control plot recording the highest plant height and was statistically different from only those at 2 m from juvenile oil palm of 3 years old.

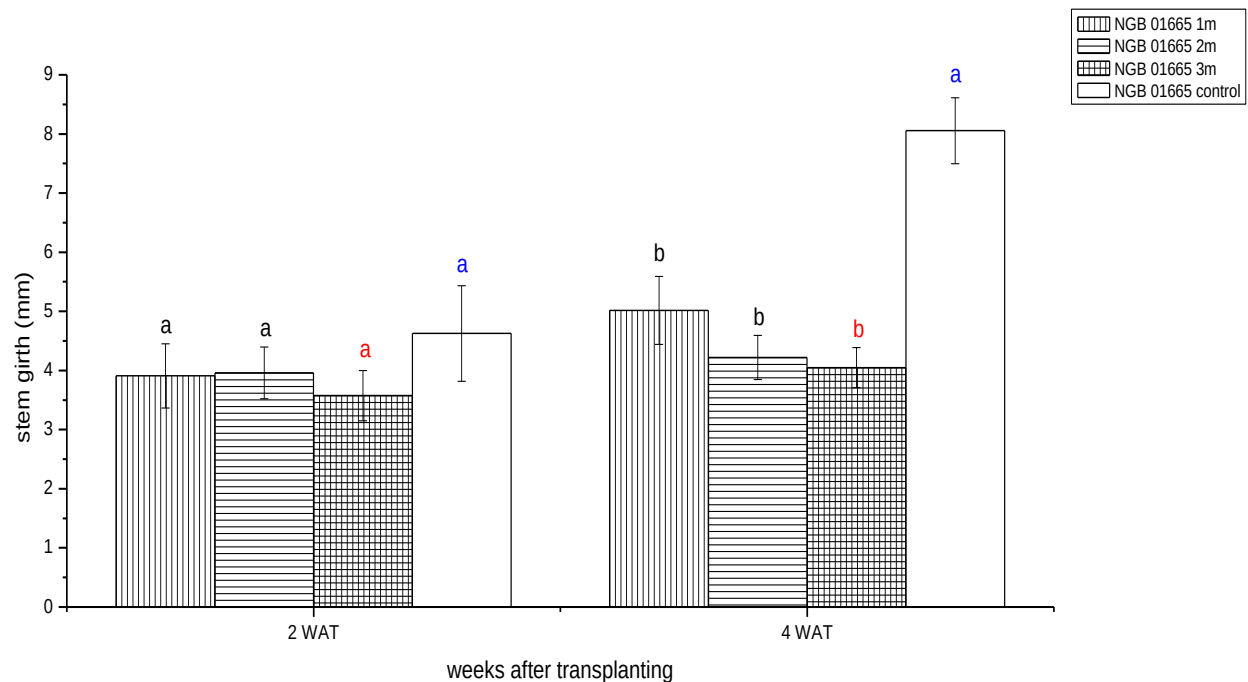


Fig. 39: Effects of intercropping on stem girth of tomato (NGB 01665) at 2 and 4 WAT

At 2 WAT, there was no significant difference across the treatments. However, the tomato plants of the control plot recorded the highest stem girth. Similarly, at 4 WAT, those at the control plot also recorded the highest stem girth which was also statistically different from all other treatments.

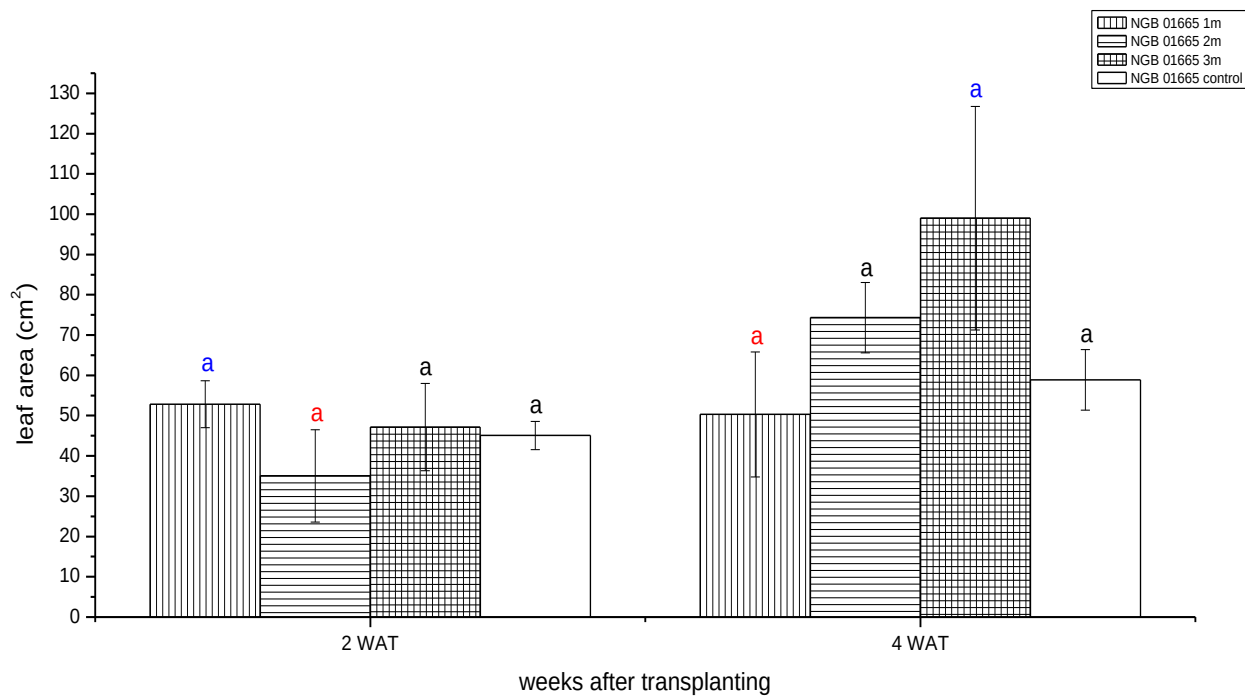


Fig. 40: Effects of intercropping on leaf area of tomato (NGB 01665) at 2 and 4 WAT

At 2 and 4 WAT, there was no statistical difference across the treatments. However, at 4 WAT, those at 3 m from juvenile oil palm recorded the highest leaf area.

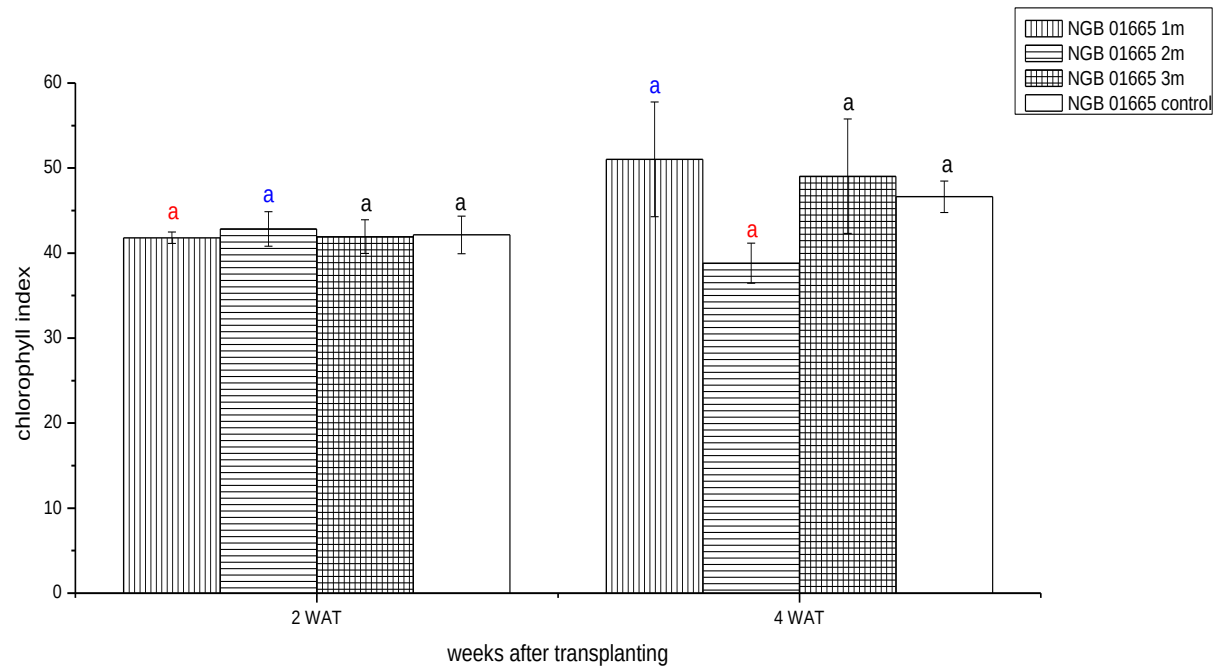


Fig. 41: Effects of intercropping on chlorophyll index of tomato (NGB 01665) at 2 and 4 WAT

Chlorophyll index at 2 and 4 WAT were not statistically different across the treatments and those of the 1 m from the juvenile oil palm recorded the highest chlorophyll index value at 4 WAT.

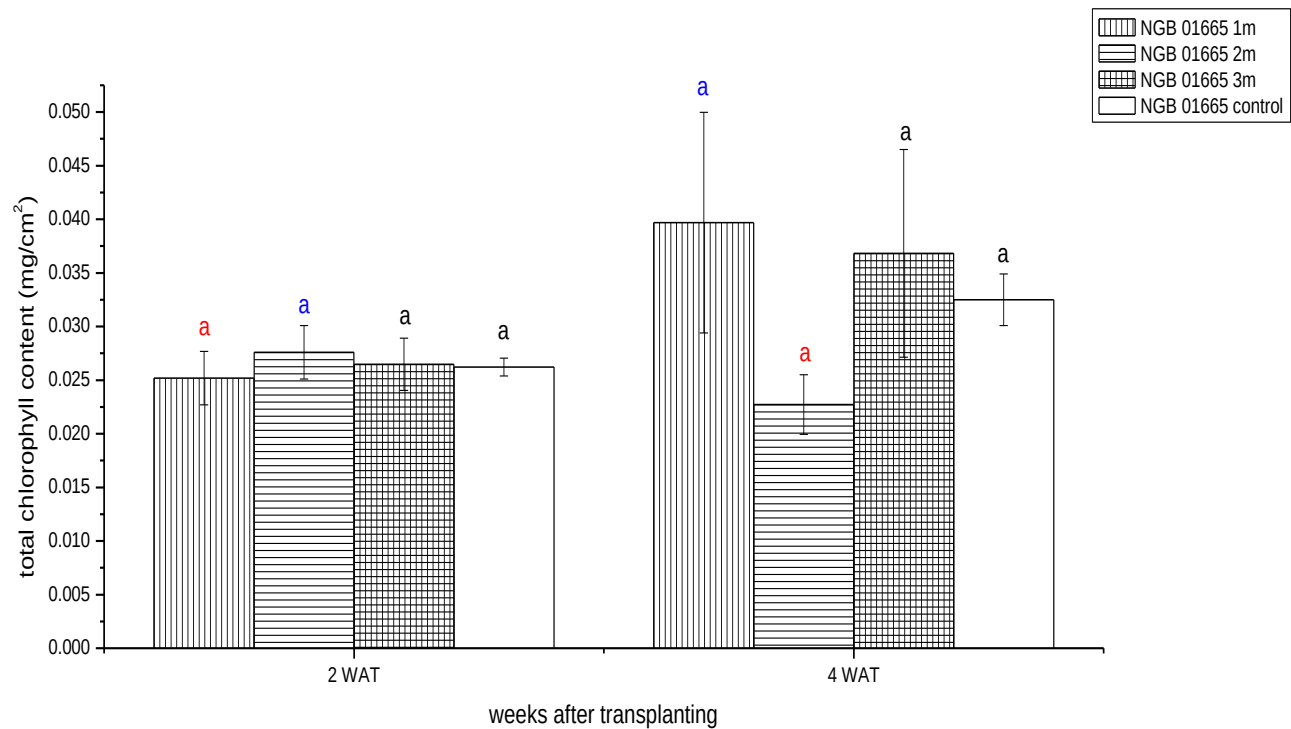


Fig. 42: Effects of intercropping on total chlorophyll content of tomato (NGB 01665) at 2 and 4 WAT

There was no statistical difference across the treatment at 2 and 4 WAT with tomato plants at 1 m from the juvenile oil palm recording the highest total chlorophyll content.

4.3.2 Growth responses of tomato (NG/AA/SEP/09/053) to intercropping with juvenile oil palm

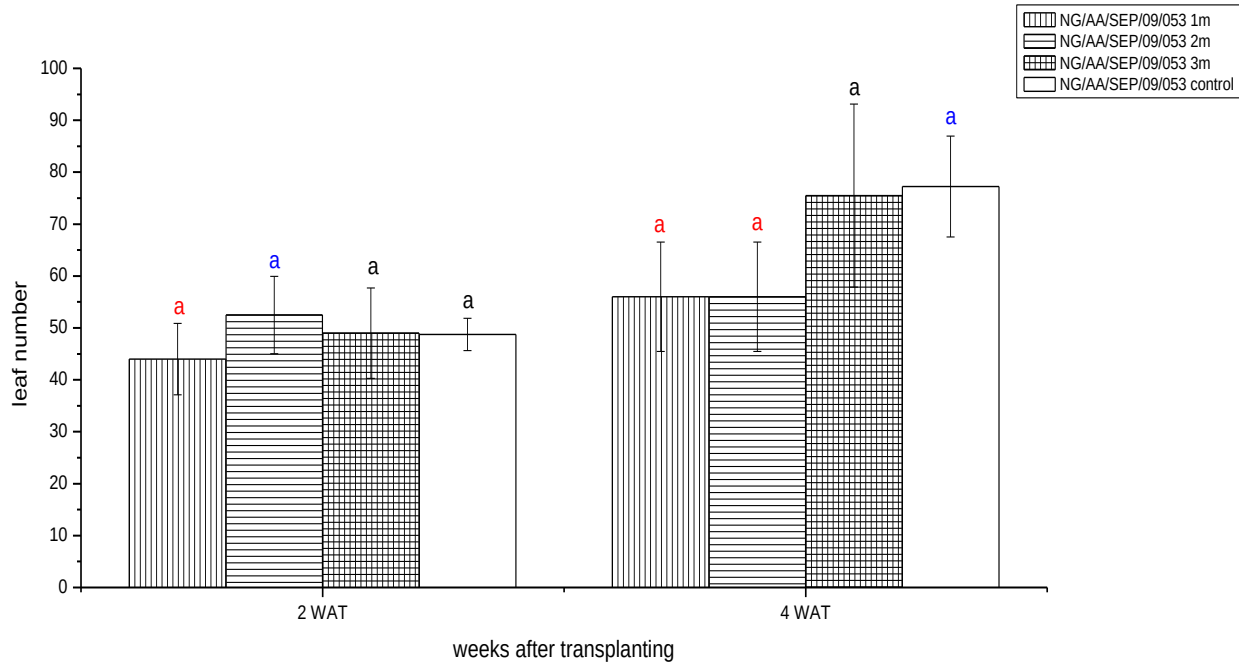


Fig. 43: Effects of intercropping on number of leaves of tomato (NG/AA/SEP/09/053) at 2 and 4 WAT

The leaf number at 2 and 4 WAT across the treatments were not statistically different. However, the control plot recorded the highest leaf number at 4 WAT.

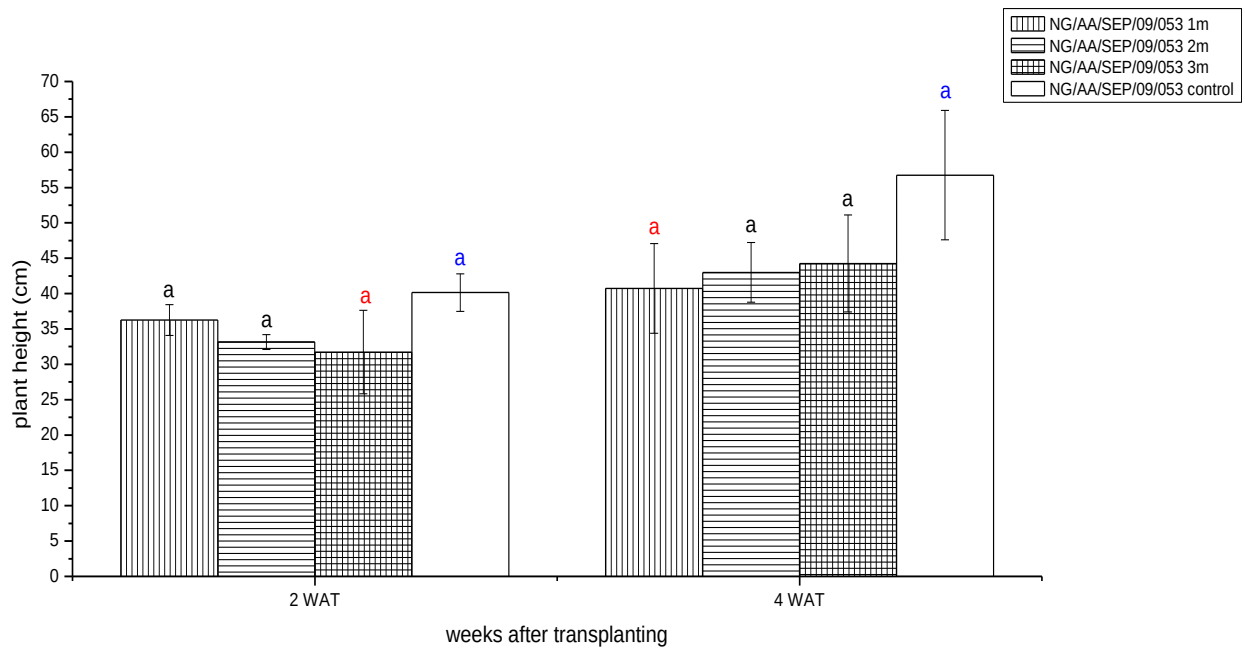


Fig. 44: Effects of intercropping on plant height of tomato (NG/AA/SEP/09/053) at 2 and 4 WAT

Similarly, the plant height across the treatments did not show statistical difference at 2 and 4 WAT with those at the control plot recording the highest at 2 and 4 WAT.

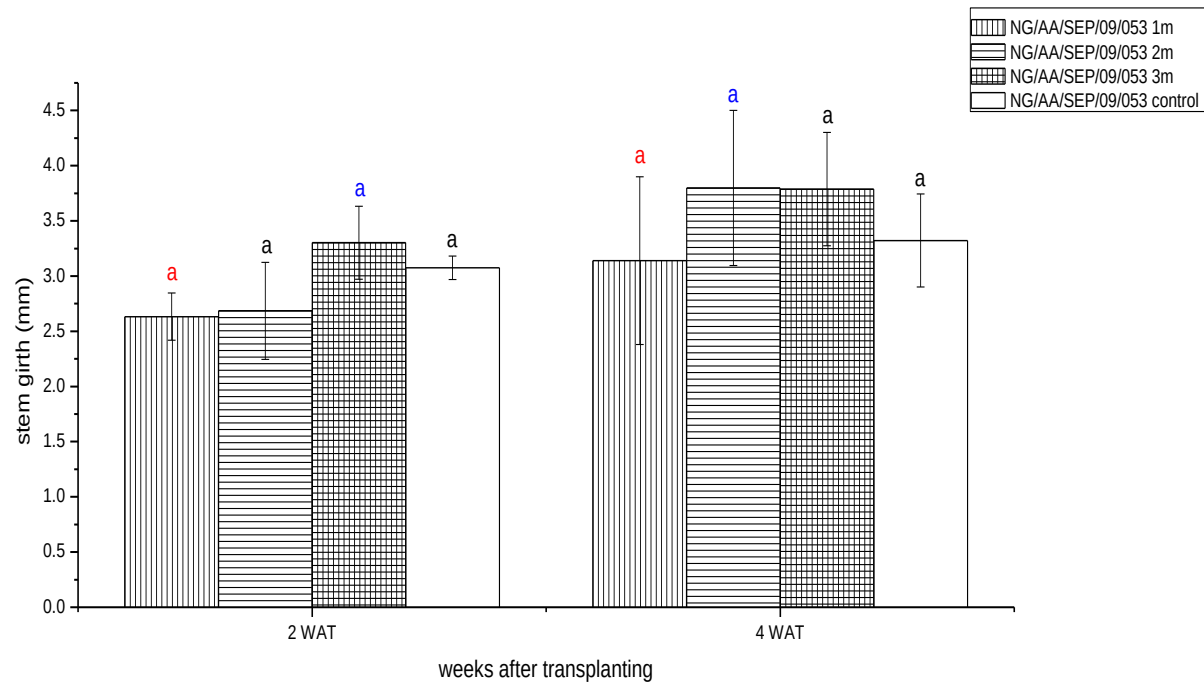


Fig. 45: Effects of intercropping on stem girth of tomato (NG/AA/SEP/09/053) at 2 and 4 WAT

There was no statistical difference in the stem girth at 2 and 4 WAT across the treatments. At 4 WAT, tomatoes planted at 2 m and 3 m from the juvenile oil palm jointly recorded the highest stem girth.

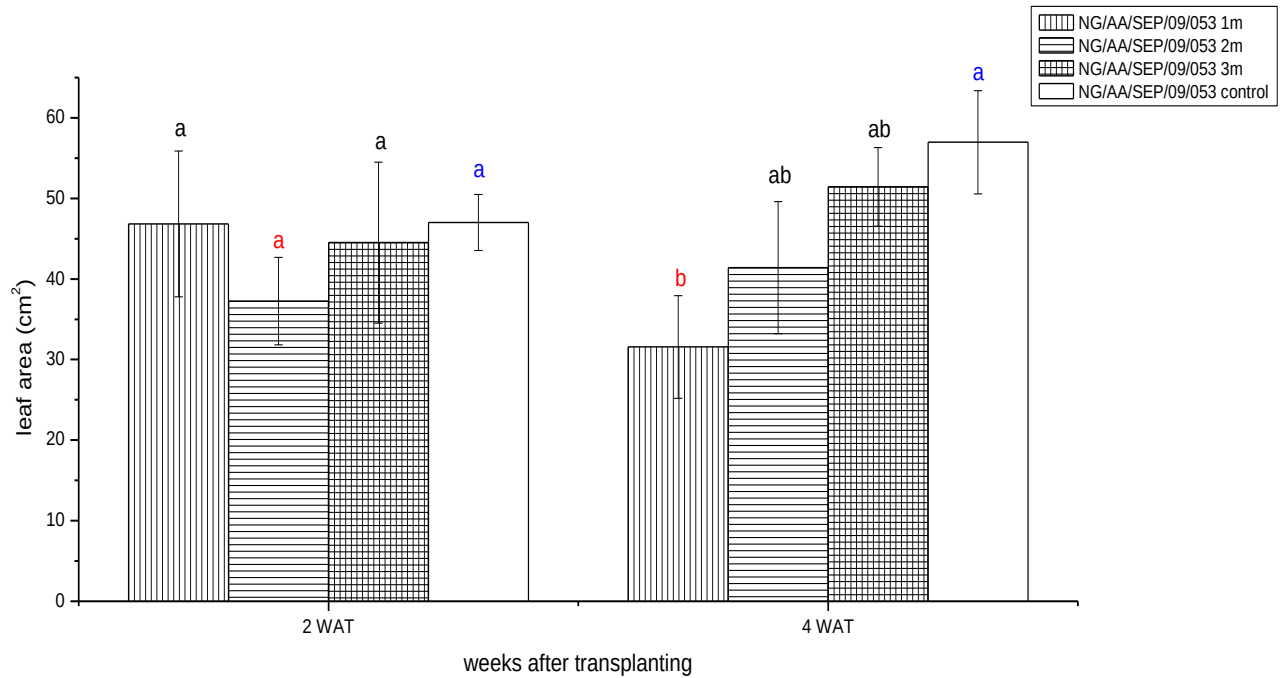


Fig. 46: Effects of intercropping on leaf area of tomato (NG/AA/SEP/09/053) at 2 and 4 WAT

At 2 WAT, there was no statistical difference in the leaf area values; however, those of the control plot recorded the highest leaf area. At 4 WAT, those of the control plot also recorded the highest leaf area which was only statistically different from those at planted at 1 m from the juvenile oil palm.

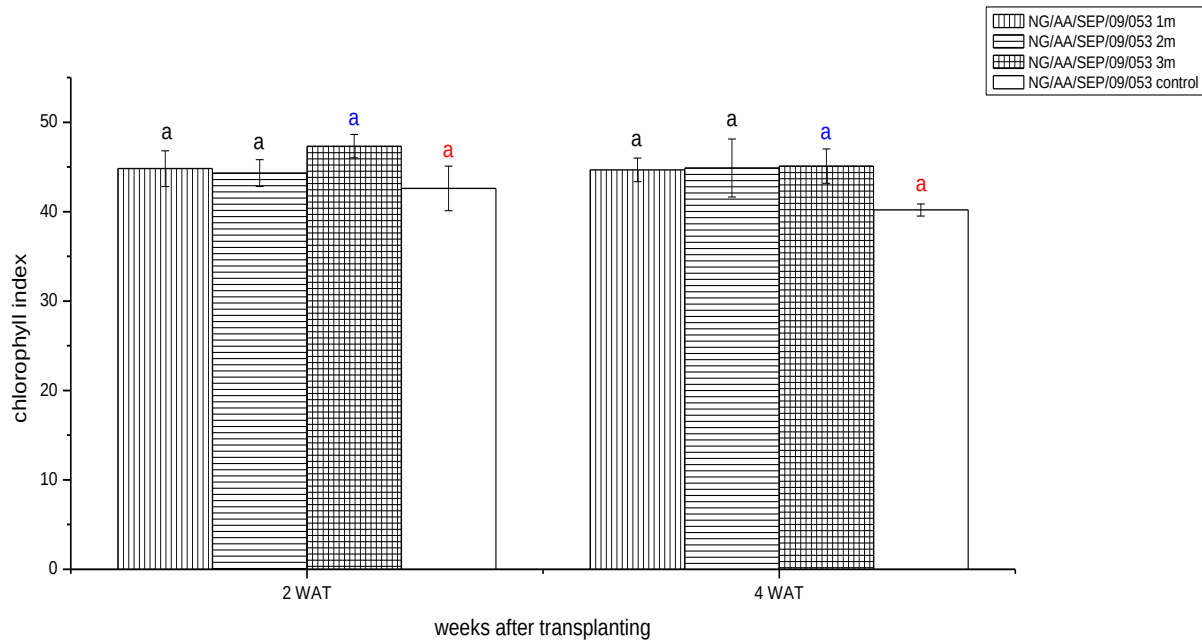


Fig. 47: Effects of intercropping on chlorophyll index of tomato (NG/AA/SEP/09/053) at 2 and 4 WAT

The chlorophyll index values at 2 and 4 WAT were not statistically different. However, at 2 and 4 WAT, those planted at 3 m from the juvenile oil palm recorded the highest chlorophyll index.

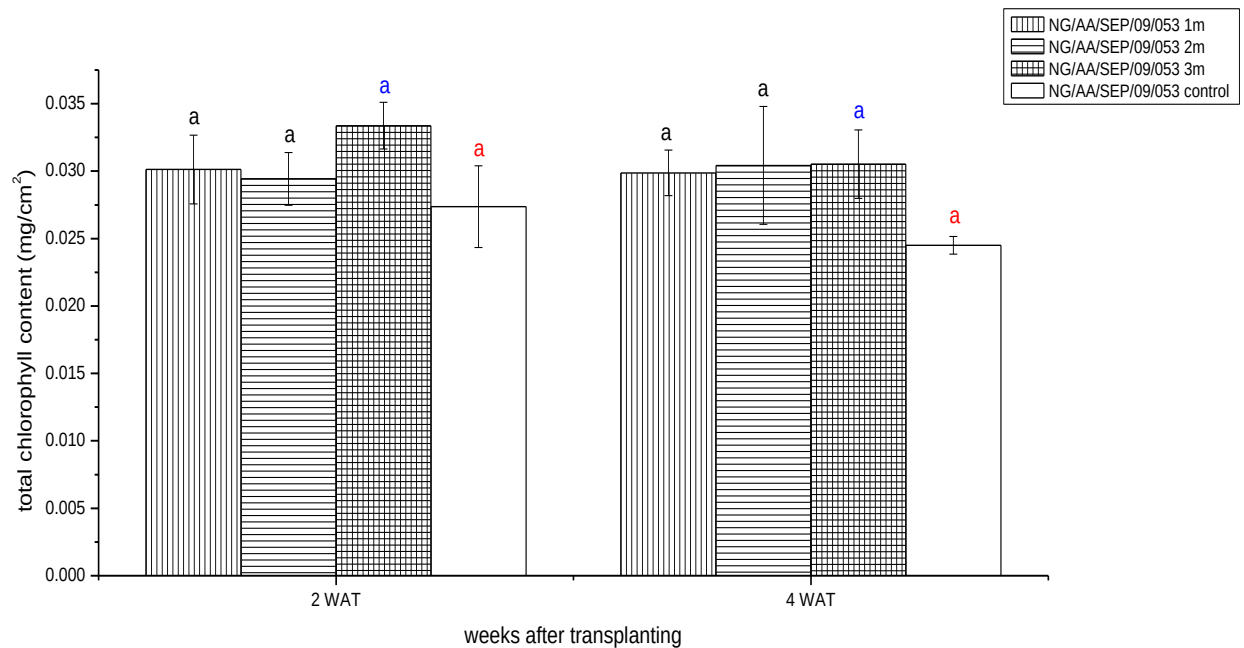


Fig. 48: Effects of intercropping on total chlorophyll content of tomato (NG/AA/SEP/09/053) at 2 and 4 WAT

Tomatoes planted at 3 m from the juvenile oil palm recorded the highest total chlorophyll content both at 2 and 4 WAT; however, the values were not statistically different from all other treatments.

4.3.3 Growth responses of pepper (NGB 01312) to intercropping with juvenile oil palm

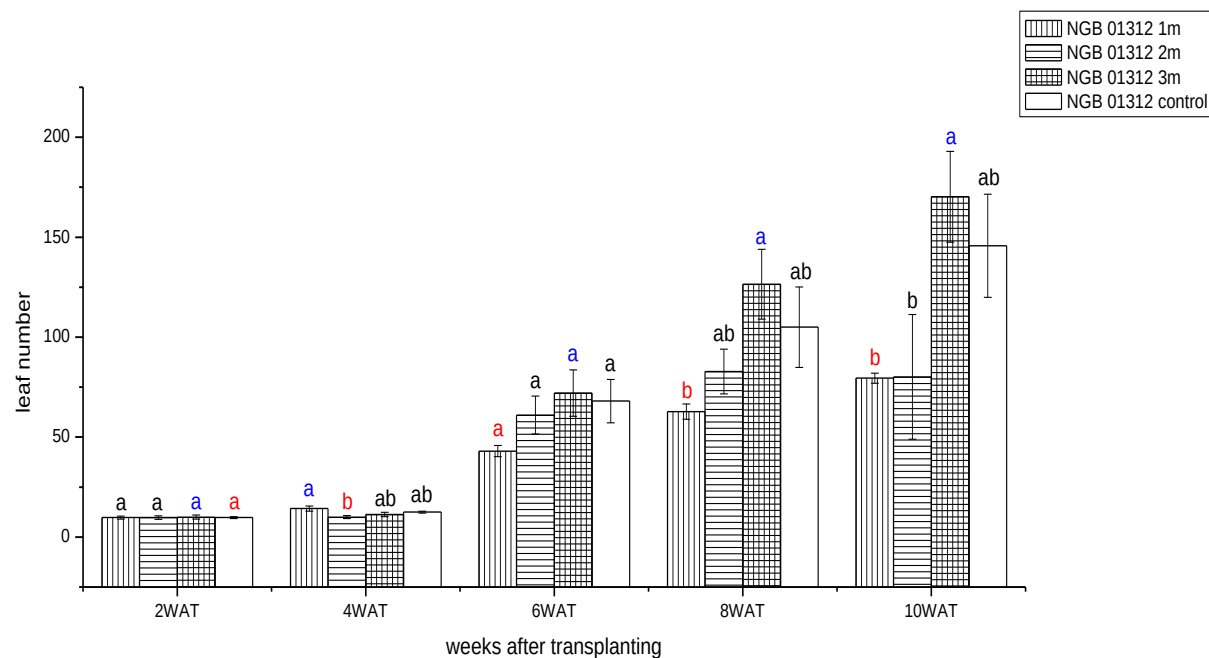


Fig. 49: Effects of intercropping on number of leaves of pepper (NGB 01312) at 2, 4, 6, 8 and 10 WAT

At 2 weeks after transplanting (WAT), leaf number recorded among the treatments was not statistically different. At 4 WAT, there was statistical difference with those at 1 m from the juvenile oil palm recording the highest leaf number and was statistically different from only those planted at 2 m from the juvenile oil palm. At 6 WAT, there was no statistical difference; however, those at 3 m from the juvenile oil palm recorded the highest leaf number. At 8 WAT and 10 WAT, those at 3 m and 1 m recorded the highest and lowest leaf numbers which were statistically different.

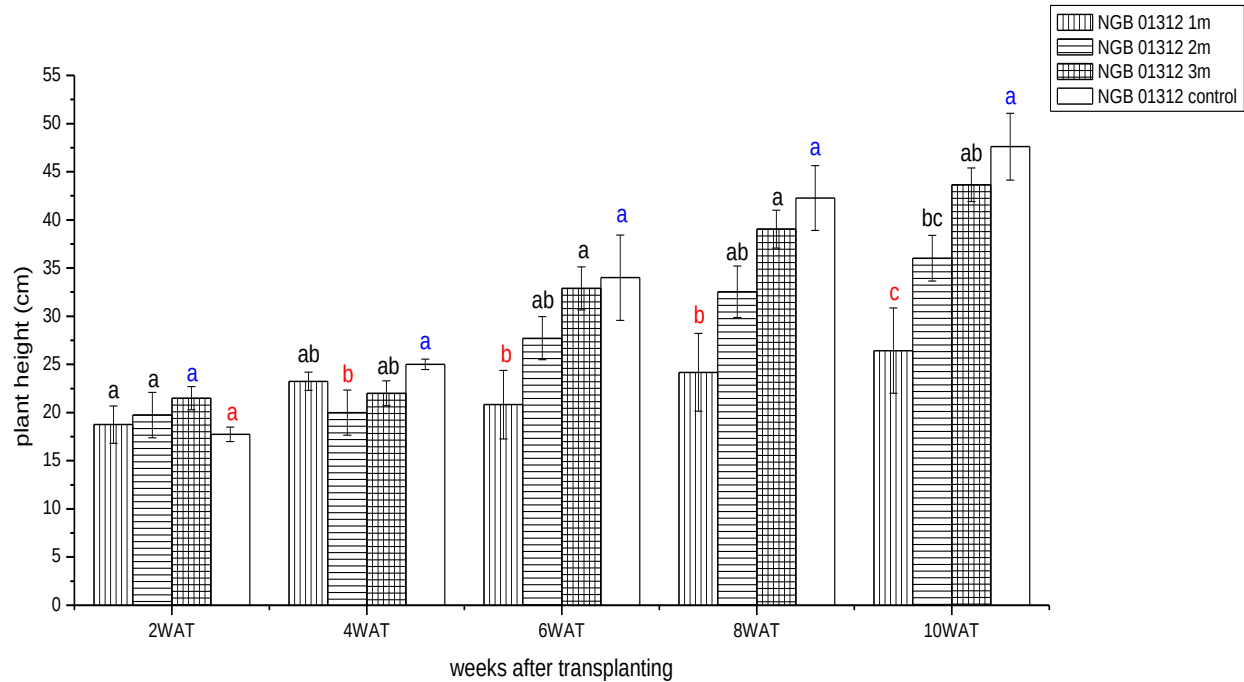


Fig. 50: Effects of intercropping on plant height of pepper (NGB 01312) at 2, 4, 6, 8 and 10 WAT

There was no statistical difference among the plant height across the treatments at 2 WAT. However, those at 3 m from juvenile oil palm recorded the highest plant height. At 4 WAT, those of the control recorded the highest plant height which was statistically different from only those at 2 m from juvenile oil palm which also recorded the lowest plant height. At 8 WAT and 10 WAT, those of the control plot and at 1 m from the juvenile oil palm recorded the highest and lowest plant height respectively.

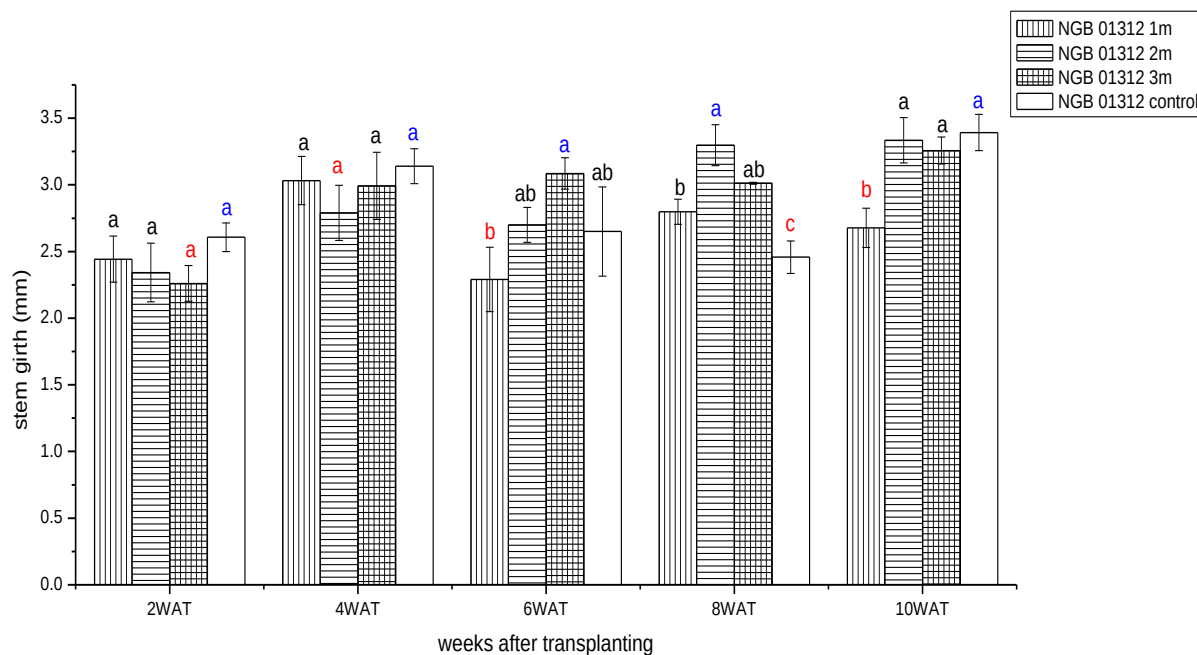


Fig. 51: Effects of intercropping on stem girth of pepper (NGB 01312) at 2, 4, 6, 8 and 10 WAT

At 2 and 4 WAT, there was no statistical difference among the treatments. However, those at control plot recorded the highest during both periods. At 6 WAT, those at 3 m from the juvenile oil palm recorded the highest stem girth which was only statistically different from those planted at 1 m from the juvenile oil palm. At 8 WAT, those of 2 m from the juvenile oil palm recorded the highest while at 10 WAT, those of the control plot recorded the highest stem girth.

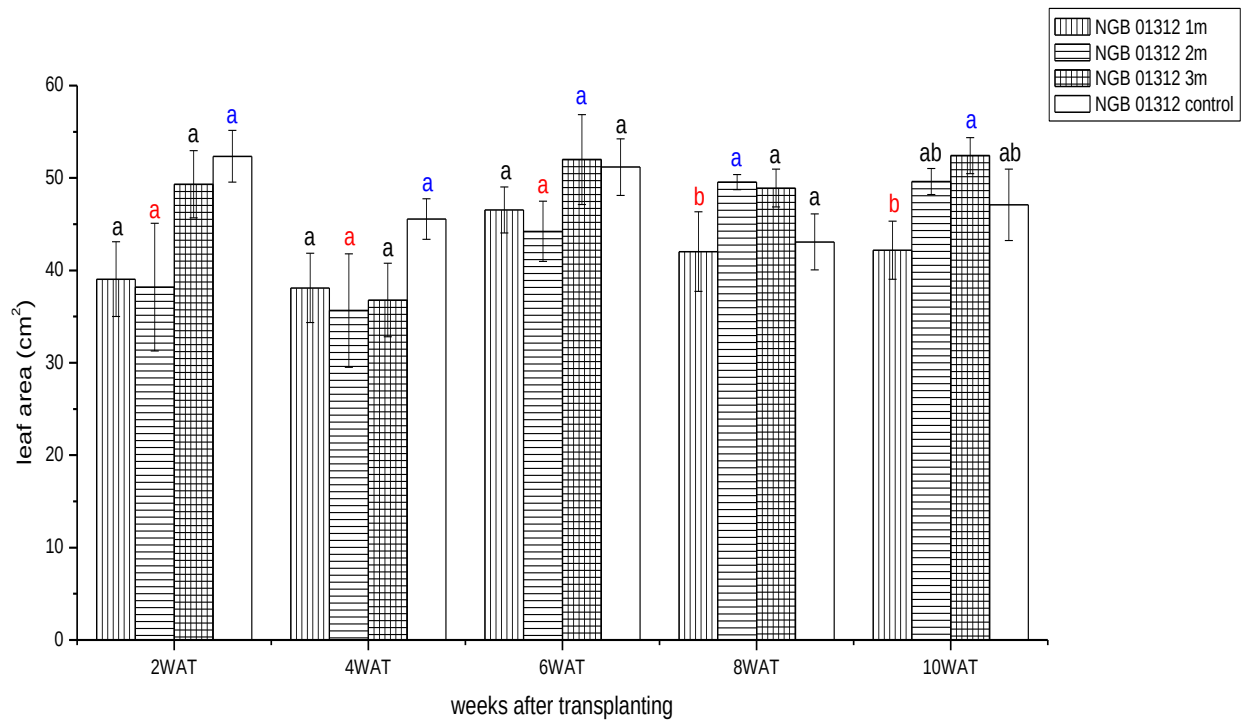


Fig. 52: Effects of intercropping on leaf area of pepper (NGB 01312) at 2, 4, 6, 8 and 10 WAT

At 2, 4 and 6 WAT, there was no statistical difference across the treatments during which those of the control plot recorded the highest except at 6 WAT where the highest was recorded by those planted at 3 m from the juvenile oil palm. At 8 and 10 WAT, those planted at 2 m and 3 m from the juvenile oil palm recorded the highest leaf areas respectively.

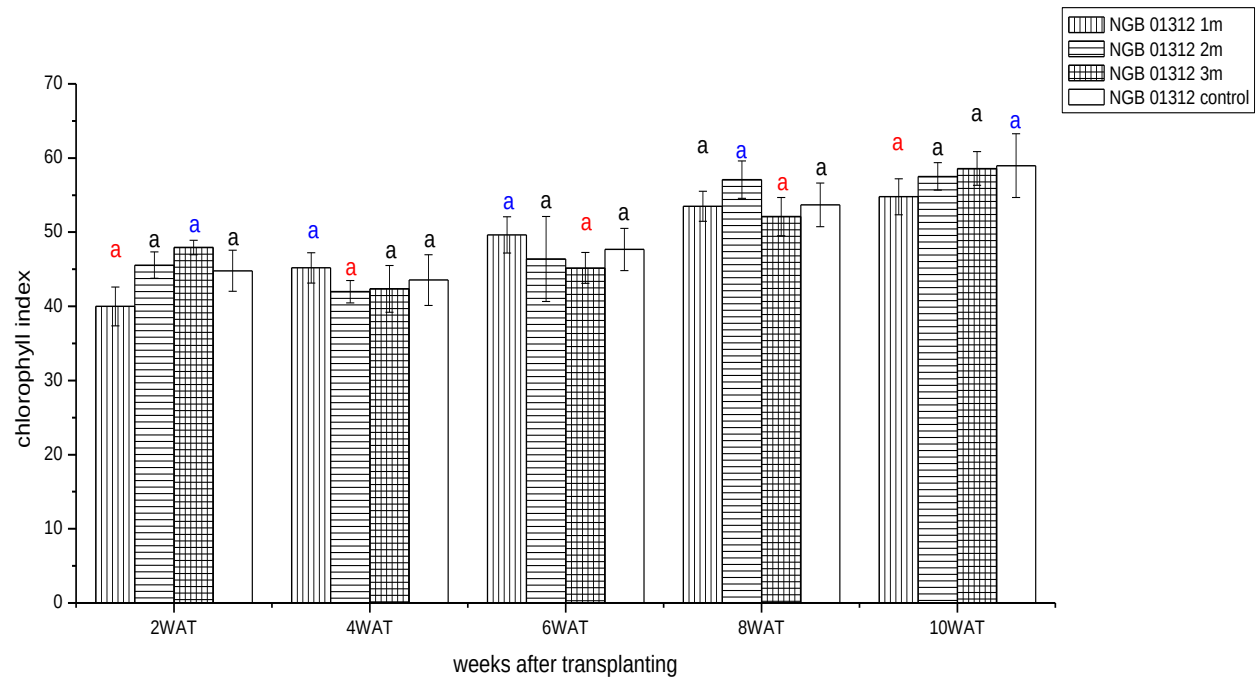


Fig. 53: Effects of intercropping on chlorophyll index of pepper (NGB 01312) at 2, 4, 6, 8 and 10 WAT

The chlorophyll index at 2, 4, 6, 8 and 10 WAT are not statistically different during each period. However, at 10 WAP, the control plot recorded the highest chlorophyll index.

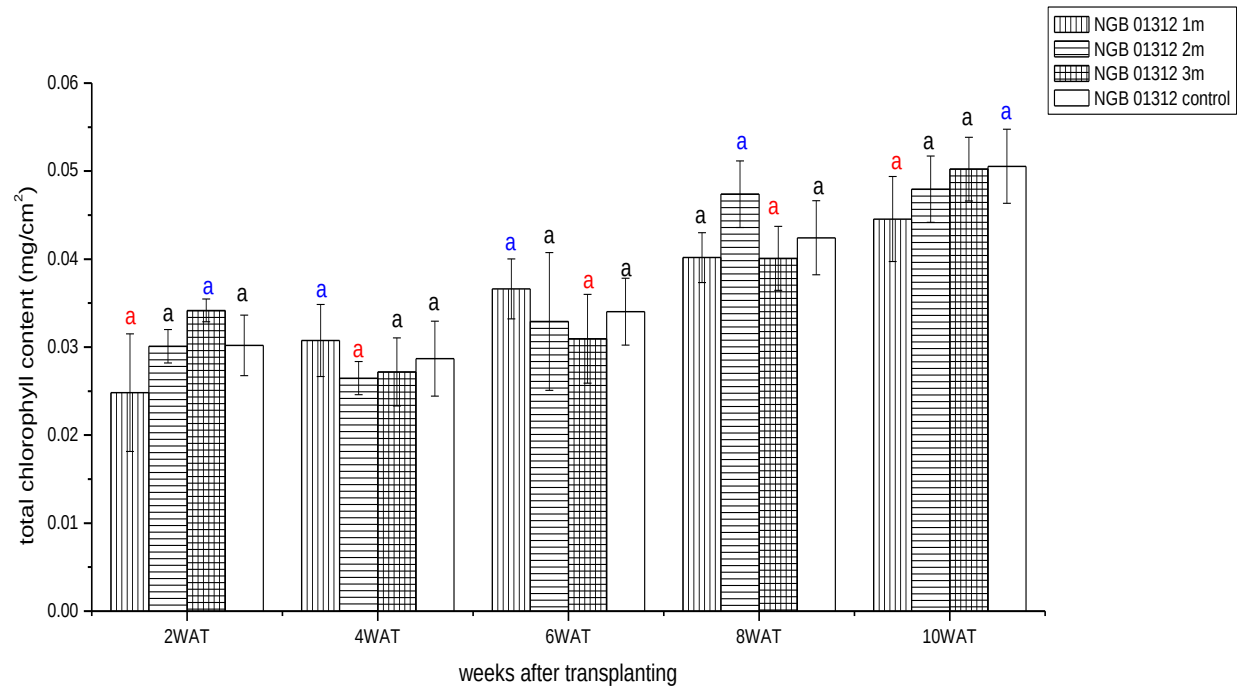


Fig. 54: Effects of intercropping on total chlorophyll content of pepper (NGB 01312) at 2, 4, 6, 8 and 10 WAT

The total chlorophyll content was not statistically different among the treatments at 2, 4, 6, 8 and 10 WAT; and at 10 WAT, those of the control plot recorded the highest total chlorophyll content.

4.3.4 Growth responses of pepper (NGB 01641) to intercropping with juvenile oil palm

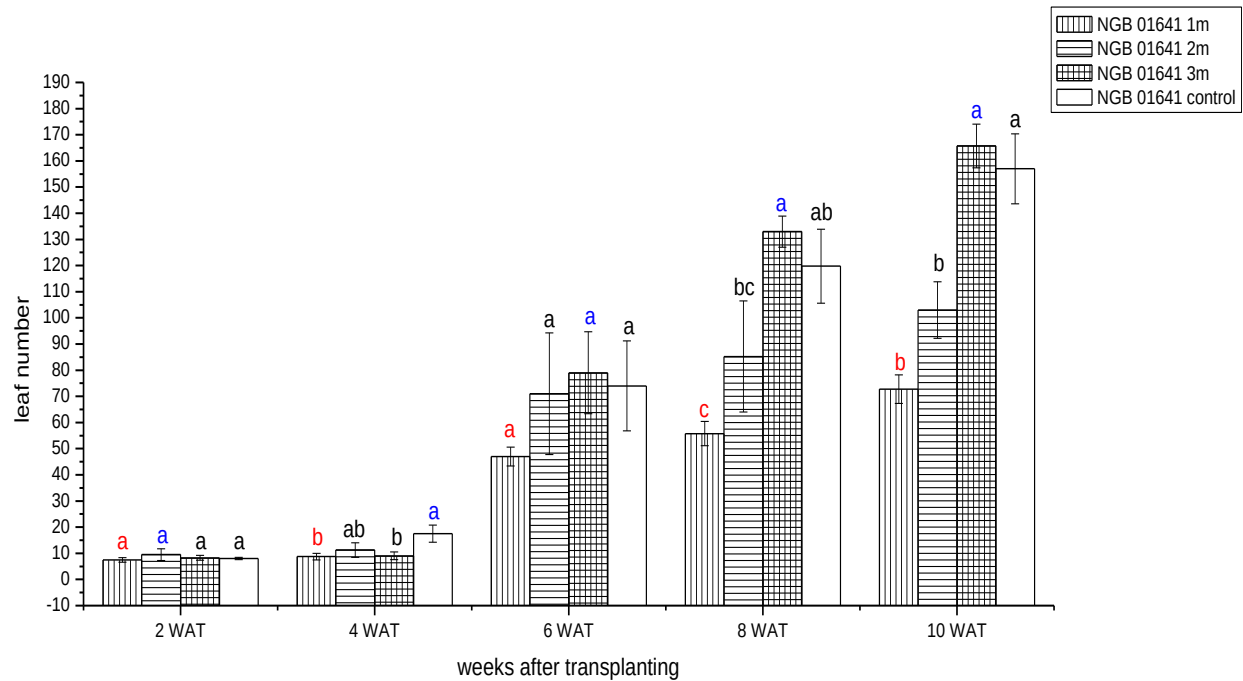


Fig. 55: Effects of intercropping on number of leaves of pepper (NGB 01312) at 2, 4, 6, 8 and 10 WAT

At 2 WAP, there was no statistical difference among the treatments. However, those at 2 m from the juvenile oil palm recorded the highest leaf number. At 4 WAT, there was no statistical difference among the treatments and those of the control plot recorded the highest leaf number which was statistically different from those at 1 m and 3 m from the juvenile oil palm. At 6 WAT, pepper plants at 3 m from the juvenile oil palm recorded the highest leaf number; however, it was not statistically different from other treatments. At 8 and 10 WAT, those at 3 m from the juvenile oil palm recorded the highest which were statistically different from those at 1 m and 2 m from the juvenile oil palm.

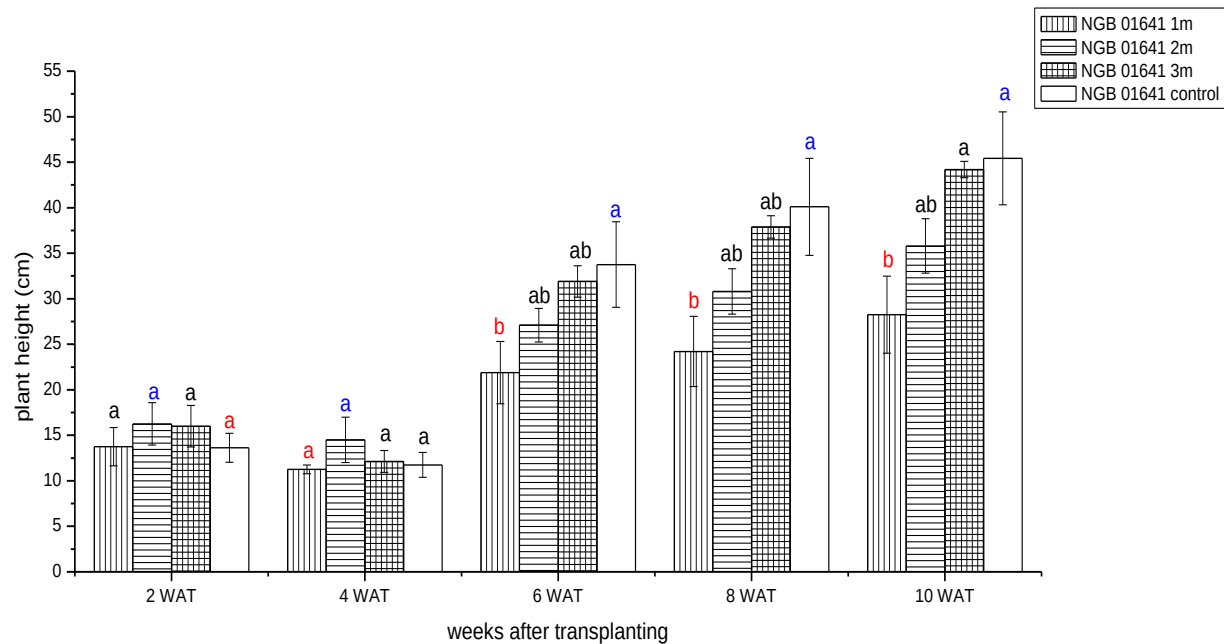


Fig. 56: Effects of intercropping on plant height of pepper (NGB 01312) at 2, 4, 6, 8 and 10 WAT

At 2 and 4 WAT, those at 2 m from the juvenile oil palm recorded the highest plant heights which were not statistically different from other treatments. At 6, 8 and 10 WAT, those of the control plot recorded the highest plant height which showed statistical difference from only those at 1 m from the juvenile oil palm.

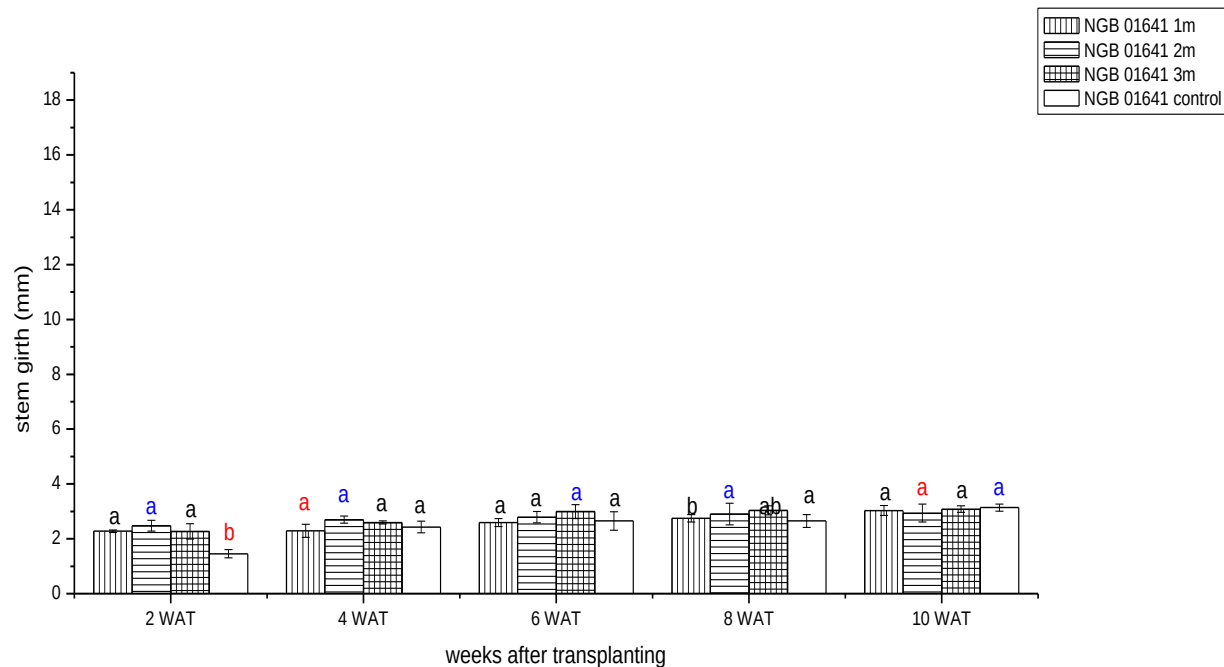


Fig. 57: Effects of intercropping on stem girth of pepper (NGB 01312) at 2, 4, 6, 8 and 10 WAT

The stem girths among the treatments were not statistically different at 2, 4, 6 and 10 WAT. At 8 WAT, those at 3 m from the juvenile oil palm recorded the highest stem girth which was statistically different from only those at 1 m from the juvenile oil palm.

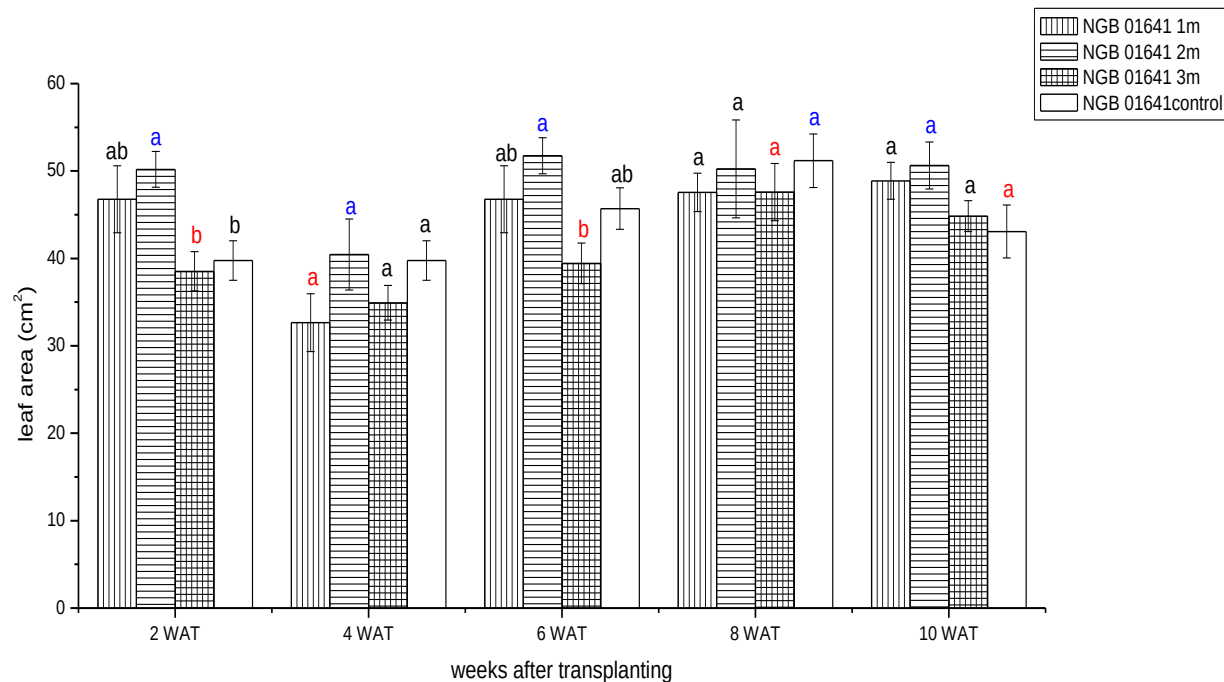


Fig. 58: Effects of intercropping on leaf area of pepper (NGB 01312) at 2, 4, 6, 8 and 10 WAT

At 2 and 4 WAT, those at 2 m recorded the highest leaf area. At 2 WAT, it was statistically different from those at 3 m from the juvenile oil palm while there was no statistical difference at 4 WAT. At 6 WAT, those at 2 m also recorded the highest leaf area which was statistically different from only those at 3 m from the juvenile oil palm. At 8 and 10 WAT, there was no statistical difference among the treatment however those at 2 m from the juvenile oil palm recorded the highest leaf area.

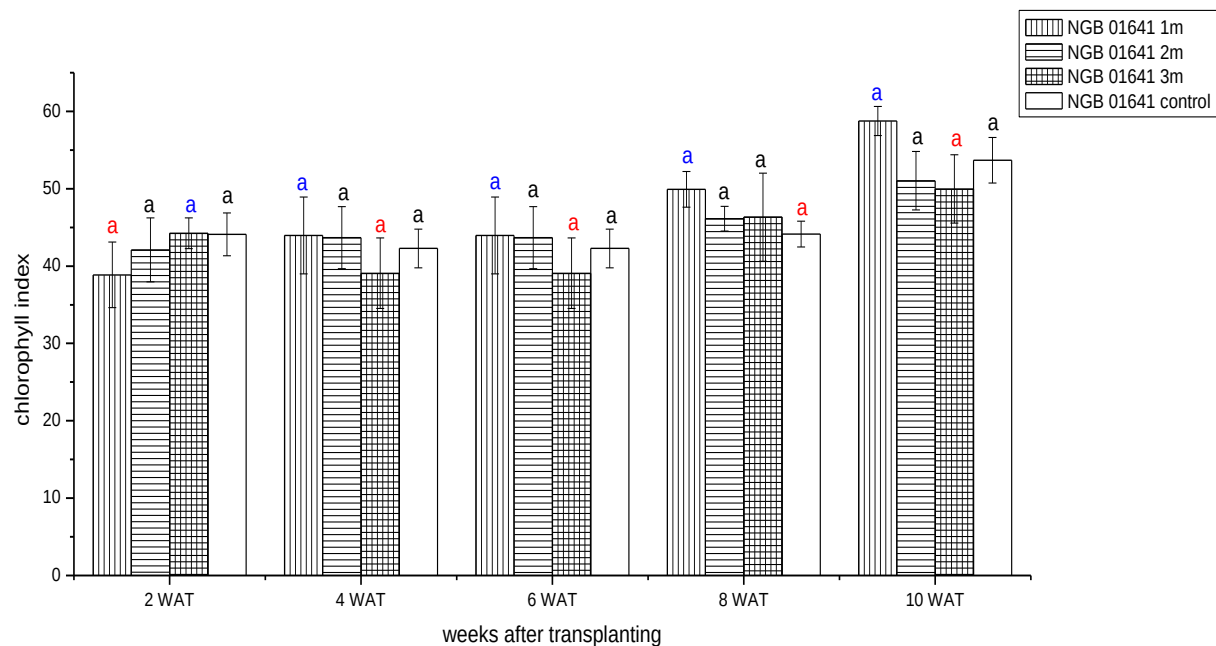


Fig. 59: Effects of intercropping on chlorophyll index of pepper (NGB 01312) at 2, 4, 6, 8 and 10 WAT

There was no statistical difference in the chlorophyll index at 2, 4, 6, 8 and 10 WAT. However, those at 1 m from the juvenile oil palm recorded the highest chlorophyll index at 10 WAT.

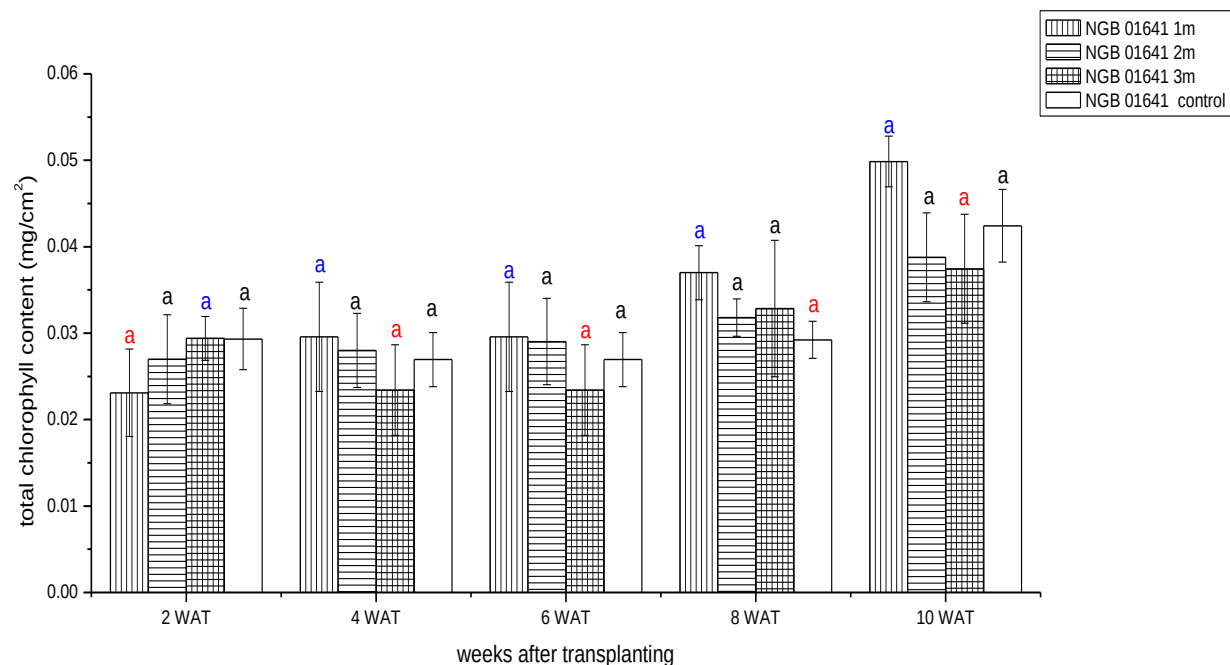


Fig. 60: Effects of intercropping on total chlorophyll content of pepper (NGB 01312) at 2, 4, 6, 8 and 10 WAT

The total chlorophyll contents among the treatments were not statistically different at 2, 4, 6, 8 and 10 WAT. However, at 10 WAT, those at 1 m from the juvenile oil palm recorded the highest total chlorophyll content.

4.3.5 Growth responses of okra (NGB 01184) to intercropping with juvenile oil palm

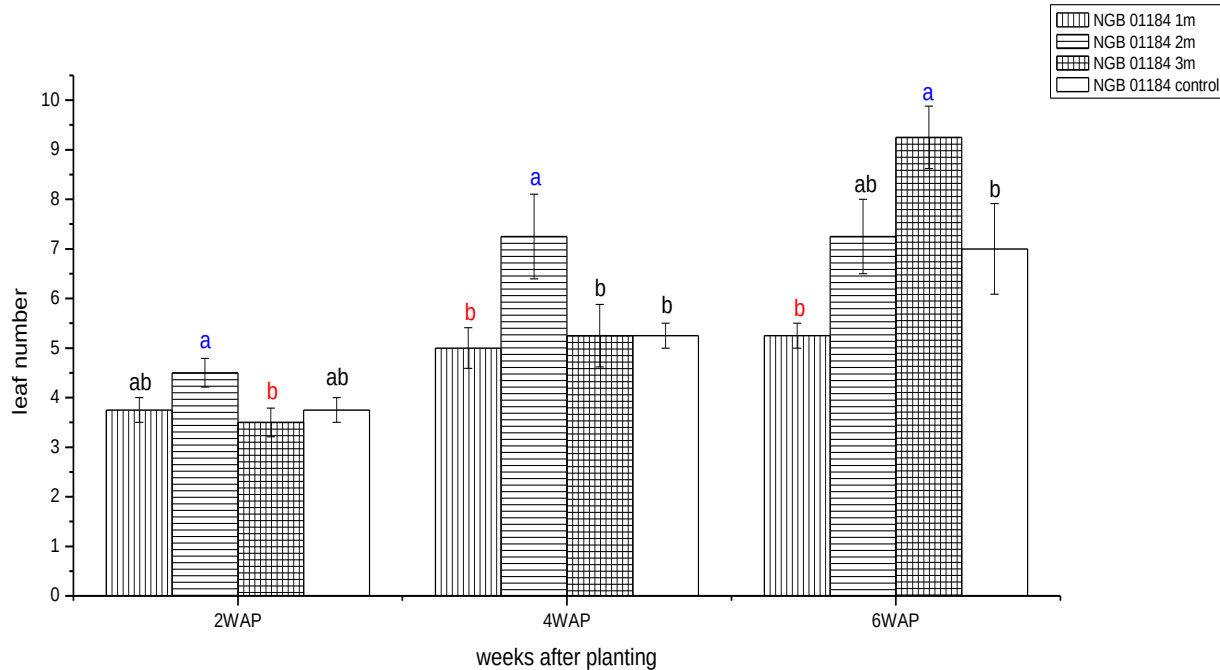


Fig. 61: Effects of intercropping on number of leaves of okra (NGB 01184) at 2, 4 and 6 WAT

At 2 and 4 WAT, okra at 2 m from the juvenile oil palm recorded the highest leaf number. At 2 WAT, this was statistically different from only those at 3 m from the juvenile oil palm while at 4 WAT it was statistically different from all other treatments. At 6 WAT, those at 3 m from the juvenile oil palm recorded the highest leaf number which was statistically different from those at 1 m from the juvenile oil palm and those at the control plot.

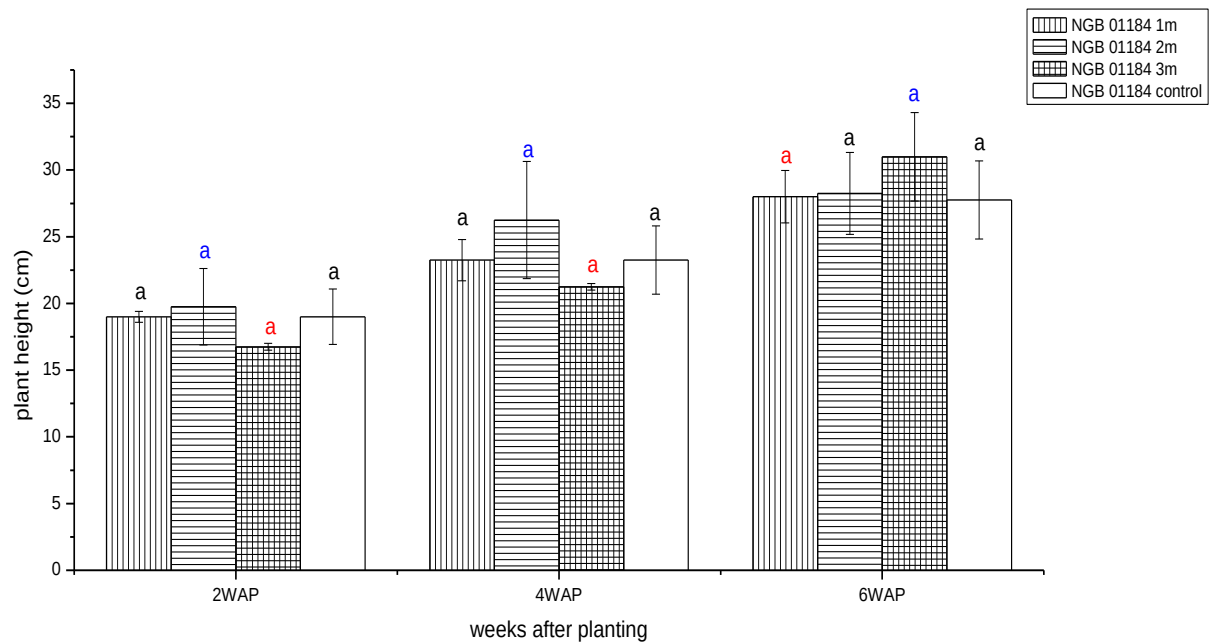


Fig. 62: Effects of intercropping on plant height of okra (NGB 01184) at 2, 4 and 6 WAT

There was no statistical difference in plant height among all the treatments at 2, 4 and 6 WAT.

However, at 6 WAT, those at 3 m from the juvenile oil palm recorded the highest plant height.

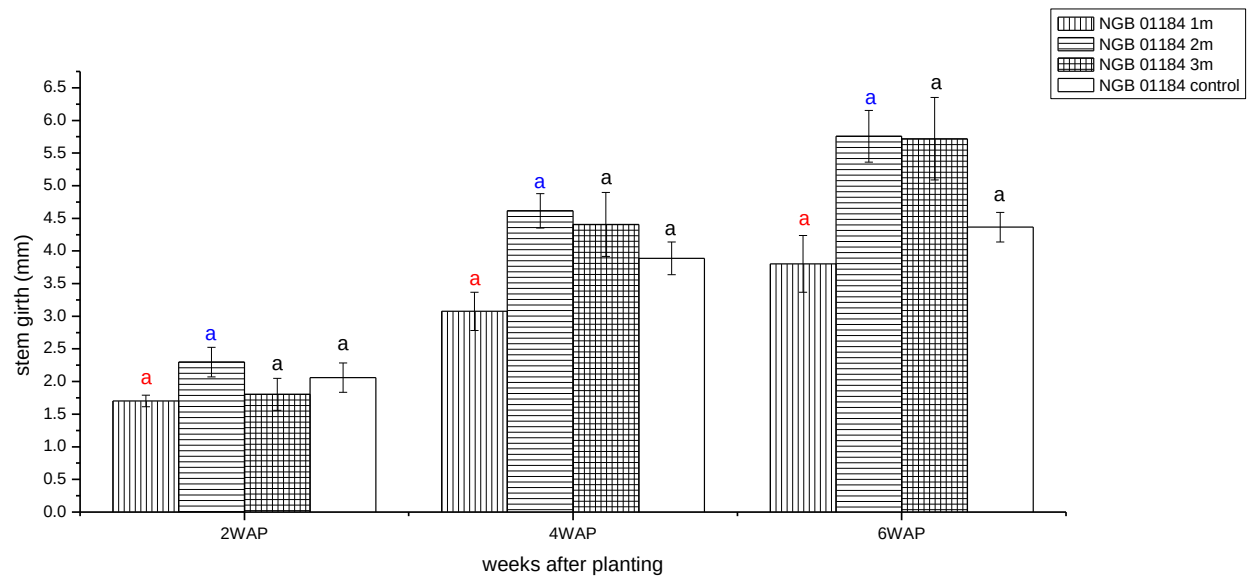


Fig. 63: Effects of intercropping on stem girth of okra (NGB 01184) at 2, 4 and 6 WAT

There was no statistical difference among the treatments at 2, 4 and 6 WAT. However, okra plants at 2 m from the juvenile oil palm recorded the highest stem girth at 6 WAT.

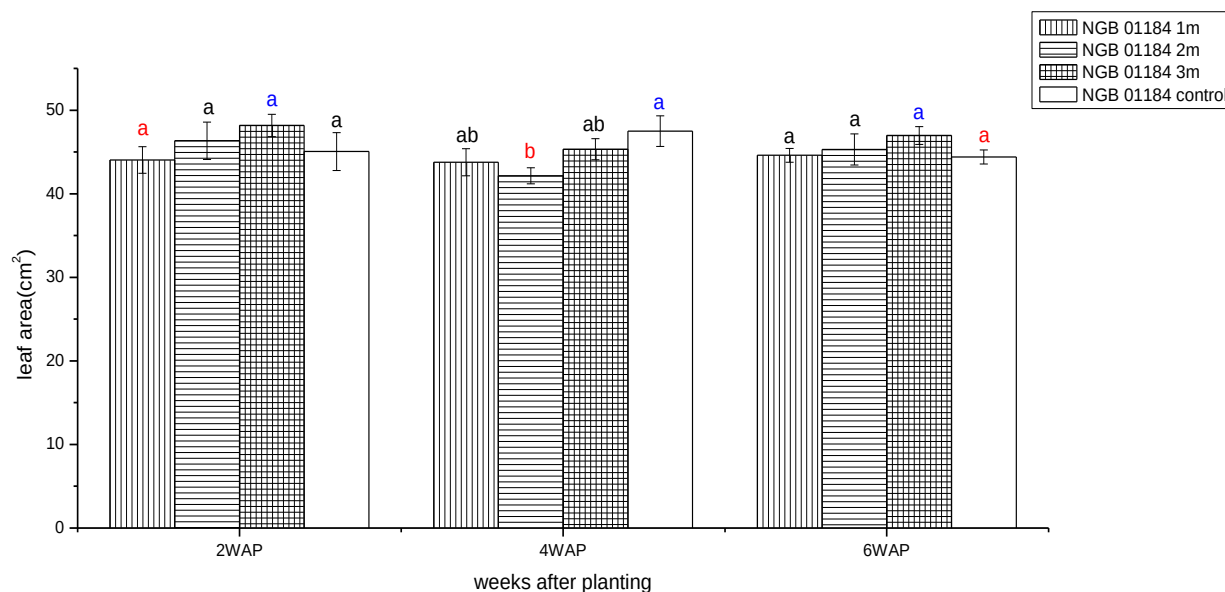


Fig. 64: Effects of intercropping on leaf area of okra (NGB 01184) at 2, 4 and 6 WAT

At 2 WAT, okra plants at 3 m from the juvenile oil palm recorded the highest leaf area. However, it was not statistically different from other treatments. At 4 WAT, those of the control plot recorded the highest leaf area which was statistically different from only those at 2 m from the juvenile oil palm. At 6 WAT, there was no statistical difference among the treatments. However, those at 3 m from the juvenile oil palm recorded the highest leaf area.

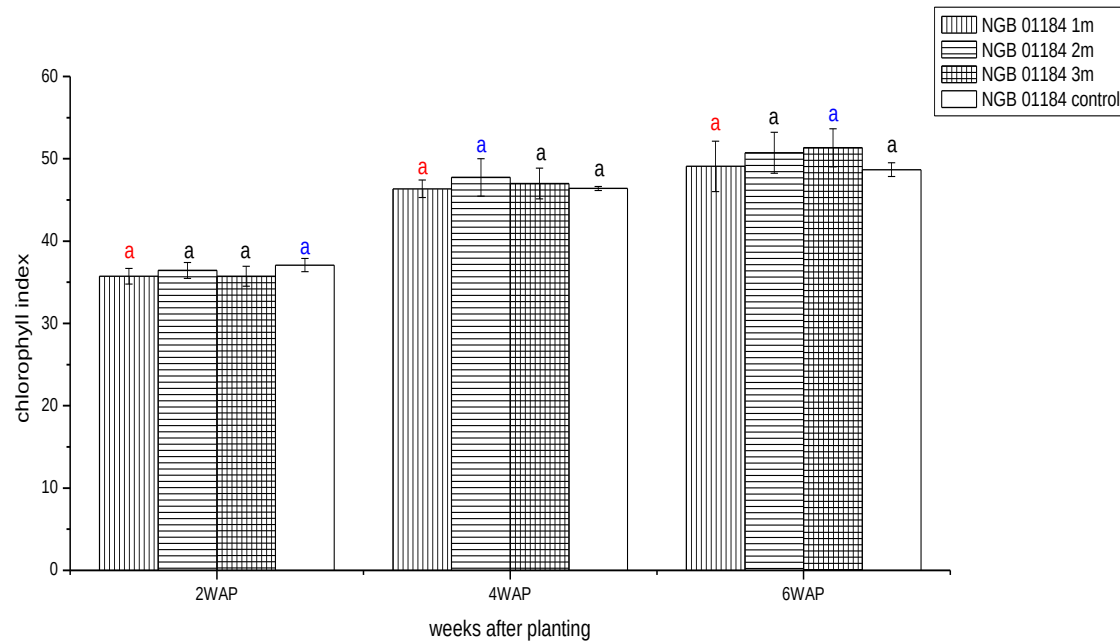


Fig. 65: Effects of intercropping on chlorophyll index of okra (NGB 01184) at 2, 4 and 6 WAT

The chlorophyll index values among the treatments were not statistically different at 2, 4 and 6 WAT. However, at 6 WAT, those at 3 m recorded the highest chlorophyll index.

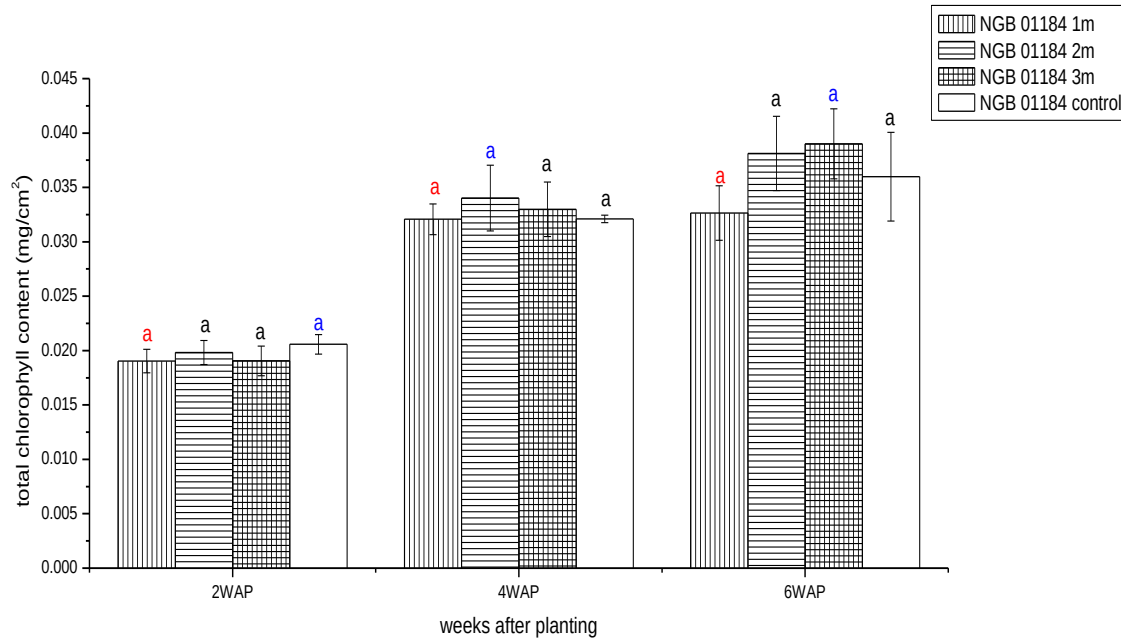


Fig. 66: Effects of intercropping on total chlorophyll content of okra (NGB 01184) at 2, 4 and 6 WAT

The total chlorophyll content among the treatments was not statistically different at 2, 4 and 6 WAT. However, okra plants at 3 m from the juvenile oil palm recorded the highest total chlorophyll content at 6 WAT.

4.3.6 Growth responses of eggplant (NGB 01737) to intercropping with juvenile oil palm

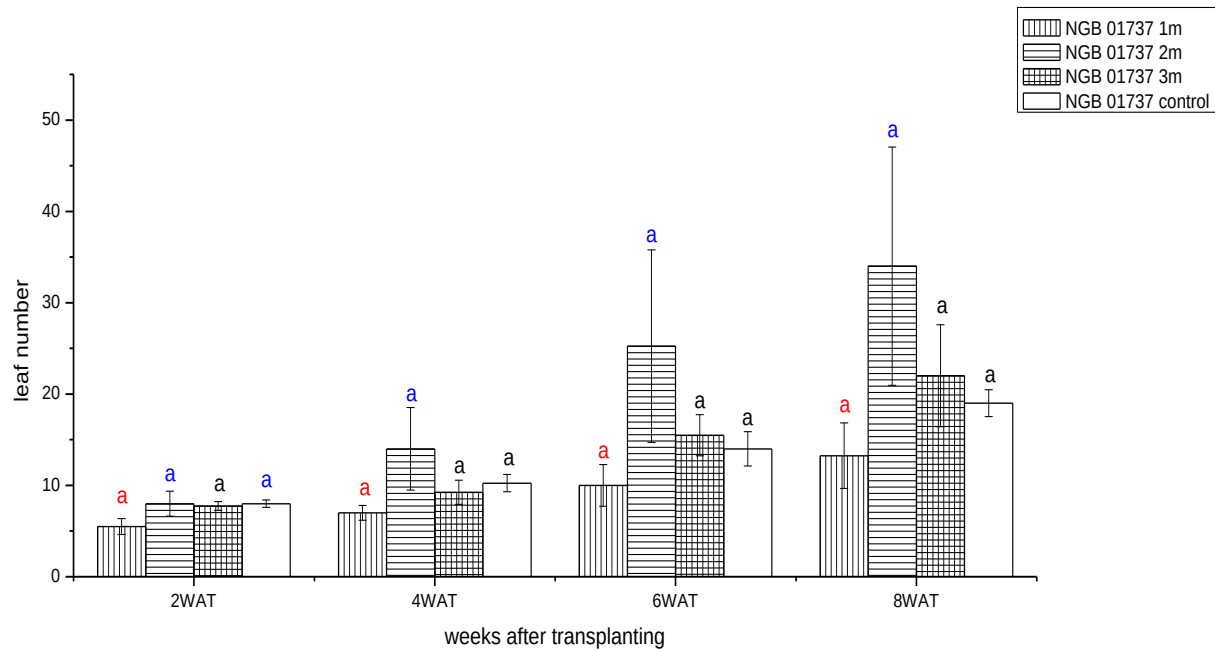


Fig. 67: Effects of intercropping on number of leaves of eggplant (NGB 01737) at 2, 4, 6 and 8 WAT

There was no statistical difference among the treatment at 2, 4, 6 and 8 WAT. However, those at 2 m from the juvenile oil palm recorded the highest leaf number during each period.

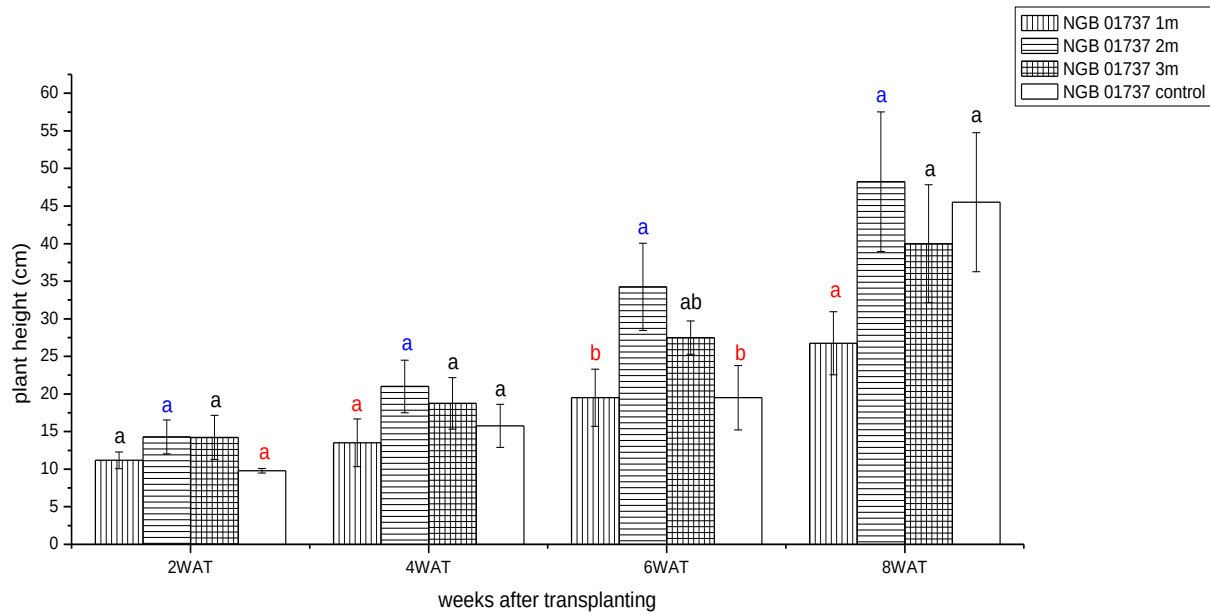


Fig. 68: Effects of intercropping on plant height of eggplant (NGB 01737) at 2, 4, 6 and 8 WAI

The mean plant heights among the treatments were not statistically different at 2 and 4 WAT. At 6 and 8 WAT, eggplants at 2 m from the juvenile oil palm recorded the highest plant height. At 4 WAT, mean height of eggplants at 2 m from the juvenile oil palm were statistically different from those at 1 m from the juvenile oil palm and the control plot; while there were no statistical difference among the treatments at 8 WAT.

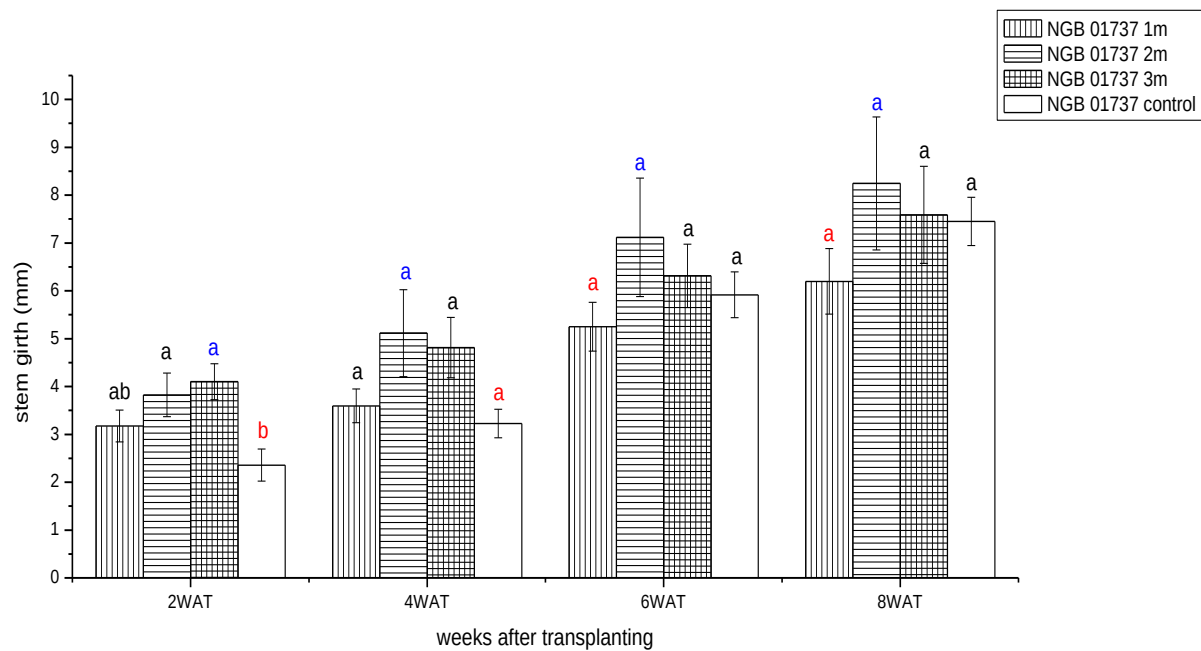


Fig. 69: Effects of intercropping on stem girth of eggplant (NGB 01737) at 2, 4, 6 and 8 WAT

Eggplants at 3 m from the juvenile oil palm recorded the highest stem girth at 2 WAT. This was only statistically different from those of the control plants. At 4, 6 and 8 WAT, there was no statistical difference among. However, those at 3 m from the juvenile oil palm recorded the highest stem girth during each period.

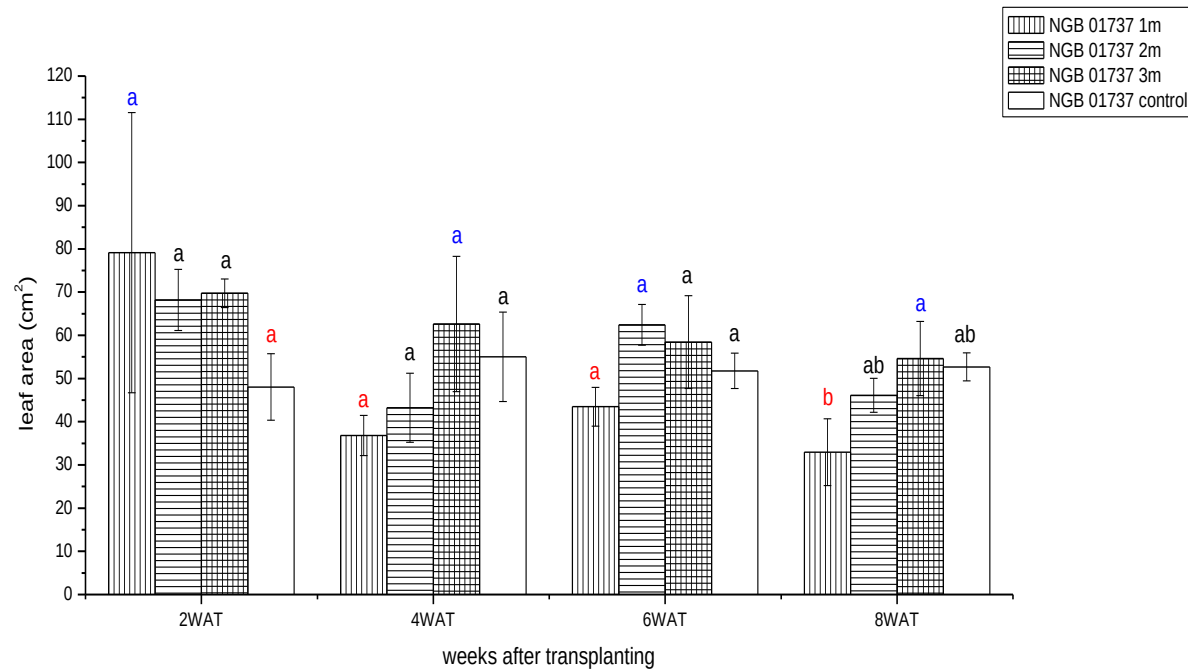


Fig. 70: Effects of intercropping on leaf area of eggplant (NGB 01737) at 2, 4, 6 and 8 WAT

There was no statistical difference among the treatments at 2, 4, 6 and 8 WAPT. However, at 10 WAT, those at 3 m from the juvenile oil palm recorded the highest leaf area which was statistically different from those at 1 m from the juvenile oil palm.

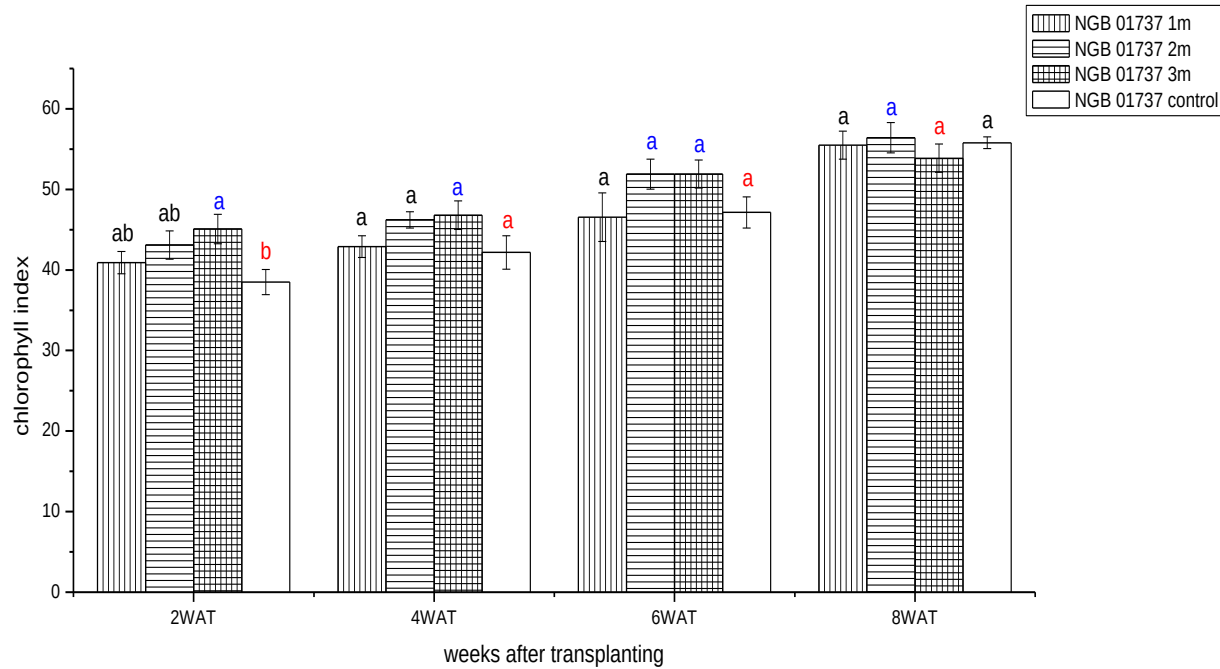


Fig. 71: Effects of intercropping on chlorophyll index of eggplant (NGB 01737) at 2, 4, 6 and 8 WAT

At 2 WAT, eggplants at 3 m from the juvenile oil palm recorded the highest chlorophyll index which was statistically different from those of the control plot. There was no statistical difference among the treatments at 4, 6 and 8 WAT. At 8 WAT, those at 2 m from the juvenile oil palm and control plot recorded the highest chlorophyll index.

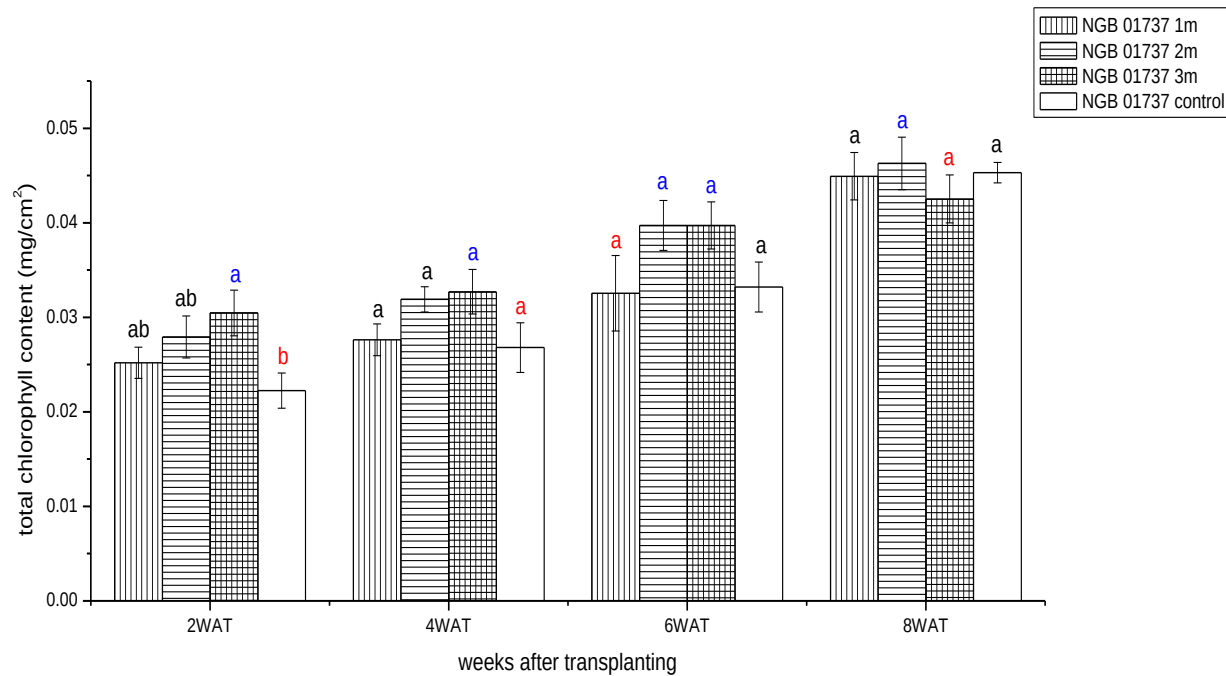


Fig. 72: Effects of intercropping on total chlorophyll content of eggplant (NGB 01737) at 2, 4, 6 and 8 WAT

The mean total chlorophyll content of eggplants at 3 m from the juvenile oil palm was the highest and was statistically different from those of the control plot. At 4, 6 and 8 WAT, there was no statistical difference among the treatments.

Table 11: Effect of intercropping on number of days to flowering and 50% flowering of vegetable crops

	Tomato (NGB 01665)		Tomato (NG/AA/SEP/09/053)		Pepper (NGB 01312)		Pepper (NGB 01641)		Okra (NGB 01184)		Eggplant (NGB 01737)	
	NDF	NDFP	NDF	NDFP	NDF	NDFP	NDF	NDFP	NDF	NDFP	NDF	NDFP
1m	45.500 ^a	52.750 ^a	46.250 ^a	52.000 ^a	106.500 ^a	113.500 ^a	106.250 ^a	113.500 ^a	41.500 ^a	46.500 ^a	48.500 ^a	56.000 ^a
2m	42.750 ^b	49.750 ^b	41.500 ^b	48.750 ^b	104.500 ^{ab}	111.000 ^a	102.500 ^{ab}	114.000 ^a	40.500 ^a	44.500 ^a	46.500 ^{ab}	53.000 ^b
3m	39.500 ^c	42.750 ^c	38.000 ^c	40.000 ^c	101.000 ^{bc}	109.000 ^a	99.500 ^b	110.000 ^{ab}	38.500 ^b	41.000 ^b	44.750 ^{bc}	46.500 ^c
control	38.500 ^c	41.000 ^c	38.000 ^c	40.500 ^c	98.000 ^c	104.000 ^a	97.500 ^b	104.750 ^b	38.500 ^b	40.500 ^b	43.500 ^c	45.500 ^c

Where NDF= Number of days to flowering

NDFP= Number of days to 50% flowering

Means with the same letter(s) along the same column are not significantly different at (P<0.05) level of significance.

4.4 Effect of intercropping on yield and yield components of fruit vegetable crops intercropped with 3 years old juvenile oil palm

Table 12: Effect of intercropping on yield components of tomato (NGB 01665)-juvenile oil palm intercrop

Treatment	Number of fruits/plant	Fruit weight/plant (g)	Weight of 100 fruits (g)	Fruit girth (mm)	Fruit length (mm)	Yield (tonha ⁻¹)
1 m	13.750 ^b	803.930 ^c	6060.580 ^b	43.168 ^b	40.182 ^c	2.424 ^b
2 m	20.000 ^b	1714.800 ^b	6795.500 ^{ab}	44.863 ^b	49.920 ^b	2.718 ^{ab}
3 m	26.750 ^a	2098.700 ^{ab}	8576.250 ^{ab}	52.698 ^a	55.942 ^a	3.431 ^{ab}
Control	33.250 ^a	2632.300 ^a	9732.780 ^a	51.578 ^a	51.820 ^{ab}	3.893 ^a

Mean along the same column with similar letter(s) are not are not significantly different at (P<0.05) level of significance.

Tomato (NGB 01665) of the control plot recorded the highest fruit number, fruit weight per plant, weight of 100 fruits, fruit girth, fruit length and yield per hectare as shown in Table 12. However, none of the yield component values of the control plot was statistically different from what was obtained from the tomato planted at 3 m from juvenile oil palm. Those planted at 2 m from the juvenile oil palm were not different statistically from the tomatoes planted at 3 m from juvenile oil palm and control plot for only weight of 100 fruits yield component. Those planted at 1 m from juvenile oil palm recorded the least performance in all the yield components (Table 12).

Table 13: Effect of intercropping on the yield components of tomato (NG/AA/SEP/09/053) - juvenile oil palm intercrop

Treatment	Number of fruits/plant	Fruit weight/plant (g)	Weight of 100 fruits (g)	Fruit girth (mm)	Fruit length (mm)	Yield (tonha ⁻¹)
1 m	15.000 ^b	1108.560 ^b	6210.496 ^a	42.270 ^a	41.337 ^c	2.484 ^a
2 m	21.000 ^b	1409.680 ^b	7055.685 ^a	45.465 ^a	45.860 ^{bc}	2.822 ^a
3 m	34.000 ^a	2153.460 ^{ab}	9259.558 ^a	48.485 ^a	51.450 ^{ab}	3.704 ^a
Control	37.750 ^a	2663.000 ^a	9058.825 ^a	49.693 ^a	54.280 ^a	3.624 ^a

Mean along the same column with similar letter(s) are not are not significantly different at (P<0.05) level of significance.

Table 13 shows that the yield components of the tomato (NG/AA/SEP/09/053) planted at 3 m from juvenile oil palm were not statistically different from those planted at the control plot. However, the highest values were recorded by those at the control plot for all the yield components except weight of 100 fruits and yield per hectare.

Table 14: Effect of intercropping on the yield components of pepper (NGB 01312) -juvenile oil palm intercrop

Treatment	Number of fruits/plant	Fruit weight/plant (g)	Weight of 100 fruits (g)	Fruit girth (mm)	Fruit length (mm)	Yield (tonha ⁻¹)
1 m	28.250 ^c	233.720 ^c	1013.908 ^a	18.37 ^c	26.000 ^a	0.405 ^a
2 m	52.000 ^b	488.970 ^{bc}	1053.165 ^a	20.880 ^{bc}	25.950 ^a	0.422 ^a
3 m	70.250 ^a	741.400 ^a	1535.640 ^a	32.910 ^a	32.250 ^a	0.614 ^a
Control	61.750 ^{ab}	960.320 ^{ab}	1351.242 ^a	30.610 ^{ab}	30.830 ^a	0.540 ^a

Mean along the same column with similar letter(s) are not are not significantly different at (P<0.05) level of significance.

Pepper (NGB 01312) intercropped at 3 m from juvenile oil palm recorded the highest values for all the yield components except fruit weight per plant; however, they were not statistically different from those planted in the control plot. Those planted at 1 m from juvenile oil palm recorded the lowest values for fruit number per plant, fruit weight per plant and fruit girth.

Table 15: Effect of intercropping on the yield components of pepper (NGB 01641) -juvenile oil palm intercrop

Treatment	Number of fruits/plant	Fruit weight/plant (g)	Weight of 100 fruits (g)	Fruit girth (mm)	Fruit length (mm)	Yield (tonha ⁻¹)
1 m	27.750 ^b	165.850 ^b	749.746 ^a	18.230 ^a	25.400 ^b	0.300 ^a
2 m	49.500 ^{ab}	465.46 ^{bc}	1189.238 ^a	20.490 ^a	26.000 ^b	0.476 ^a
3 m	77.00 ^a	952.590 ^a	1425.406 ^a	29.858 ^a	36.900 ^a	0.570 ^a
Control	61.000 ^a	678.320 ^{ab}	1351.028 ^a	30.338 ^a	31.150 ^{ab}	0.541 ^a

Mean along the same column with similar letter(s) are not are not significantly different at (P<0.05) level of significance.

Pepper (NGB 01641) intercropped at 3 m from juvenile oil palm recorded the highest values for all the yield components except fruit girth. However, the values of the yield components were not statistically different from respective values for those planted at the control plot (Table 15).

Table 16: Effect of intercropping on the yield components of okra (NGB 01184) -juvenile oil palm intercrop

Treatment	Number of fruits/plant	Fruit weight/plant (g)	Weight of 100 fruits (g)	Fruit girth (mm)	Fruit length (mm)	Yield (tonha ⁻¹)
1 m	13.500 ^c	63.075 ^c	479.830 ^c	16.075 ^{ab}	43.803 ^b	0.198 ^b
2 m	21.250 ^b	102.970 ^{bc}	520.560 ^{bc}	15.100 ^b	45.621 ^b	0.217 ^b
3 m	28.250 ^a	219.530 ^a	889.470 ^a	18.173 ^a	64.215 ^a	0.321 ^a
Control	29.000 ^a	162.740 ^{ab}	737.770 ^{ab}	17.278 ^{ab}	64.243 ^a	0.369 ^a

Mean along the same column with similar letter(s) are not are not significantly different at (P<0.05) level of significance.

Table 16 shows that the okra (NGB 01184) intercropped at 3 m from the juvenile oil palm recorded highest values for all the yield components except fruit girth; however, they were not statistically different from those planted at the control plot. Those okras planted at 2 m from juvenile oil palm were also not statistically different from those at 3 m from the juvenile oil palm and the control except fruit weight per plant and fruit length. Those at 1 m from juvenile oil palm recorded the least performance (Table16).

Table 17: Effect of intercropping on the yield components of eggplant (NGB 01737) - juvenile oil palm intercrop

Treatment	Number of fruits/plant	Fruit weight/plant (g)	Weight of 100 fruits (g)	Fruit girth (mm)	Fruit length (mm)	Yield (tonha ⁻¹)
1 m	5.500 ^b	196.908 ^a	2653.900 ^c	48.489 ^b	29.580 ^b	1.617 ^b
2 m	6.250 ^b	220.785 ^a	3800.300 ^{bc}	52.920 ^{ab}	38.195 ^a	1.520 ^{bc}
3 m	9.500 ^a	234.380 ^a	5156.800 ^a	55.230 ^a	34.215 ^{ab}	2.063 ^a
Control	8.750 ^a	213.610 ^a	4111.300 ^{ab}	56.169 ^a	34.805 ^{ab}	1.645 ^{ab}

Mean along the same column with similar letter(s) are not are not significantly different at (P<0.05) level of significance.

Table 17 shows that eggplant (NGB 01737) intercropped at 3 m recorded the highest values for all the yield components except fruit girth and fruit length. The eggplants planted at the control plot recorded higher fruit girth and length; however, the values were not statistically different from those intercropped at 3 m from juvenile oil palm. Those intercropped at 2 m also recorded values of fruit weight per plant and fruit length that were higher than that recorded for eggplants at the control plot; however, there was no statistical difference.

Table 18: Interaction of Tomato accessions and intercropping distances on growth parameters and yield components of tomato accessions NGB 01665 and NG/AA/SEP/09/053 during first experimental trial

Factors		Number of leaves	Plant height (cm)	Stem girth (mm)	Leaf area (cm ²)	Dry matter (g)	Chlorophyll index	Total chlorophyll content (g/cm ²)	Number of fruits	Fruit weight (g)	Weight of 100 fruits (g)	Fruit circumference (mm)	Fruit length (mm)	Yield/hectare (tonnes/hectare)
Accessions	Tomato NGB 01665	100.156	51.303	4.676	57.833	2.233	44.277	0.03	23.438	1812	7791	48.076	49.366	3.116
	Tomato NG/AA/SEP/09/053	60.156	40.753	3.218	44.624	2.498	44.239	0.029	26.938	1834	7896	46.478	48.232	3.158
Standard error		7.901	3.082	0.210	4.202	0.198	1.078	0.002	2.067	152.575	482.003	0.774	0.912	0.193
Distance	1m	69.625 ^b	43.344 ^b	3.674 ^b	45.382 ^a	2.153 ^a	45.662 ^a	0.031 ^a	14.375 ^b	956.247 ^c	6136 ^b	42.719 ^b	40.760 ^c	2.454 ^b
	2m	62.438 ^b	38.975 ^b	3.666 ^b	47.013 ^a	2.245 ^a	42.712 ^a	0.028 ^a	20.500 ^b	1562 ^{bc}	6926 ^b	45.164 ^b	47.890 ^b	2.770 ^b
	3m	60.688 ^b	39.069 ^b	3.678 ^b	60.536 ^a	2.583 ^a	45.850 ^a	0.032 ^a	30.375 ^a	2126 ^{ab}	8918 ^a	50.591 ^a	53.696 ^a	3.567 ^a
	Control	127.875 ^a	62.725 ^a	4.770 ^a	51.983 ^a	2.480 ^a	42.807 ^a	0.028 ^a	35.500 ^a	2648 ^a	9396 ^a	50.635 ^a	53.050 ^a	3.758 ^a
Standard error		11.173	4.359	0.297	5.943	0.280	1.524	0.002	2.924	215.744	681.655	1.095	1.289	0.273
Interaction	Accession X Distance	*	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Where “*” means interaction was significant and “NS” means interaction was not significant for the respective growth and reproductive parameter.

Table 18 shows the interaction analysis between tomato accessions (NGB 01665 and NG/AA/SEP/09/053) during the second trial. There was no significant interaction in the growth and reproductive parameters between the 2 accessions of tomato except in number of leaves and stem girth as shown in Table 18.

Tomato NGB 01665 recorded highest values in number of leaves, plant height, stem girth, leaf area, chlorophyll index, total chlorophyll content, fruit circumference and fruit length (100.15, 51.30 cm, 4.68 mm, 57.83 cm², 44.28, 0.03 g/cm², 48.08 mm and 49.37 mm respectively).

Based on the intercropping distances, tomato planted at 3 m from the juvenile oil palm highest values for leaf area, dry matter, chlorophyll index, total chlorophyll content and fruit length (60.54 cm², 2.58 g, 45.85, 0.032 g/cm², 53.70 mm respectively).

Table 19: Interaction of pepper accessions and intercropping distances on growth parameters and yield components of tomato accessions NGB 01665 and NG/AA/SEP/09/053 during first experimental trial

Factors		Leaf number	Plant height (cm)	Stem girth (mm)	Leaf area (cm ²)	Dry matter (g)	Chlorophyll index	Total chlorophyll content (g/cm ²)	Fruit number	Fruit weight (mm)	Weight of 100 fruits (g)	Fruit circumference (mm)	Fruit length (mm)	Yield/hectare (tonnes/hectare)
Accessions	Pepper NGB 01312	59.192	28.760	2.828	45.191	2.039	49.324	0.037	53.062	606.106	1238.000	25.694	28.731	495.125
	Pepper NGB 01641	62.150	25.526	4.506	44.531	2.063	45.362	0.571	53.812	565.560	1179.000	24.729	29.863	471.625
Standard error		5.941	1.210	0.341	0.857	0.208	0.958	0.382	4.204	57.369	107.163	1.804	1.069	42.893
Distance	1m	40.100 ^c	21.275 ^c	3.514 ^a	43.050 ^a	1.064 ^c	47.857 ^a	0.035 ^a	28.000 ^c	199.789 ^c	881.827 ^b	18.299 ^b	25.700 ^b	352.250 ^b
	2m	52.360 ^{bc}	26.050 ^{bc}	3.997 ^a	46.048 ^a	1.783 ^{bc}	47.512 ^a	1.113 ^a	50.750 ^b	477.218 ^b	1121.000 ^{ab}	20.686 ^b	25.925 ^b	448.625 ^{ab}
	3m	78.500 ^a	30.120 ^{ab}	3.696 ^a	44.476 ^a	2.541 ^{ab}	46.486 ^a	0.033 ^a	73.625 ^a	956.457 ^a	1481.000 ^a	31.386 ^a	34.575 ^a	592.250 ^a
	Control	71.725 ^{ab}	31.128 ^a	3.461 ^a	45.870 ^a	2.816 ^a	47.516 ^a	0.034 ^a	61.375 ^{ab}	709.869 ^b	1351.000 ^a	30.474 ^a	30.474 ^a	540.375 ^a
Standard error		8.402	1.711	0.482	1.211	0.294	1.354	0.540	5.945	81.132	151.552	2.551	1.512	60.661
Interaction	Accession X Distance	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS

Where “*” means interaction was significant and “NS” means interaction was not significant for the respective growth and reproductive parameter.

Interaction analysis of the 2 pepper accessions (NGB 01312 and NGB 01641) was not significant for all the growth and reproductive parameters except in leaf area where the interaction was significant as shown in Table 19 during the second trial of the experiment.

Pepper NGB 01312 recorded highest values in number of leaves (78.50) and all the reproductive parameters examined.

Table 20: Partial land equivalency ratio (LER) of fruit vegetable crops-juvenile oil palm intercrops during 3rd year of plantation establishment

Vegetable crop accession	Intercrop distance	LER
Tomato (NGB 01665)	1m	0.305
	2m	0.652
	3m	0.797
Tomato (NG/AA/SEP/09/053)	1m	0.416
	2m	0.529
	3m	0.809
Pepper (NGB 01312)	1m	0.243
	2m	0.509
	3m	0.772
Pepper (NGB 01641)	1m	0.245
	2m	0.686
	3m	1.404
Okra (NGB 01184)	1m	0.397
	2m	0.658
	3m	1.447
Eggplant (NGB 01737)	1m	0.922
	2m	1.034
	3m	1.097

Table 20 shows the partial land equivalency ratio of the fruit vegetables during the third year of plantation establishment. Vegetable crops intercropped at 3 m from the juvenile oil palm recorded the highest partial LER values among the intercropping regimes. Pepper (NGB 01641) and okra (NGB 01184) recorded partial LER values greater than unity. Eggplant (NGB 01737) intercropped at 2 and 3 m recorded partial LER values higher than unity (that is, 1) as shown in Table 20.

4.5 Effect of intercropping on the growth of intercropped and non-intercropped juvenile oil palm during 2nd year of plantation establishment

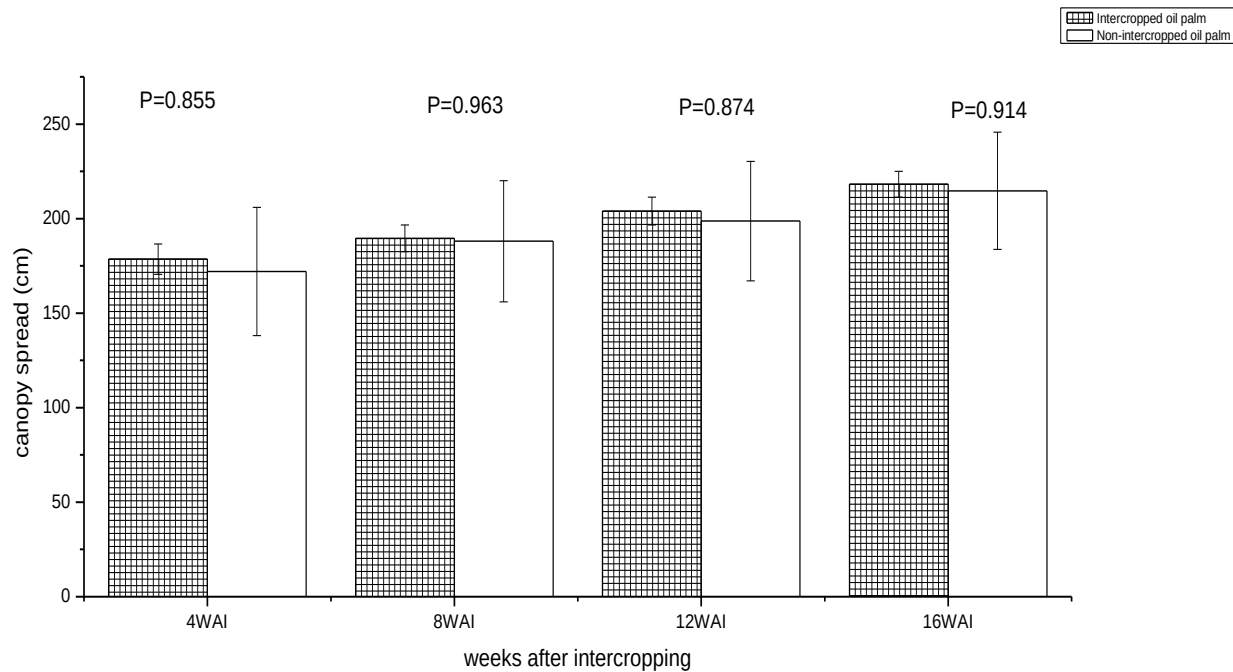


Fig. 73: Canopy Spread of intercropped and non-intercropped juvenile oil palms at 4, 8, 12 and 16 weeks after intercropping. (n= 6).

Bars with the same letter are not significantly different at 95% degree of freedom ($P \leq 0.05$).

Fig. 73 shows that there was no statistical difference between the canopy spread of the intercropped and non-intercropped juvenile oil palm at 4 weeks after intercropping through 16 weeks after intercropping, as none of the P-values are greater or equal to 0.05.

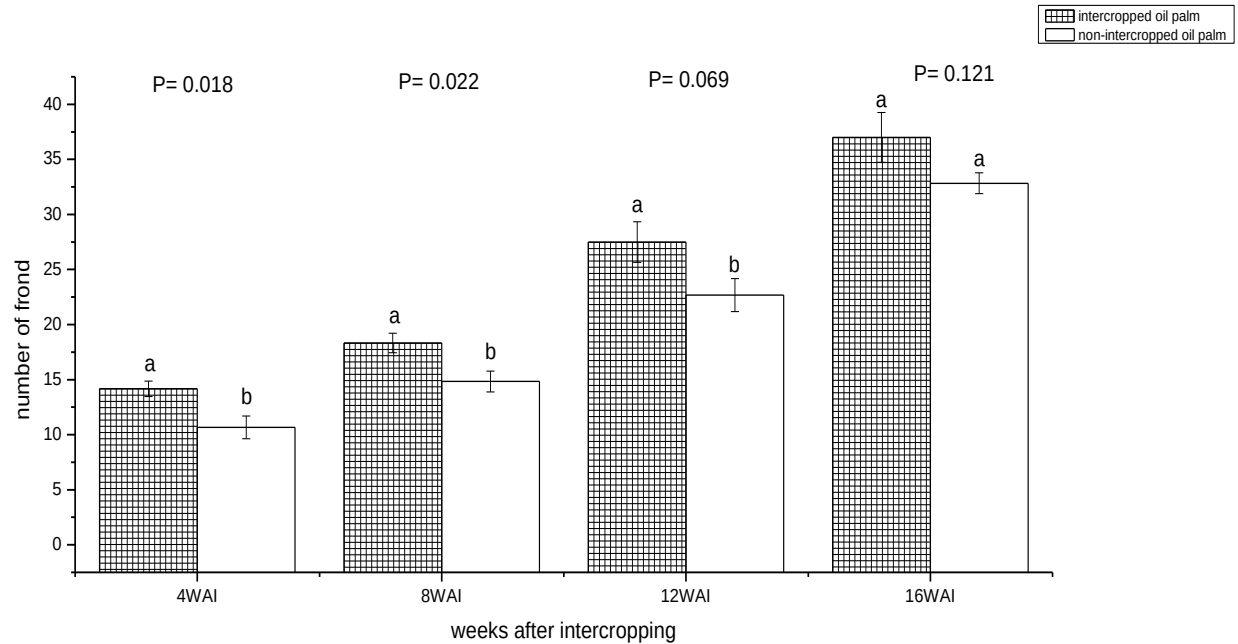


Fig. 74: Number of frond of intercropped and non-intercropped juvenile oil palms at 4, 8, 12 and 16 weeks after intercropping. (n= 6).

Bars with the same letter are not significantly different at 95% degree of confidence ($P \leq 0.05$).

The number of frond of intercropped juvenile oil palm was higher and statistically significant from that of the non-intercropped juvenile oil palm at 4, 8 and 12 weeks after intercropping. However, the mean numbers of frond were not statistically different at 16 weeks after intercropping.

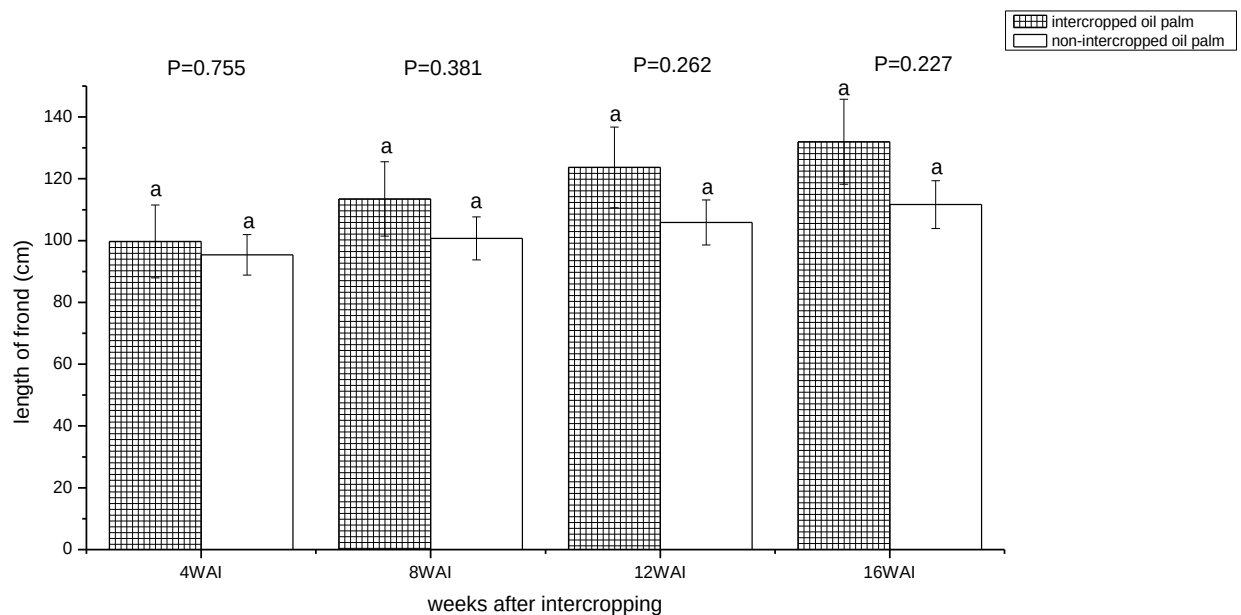


Fig. 75: Length of frond of intercropped and non-intercropped juvenile oil palms at 4, 8, 12 and 16 weeks after intercropping. (n= 6).

Bars with the same letter are not significantly different at 95% degree of confidence ($P \leq 0.05$).

Fig. 75 shows the length of frond of intercropped and non-intercropped juvenile oil palms which were not statistically different at 4 weeks after intercropping (WIA) through 16 WAI, with intercropped juvenile oil palm recording higher values.

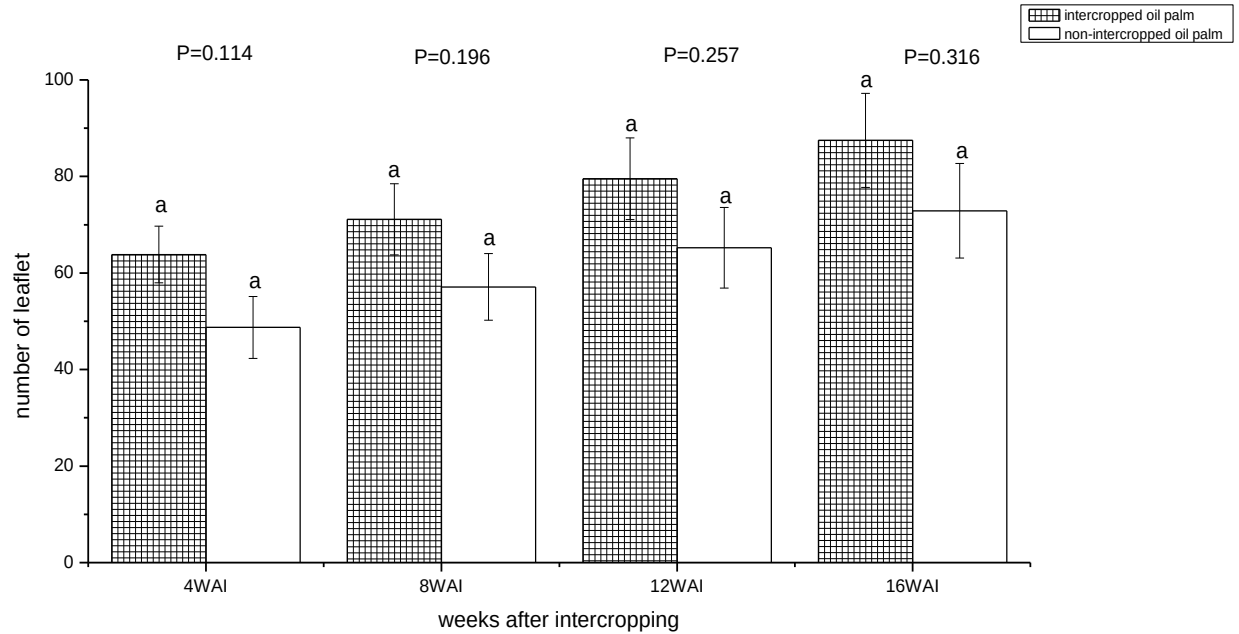


Fig. 76: Number of leaflet of intercropped and non-intercropped juvenile oil palms at 4, 8, 12 and 16 weeks after intercropping. (n= 6).

Bars with the same letter are not significantly different at 95% degree of confidence ($P \leq 0.05$).

Fig. 76 shows that there was no statistical significant between the number of leaflets of intercropped and non-intercropped juvenile oil palm. However, the intercropped juvenile oil palm recorded higher mean number of leaflets at 4 WAI through 16 WAI.

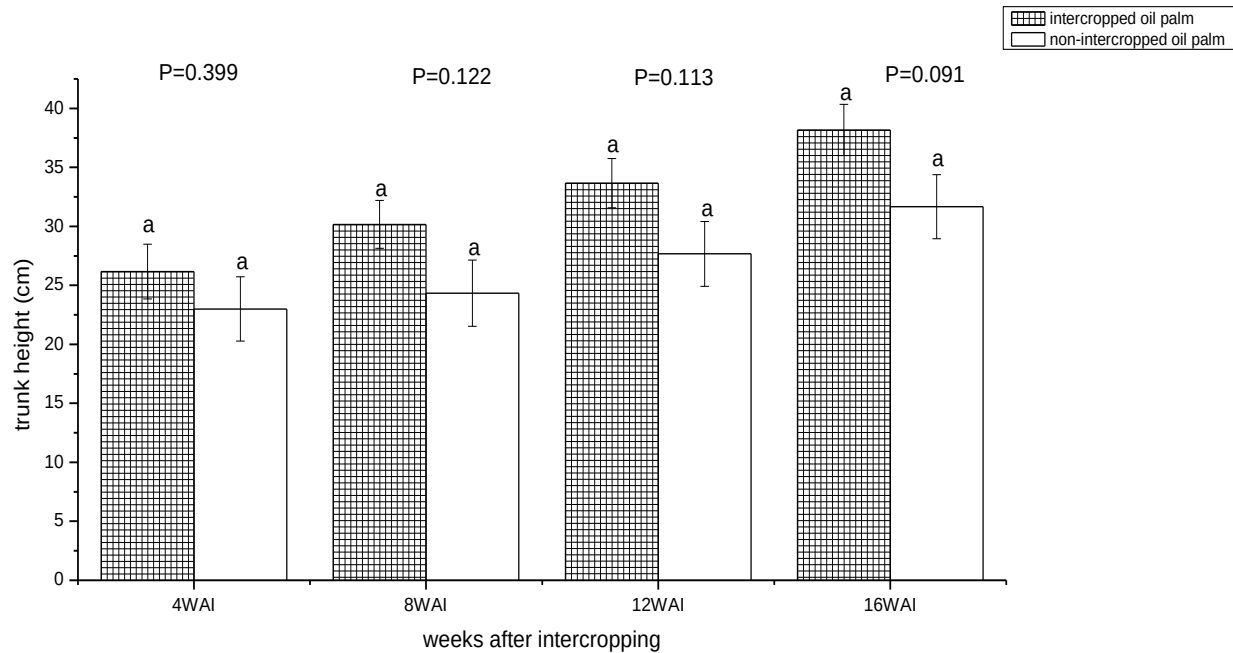


Fig. 77: Trunk height of intercropped and non-intercropped juvenile oil palms at 4, 8, 12 and 16 weeks after intercropping. (n= 6).

Bars with the same letter are not significantly different at 95% degree of confidence ($P \leq 0.05$).

Fig. 77 shows the trunk height of intercropped and non-intercropped juvenile oil palm with the intercropped juvenile oil palm recording higher trunk height values; however, no significant difference was recorded at 4 WAI through 16 WAI.

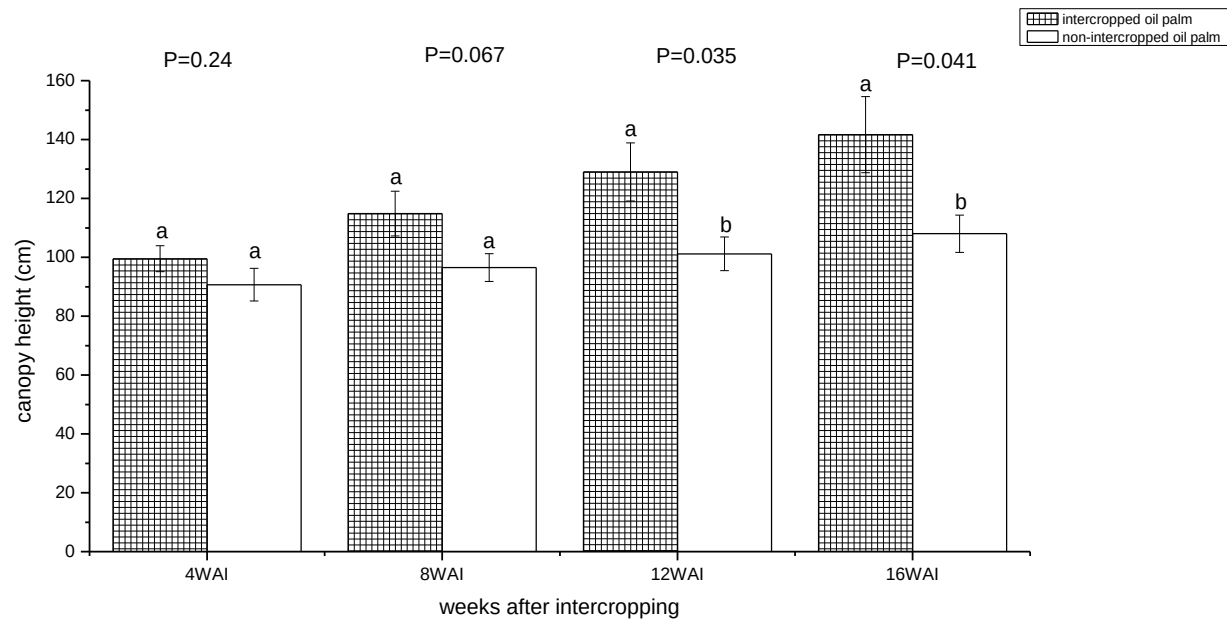


Fig. 78: Canopy height of intercropped and non-intercropped juvenile oil palms after 4, 8, 12 and 16 weeks after intercropping. (n= 6).

Bars with the same letter are not significantly different at 95% degree of confidence ($P \leq 0.05$).

Fig. 78 shows that the canopy height of intercropped juvenile oil palms were higher than the non-intercropped juvenile oil palms; however, they were not statistically significant at 4 and 8 WAI. At 12 and 16 WAI, there were significant differences.

4.6 Effect of intercropping on the growth of intercropped and non-intercropped juvenile oil palm during 3rd year of plantation establishment

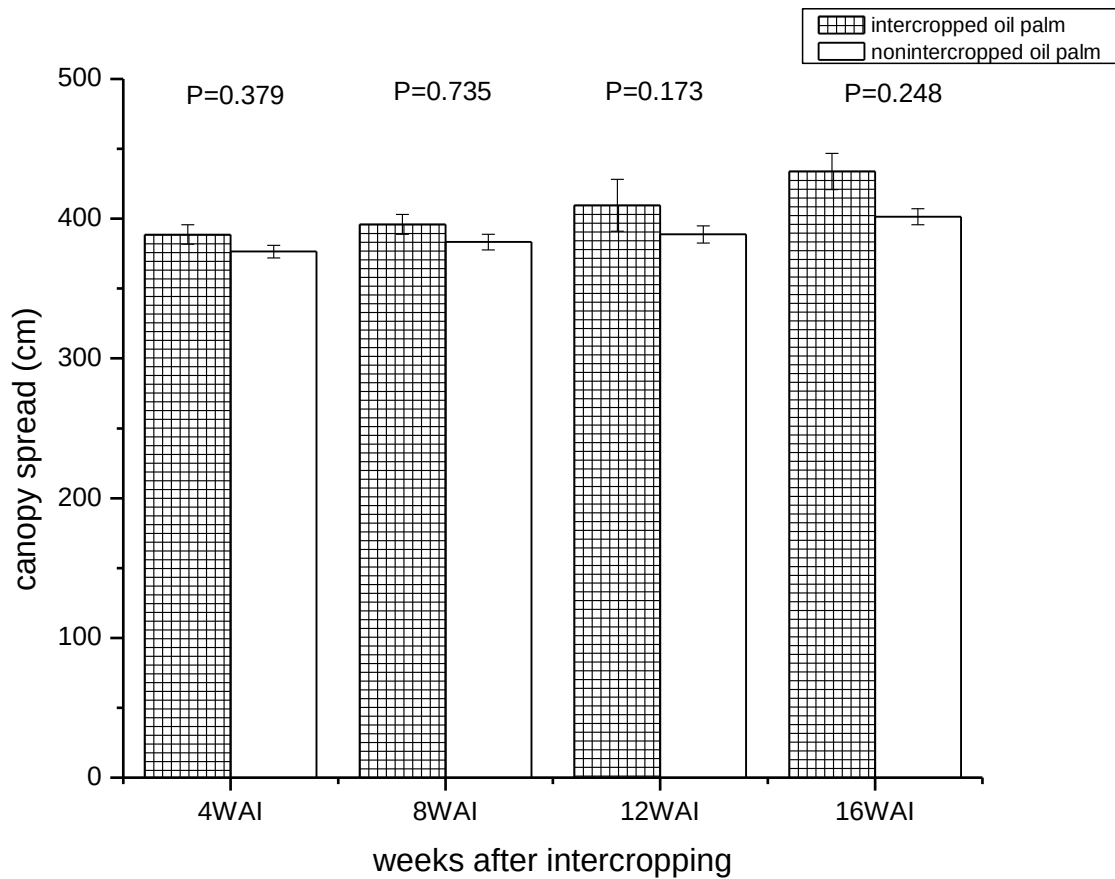


Fig. 79: Effects of intercropping on canopy spread of intercropped and non-intercropped juvenile oil palms at 4, 8, 12 and 16 weeks after intercropping.

Bars with $P \leq 0.05$ are statistically significant at 95% degree of confidence.

The intercropped oil palms recorded higher canopy spread at 4, 8, 12 and 16 weeks after intercropping (WAI). However there was no statistical significance between the canopy spread of intercropped and the non-intercropped juvenile oil palm from 4 WAI to 16 WAI.

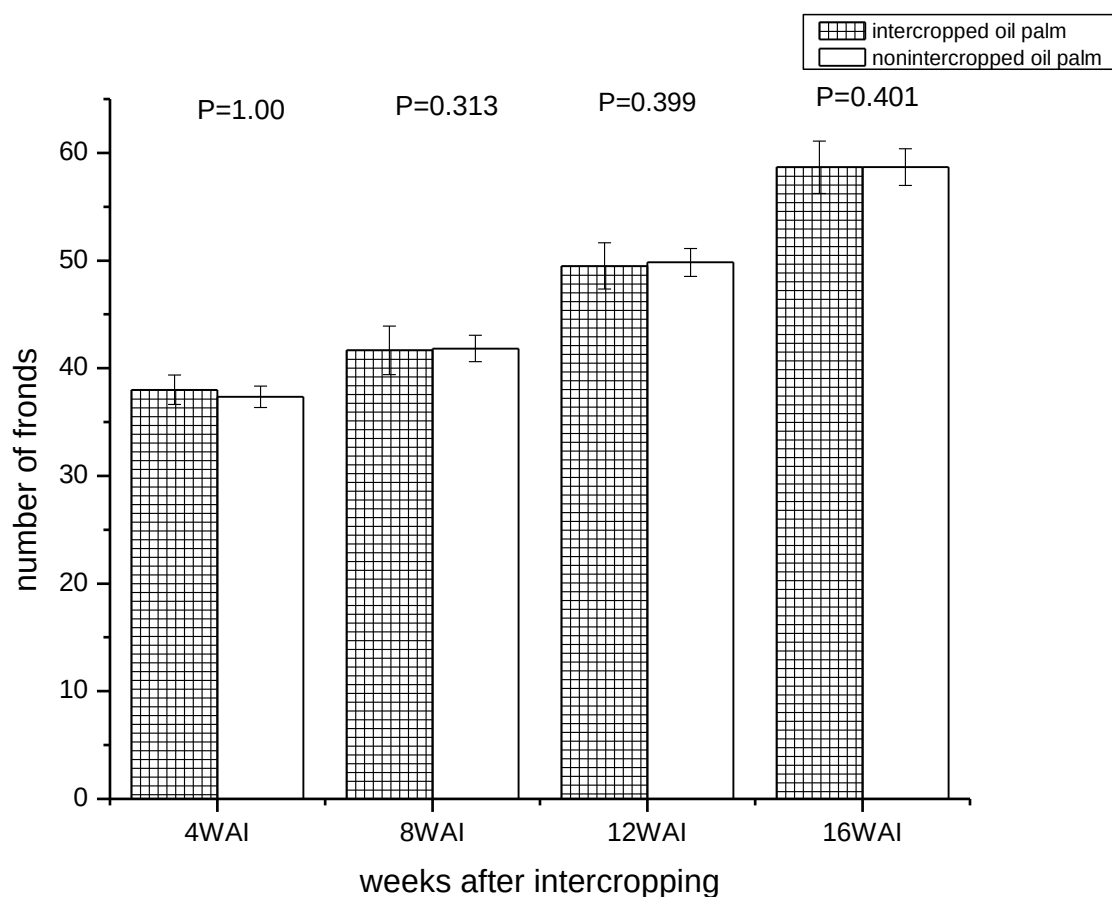


Fig. 80: Effects of intercropping on number of fronds of intercropped and non-intercropped juvenile oil palms at 4, 8, 12 and 16 weeks after intercropping

Bars with $P \leq 0.05$ are statistically significant at 95% degree of confidence.

At 4 WAI, the intercropped oil palm recorded higher number of fronds. The non-intercropped juvenile oil palms recorded higher number of fronds at 8 and 12 WAI. At 16WAI, the intercropped and non-intercropped juvenile oil palm recorded the same mean number of fronds. The mean values of number of fronds for the intercropped and the non-intercropped juvenile oil palms were not statistically significant at 4 WAI through 16 WAI.

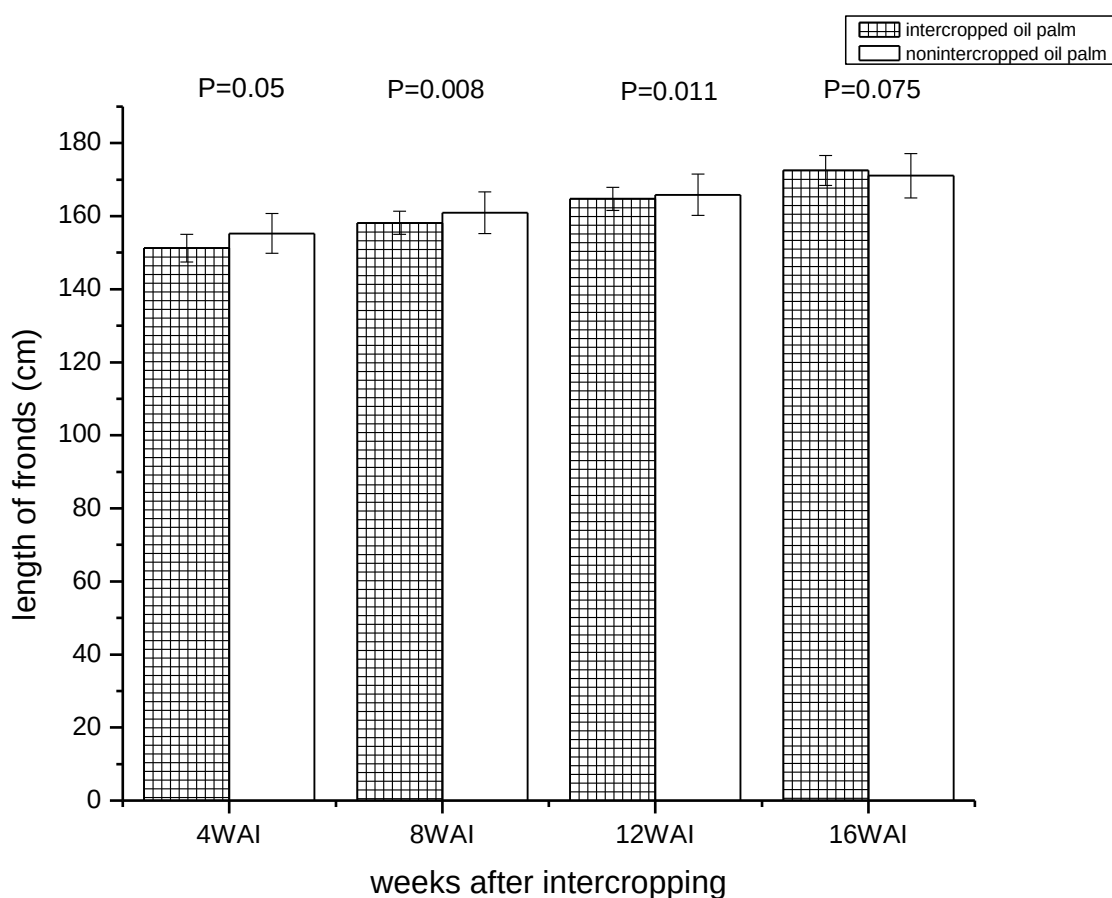


Fig. 81: Effects of intercropping on length of fronds of intercropped and non-intercropped juvenile oil palms at 4, 8, 12 and 16 weeks after intercropping

Bars with $P \leq 0.05$ are statistically different at 95% degree of confidence.

At 4, 8 and 12 WAI, the non-intercropped juvenile oil palms recorded higher length of fronds and were statistically higher than the intercropped oil palms. At 16 WAI, the intercropped oil palms recorded higher length of fronds; however it was not statistically significant.

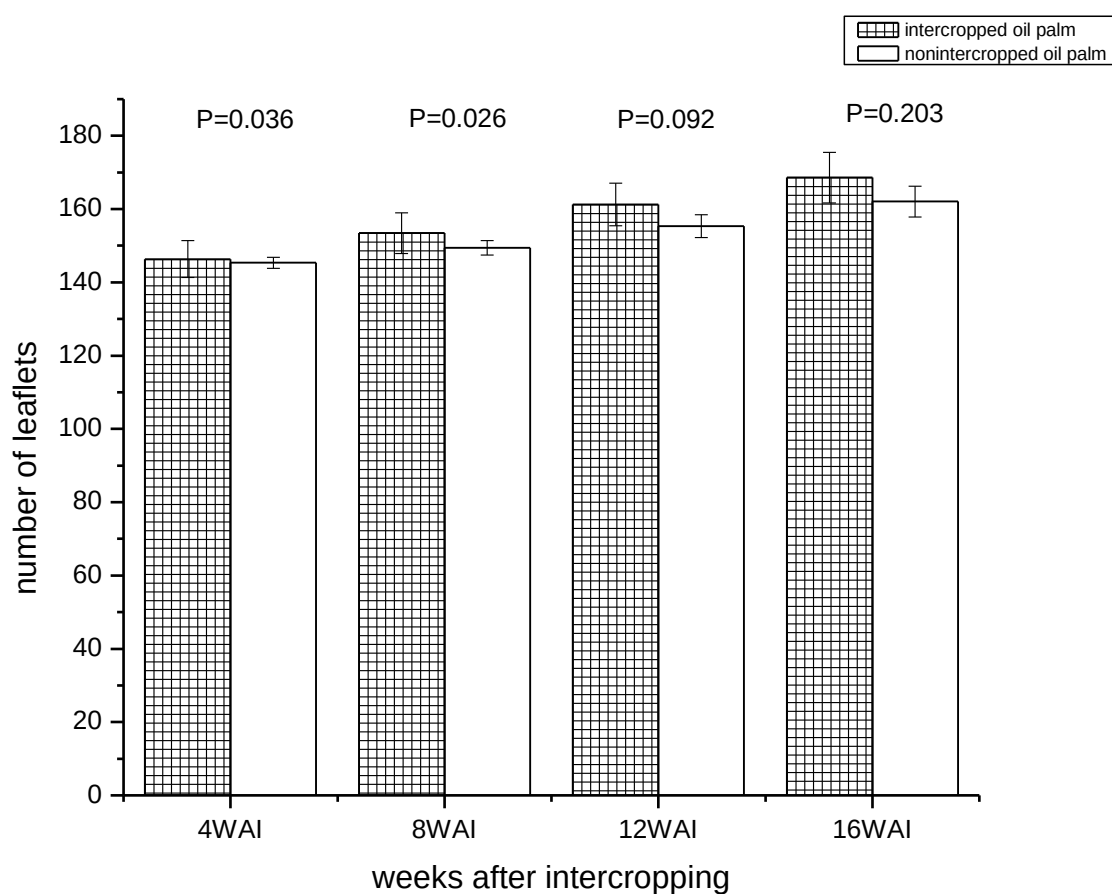


Fig. 82: Effects of intercropping on number of leaflets of intercropped and non-intercropped juvenile oil palms at 4, 8, 12 and 16 weeks after intercropping

Bars with $P \leq 0.05$ are statistically different at 95% degree of confidence.

At 4, 8, 12 and 16 WAI, the intercropped juvenile oil palm recorded higher number of leaflets. However, they were statistically significant at 4 and 8 WAI.

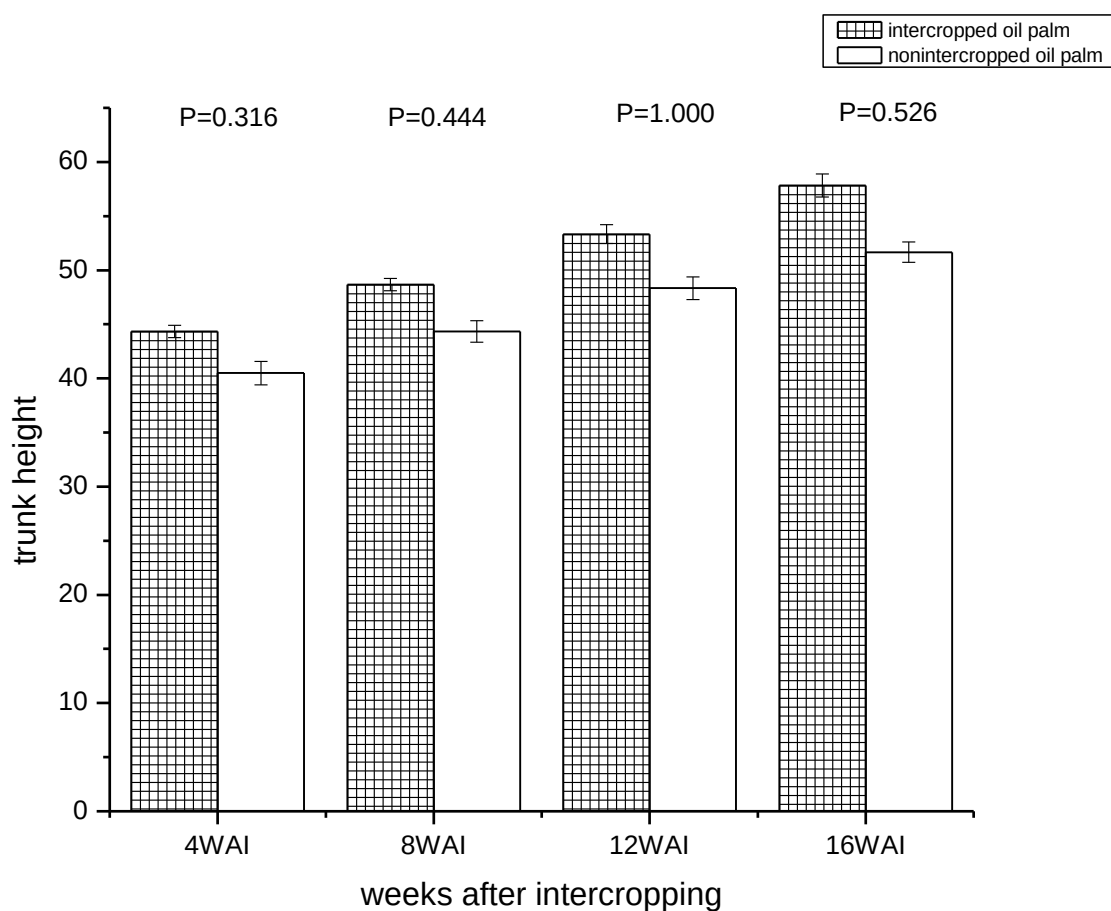


Fig. 83: Effects of intercropping on trunk height of intercropped and non-intercropped juvenile oil palms at 4, 8, 12 and 16 weeks after intercropping

Bars with $P \leq 0.05$ are statistically different at 95% degree of confidence.

The intercropped juvenile oil palms recorded higher trunk height at 4, 8, 12 and 16 WAI; however they were not statistically significant at 4 WAI through 16 WAI.

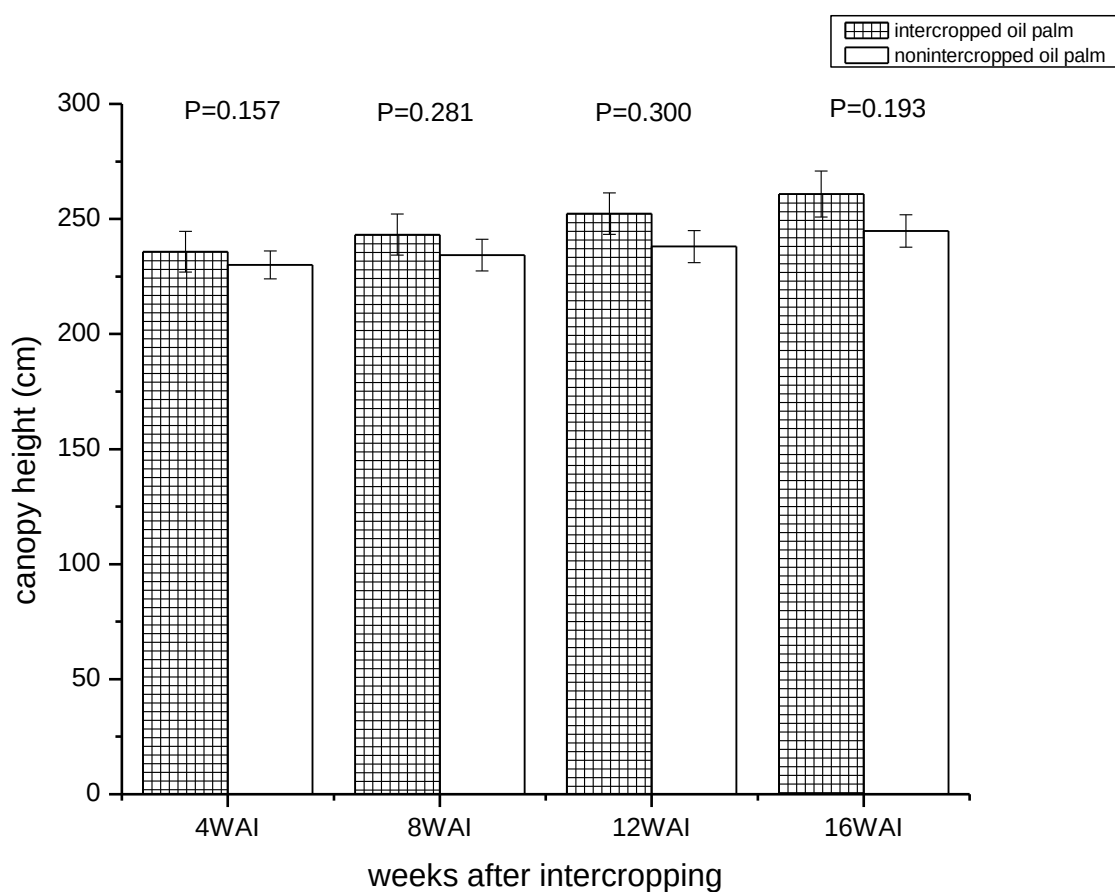


Fig. 84: Effects of intercropping on canopy height of intercropped and non-intercropped juvenile oil palms at 4, 8, 12 and 16 weeks after intercropping

Bars with $P \leq 0.05$ are statistically different at 95% degree of confidence.

Intercropped juvenile oil palms recorded higher canopy spread at 4 WAI through 16 WAI; however, they were not statistically significant.

4.7 Weed species distribution in fruit vegetables-juvenile oil palm plots

4.7.1 Weed flora and species parameters for intercropped plots

Twenty-eight different weed species were found at 3 WAI across the 7 plots sampled. Five species belong to Asteraceae (17.857%), 4 species belong to each of Euphorbiaceae and Poaceae, 2 belong to Malvaceae, 1 species belongs to each of Rubiaceae, Commelinaceae, Convolvulaceae, Cyperaceae, Cleomaceae, Lamiaceae, Portulacaceae, Leguminosae-Papilionoideae, Urticaceae, aizoaceae, Piperaceae, Nyctaginaceae and Loganiaceae.

At 6 weeks after intercropping, 21 weed species were found across the 7 plots sampled. Four (4) of the weed species belong to Poaceae family (19.048%); 3 weed species each belong to families Asteraceae and Euphorbiaceae; 1 weed species each belong to families Portulacaceae, Commelinaceae, Cyperaceae, Piperaceae, Rubiaceae, Solanaceae, Malvaceae, Loganiaceae, Nyctagianaceae, Lamiaceae and Cleomaceae.

After consecutive harvesting of fruits from the vegetables, 20 weed species were found across the 7 plots sampled. Four (4) weed species belong to Poaceae family (20%); 3 weed species belong to Euphorbiaceae family; 2 weed species each belong to Asteraceae and Solanaceae; and 1 weed species each belongs to Commelinaceae, Cyperaceae, Rubiaceae, Laganiaceae, Piperaceae, Malvaceae, Nyctaginaceae, Portulacaceae and Leguminosae-papilionoideae.

The result showed a reduction in the number of weed species at 3 WAI (28) through 6 WAI (21) till after harvesting of fruits from the intercropped vegetables (20).

Summarily:

At 3 WAI, a total of 23 broadleaves, 4 grasses and 1 sedge weed species were found.

At 6 WAI, a total of 16 broadleaves, 4 grasses and 1 sedge weed species were found.

After harvesting, a total of 15 broadleaves, 4 grasses and 1 sedge weed species were found.

Results of weed flora and species parameters at fruit vegetable/ juvenile oil palm intercropped plots are presented in Tables 21 – 41.

Table 21: Weed flora and species parameters for tomato (NGB 01665) plot at 3 WAI

	Weed species	Q1	Q2	Q3	Q4	Q5	Total	Frequency	Density	Relative frequency	Relative density	Importance value	Abundance	Dominance	Relative dominance
1	<i>Ageratum conizoides</i> Linn.	6	10	5	4	10	35	5	28.0	9.4	6.7	16.1	8.1	560.0	6.2
2	<i>Borreria ocymoides</i> (Burm. f.) DC.	32	62	28	45	30	193	5	154.4	9.4	36.9	46.3	23.2	3088.0	34.1
3	<i>Brachiaria deflexa</i> (Schumach.) C.E. Hubbard ex Robyns	5	12	5	4	0	26	4	26.0	7.5	6.2	13.8	6.9	650.0	7.2
4	<i>Cleome rutidosperma</i> DC.	0	1	0	2	0	1	1	4.0	7.5	1.0	8.5	4.3	400.0	4.4
5	<i>Commelina benghalensis</i> L.	6	5	6	6	5	28	5	22.5	9.4	5.4	14.8	7.4	450.0	5.0
6	<i>Digitaria horizontalis</i> Willd.	12	21	11	5	5	53	5	43.2	9.4	10.3	19.8	9.9	864.0	9.5
7	<i>Euphorbia heterophylla</i> Linn.	0	1	1	1	0	4	3	5.3	5.7	1.3	6.9	3.5	177.7	2.0
8	<i>Euphorbia hirta</i> Linn.	1	3	5	1	0	10	4	10.0	7.5	2.4	9.9	5.0	250.0	2.8
9	<i>Evolvulus alsinoides</i> (Linn.) Linn.	4	2	4	4	15	29	5	23.5	9.4	5.6	15.1	7.5	470.0	5.2
10	<i>Mariscus alternifolius</i> Vahl. (=M. umbellatus Vahl.)	23	6	21	14	12	76	5	60.8	9.4	14.5	24.0	12.0	1216.0	13.4
11	<i>Paspalum conjugatum</i> Berg.	0	1	0	1	2	4	3	5.3	5.7	1.3	6.9	3.5	177.7	2.0
12	<i>Phyllanthus amarus</i> Schum. & Thonn.	8	5	12	6	8	39	5	31.2	9.4	7.5	16.9	8.4	624.0	6.9
13	<i>Sida acuta</i> Burm. f.	1	0	0	1	1	3	3	4.0	5.7	1.0	6.6	3.3	133.3	1.5

WAI: weeks after intercropping

Q 1 – 5: Quadrat 1 – 5.

Table 22: Weed flora and species parameters for tomato (NGB 01665) plot at 6 WAI

Weed species	Q1	Q2	Q3	Q4	Q5	Total	Frequency	Density	Relative frequency	Relative density	Importance value	Abundance	Dominance	Relative dominance
1 <i>Ageratum conizoides</i> Linn.	15	6	6	8	4	39	5	31.2	10.9	7.6	18.5	9.2	624.0	7.0
2 <i>Bidens pilosa</i> Linn.	6	13	0	7	5	31	4	31.0	8.7	7.6	16.3	8.1	775.0	8.6
3 <i>Boerhavia diffusa</i> L.	2	10	1	6	6	25	5	20.0	10.9	4.9	15.7	7.9	400.0	4.5
4 <i>Borreria ocymoides</i> (Burm. f.) DC.	6	16	18	6	9	49	5	39.2	10.9	9.6	20.4	10.2	784.0	8.7
5 <i>Commelina benghalensis</i> L.	1	1	0	0	0	2	2	4.0	4.3	1.0	5.3	2.7	200.0	2.2
6 <i>Croton lobatus</i> L.	2	2	0	1	0	5	3	6.7	6.5	1.6	8.1	4.1	222.2	2.5
7 <i>Hyptis lanceolata</i> Poir.	2	1	0	0	0	3	2	6.0	4.3	1.5	5.8	2.9	300.0	3.3
8 <i>Mariscus alternifolius</i> Vahl. (=M. <i>umbellatus</i> Vahl.)	15	10	9	15	6	55	5	44.0	10.9	10.7	21.6	10.8	880.0	9.8
9 <i>Peperomia pellucida</i> (L.) H. B. & K.	30	28	56	41	76	231	5	184.8	10.9	45.1	55.9	28.0	3696.0	41.2
10 <i>Setaria barbata</i> (Lam.) Kunth	18	6	5	3	7	39	5	31.2	10.9	7.6	18.5	9.2	624.0	7.0
11 <i>Sida acuta</i> Burm. f.	0	0	1	0	1	2	2	4.0	4.3	1.0	5.3	2.7	200.0	2.2
12 <i>Solanum nigrum</i> L.	3	2	0	1	0	6	3	8.0	6.5	2.0	8.5	4.2	266.7	3.0

WAI: weeks after intercropping

Q 1 – 5: Quadrat 1 – 5.

Table 23: Weed flora and species parameters for tomato (NGB 01665) plot after harvesting

	Weed species	Q1	Q2	Q3	Q4	Q5	Total	Frequency	Density	Relative frequency	Relative density	Importance value	Abundance	Dominance	Relative dominance
1	<i>Ageratum conizoides</i> Linn.	53	32	28	41	32	185	5	148.0	10.2	34.9	45.1	22.5	2960.0	31.3
2	<i>Bidens pilosa</i> Linn.	0	3	0	2	8	13	3	17.3	6.1	4.1	10.2	5.1	577.8	6.1
3	<i>Borreria ocymoides</i> (Burm. f.) DC.	3	4	12	9	15	43	5	34.4	10.2	8.1	18.3	9.2	688.0	7.3
4	<i>Commelina benghalensis</i> L.	8	14	14	10	6	52	5	41.6	10.2	9.8	20.0	10.0	832.0	8.8
5	<i>Euphorbia heterophylla</i> Linn.	0	4	0	4	3	11	3	14.7	6.1	3.5	9.6	4.8	488.9	5.2
5	<i>Mariscus alternifolius</i> Vahl. (=M. <i>umbellatus</i> Vahl.)	6	13	4	6	3	32	5	25.6	10.2	6.0	16.2	8.1	512.0	5.4
6	<i>Peperomia pellucida</i> (L.) H. B. & K.	0	2	5	0	8	15	3	20.0	6.1	4.7	10.8	5.4	666.7	7.1
7	<i>Phyllanthus amarus</i> Schum. & Thonn.	1	5	0	3	2	11	4	11.0	8.2	2.6	10.8	5.4	275.0	2.9
8	<i>Physalis angulata</i> Linn.	3	1	0	1	0	4	3	5.3	6.1	1.3	7.4	3.7	177.8	1.9
9	<i>Spigelia anthelmia</i> Linn.	20	25	12	10	19	86	5	68.8	10.2	16.2	26.4	13.2	1376.0	14.6
10	<i>Solanum nigrum</i> L.	2	10	2	14	6	34	5	27.2	10.2	6.4	16.6	8.3	544.0	5.8

WAI: weeks after intercropping

Q 1 – 5: Quadrat 1 – 5.

Table 24: Weed flora and species parameters for tomato (NG/AA/SEP/09/053) plot at 3 WAI

Weed species		Q1	Q2	Q3	Q4	Q5	Total	Frequency	Density	Relative frequency	Relative density	Importance value	Abundance	Dominance	Relative dominance
1	<i>Ageratum conizoides</i> Linn.	3	15	16	18	10	62	5	49.6	9.6	16.5	26.1	13.0	992.0	11.9
2	<i>Axonopus compressus</i> (Sw.) P. Beauv.	0	1	1	2	3	7	4	7.0	7.7	2.3	10.2	5.0	175.0	2.1
3	<i>Bidens pilosa</i> Linn.	1	0	1	0	2	4	3	5.3	5.8	1.8	7.5	3.8	177.7	2.1
4	<i>Borreria ocymoides</i> (Burm. f.) DC.	38	5	6	5	8	62	5	49.6	9.6	16.5	26.1	13.0	992.0	11.9
5	<i>Brachiaria deflexa</i> (Schumach.) C.E. Hubbard ex Robyns	12	8	8	10	4	42	5	33.6	9.6	11.2	20.8	10.4	672.0	7.5
6	<i>Digitaria horizontalis</i> Willd.	7	9	3	9	10	38	5	30.4	9.6	10.1	19.7	9.9	608.0	7.3
7	<i>Euphorbia hirta</i> Linn.	0	1	0	0	0	1	1	4.0	1.9	2.3	3.3	1.6	400.0	4.8
8	<i>Evolvulus alsinoides</i> (Linn.) Linn.	0	2	0	3	1	6	3	8.0	5.8	2.7	8.4	4.2	266.7	3.2
9	<i>Hyptis lanceolata</i> Poir.	2	0	0	0	0	2	1	8.0	1.9	2.7	4.6	2.3	800.0	9.6
10	<i>Mariscus alternifolius</i> Vahl. (= <i>M. umbellatus</i> Vahl.)	2	0	1	0	0	3	2	6.0	3.8	2.0	5.8	2.9	300.0	3.6
11	<i>Paspalum conjugatum</i> Berg.	0	2	0	0	2	4	2	8.0	3.8	2.7	6.5	3.3	400.0	4.8
12	<i>Pouzolzia guineensis</i> Benth.	0	1	1	0	0	2	2	4.0	3.8	1.3	5.2	2.6	200.0	2.4
13	<i>Synedrella nodiflora</i> Gaertn.	5	16	15	8	6	50	5	40.0	9.6	13.3	22.9	11.4	800.0	9.6
14	<i>Talinum triangulare</i> (Jacq.) Willd.	0	4	4	0	6	14	3	18.7	5.8	6.2	12.0	6.0	622.3	7.5
15	<i>Tephrosia pedicellata</i> Bak.	0	3	0	1	0	4	2	8.0	3.8	2.7	6.5	3.3	400.0	4.8
16	<i>Tridax procumbens</i> Linn.	8	4	3	0	6	21	4	21.0	7.7	7.0	14.7	7.3	525.0	6.3

WAI: weeks after intercropping

Q 1 – 5: Quadrat 1 – 5.

Table 25: Weed flora and species parameters for tomato (NG/AA/SEP/09/053) plot at 6 WAI

	Weed species	Q1	Q2	Q3	Q4	Q5	Total	Frequency	Density	Relative frequency	Relative density	Importance value	Abundance	Dominance	Relative dominance
1	<i>Ageratum conizoides</i> Linn.	21	14	12	6	14	67	5	53.6	12.2	20.6	32.8	16.4	1072.0	17.7
2	<i>Bidens pilosa</i> Linn.	4	18	5	5	14	46	5	36.8	12.2	14.1	26.3	13.2	736.0	12.2
3	<i>Borreria ocymoides</i> (Burm. f.) DC.	0	4	1	3	0	8	3	10.7	7.3	4.1	11.4	5.7	355.6	5.9
4	<i>Commelina benghalensis</i> L.	17	2	10	10	6	45	5	36.0	12.2	13.8	26.0	13.0	720.0	11.9
5	<i>Euphorbia hirta</i> Linn.	0	2	1	0	2	5	3	6.7	7.3	2.6	9.9	4.9	233.3	3.9
6	<i>Mariscus alternifolius</i> Vahl. (=M. <i>umbellatus</i> Vahl.)	0	2	2	0	0	4	2	8.0	4.9	3.0	7.9	4.0	400.0	6.6
7	<i>Peperomia pellucida</i> (L.) H. B. & K.	10	7	5	12	7	41	5	32.8	12.2	12.6	24.8	12.4	656.0	10.8
8	<i>Phyllanthus amarus</i> Schum. & Thonn.	0	2	0	1	1	4	3	5.3	7.3	2.0	9.4	4.7	177.7	2.9
9	<i>Setaria barbata</i> (Lam.) Kunth	11	25	17	11	9	73	5	58.4	12.2	22.4	34.0	17.3	1168.0	876.0
10	<i>Solanum nigrum</i> L.	0	1	1	1	0	3	3	4.0	7.3	1.5	8.9	4.4	133.3	2.2
11	<i>Talinum triangulare</i> (Jacq.) Willd.	1	0	0	3	0	4	2	8.0	4.9	3.0	7.9	4.0	400.0	6.6

WAI: weeks after intercropping

Q 1 – 5: Quadrat 1 – 5.

Table 26: Weed flora and species parameters for tomato (NG/AA/SEP/09/053) plot after harvesting

Weed species		Q1	Q2	Q3	Q4	Q5	Total	Frequency	Density	Relative frequency	Relative density	Importance value	Abundance	Dominance	Relative dominance
1	<i>Ageratum conizoides</i> Linn.	5	2	0	12	6	25	4	25.0	9.3	8.1	17.4	8.7	625.0	8.1
2	<i>Bidens pilosa</i> Linn.	1	0	1	2	2	6	4	6.0	9.3	2.0	11.6	5.6	150.0	1.9
3	<i>Borreria ocymoides</i> (Burm. f.) DC.	36	25	38	16	18	133	5	106.4	11.6	34.6	46.3	23.1	2128.0	27.5
4	<i>Brachiaria deflexa</i> (Schumach.) C.E. Hubbard ex Robyns	13	6	6	2	9	36	5	28.8	11.6	9.4	21.0	10.5	576.0	7.4
5	<i>Brachiaria lata</i> (Schumach) C.E. Hubbard	8	8	6	2	0	24	4	24.0	9.3	7.8	17.1	8.6	600.0	7.7
6	<i>Commelina benghalensis</i> L.	0	0	6	4	4	14	3	18.7	7.0	6.1	13.1	6.5	622.2	8.0
7	<i>Euphorbia hirta</i> Linn.	0	1	0	0	1	2	2	4.0	4.7	1.3	6.0	3.0	200.0	2.6
8	<i>Mariscus alternifolius</i> Vahl. (=M. <i>umbellatus</i> Vahl.)	7	7	1	6	2	23	5	18.4	11.6	6.0	17.6	8.8	368.0	4.7
9	<i>Phyllanthus amarus</i> Schum. & Thonn.	4	3	11	7	7	32	5	25.6	11.6	8.3	20.0	10.0	517.0	6.6
10	<i>Setaria barbata</i> (Lam.) Kunth	6	4	15	13	10	48	5	38.4	11.6	12.5	24.1	12.1	768.0	9.9

WAI: weeks after intercropping

Q 1 – 5: Quadrat 1 – 5.

Table 27: Weed flora and species parameters for pepper (NGB 01312) plot at 3 WAI

Weed species		Q1	Q2	Q3	Q4	Q5	Total	Frequency	Density	Relative frequency	Relative density	Importance value	Abundance	Dominance	Relative dominance
1	<i>Acalypha fimbriata</i> Schum. & Thonn. (<i>Acalypha ciliata</i> Forsk.)	1	0	0	0	3	4	2	8.0	3.3	1.9	5.3	2.6	400.0	5.3
2	<i>Ageratum conizoides</i> Linn.	7	4	12	6	2	31	5	24.8	8.3	6.0	14.3	7.2	496.0	6.6
3	<i>Bidens pilosa</i> Linn.	8	1	9	7	12	37	5	29.6	8.3	7.2	15.5	7.7	592.0	7.9
4	<i>Borreria ocymoides</i> (Burm. f.) DC.	26	35	42	42	40	185	5	148.0	8.3	35.8	44.1	22.1	296.0	4.0
5	<i>Brachiaria deflexa</i> (Schumach.) C.E. Hubbard ex Robyns	14	4	6	9	4	37	5	29.6	8.3	7.2	15.5	7.7	592.0	7.9
6	<i>Cleome rutidosperma</i> DC.	0	1	0	0	0	1	1	4.0	1.7	1.0	2.6	1.3	400.0	5.3
7	<i>Corchorus olitorius</i> Linn.	1	0	0	0	3	4	2	8.0	8.3	1.9	5.3	2.6	400.0	5.3
8	<i>Digitaria horizontalis</i> Willd.	1	14	3	5	6	29	5	23.2	8.3	5.6	13.9	7.0	464.0	6.2
9	<i>Euphorbia heterophylla</i> Linn.	1	0	1	0	0	2	2	4.0	3.3	1.0	4.3	2.2	200.0	2.7
10	<i>Euphorbia hirta</i> Linn.	0	2	3	1	0	6	3	8.0	5.0	1.9	6.9	3.5	266.7	3.6
11	<i>Hyptis lanceolata</i> Poir.	1	0	7	6	2	16	4	16.0	6.7	3.9	10.5	5.3	400.0	5.3
12	<i>Pouzolzia guineensis</i> Benth.	1	0	5	0	2	8	3	10.7	5.0	2.6	7.6	3.8	355.7	4.8
13	<i>Sclerocarpus africanus</i> Jacq. Ex. Murr.	10	6	15	2	10	43	5	34.4	8.3	8.3	16.7	8.3	688.0	9.2
14	<i>Synedrella nodiflora</i> Gaertn.	0	12	10	6	8	36	4	36.0	6.7	8.7	15.4	7.7	900.0	12.0
15	<i>Talinum triangulare</i> (Jacq.) Willd.	0	2	0	0	1	3	2	6.0	3.3	1.5	4.8	2.4	300.0	4.0
16	<i>Tephrosia pedicellata</i> Bak.	2	0	7	0	4	13	3	17.3	5.0	4.2	9.2	4.6	577.7	7.7
17	<i>Trianthema portulacastrum</i> Linn.	1	0	1	3	1	6	4	6.0	6.7	1.5	8.1	4.1	150.0	2.0

WAI: weeks after intercropping

Q 1 – 5: Quadrat 1 – 5.

Table 28: Weed flora and species parameters for pepper (NGB 01312) plot at 6 WAI

Weed species	Q1	Q2	Q3	Q4	Q5	Total	Frequency	Density	Relative frequency	Relative density	Importance value	Abundance	Dominance	Relative dominance
1 <i>Ageratum conizoides</i> Linn.	10	27	5	4	10	56	5	44.8	10.0	8.8	18.8	9.4	896.0	7.0
2 <i>Axonopus compressus</i> (Sw.) P. Beauv.	33	10	17	23	16	99	5	79.2	10.0	15.5	25.5	12.7	1584.0	12.3
3 <i>Bidens pilosa</i> Linn.	44	36	22	16	25	143	5	114.4	10.0	22.4	32.4	16.2	2288.0	17.8
4 <i>Boerhavia diffusa</i> L.	2	5	0	3	1	11	4	11.0	8.0	2.1	10.1	5.1	275.0	2.1
5 <i>Commelina benghalensis</i> L.	14	1	12	5	5	37	5	29.6	10.0	5.8	15.8	7.9	592.0	4.6
6 <i>Croton lobatus</i> L.	0	3	0	0	0	3	1	12.0	2.0	2.3	4.3	2.2	1200.0	9.3
7 <i>Hyptis lanceolata</i> Poir.	0	3	1	0	0	4	2	8.0	4.0	1.6	5.6	2.8	400.0	3.1
8 <i>Mariscus alternifolius</i> Vahl. (= <i>M. umbellatus</i> Vahl.)	53	7	13	21	11	105	5	84.0	10.0	16.4	26.4	13.2	1680.0	13.1
9 <i>Peperomia pellucida</i> (L.) H. B. & K.	10	11	3	6	6	36	5	28.8	10.0	5.6	15.6	7.8	576.0	4.5
10 <i>Phyllanthus amarus</i> Schum. & Thonn.	0	2	0	1	3	6	3	8.0	6.0	1.6	7.6	3.8	266.7	2.1
11 <i>Setaria barbata</i> (Lam.) Kunth	12	46	22	24	14	118	5	94.4	10.0	18.4	28.4	14.2	1888.0	14.7
12 <i>Spigelia anthelmia</i> Linn.	9	15	7	2	5	38	5	30.4	10.0	5.9	15.9	8.0	608.0	4.7
13 <i>Tridax procumbens</i> Linn.	0	4	0	0	2	6	2	12.0	4.0	2.3	6.3	3.2	600.0	4.7

WAI: weeks after intercropping

Q 1 – 5: Quadrat 1 – 5.

Table 29: Weed flora and species parameters for pepper (NGB 01312) plot after intercropping

Weed species	Q1	Q2	Q3	Q4	Q5	Total	Frequency	Density	Relative frequency	Relative density	Importance value	Abundance	Dominance	Relative dominance
1 <i>Ageratum conizoides</i> Linn.	10	12	20	14	15	71	5	56.8	11.1	11.1	22.2	11.1	1136.0	9.1
2 <i>Borreria ocymoides</i> (Burm. f.) DC.	75	56	38	32	35	236	5	188.8	11.1	37.0	48.1	24.0	3776.0	30.3
3 <i>Brachiaria deflexa</i> (Schumach.) C.E. Hubbard ex Robyns	6	0	12	9	6	33	4	33.0	8.9	6.5	15.3	7.7	825.0	6.6
4 <i>Brachiaria lata</i> (Schumach) C.E. Hubbard	0	7	7	0	3	17	3	22.7	6.7	4.4	11.1	5.6	755.6	6.1
5 <i>Commelina benghalensis</i> L.	6	6	5	6	12	35	5	28.0	11.1	5.5	16.6	8.3	560.0	4.5
6 <i>Euphorbia heterophylla</i> Linn.	3	2	4	7	0	16	4	16.0	8.9	3.1	12.0	6.0	400.0	3.2
7 <i>Euphorbia hirta</i> Linn.	0	8	6	0	0	14	2	28.0	4.4	5.5	9.9	5.0	1400.0	11.2
8 <i>Mariscus alternifolius</i> Vahl. (=M. <i>umbellatus</i> Vahl.)	0	8	2	6	4	20	4	20.0	8.9	3.9	12.8	6.4	500.0	4.0
9 <i>Spigelia anthelmia</i> Linn.	4	0	0	2	2	8	3	4.6	6.7	0.9	7.6	3.8	152.4	1.2
10 <i>Sporobolous pyramidalis</i> P. Beauv.	36	13	14	21	24	108	5	86.4	11.1	16.9	28.0	14.0	1728.0	13.9
11 <i>Talinum triangulare</i> (Jacq.) Willd.	0	3	0	1	1	5	3	6.7	6.7	1.3	8.0	4.0	222.2	1.8
12 <i>Tridax procumbens</i> Linn.	0	6	4	0	0	10	2	20.0	4.4	3.9	8.4	4.2	1000.0	8.0

WAI: weeks after intercropping

Q 1 – 5: Quadrat 1 – 5.

Table 30: Weed flora and species parameters for pepper (NGB 01641) plot at 3 WAI

Weed species	Q1	Q2	Q3	Q4	Q5	Total	Frequency	Density	Relative frequency	Relative density	Importance value	Abundance	Dominance	Relative dominance
1 <i>Bidens pilosa</i> Linn.	2	10	17	3	8	40	5	32.0	8.3	8.3	16.7	8.3	640.0	9.2
2 <i>Borreria ocymoides</i> (Burm. f.) DC.	33	30	28	40	18	149	5	119.2	8.3	31.0	39.4	19.7	23.8	0.3
3 <i>Brachiaria deflexa</i> (Schumach.) C.E. Hubbard ex Robyns	12	22	18	9	4	65	5	52.0	8.3	13.5	21.9	10.9	1040.0	14.9
4 <i>Corchorus olitorius</i> Linn.	1	0	0	1	0	2	2	4.0	3.3	1.0	4.4	2.2	200.0	2.9
5 <i>Digitaria horizontalis</i> Willd.	7	0	3	2	4	16	4	16.0	6.7	4.2	10.8	5.4	400.0	5.7
6 <i>Euphorbia heterophylla</i> Linn.	5	3	4	8	12	32	5	42.7	8.3	11.1	19.4	9.7	853.4	12.2
7 <i>Hyptis lanceolata</i> Poir.	0	1	1	2	0	4	3	5.3	5.0	1.4	6.4	3.2	177.7	2.5
8 <i>Mariscus alternifolius</i> Vahl. (=M. <i>umbellatus</i> Vahl.)	2	0	8	0	3	13	3	17.3	5.0	9.0	14.0	7.0	577.7	8.3
9 <i>Paspalum conjugatum</i> Berg.	1	0	1	1	3	6	4	6.0	6.7	1.6	8.2	4.1	150.0	2.1
10 <i>Peperomia pellucida</i> (L.) H. B. & K.	0	1	0	0	0	1	1	4.0	1.7	1.0	2.7	1.4	400.0	5.7
11 <i>Phyllanthus amarus</i> Schum. & Thonn.	0	1	3	3	2	9	4	9.0	6.7	2.3	9.0	4.5	225.0	3.2
12 <i>Pouzolzia guineensis</i> Benth.	0	1	0	0	2	3	2	6.0	3.3	1.6	4.9	2.4	300.0	4.3
13 <i>Solanum nigrum</i> L.	1	0	0	1	3	5	3	6.7	5.0	1.7	5.7	2.9	222.3	3.2
14 <i>Synedrella nodiflora</i> Gaertn.	6	14	8	10	3	41	5	32.8	8.3	8.5	16.9	8.4	656.0	9.4
15 <i>Talinum triangulare</i> (Jacq.) Willd.	2	0	3	3	1	9	4	9.0	6.7	2.3	9.0	4.5	225.0	3.2
16 <i>Tephrosia pedicellata</i> Bak.	2	0	0	0	3	5	2	10.0	3.3	2.6	5.9	3.0	500.0	7.2
17 <i>Tridax procumbens</i> Linn.	1	2	0	0	6	9	3	12.0	5.0	3.1	8.1	4.1	400.0	5.7

WAI: weeks after intercropping

Q 1 – 5: Quadrat 1 – 5.

Table 31: Weed flora and species parameters for pepper (NGB 01641) plot at 6 WAI

Weed species		Q1	Q2	Q3	Q4	Q5	Total	Frequency	Density	Relative frequency	Relative density	Importance value	Abundance	Dominance	Relative dominance
1	<i>Ageratum conizoides</i> Linn.	16	15	20	12	8	71	5	56.8	9.6	16.2	25.8	12.9	1136.0	13.8
2	<i>Bidens pilosa</i> Linn.	2	0	0	1	0	3	2	6.0	3.8	1.7	5.6	2.8	300.0	3.7
3	<i>Borreria ocymoides</i> (Burm. f.) DC.	21	41	12	15	6	95	5	76.0	9.6	21.7	31.3	15.6	1520.0	18.5
3	<i>Brachiaria lata</i> (Schumach) C.E.	0	7	0	3	6	16	3	21.3	5.8	6.1	11.9	5.9	711.1	8.7
4	<i>Cleome rutosperma</i> DC.	0	5	1	0	1	7	3	9.3	5.8	2.7	8.4	4.2	311.1	3.8
5	<i>Commelina benghalensis</i> L.	0	2	0	2	0	4	2	8.0	3.8	2.3	6.1	3.1	400.0	4.9
6	<i>Digitaria horizontalis</i> Willd.	0	1	0	0	1	2	2	4.0	3.8	1.1	5.0	2.5	200.0	2.4
7	<i>Euphorbia hirta</i> Linn.	13	1	6	6	4	30	5	24.0	9.6	6.8	16.5	8.2	480.0	5.8
8	<i>Mariscus alternifolius</i> Vahl. (= <i>M. umbellatus</i> Vahl.)	11	13	15	3	5	47	5	37.6	9.6	10.7	20.3	10.2	752.0	9.2
9	<i>Peperomia pellucida</i> (L.) H. B. & K.	11	2	7	0	4	24	4	24.0	7.7	6.8	14.5	7.3	600.0	7.3
10	<i>Phyllanthus amarus</i> Schum. & Thonn.	2	0	1	0	1	4	3	5.3	5.8	1.5	7.3	3.6	177.8	2.2
11	<i>Setaria barbata</i> (Lam.) Kunth	29	6	20	12	10	77	5	61.6	9.6	17.6	27.2	13.6	1232.0	15.0
12	<i>Spigelia anthelmia</i> Linn.	5	1	7	1	2	16	5	12.8	9.6	3.6	13.3	6.6	256.0	3.1
13	<i>Talinum triangulare</i> (Jacq.) Willd.	1	0	1	1	0	3	3	4.0	5.8	1.1	6.9	3.5	133.3	1.6

WAI: weeks after intercropping

Q 1 – 5: Quadrat 1 – 5.

Table 32: Weed flora and species parameters for pepper (NGB 01641) plot after harvesting

Weed species	Q1	Q2	Q3	Q4	Q5	Total	Frequency	Density	Relative frequency	Relative density	Importance value	Abundance	Dominance	Relative dominance
1 <i>Ageratum conizoides</i> Linn.	7	0	0	6	2	15	3	20.0	6.8	4.9	11.8	5.9	666.7	6.8
2 <i>Bidens pilosa</i> Linn.	0	0	6	2	1	9	3	12.0	6.8	3.0	9.8	4.9	400.0	4.1
3 <i>Boerhavia diffusa</i> L.	0	9	2	0	3	14	3	18.7	6.8	4.6	11.4	5.7	622.2	6.3
4 <i>Borreria ocymoides</i> (Burm. f.) DC.	22	41	18	6	32	119	5	95.2	11.6	23.5	34.9	17.4	1904.0	19.3
5 <i>Brachiaria deflexa</i> (Schumach.) C.E. Hubbard ex Robyns	21	57	19	28	37	162	5	129.6	11.4	32.0	43.3	21.7	2592.0	26.3
6 <i>Brachiaria lata</i> (Schumach) C.E. Hubbard	9	15	16	23	21	84	5	16.8	11.4	4.1	15.5	7.8	336.0	3.4
7 <i>Commelina benghalensis</i> L.	9	2	3	0	0	14	3	18.7	6.8	4.6	11.4	5.7	622.2	6.3
8 <i>Euphorbia heterophylla</i> Linn.	0	7	2	4	0	13	3	17.3	6.8	4.3	11.1	5.0	577.8	5.9
9 <i>Euphorbia hirta</i> Linn.	2	1	6	0	2	11	4	11.0	9.1	2.7	11.8	5.9	275.0	2.8
10 <i>Mariscus alternifolius</i> Vahl. (=M. <i>umbellatus</i> Vahl.)	17	0	4	10	3	34	4	34.0	9.1	8.4	17.5	8.7	850.0	8.6
11 <i>Phyllanthus amarus</i> Schum. & Thonn.	11	3	0	6	4	24	4	24.0	9.1	5.9	15.0	7.5	600.0	6.1
12 <i>Sida acuta</i> Burm. f.	0	2	0	2	0	4	2	8.0	4.5	2.0	6.5	3.2	400.0	4.1

WAI: weeks after intercropping

Q 1 – 5: Quadrat 1 – 5.

Table 33: Weed flora and species parameters for okra (NGB 01184) plot at 3 WAI

Weed species		Q1	Q2	Q3	Q4	Q5	Total	Frequency	Density	Relative frequency	Relative density	Importance value	Abundance	Dominance	Relative dominance
1	<i>Acalypha fimbriata</i> Schum. & Thonn. (<i>Acalypha ciliata</i> Forsk.)	0	1	1	2	1	5	4	5.0	8.5	1.1	9.6	4.8	125.0	1.2
2	<i>Ageratum conizoides</i> Linn.	1	1	2	0	5	9	4	9.0	8.5	1.9	10.5	5.2	225.0	2.2
3	<i>Axonopus compressus</i> (Sw.) P. Beauv.	1	1	0	0	0	2	2	4.0	4.3	0.9	5.1	2.6	200.0	1.9
4	<i>Bidens pilosa</i> Linn.	0	1	0	1	0	2	2	4.0	4.3	0.9	5.1	2.6	200.0	1.9
5	<i>Borreria ocymoides</i> (Burm. f.) DC.	3	0	9	1	0	13	3	17.3	6.4	3.8	10.1	5.1	577.7	5.6
6	<i>Brachiaria deflexa</i> (Schumach.) C.E. Hubbard ex Robyns	4	7	4	7	0	22	4	22.0	8.5	4.8	13.3	6.6	550.0	5.3
7	<i>Cleome rutidosperma</i> DC.	4	0	2	0	1	7	3	9.3	6.4	2.0	8.4	4.2	311.0	3.1
8	<i>Commelina benghalensis</i> L.	3	6	5	2	3	19	5	15.2	10.6	3.3	13.9	7.0	304.0	2.9
9	<i>Euphorbia hirta</i> Linn.	1	3	0	0	1	5	3	12.0	6.4	2.6	9.0	4.5	400.0	3.9
10	<i>Mariscus alternifolius</i> Vahl. (= <i>M. umbellatus</i> Vahl.)	0	6	4	1	1	12	4	12.0	8.5	2.6	11.1	5.6	300.0	2.9
11	<i>Peperomia pellucida</i> (L.) H. B. & K.	3	0	6	2	2	13	4	13.0	8.5	2.8	11.3	5.7	325.0	3.1
12	<i>Synedrella nodiflora</i> Gaertn.	64	122	84	77	68	415	5	332.0	10.6	71.9	82.5	41.3	6640.0	64.3
13	<i>Talinum triangulare</i> (Jacq.) Willd.	2	3	1	1	0	7	4	7.0	8.5	1.5	10.0	5.0	175.0	1.7

WAI: weeks after intercropping

Q 1 – 5: Quadrat 1 – 5.

Table 34: Weed flora and species parameters for okra (NGB 01184) plot at 6 WAI

Weed species	Q1	Q2	Q3	Q4	Q5	Total	Frequency	Density	Relative frequency	Relative density	Importance value	Abundance	Dominance	Relative dominance
1 <i>Ageratum conizoides</i> Linn.	24	24	30	18	22	118	5	94.4	10.6	20.4	31.1	15.5	1888.0	18.5
2 <i>Bidens pilosa</i> Linn.	4	0	5	0	6	15	3	20.0	6.4	4.3	10.7	5.4	666.7	6.5
3 <i>Borreria ocymoides</i> (Burm. f.) DC.	52	36	30	28	41	187	5	149.6	10.6	32.3	43.0	21.5	2992.0	4.6
4 <i>Commelina benghalensis</i> L.	7	4	0	1	3	15	4	15.0	8.5	3.2	11.8	5.9	375.0	3.7
5 <i>Euphorbia hirta</i> Linn.	8	0	5	3	3	19	4	19.0	8.5	4.1	12.6	6.3	475.0	2.7
6 <i>Mariscus alternifolius</i> Vahl. (= <i>M. umbellatus</i> Vahl.)	3	3	0	1	1	8	4	8.0	8.5	1.7	10.2	5.1	200.0	2.0
7 <i>Peperomia pellucida</i> (L.) H. B. & K.	1	6	2	2	0	11	4	11.0	8.5	2.4	10.9	5.4	275.0	659.0
8 <i>Setaria barbata</i> (Lam.) Kunth	21	27	28	36	20	132	5	105.6	10.6	22.8	33.5	16.7	2112.0	20.0
9 <i>Sida acuta</i> Burm. f.	0	2	0	1	1	4	3	5.3	6.4	1.2	7.5	3.8	177.7	4.9
10 <i>Solanum nigrum</i> L.	0	3	0	2	0	5	2	10.0	4.3	2.2	6.4	3.2	500.0	29.2
11 <i>Spigelia anthelmia</i> Linn.	0	1	1	0	2	4	3	5.3	6.4	1.2	7.5	3.8	177.7	1.7
12 <i>Talinum triangulare</i> (Jacq.) Willd.	2	4	7	4	7	24	5	19.2	10.6	4.2	14.8	7.4	384.0	3.8

WAI: weeks after intercropping

Q 1 – 5: Quadrat 1 – 5.

Table 35: Weed flora and species parameters for okra (NGB 01184) plot after harvesting

Weed species	Q1	Q2	Q3	Q4	Q5	Total	Frequency	Density	Relative frequency	Relative density	Importance value	Abundance	Dominance	Relative dominance
1 <i>Ageratum conizoides</i> Linn.	53	28	42	37	50	210	5	168.0	11.6	35.7	47.4	23.7	3360.0	30.3
2 <i>Bidens pilosa</i> Linn.	4	4	0	1	0	9	3	12.0	7.0	2.6	4.5	4.8	400.0	3.6
3 <i>Borreria ocymoides</i> (Burm. f.) DC.	15	22	13	22	17	89	5	71.2	11.6	15.1	26.8	13.4	1424.0	12.8
4 <i>Commelina benghalensis</i> L.	0	1	2	0	0	3	2	6.0	4.7	1.3	5.9	3.0	300.0	2.7
5 <i>Euphorbia heterophylla</i> Linn.	6	0	3	9	9	27	4	27.0	9.3	5.7	15.0	7.5	675.0	6.1
6 <i>Mariscus alternifolius</i> Vahl. (=M. <i>umbellatus</i> Vahl.)	3	4	0	0	3	10	3	13.3	7.0	28.4	35.3	17.7	444.4	4.0
7 <i>Peperomia pellucida</i> (L.) H. B. & K.	0	0	2	5	3	10	3	13.3	7.0	2.8	9.8	4.9	444.4	4.0
8 <i>Solanum nigrum</i> L.	2	10	2	0	0	14	3	18.7	7.0	4.0	10.9	5.5	622.2	5.6
9 <i>Spigelia anthelmia</i> Linn.	0	7	4	6	0	17	3	22.7	7.0	4.8	11.8	5.9	755.6	6.8
10 <i>Sporobolous pyramidalis</i> P. Beauv.	14	30	16	19	9	88	5	70.4	11.6	15.0	26.6	13.3	1408.0	12.7
11 <i>Talinum triangulare</i> (Jacq.) Willd.	0	4	1	0	0	5	2	10.0	4.7	2.1	6.8	3.4	500.0	4.5
12 <i>Tephrosia pedicellata</i> Bak.	5	13	3	5	11	47	5	37.6	11.6	8.0	19.6	9.8	752.0	6.8

WAI: weeks after intercropping

Q 1 – 5: Quadrat 1 – 5.

Table 36: Weed flora and species parameters for eggplant (NGB 01737) plot at 3 WAI

Weed species	Q1	Q2	Q3	Q4	Q5	Total	Frequency	Density	Relative frequency	Relative density	Importance value	Abundance	Dominance	Relative dominance
1 <i>Ageratum conizoides</i> Linn.	3	5	12	4	0	24	4	24.0	6.5	5.8	12.3	6.1	600.0	6.3
2 <i>Bidens pilosa</i> Linn.	1	0	0	0	2	3	2	6.0	3.2	1.5	4.7	2.3	300.0	3.1
3 <i>Boerhavia diffusa</i> L.	1	0	1	2	0	4	3	5.3	4.8	1.3	6.1	3.1	177.7	1.9
4 <i>Borreria ocymoides</i> (Burm. f.) DC.	4	4	0	0	6	14	3	18.7	4.8	4.5	9.4	4.7	622.3	6.5
5 <i>Brachiaria deflexa</i> (Schumach.) C.E. Hubbard ex Robyns	8		6	8	5	27	4	27.0	6.5	6.6	13.0	6.5	675.0	7.0
6 <i>Cleome rutidosperma</i> DC.	0	2	2	1	3	8	4	8.0	6.5	1.9	8.4	4.2	200.0	2.1
7 <i>Commelina benghalensis</i> L.	0	5	5	2	12	24	4	24.0	6.5	5.8	12.3	6.1	600.0	6.3
8 <i>Euphorbia heterophylla</i> Linn.	3	0	1	2	3	9	4	9.0	6.5	2.2	8.6	4.3	225.0	2.3
9 <i>Euphorbia hirta</i> Linn.	0	2	1	0	3	6	3	8.0	4.8	1.9	6.8	3.4	266.7	2.8
10 <i>Mariscus alternifolius</i> Vahl. (= <i>M. umbellatus</i> Vahl.)	4	5	18	8	15	50	5	40.0	8.1	9.7	17.8	8.9	800.0	8.3
11 <i>Paspalum conjugatum</i> Berg.	9	0	12	10	6	37	4	37.0	6.5	9.0	15.5	7.7	925.0	9.6
12 <i>Peperomia pellucida</i> (L.) H. B. & K.	2	18	22	3	9	54	5	43.2	8.1	10.5	18.6	9.3	864.0	9.0
13 <i>Phyllanthus amarus</i> Schum. & Thonn.	1	0	0	3	1	5	3	6.7	4.8	1.6	6.5	3.2	222.3	2.3
14 <i>Spigelia anthelmia</i> Linn.	2	1	1	1	2	7	5	5.6	8.1	1.4	9.4	4.7	112.0	1.2
15 <i>Synedrella nodiflora</i> Gaertn.	44	26	46	30	32	178	5	142.4	8.1	34.7	42.7	21.4	2848.0	29.7
16 <i>Talinum triangulare</i> (Jacq.) Willd.	0	2	1	2	1	6	4	6.0	6.5	1.5	7.9	4.0	150.0	1.6

WAI: weeks after intercropping

Q 1 – 5: Quadrat 1 – 5.

Table 37: Weed flora and species parameters for eggplant (NGB 01737) plot at 6 WAI

	Weed species	Q1	Q2	Q3	Q4	Q5	Total	Frequency	Density	Relative frequency	Relative density	Importance value	Abundance	Dominance	Relative dominance
1	<i>Ageratum conizoides</i> Linn.	25	22	28	20	18	113	5	90.4	11.1	27.3	38.4	19.2	1808.0	24.0
2	<i>Borreria ocymoides</i> (Burm. f.) DC.	12	14	10	15	28	79	5	63.2	11.1	19.1	30.2	15.1	1264.0	16.8
3	<i>Brachiaria lata</i> (Schumach) C.E.	1	0	0	0	0	1	1	4.0	2.2	1.2	3.4	1.7	400.0	5.3
4	<i>Cleome rutidosperma</i> DC.	1	0	0	1	1	3	3	4.0	6.7	1.2	7.9	3.9	133.3	1.8
5	<i>Commelina benghalensis</i> L.	5	6	5	5	8	29	5	23.2	11.1	7.0	18.1	9.1	464.0	6.2
6	<i>Mariscus alternifolius</i> Vahl. (=M. <i>umbellatus</i> Vahl.)	1	1	0	1	1	4	4	4.0	8.9	1.2	10.1	5.0	100.0	1.3
7	<i>Peperomia pellucida</i> (L.) H. B. & K.	7	3	2	9	4	25	5	20.0	11.1	6.0	17.1	8.6	400.0	5.3
8	<i>Phyllanthus amarus</i> Schum. & Thonn.	0	3	1	2	0	6	3	8.0	6.7	2.4	9.1	4.5	266.7	3.5
9	<i>Setaria barbata</i> (Lam.) Kunth	16	31	41	10	12	110	5	88.0	11.1	26.5	37.7	18.8	1760.0	23.4
10	<i>Spigelia anthelmia</i> Linn.	3	6	2	1	0	12	4	12.0	8.9	3.6	12.5	6.3	300.0	4.0
11	<i>Talinum triangulare</i> (Jacq.) Willd.	1	3	1	0	0	5	3	6.7	6.7	2.0	8.7	4.3	222.2	3.0
12	<i>Tridax procumbens</i> Linn.	3	1	0	0	0	4	2	8.0	4.4	2.4	6.9	3.4	400.0	5.3

WAI: weeks after intercropping

Q 1 – 5: Quadrat 1 – 5.

Table 38: Weed flora and species parameters for eggplant (NGB 01737) plot after harvesting

Weed species	Q1	Q2	Q3	Q4	Q5	Total	Frequency	Density	Relative frequency	Relative density	Importance value	Abundance	Dominance	Relative dominance
1 <i>Ageratum conizoides</i> Linn.	5	7	7	12	4	35	5	28.0	11.4	7.1	18.5	9.3	560.0	6.2
2 <i>Bidens pilosa</i> Linn.	0	4	0	0	4	8	2	16.0	4.5	4.1	8.6	4.3	800.0	8.8
3 <i>Borreria ocymoides</i> (Burm. f.) DC.	27	20	19	27	19	112	5	89.6	11.4	22.8	34.2	17.1	1792.0	19.8
4 <i>Brachiaria deflexa</i> (Schumach.) C.E. Hubbard ex Robyns	30	17	12	12	18	89	5	71.2	11.4	18.1	29.5	14.7	1424.0	15.7
5 <i>Brachiaria lata</i> (Schumach) C.E. Hubbard	1	3	0	0	0	4	2	8.0	4.5	2.0	6.6	3.3	400.0	4.4
6 <i>Commelina benghalensis</i> L.	14	12	14	21	20	81	5	64.8	11.4	16.5	27.9	13.9	1296.0	14.3
7 <i>Euphorbia heterophylla</i> Linn.	0	7	4	0	7	18	3	24.0	6.8	6.1	12.9	6.5	600.0	6.6
8 <i>Euphorbia hirta</i> Linn.	0	7	3	15	1	26	4	26.0	9.1	6.6	15.7	7.9	650.0	7.2
9 <i>Mariscus alternifolius</i> Vahl. (=M. <i>umbellatus</i> Vahl.)	6	8	0	6	3	23	4	23.0	9.1	5.9	14.9	7.5	575.0	6.4
10 <i>Phyllanthus amarus</i> Schum. & Thonn.	3	4	5	10	6	28	5	22.4	11.4	5.7	17.1	8.5	448.0	5.0
11 <i>Sporobolous pyramidalis</i> P. Beauv.	8	2	5	5	0	20	4	20.0	9.1	5.1	14.2	7.1	500.0	5.5

WAI: weeks after intercropping

Q 1 – 5: Quadrat 1 – 5.

Table 39: Weed flora and species parameters for control plot at 3 WAI

Weed species		Q1	Q2	Q3	Q4	Q5	Total	Frequency	Density	Relative frequency	Relative density	Importance value	Abundance	Dominance	Relative dominance
1	<i>Ageratum conizoides</i> Linn.	81	106	78	64	30	269	5	53.8	7.7	16.1	23.8	11.9	1076.0	15.1
2	<i>Bidens pilosa</i> Linn.	12	18	6	12	4	52	5	41.6	7.7	12.4	20.1	10.1	832.0	11.7
3	<i>Borreria ocymoides</i> (Burm. f.) DC.	6	24	42	6	7	85	5	68.0	7.7	20.3	28.0	14.0	1360.0	19.1
4	<i>Brachiaria deflexa</i> (Schumach.) C.E. Hubbard ex Robyns	12	10	8	14	3	47	5	37.6	7.7	11.2	18.9	9.5	752.0	10.6
5	<i>Cleome rutidosperma</i> DC.	1	6	3	1	1	12	5	9.6	7.7	2.9	10.6	5.3	192.0	2.7
6	<i>Commelina benghalensis</i> L.	2	1	0	1	0	4	3	5.3	4.6	1.6	6.2	3.1	177.7	2.5
7	<i>Digitaria horizontalis</i> Willd.	8	12	9	3	1	33	5	26.4	7.7	7.9	15.6	7.8	528.0	7.4
8	<i>Euphorbia hirta</i> Linn.	1	5	0	2	1	9	4	9.0	6.2	2.7	8.8	4.4	225.0	3.2
9	<i>Mariscus alternifolius</i> Vahl. (=M. <i>umbellatus</i> Vahl.)	5	5	2	11	6	29	5	23.2	7.7	6.9	14.6	7.3	464.0	6.5
10	<i>Peperomia pellucida</i> (L.) H. B. & K.	3	19	4	2	6	34	5	27.2	7.7	8.1	15.8	7.9	544.0	7.6
11	<i>Spigelia anthelmia</i> Linn.	1	4	0	2	0	7	3	9.3	4.6	2.8	7.4	3.7	311.0	4.4
12	<i>Synedrella nodiflora</i> Gaertn.	1	6	5	0	2	14	4	14.0	6.2	4.2	10.3	5.2	350.0	4.9
13	<i>Talinum triangulare</i> (Jacq.) Willd.	1	4	0	0	2	7	3	9.3	4.6	2.8	7.4	3.7	311.0	4.4

WAI: weeks after intercropping

Q 1 – 5: Quadrat 1 – 5.

Table 40: Weed flora and species parameters for control plot at 6 WAI

Weed species	Q1	Q2	Q3	Q4	Q5	Total	Frequency	Density	Relative frequency	Relative density	Importance value	Abundance	Dominance	Relative dominance
1 <i>Ageratum conizoides</i> Linn.	22	23	30	15	17	107	5	85.6	9.4	15.5	25.0	12.5	1712.0	15.1
2 <i>Bidens pilosa</i> Linn.	48	30	26	18	32	154	5	123.2	9.4	22.4	31.8	15.9	2464.0	21.8
3 <i>Borreria ocymoides</i> (Burm. f.) DC.	8	16	18	20	20	82	5	65.6	9.4	11.9	21.3	10.7	1312.0	11.6
4 <i>Commelina benghalensis</i> L.	16	35	17	16	30	114	5	91.2	9.4	16.6	26.0	13.0	1824.0	16.1
5 <i>Euphorbia hirta</i> Linn.	4	3	12	2	4	25	5	20.0	9.4	3.6	13.1	6.5	400.0	3.5
6 <i>Mariscus alternifolius</i> Vahl. (= <i>M. umbellatus</i> Vahl.)	12	15	7	8	3	45	5	36.0	9.4	6.5	16.0	8.0	720.0	6.4
7 <i>Peperomia pellucida</i> (L.) H. B. & K.	2	0	6	4	1	13	4	13.0	7.5	2.4	9.9	5.0	325.0	2.9
8 <i>Digitaria horizontalis</i> Willd.	1	0	1	0	0	2	2	4.0	3.8	0.7	4.5	2.3	200.0	1.8
9 <i>Setaria barbata</i> (Lam.) Kunth	18	32	14	25	20	109	5	87.2	9.4	15.8	25.3	12.6	1744.0	15.4
10 <i>Spigelia anthelmia</i> Linn.	5	1	1	0	2	9	4	9.0	7.5	1.6	9.2	4.6	225.0	2.0
11 <i>Talinum triangulare</i> (Jacq.) Willd.	2	3	1	1	0	7	4	7.0	7.5	1.3	8.8	4.4	175.0	1.5
12 <i>Tridax procumbens</i> Linn.	5	2	0	1	1	9	4	9.0	7.5	1.6	9.2	4.6	225.0	2.0

WAI: weeks after intercropping

Q 1 – 5: Quadrat 1 – 5.

Table 41: Weed flora and species parameters for control plot after harvesting

Weed species	Q1	Q2	Q3	Q4	Q5	Total	Frequency	Density	Relative frequency	Relative density	Importance value	Abundance	Dominance	Relative dominance
1 <i>Bidens pilosa</i> Linn.	0	4	5	1	1	11	4	11.0	8.9	1.6	10.5	5.2	275.0	1.8
2 <i>Borreria ocymoides</i> (Burm. f.) DC.	174	22	62	38	56	422	5	337.6	11.1	48.4	59.5	29.8	6752.0	44.0
3 <i>Brachiaria deflexa</i> (Schumach.) C.E. Hubbard ex Robyns	14	6	19	6	11	56	5	48.8	11.1	6.4	17.5	8.8	896.0	5.8
4 <i>Brachiaria lata</i> (Schumach) C.E. Hubbard	13	9	11	19	15	67	5	53.6	11.1	7.7	13.8	9.4	1072.0	7.0
5 <i>Commelina benghalensis</i> L.	17	27	18	29	27	118	5	94.4	11.1	13.5	24.6	12.3	1888.0	12.3
6 <i>Digitaria horizontalis</i> Willd.	0	6	1	5	0	12	3	16.0	6.7	2.3	9.0	4.5	533.3	3.5
7 <i>Euphorbia heterophylla</i> Linn.	0	0	2	0	0	2	1	8.0	2.2	1.1	3.4	1.7	800.0	5.2
8 <i>Hyptis lanceolata</i> Poir.	3	0	2	2	7	14	4	14.0	8.9	2.0	10.9	5.4	350.0	2.3
9 <i>Mariscus alternifolius</i> Vahl. (=M. <i>umbellatus</i> Vahl.)	14	11	5	0	3	33	4	23.0	8.9	4.7	13.6	6.8	825.0	5.4
10 <i>Sida acuta</i> Burm. f.	0	1	0	1	1	3	3	4.0	6.7	0.6	7.2	3.6	133.3	0.9
11 <i>Sporobolous pyramidalis</i> P. Beauv.	32	10	10	18	13	83	5	66.4	11.1	9.5	20.6	10.3	1328.0	8.7
12 <i>Talinum triangulare</i> (Jacq.) Willd.	2	6	3	0	0	11	3	14.7	6.7	2.1	8.8	4.4	488.9	3.2

WAI: weeks after intercropping

Q 1 – 5: Quadrat 1 – 5.

4.7.2 Weed species richness and abundance in fruit vegetables-juvenile oil palm plots

Table 42: Effects of intercropping distance on weed species abundance and richness in juvenile oil palm – tomato (NGB 01665) plot

Intercropping distance	Weed species abundance			Weed species richness		
	3 WAI	6 WAI	End of harvest	3 WAI	6 WAI	End of harvest
1 m	10.200 ^b	9.800 ^{ab}	7.800 ^b	88.400 ^a	89.400 ^b	83.400 ^b
2 m	10.800 ^{ab}	8.600 ^b	10.000 ^a	104.60 ^a	93.200 ^b	98.800 ^b
3 m	10.000 ^b	8.400 ^b	10.000 ^a	111.600 ^a	98.400 ^b	117.20 ^b
Control	11.800 ^a	10.800 ^a	9.000 ^{ab}	103.200 ^a	125.800 ^a	162.600 ^a

At 3 WAI, control plot recorded the highest weed species abundance (11.800) which was significantly different from other treatments except for plot at 2 m sub-plot from juvenile oil palm.

Similarly at 6 WAI, the control plot also recorded a significantly high weed species abundance (10.800) while the lowest was recorded by tomato at 3 m from juvenile oil palm (8.4 00).

Plot at 2 m and 3 m from juvenile oil palm at the end of harvest recorded highest weed species abundance (10.000) however it was not significantly different from the control plot (9.000). There was reduction in weed species abundance across the periods except 3 m from juvenile oil palm.

The weed species richness was not significantly different at 3 WAI with the highest and lowest values recorded by control and 1 m from juvenile oil palm (103.200 and 88.400) respectively.

Similar result was obtained at 6 WAI and at the end of harvest, however control plot was significantly higher than others at $P < 0.05$ level of significance (Table 42). There was reduction in weed species richness at 1 m and 2 m sub-plots; while an increase was recorded at 3 m from juvenile oil palm and control plots (Table 42).

Table 43: Effects of intercropping distance on weed species abundance and richness in juvenile oil palm – tomato (NG/AA/SEP/09/053) plot

Intercropping distance	Weed species abundance			Weed species richness		
	3 WAI	6 WAI	End of harvest	3 WAI	6 WAI	End of harvest
1 m	12.000 ^a	7.800 ^b	7.800 ^a	65.400 ^b	56.000 ^c	55.800 ^b
2 m	9.200 ^b	7.800 ^b	8.600 ^a	57.200 ^b	50.400 ^c	77.200 ^b
3 m	10.200 ^{ab}	9.600 ^a	8.800 ^a	79.200 ^{ab}	81.600 ^b	94.400 ^b
Control	11.800 ^a	10.800 ^a	9.000 ^a	103.200 ^a	125.800 ^a	162.600 ^a

At 3 WAI, 1 m plot recorded higher weed species abundance value (12.000) and the lowest was recorded by 2 m from juvenile oil palm (9.200). At 6 WAI, control plot recorded the highest weed species abundance and the lowest was recorded by 1 m and 2 m from juvenile oil palm (7.800). There was no significant difference at the end of harvest; however control plot and 1 m from juvenile oil palm recorded the highest and lowest values of weed species abundance values (9.000 and 7.800) respectively. There was reduction in weed species abundance across the periods for the control plot and in all the intercropping regimes.

There was significantly higher weed species richness at control plot, though was not significantly different from 3 m from juvenile oil palm. The control plot also recorded significantly higher weed species abundance value (125.800) at 6 WAI and the lowest was recorded at 2 m from juvenile oil palm (50.400).

Weed species richness value of 162.600 was recorded at the control plot after harvesting which was significantly higher than others. Lowest weed species richness value was obtained at 1 m from juvenile oil palm. An increase was recorded for weed species richness in the control plot and across all the intercropping regimes except 1 m from juvenile oil palm (Table 43).

Table 44: Effects of intercropping distance on weed species abundance and richness in juvenile oil palm – pepper (NGB 01312) plot

Intercropping distance	Weed species abundance			Weed species richness		
	3 WAI	6 WAI	End of harvest	3 WAI	6 WAI	End of harvest
1 m	12.400 ^a	9.800 ^{bc}	8.600 ^{ab}	93.600. ^{bc}	96.800 ^c	96.800 ^b
2 m	12.400 ^a	11.400 ^a	9.600 ^a	75.800 ^c	130.000 ^b	117.600 ^b
3 m	13.000 ^a	9.400 ^c	7.800 ^b	121.000 ^a	165.400 ^a	114.800 ^b
Control	11.800 ^a	10.800 ^{ab}	9.000 ^a	103.200 ^{ab}	125.800 ^b	162.600 ^a

At 3 WAI, there was no significant difference in the weed species abundance at ($P < 0.05$) level of significance. However, highest value was obtained at the 3 m from juvenile oil palm. At 6 WAI, the highest and lowest weed species abundance were obtained at 2 m and 3 m from juvenile oil palm (11.400 and 9.400) respectively. At the end of harvest, similar result was obtained however 3 m from juvenile oil palm recorded lowest weed species abundance value. There was reduction in weed species abundance across the periods for the control plot and all the intercropping regimes.

Weed species richness was significantly highest at 3 m from juvenile oil palm and lowest at 2 m from juvenile oil palm at 3 WAI (121.000 and 75.800) respectively. At 6 WAI, 3 m from juvenile oil palm also recorded the highest weed species richness value though the lowest was obtained at 1 m from juvenile oil palm. Control plot recorded significantly higher weed species richness of 162.600; lowest value was obtained at 1 m from juvenile oil palm (96.800). An

increase was recorded for weed species richness in the control plot and across all the intercropping regimes except those at 3 m from juvenile oil palm (Table 44).

Table 45: Effects of intercropping distance on weed species abundance and richness in juvenile oil palm – pepper (NGB 01641) plot

Intercropping distance	Weed species abundance			Weed species richness		
	3 WAI	6 WAI	End of harvest	3 WAI	6 WAI	End of harvest
1 m	11.200 ^a	10.600 ^a	9.000 ^a	80.400 ^a	48.400 ^c	82.200 ^c
2 m	12.600 ^a	10.600 ^a	8.600 ^a	81.200 ^a	88.800 ^b	105.400 ^{bc}
3 m	11.400 ^a	10.800 ^a	9.000 ^a	95.400 ^a	100.600 ^b	125.800 ^{ab}
Control	11.800 ^a	10.800 ^a	9.000 ^a	103.200 ^a	125.800 ^a	162.600 ^a

At 3 WAI, there was no significant difference in the weed species abundance values obtained from the intercropping regimes. However, the highest and lowest values were obtained from 2 m and 1 m from juvenile oil palm (12.600 and 11.200) respectively.

Similar results were obtained for the weed species abundance at 6 WAI and at the end harvest with no significant difference in the weed species abundance values. However, the control plot recorded the highest values of weed species abundance during both periods were (10.800 and 9.000) respectively.

Across these periods, there was reduction in the weed species abundance for the control plot and 2 m from juvenile oil palm; there was increase at 1m, and 3 m from juvenile oil palm maintained the same value.

Weed species richness was not significantly different at 3 WAI; though control plot and 1 m from juvenile oil palm recorded the highest and lowest values of (103.200 and 80.400) respectively.

The control plot recorded the significantly highest weed species richness at 6 WAI (125.800) and the lowest value was obtained from 1 m from juvenile oil palm (48.400). Similarly at the end of harvest the control plot still recorded the highest value of weed species richness (162.200) while the lowest value was obtained from 1 m from juvenile oil palm t (82.200). Across the periods of enumeration, control plot and 2 m from juvenile oil palm recorded increase in weed species richness; while there was reduction in 1 and 3 m from juvenile oil palm (Table 45).

Table 46: Effects of intercropping distance on weed species abundance and richness in juvenile oil palm – okra (NGB 01184) plot

Intercropping distance	Weed species abundance			Weed species richness		
	3 WAI	6 WAI	End of harvest	3 WAI	6 WAI	End of harvest
1 m	8.800 ^b	10.400 ^{ab}	8.000 ^b	96.400 ^b	94.000 ^c	91.800 ^b
2 m	9.400 ^b	8.800 ^c	8.800 ^{ab}	91.200 ^b	106.800 ^b	107.000 ^b
3 m	9.600 ^b	9.600 ^{bc}	9.600 ^a	141.600 ^a	120.800 ^a	121.400 ^b
Control	11.800 ^a	10.80 ^a	9.000 ^{ab}	103.400 ^b	125.800 ^a	162.600 ^a

At 3 WAI, control plot recorded the highest weed species abundance of 11.800 and the lowest was obtained from 1 m from juvenile oil palm. Similarly the control plot recorded the highest weed species abundance at 6 WAI (10.800); however the lowest value was obtained from 2 m from juvenile oil palm (8.8000).

At the end of harvest, the highest and lowest values of weed species abundance were obtained at 3 m and 1 m from juvenile oil palm (9.600 and 8.000) respectively.

Across the periods of study, there was reduction in weed species abundance in all the intercropping regimes except 3 m from juvenile oil palm.

Weed species richness was significantly highest at 3 m from juvenile oil palm at 3 WAI and the lowest value was obtained from 2 m from juvenile oil palm. At 6 WAI, the control plot and 1 m

from juvenile oil palm recorded the highest and lowest weed species richness values (125.800 and 94.000) respectively.

At the end of harvest, the control plot recorded significantly higher weed species richness (162.600) while 1 m from juvenile oil palm recorded the lowest (91.800).

Across the periods, there was increase in weed species richness at the 2 m from juvenile oil palm and control plot; while 1 m and 3 m regimes recorded reduction (Table 46).

Table 47: Effects of intercropping distance on weed species abundance and richness in juvenile oil palm – eggplant (NGB 01737) plot

Intercropping distance	Weed species abundance			Weed species richness		
	3 WAI	6 WAI	End of harvest	3 WAI	6 WAI	End of harvest
1 m	13.600 ^a	7.800 ^c	8.600 ^a	82.800 ^b	63.200 ^d	76.000 ^b
2 m	11.200 ^b	8.800 ^{bc}	9.000 ^a	79.600 ^b	82.800 ^c	87.20 ^b
3 m	12.400 ^b	9.600 ^{ab}	8.600 ^a	122.000 ^a	97.000 ^b	101.800 ^b
Control	11.800 ^b	10.800 ^a	9.000 ^a	103.200 ^{ab}	125.800 ^a	162.600 ^a

At 3 WAI, 1 m from juvenile oil palm recorded the highest weed species abundance (13.600) which was significantly different from other intercropping regimes at ($P < 0.05$) level of significance. Lowest value was recorded at 2 m from juvenile oil palm (11.200).

Highest weed species abundance was obtained from control plot at 6 WAI (10.800) and lowest value was recorded at 1 m from juvenile oil palm (7.800).

There was no significant difference in weed species abundance values at the end of harvest; however, the control plot and those at 2 m from juvenile oil palm recorded the highest value (9.000).

There was increase in weed species abundance across the periods for all the intercropping regimes and the control plot.

Highest weed species richness was obtained from 3 m from juvenile oil palm at 3WAI (122.000); while 2 m from juvenile oil palm recorded the lowest value (79.600). At 6 WAI, the control plot and 1 m from juvenile oil palm recorded the highest and lowest weed species richness respectively (125.800 and 63.200) respectively.

Similarly control plot recorded the highest value of weed species richness at the end of harvest (162.00); while 1 m from juvenile oil palm recorded the lowest value (76.000).

Across the periods, 1 m and 3 m intercropping regimes recorded reduction in weed species richness; while 2 m from juvenile oil palm and control plot recorded increase (Table 47).

4.7.3 Weed species distribution – Simpson’s Diversity Indices

The lowest value of Simpson’s Diversity Index (0.134) was obtained from pepper (NGB 01641)/juvenile oil palm intercrop plot at 3 WAI. This plot has the highest weed species distribution at 3 WAI while the control plot has the lowest weed species distribution by recording the highest value of Simpson’s Diversity Index (0.242).

At 6 WAI, the control plot has the highest weed species distribution by recording the lowest and highest values of Simpson’s Diversity Index and Simpson’s Reciprocal Index respectively (0.123 and 8.130). Tomato (NGB 01665)-juvenile oil palm intercrop plot recorded the lowest weed species distribution.

Similarly, the control plot recorded the highest weed species distribution; however, the lowest distribution of weed species was recorded at eggplant (NGB 01737)-juvenile oil palm intercrop plot with Simpson’s Diversity Index and Reciprocal Index of 0.156 and 6.410 respectively.

Simpson’s Diversity Index (D), Simpson Index of Diversity and Simpson’s Reciprocal Index for the fruit vegetables-juvenile oil palm intercrop plots at 3 WAI, 6 WAI and after harvesting are presented on Table 48.

Table 48: Simpson's Diversity indices of juvenile oil palm-vegetable intercrops at 3 WAI, 6 WAI and after harvesting

Simpson's diversity	3 WAI			6 WAI			End of harvest		
	D	1-D	¹ /D	D	1-D	¹ /D	D	1-D	¹ /D
Plot A	0.198	0.802	5.051	0.266	0.734	3.759	0.200	0.800	5.000
Plot B	0.186	0.814	5.376	0.173	0.827	5.780	0.201	0.799	4.975
Plot C	0.201	0.799	4.975	0.142	0.858	7.042	0.230	0.770	4.348
Plot D	0.134	0.866	7.463	0.153	0.847	6.536	0.197	0.803	5.076
Plot E	0.616	0.384	1.623	0.230	0.770	4.348	0.226	0.774	4.425
Plot F	0.195	0.805	5.128	0.213	0.787	4.695	0.156	0.844	6.410
Plot G	0.242	0.758	4.132	0.123	0.877	8.130	0.300	0.700	3.333

Plot A – G: juvenile oil palm – tomato (NGB 01665), : juvenile oil palm – tomato (NG/AA/SEP/09/053), : juvenile oil palm –pepper (NGB 01312), : juvenile oil palm –pepper (NGB 01641), : juvenile oil palm –okra (NGB 01184); : juvenile oil palm – eggplant (NGB 01737) and control plot.

D: Simpson's diversity index, 1 – D: Simpson's index of diversity and ¹/D: Simpson's reciprocal index of diversity.

4.7.4 Effect of intercropping on weed density and smothering efficiency of fruit vegetable-juvenile oil palm intercrop

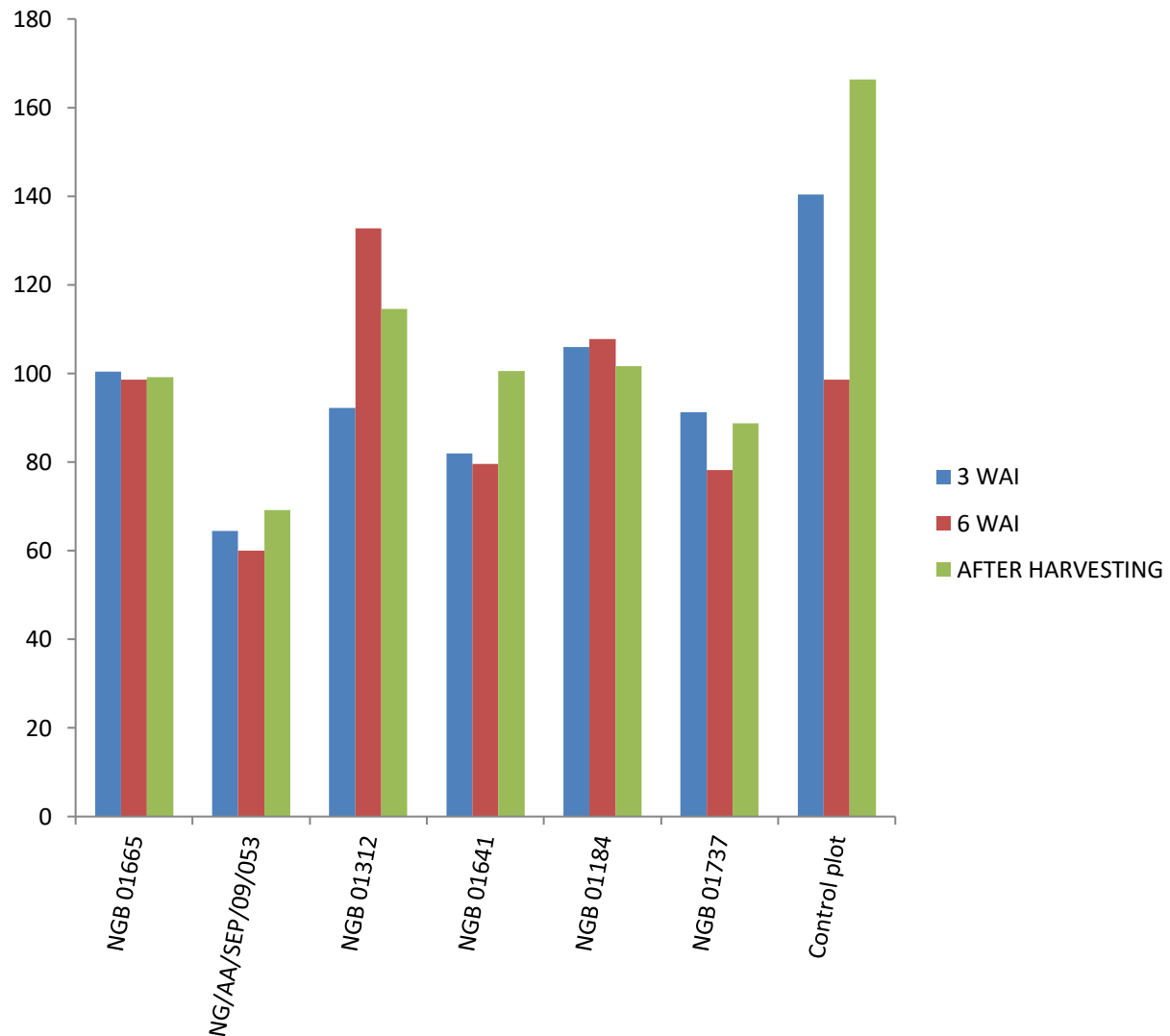


Fig. 85: Weed species density per plot (countm⁻²) at 3 WAI, 6 WAI and after harvesting of vegetable fruits.

Weed species density per plot at 3 WAI was highest at control plot (140.4 m^{-2}) while pepper (NGB 01312) plot recorded the highest weed species density per plot at 6 WAI (132.8 m^{-2}). After harvesting, the control plot also recorded the highest value of weed species density per plot (166.4 m^{-2}). Lowest weed density at 3 WAI, 6 WAI and after harvesting of the vegetable fruits was recorded by was recorded in tomato (NG/AA/SEP/09/053)/ juvenile oil palm plot (64.4 , 60 and 68.2 m^{-2}) respectively.

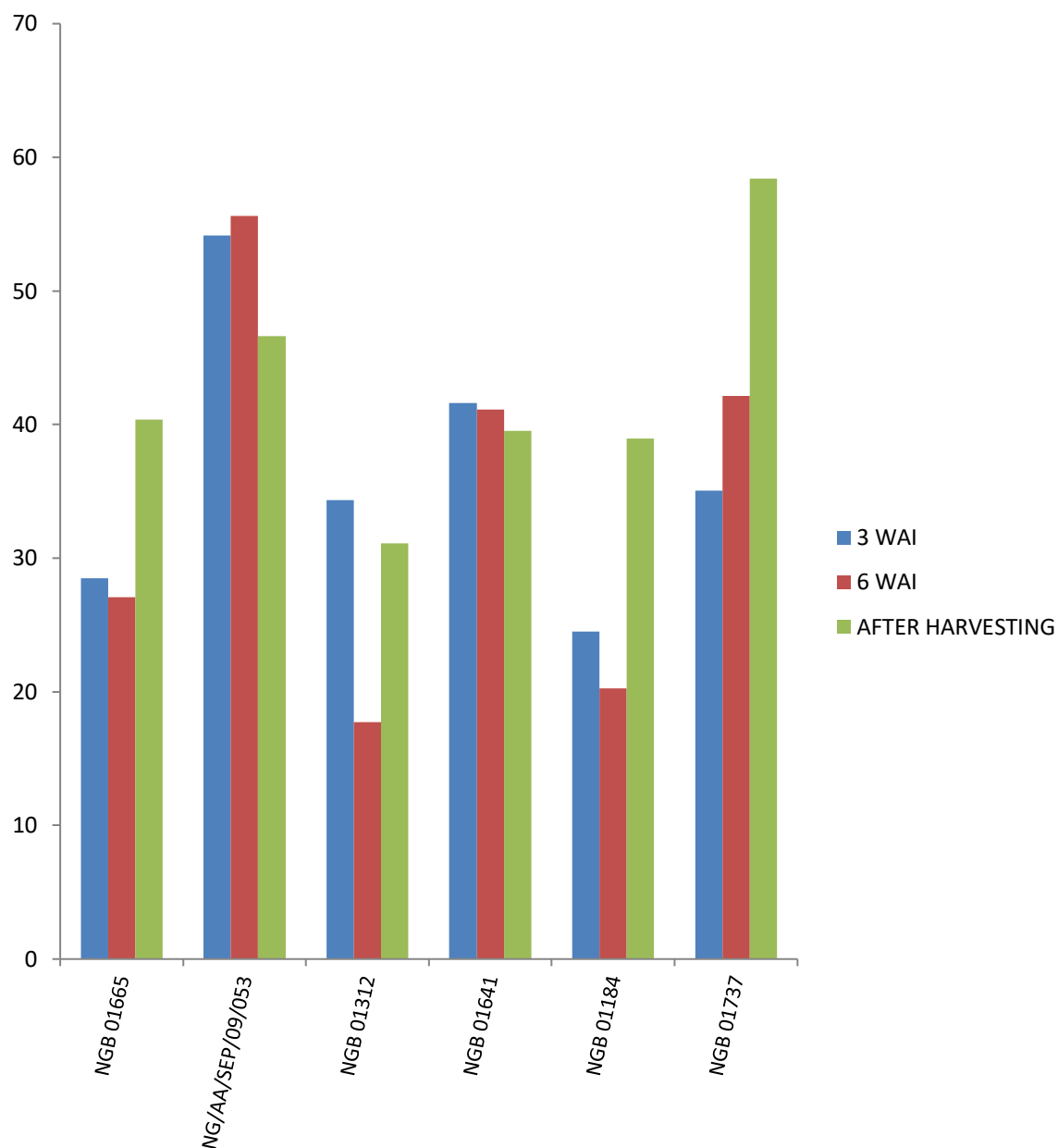


Fig. 86: Weed smothering effect (%) of fruit vegetables – juvenile oil palm intercrop plots at 3 WAI, 6 WAI and after harvesting of vegetable fruits.

The highest values of weed smothering effect at 3 WAI and 6 WAI were recorded at in tomato (NG/AA/SEP/09/053) – juvenile oil palm plot (54.13% and 55.62%) respectively. However, the lowest values of weed smothering effect at 3 WAI was obtained in okra (NGB 01184) – juvenile

oil palm plot (24.5%); at 6 WAI the pepper (NGB 01312) – juvenile oil palm plot recorded the lowest weed smothering effect (17.75%); while at the end of harvest pepper (NGB 01312) and eggplant – juvenile oil palm plots recorded the least and highest weed smothering effect (31.13% and 58.41%) respectively.

Table 49: Weed above ground biomass (g/m²) of experimental plots at 3 WAI, 6 WAI and after harvesting of intercropped fruit vegetables.

Experimental plot	3 WAI (g)	6WAI (g)	After harvesting (g)
Tomato NGB 01665	47.196 ^a	19.596 ^{bc}	39.680 ^b
Tomato NG/AA/SEP/09/053	25.388 ^c	15.250 ^c	19.878 ^c
Pepper NGB 01312	32.096 ^{abc}	21.666 ^b	37.008 ^b
Pepper NGB 01641	28.612 ^{bc}	14.108 ^c	36.284 ^b
Okra NGB 01184	42.026 ^{ab}	18.136 ^{bc}	36.286 ^b
Eggplant NGB 01737	32.918 ^{abc}	15.672 ^{bc}	43.572 ^b
Control	32.792 ^{abc}	36.102 ^a	74.918 ^a

WAI: weeks after intercropping.

Tomato (NG/AA/SEP/09/053) – juvenile oil palm plot recorded the lowest weed above ground biomass at 3 WAI (25.388 g/m²) though was not statistically significant from pepper (NGB 01312), pepper (NGB 01641), eggplant (NGB 01737) and control plots. At 6 WAI, pepper (NGB 01641) recorded the lowest weed above ground biomass (14.108 g/m²). Also at the end of harvest, tomato (NG/AA/SEP/09/053) – juvenile oil palm plot recorded the lowest weed above ground biomass (19.878 g/m²) which was statistically significant from other plots.

However, at 3 WAI tomato (NG/AA/SEP/09/053) recorded the highest above ground biomass (47.196 g/m²) though was not statistically significant from pepper, okra, eggplant – juvenile oil palm plots and the control plot (32.096, 42.026, 32.918 and 32.792 g/m²) respectively. At 6 WAI and at the end of harvest, the highest weed above ground biomass was recorded by the control plot (36.102 and 74.918 g/m²) respectively and was statistically significant from other experimental plots.

Table 50a: Physicochemical properties of the experimental plot before planting and after harvesting

Properties Plot		pH value	Total organic carbon (%)	Organic matter (%)	Nitrate ion (mg/L)	Available phosphorus (%)	Particle size distribution		
							Sand (%)	Silt (%)	Clay (%)
Pre-planting	NGB 01665	6.02	1.47	2.542	1.44	1.84	47.60	12.48	39.92
	NG/AA/SEP/09/053	5.10	1.40	2.421	1.27	1.65	58.45	13.64	27.91
	NGB 01312	5.86	1.46	2.524	1.41	1.78	47.36	14.21	38.43
	NGB 01641	5.99	1.41	2.438	1.40	1.70	59.32	13.84	26.84
	NGB 01184	6.08	1.35	2.334	1.23	1.62	46.76	12.78	40.46
	NGB 01737	6.09	1.40	2.421	1.28	1.68	48.42	13.76	37.82
	Control	6.36	1.58	2.732	1.65	1.88	44.68	14.35	40.97
Post-harvest	NGB 01665	6.38	1.49	2.576	1.45	1.96	49.62	13.88	36.50
	NG/AA/SEP/09/053	6.23	1.36	2.351	1.25	1.66	50.84	13.90	35.26
	NGB 01312	2.04	2.64	4.565	2.78	2.98	48.66	13.69	37.65
	NGB 01641	4.86	1.34	2.317	1.23	1.60	43.98	14.62	41.40
	NGB 01184	5.62	1.40	2.421	1.27	1.67	45.86	13.86	40.28
	NGB 01737	6.02	1.41	2.438	1.40	1.72	47.73	14.36	37.91
	Control	6.23	1.50	2.594	1.46	1.97	42.87	14.38	42.75

Table 50b: Physicochemical properties of the experimental plot before planting and after harvesting

Properties Plot		Electrical conductivity	Titratable acidity	Exchangeable cations				Effective cation exchange capacity (%)
				Ca ²⁺ (mg/kg)	Mg ²⁺ (mg/kg)	Na ⁺ (mg/kg)	K ⁺ (mg/kg)	
Pre-planting	NGB 01665	6.02	1.47	1.41	0.19	0.84	0.191	2.665
	NG/AA/SEP/09/053	5.10	1.40	1.39	0.19	0.82	0.188	2.616
	NGB 01312	5.86	1.46	1.40	0.18	0.83	0.190	2.632
	NGB 01641	5.99	1.41	1.40	0.18	0.82	0.192	2.622
	NGB 01184	6.08	1.35	1.39	0.20	0.80	0.186	2.600
	NGB 01737	6.09	1.40	1.37	0.17	0.80	0.185	2.553
	Control	6.36	1.58	1.53	0.22	0.87	0.194	2.954
Post-planting	NGB 01665	6.38	1.49	1.42	0.20	0.85	0.192	2.698
	NG/AA/SEP/09/053	6.23	1.36	1.35	0.16	0.78	0.188	2.504
	NGB 01312	2.04	2.64	1.58	0.26	0.89	0.198	4.298
	NGB 01641	4.86	1.34	1.33	0.14	0.76	0.185	2.439
	NGB 01184	5.62	1.40	1.38	0.18	0.81	0.187	2.585
	NGB 01737	6.02	1.41	1.39	0.19	0.82	0.186	2.616
	Control	6.23	1.50	1.43	0.20	0.85	0.191	2.707

Table 51: Yield and gross return of fruit vegetables intercropped at different distances to juvenile oil palm during 2nd year of field establishment

Vegetable crop accessions	Spacing regime	Area covered (m ²)	Yield (kg)	Average market price/ kg (₦)	Gross return (₦)
Okra (NGB 01184)	1m	38.4	9.464	591.53	5,598.32
	2m	38.4	15.689	591.53	9,280.58
	3m	19.2	17.238	591.53	10,196,.72
Tomato (NGB 01665)	1m	38.4	123.484	165.27	20,407.71
	2m	38.4	216.393	165.27	35,785.42
	3m	19.2	161.18	165.27	26,637.57
Tomato (NG/AA/SEP/09/053)	1m	38.4	170.275	165.27	28,140.64
	2m	38.4	263.393	165.27	43,529.91
	3m	19.2	165.386	165.27	27,332.64
Pepper (NGB 01312)	1m	38.4	35.899	574.39	20,620.32
	2m	38.4	75.106	574.39	43,140.29
	3m	19.2	56.940	574.39	32,705.88
Pepper (NGB 01641)	1m	38.4	25.475	574.39	14,632.64
	2m	38.4	71.500	574.39	41,069.03
	3m	19.2	73.160	574.39	42,022.52
Eggplant (NGB 01737)	1m	38.4	30.245	478.82	14,481.91
	2m	38.4	33.913	478.82	16,238.23
	3m	19.2	26.886	478.82	12,873.56
					494,693.915

Cost of Cultivation, Net Return and Cost benefit Ratio are **₦343,000.00**, **₦151,692.915** and **1.442** respectively.

Table 51 shows the yield and gross return of fruit vegetables intercropped at different distances to juvenile oil palm. Highest gross return of **₦43,529.91** was obtained from tomato (NG/AA/SEP/09/053) intercropped at 2 m from juvenile oil palm. Lowest gross return of **₦5,598.32** was obtained from okra (NGB 01184) intercropped at 1 m from the juvenile oil palm.

CHAPTER FIVE

DISCUSSION

5.1 Soil Assessment

The results of the particle size indicated that all the experimental plots within the plantation were sand-loam and by rating of FAO, the soil is medium textured. This quality indicated that the soil is suitable for oil palm cultivation (FAO, 1987) and this is in accordance with earlier work by Ukaegbu *et al.* (2015).

Organic matter content of the soil before and after intercropping ranged between 2.317 g/kg and 4.565 g/kg ; indicating that the land was fertile and suitable for oil palm cultivation. This is in accordance with earlier report by Ibanga and Iren (2006) who worked on chemical properties and management of the “acid sand” supporting oil palm plantations in south eastern Nigeria.

The effective cation exchange capacity (ECEC) ranged between 2.439 % and 4.298%, both after intercropping; signifying a low ability to retain nutrient according to an earlier report by Ukaegbu *et al.* (2015) who worked on suitability assessment of soil supporting oil palm plantations in the coastal plains sand in Imo State, Nigeria.

The result showed that soil of the experimental plots were all slightly acidic both before intercropping and after intercropping except the more acid soil recorded at pepper (NGB 01312) plot (pH 2.04). This was also reflected in the titratable acidity value with the same pepper plot recording highest value (2.64 cmol/kg) after intercropping. However, the crop seems to withstand the acidity and this observation is in agreement with an earlier report by Jacquemard *et al.* (1998) who reported that oil palm can cope with acid soil with a pH lower than 4.

Following the rating of Chude *et al.* (2011), none of the experimental plots is deficient in nitrate before and after intercropping. The nitrate concentration ranged between 1.23 mg/l and 2.78

mg/l. the high concentration of nitrate is also associated with the high organic matter recorded in the experimental plots. However, following the rating of Chude *et al.* (2011) the phosphorus content of the soil was low; ranging between (1.60 mg/kg and 2.98 mg/kg). However this might on the other hand affect the availability of trace elements according to a report by NIFOR (2009).

Physicochemical properties of the soil of the experimental plots within the juvenile plantation were suitable for oil palm plantation and intercropping did not show detrimental effect on the soil. This agrees with earlier findings by Ukaegbu *et al.* (2015) who investigated the suitability of soils of oil palm plantations in coastal plains sand of Imo State Nigeria, they reported that oil palms in areas that have high organic matter, total N and exchangeable K were not limited in their growth and the soils were assessed suitable for oil palm cultivation.

The higher canopy spread, number and length of fronds, number of leaflet, and trunk and canopy heights recorded during this study at the second- and third-year of field establishment are also in agreement with the findings of Okyere *et al.* (2014) who reported that intercropping of oil palm with food crops such as plantain and or cassava had no adverse effects on the growth, development and yield of juvenile oil palm.

5.2 Intercropping

Intercropping is claimed to be one of the most significant cropping techniques in sustainable agriculture; to its utilization a number of environmental benefits, from promoting land biodiversity to diversifying agricultural outcome. This model integrates low, medium, and tall plants, as well as plants of short, medium, and long life cycles, including trees (Nchanji *et al.*, 2016).

5.3.1 Effect of intercropping on fruit vegetable crops

Apart from those intercropped at 1m to the juvenile oil palms, significant performance of the vegetable crops was recorded in terms of physiological responses when compared with that of the control.

5.3.1.1 Effect of intercropping on growth and yield components of tomato (NGB 01665)

At first trial when the juvenile oil palms were 2 years old, tomatoes of the control plot had the best performance in growth by recording highest values of number of leaves, plant height and stem girths which were statistically significant from those at 1 and 2 m away from juvenile oil palm. This result indicate that tomato (NGB 01665) has preference for sunshine as the partial shade cast on those at 1 and 2 m from juvenile oil palm could be responsible for their poor performances. Njoroge and Kimemia (1995) worked on the economic benefits of intercropping young *Coffea arabica* and *C. robusta* with food crops. They reported that intercropping tomatoes among other crops were found to be economically viable.

Similar results were obtained for the second trial, when the juvenile oil palms were 3 years old but were not statistically significant from those planted at 3 m from juvenile oil palms.

The results of the yield and yield components for first and second trial indicated that tomato (NGB 01665) planted at the control plot gave the best performance however it was not statistically different from those intercropped at 3 m from the juvenile oil palm.

Hutagalung (1995) investigated the intercropping of red pepper, tomato, cabbage and yard-long bean in mango orchard reported that tomato gave high returns from intercropping followed by pepper. He concluded that the presence of vegetable crop within young mango trees will contribute additional income to farmers. This indicates that the tomato plants may only tolerate the canopy and perform significantly well if they are intercropped at minimum of 3 m from the

juvenile oil palm. Intercropping advantage was not recorded for any of the intercropping distances during both trials when the juvenile oil palms were 2 and 3 year old, with LER values less than unity. This indicates their poor performance when intercropped with juvenile oil palm especially at 1 and 2 m from juvenile oil palms.

5.3.1.2 Effect of intercropping on growth and yield components of tomato (NG/AA/SEP/09/053)

The tomato plants at 3 m from juvenile oil palm recorded a good performance in terms of number of leaves, plant height, stem girth and leaf area but the values were not statistically significant from those planted in the control plot. Those planted at 1 and 2 m from the juvenile oil palm recorded the poorest performance during the first and second trials. This may be that tomato could not tolerate the canopy shade from the juvenile oil palm at 1 and 2 m or due to other factors like weed competition and nutrient.

Similarly tomato plants of the control plot recorded the highest number of fruit, fruit weight and yield per hectare during the first and second trials. However, these values were not statistically significant from those recorded from tomatoes planted at 3 m from the juvenile oil palm. Sadiq (2011) examined the growth and productivity response of tomato with pepper intercrop and reported high performances of tomatoes and pepper in terms of growth and yield when intercropped with juvenile tree crops.

Tomato plants intercropped and those of the control plot (sole) also showed a reduction in yield which could be attributed to the increase in the canopy spread of the juvenile oil palm for those in the intercropped and nutrient depletion in the monoculture.

This observation further indicate that tomato plants are sun loving and will give oil palm plantation farmers significant yield when intercropped at 3 m from the juvenile oil palm. More

so, the tomato (NG/AA/SEP/09/053) only recorded LER value close to unity (intercrop advantage) when they were planted at 3 m from juvenile oil palm during the first year.

5.3.1.3 Effect of intercropping on growth and yield components of pepper NGB 01312

Pepper (NGB 01312) planted at 1 m from the juvenile oil palm recorded the poorest performance in growth during both planting trials. Pepper planted at 3 m recorded better performance than those planted at the control plot; however, the values were not statistically significant from respective values obtained from those of the control plot.

Yield and yield components: pepper NGB 01312 planted at 3 m from juvenile oil palm performed best in terms of number of fruit and yield per hectare when compared with other intercropped distances and those at the control plot. This could be that the pepper plants require long period of sunshine with some level of shading which their location at 3 m from the juvenile oil palm provided. Similar results were also obtained during the second trial; however there were reduction in the values. It has been reported that excessive hot weather can cause peppers to drop their blossoms, and or fruit, so providing some shade is helpful- not full shade just some shade (Olasantan *et al.*, 2007).

Olasantan *et al.* (2007) investigated the influence of cassava intercrop on growth and fruit yields of pepper, observed that weed growth and canopy temperature were lower with intercropping. They reported that intercropped pepper were 25-28% higher, on average, than in pure stands. They concluded that pepper can be grown between taller canopy crops to provide a suitable environment for growth, but crops with relatively moderate leaf area index should be selected in mixture with pepper. Partial shade provided by the juvenile oil palms in this study could be responsible for the performance of pepper intercropped with the juvenile oil palm at 3 m from

the juvenile oil palms in terms of yield which recorded higher number of fruits, girth and length of fruit, and yield, than those of the control (sole).

Pepper (NGB 01312) did not record an intercropping advantage in the three intercropping distances with LER values that were lower than unity. However, during the first year, those planted at 3 m from juvenile oil palm recorded values close to unity. This observation indicates that pepper (NGB 01312) will give a significant performance when intercropped at a minimum of 3 m away from the juvenile oil palm.

5.3.1.4 Effect of intercropping on growth and yield components of pepper (NGB 01641)

Pepper (NGB 01641) planted at 3 m from juvenile oil palm recorded the best performance in growth, however it was not statistically significant from those at the control plot during both trials. Yield and yield components: pepper (NGB 01641) planted at 3 m from juvenile oil palm recorded highest fruit number and fruit weight per plant. This increase is however not statistically significant from those at the control plot. This further corroborates the possible need of long period sunshine requirement of pepper as observed in the pepper (NGB 01312) however; certain level of shade has been shown to improve growth and yield of crop.

According to Fajinmi and Odebode (2010), higher yield per hectare was obtained from intercropped pepper than from sole cropping.

It was also observed that as the canopy spread increased there was a reduction in the yield from first to second trials when the oil palms were a year older. The pepper at 3 m might have maintained a higher yield despite the increase in the canopy spread of the juvenile oil palm due to the reduction in weed abundance, richness and competition observed in the intercropped plots than the control plot.

Oyedele *et al.* (2015) investigated the productivity response of spice and vegetable crops in citrus juvenile orchard. They reported that pepper plant height and yield were higher either at 2 m or 3 m away from the juvenile citrus tree which indicates that pepper may perform better as an intercrop with juvenile citrus at spacing farther than 1 m from the citrus. They attributed this observation to the canopy cover of the citrus tree. This finding further corroborates the findings of Oyedele *et al.* (2011) who reported that intercropping did not prevent the optimum growth and yield of citrus and concluded that pepper responded positively in the intercrop with juvenile citrus trees and can be adopted by farmers in southwest of Nigeria.

The shade cast by the fronds of the juvenile oil palm may be responsible for the reduction in weed abundance and richness, which has consequently reduced weed competition and helped the pepper planted at 3 m from juvenile oil palm to maintain good yield. Pepper (NGB 01461) planted at 3 m from juvenile oil palm indicated good performance by recording a yield advantage with LER value above unity.

Aiyelaagbe (2000), observed the productivity of an intercropped sweet orange orchard with pepper. He reported that intercropping the tree crop with pepper gave high productivity without impairing fruit yield of the tree crop.

5.3.1.5 Effect of intercropping on growth and yield components of okra (NGB 01184)

Initially at 2 WAP, okra (NGB 01184) intercropped at 2m from the juvenile oil palm recorded the highest values for number of leaf, plant height and stem girth while those intercropped at 1m from the juvenile oil palm has the least performance with lowest values of stem girth, leaf area, chlorophyll index and total chlorophyll content. During vegetative growth, those intercropped at 3m from the juvenile oil palm recorded the best performance having the highest values of number of leaf, plant height, leaf area, chlorophyll index and total chlorophyll content. However,

those intercropped at 1m from the juvenile oil palm recorded the least performance with least values of number of leaf, plant height, stem girth, chlorophyll index and total chlorophyll content. This result indicate that there were no statistical significance between okra intercropped at different spacing regimes and the sole okra; however those at 3 m from juvenile oil palm recorded the highest values in all the parameters examined except stem girth at 6 weeks after intercropping. These observations are in agreement with Olubode *et al.* (2012) who recorded no significant difference in sole and okra intercropped with juvenile pawpaw. More so, Muoneke *et al.* (1997) and Njoku *et al.* (2007) reported that the taller okra plants obtained in intercrops with maize and sweet potato were an adaptation to display their leaves to absorb maximum solar radiation, hence intercropping generally increased okra plant height.

However, this good performance recorded by okra planted at 3 m from juvenile oil palm contradicts the findings by Olubode *et al.* (2012) who recorded growth and yield reduction of component crops when intercropped okra. He attributed the observation to competition by the component crops for limited growth resources. He further reported that serious growth retardation in okra under mature pawpaw could be due to the height advantage of the pawpaw leading to reduction in light transmission to the okra intercrop rather than moisture or nutrient resources.

They reported that plant height of Okra was significantly ($p > 0.05$) greater under intercropping than in sole cropping. The greater population of plants under intercropping and competition for light and other growth resources might have induced higher plant growth of okra. Although the number of leaves per plant was not significantly ($p > 0.05$) affected by intercropping, the leaf area per plant was significantly ($p > 0.05$) greater in sole crop stands than in the intercropped stands. This might be competitive effect for growth resources when both crops were in a mixture.

Muoneke and Mbah (2007) in their work on productivity of cassava/okra intercropping systems reported that the reduction in Leaf Area Index of intercropped cassava stands was due to reduction in their surface leaf area surface even with more leaf production.

Yield and yield components: during the first trial when the juvenile oil palms were 2 years old, okra planted at 3 m from the juvenile oil palms recorded the highest fruit weight per plant and yield per hectare. Similar results were obtained during second trial when the juvenile oil palms were 3 years old. Okra planted at 2 m from juvenile oil palm also recorded fruit number per plant and yield per hectare that were not statistically significant from what were recorded for okra plants of the control plot. Also, the okra planted at 3 m from juvenile oil palm recorded an intercrop advantage with LER value above unity during the first and second trial. These observations indicated that okra (NGB 01184) can tolerate the shade effect from the canopy of the juvenile oil palm and the weed suppression effect caused by the canopy helped to reduce competition for resources with the okra plants. The results implied that intercropping did not significantly ($p > 0.05$) have negative influence on yield of okra at 3 m from the juvenile oil palm.

Orluchukwu and Udensi (2013) examined the effects of intercropping pattern of okra, maize, pepper on weeds infestations and okra yield. They reported a higher mean fruit yield in sole cropping compared to the intercrop. This observation is contrary to the finding in this study where the yield of okra (NGB 01184) was higher for okra intercropped at 3 m from the juvenile oil palm than the control (sole).

Reduction in the growth and yield parameters examined during second trial when the juvenile oil palms are 3 years old may also be as a result of competition for resources especially light for those okra planted at 1 and 2 m from the juvenile oil palm. This observation is in accordance

with earlier findings of Aiyelaagbe and Jolaoso (1992); Magdy *et al.* (2007) and Olubode *et al.* (2012) who reported that it may be due to competition by the components for limited growth resources.

5.3.1.6 Effect of intercropping on growth and yield components of eggplant (NGB 01737)

Eggplants (NGB 01737) planted at 2 and 3 m from the juvenile oil palm performed in terms of growth. Those planted at 3 m from juvenile oil palm recorded the best performance but was not statistically significant from the control and those planted at 2 m from juvenile oil palm.

Yield and yield components: During the first trial, eggplant at 3 m from juvenile oil palm recorded the highest fruit number, fruit weight and yield per hectare while those at 2 m from juvenile oil palm recorded lower fruit weight and yield which were however not statistically significant from those at the control. At the second trial, those eggplants at 3 m from juvenile oil palm similarly recorded the best performance in terms of number of fruit, weight of fruits per plant, weight of 100 fruits and yield per hectare. However, all these high values were not statistically significant from those recorded by those planted in the control plot. Also eggplants at 2 m from juvenile oil palm recorded weight of 100 fruits and yield per hectare that were lower but not statistically significant from respective values recorded from eggplants at the control plot. The eggplant's good performance even at 2 m from the juvenile oil palm may be because of its leaf morphology and architecture; helping the crop to suppress weeds and also inclined to trap more and maximize the available sunlight to grow and produce significant yield.

Nwofia *et al.* (2017) who investigated the effect of intercropping on of vegetable crops on performance of eggplant reported that intercropping eggplant produced a high degree of complementarity, with intercrop recording high land equivalent ratio. They concluded that intercropping eggplant enhances productivity and financial return.

Furthermore the shade provided by the juvenile oil palm may also help in suppressing weeds and this observation indicated that the vegetable crop performs best under partial shade than in monocrop. During first trial, only those eggplants intercropped at 3 m to juvenile oil palm recorded higher intercropping advantage. During the second trial, the eggplant recorded an intercrop advantage with LER values exceeding unity for those intercropped at 2 and 3 m from the juvenile oil palms.

This implied that the inter-specific competition between the two crops did not affect garden egg significantly. Irrespective of the cropping systems, the highest plant height, number of leaves and leaf area per plant were obtained.

Similarly, the reproductive parameters of the vegetable crops recorded significant performance when compared with the control. These observations were in accordance with earlier reports by Islam *et al.* (2011) that spacing regimes lead to high growth and fruit yield per hectare.

However, the poor performance of vegetable crops intercropped at 1m (experiencing higher shading) was also reported by Olubode *et al.* (2012) who intercropped okra with juvenile and mature pawpaw orchard.

The economic yield was higher in the intercropped okra, pepper and eggplant accessions at 3m from juvenile oil palm. This also is in agreement with earlier work by Emuh *et al.* (2006) who reported higher aggregate yield in intercrop than in their sole crop.

Varietal advantages were also recorded for tomato and pepper accessions as tomato (NG/AA/SEP/09/053) and pepper (NGB 01312) gave higher yield per hectare than tomato NGB 01665 and pepper (NGB 01641) respectively.

Vegetable crops intercropped at 3m recorded higher yield advantage with land equivalency ratio greater than 1, similar observation has been earlier reported by Lyock *et al.* (2013) that intercropped treatments have yield advantages over sole crop.

Significantly high Gross returns and cost benefit ratio observed in this study have similarly been reported by Seran and Brintha (2009) that cost benefit ratio was significantly high in intercropped vegetable than in sole crop.

During the first trial, the interaction result of the two accessions of tomato showed that there was significant interaction of the number of leaf, stem girth and leaf area, and the accessions. This indicates that the interaction between tomato accessions and intercropping distance significantly had effects on number of leaf, stem girth and leaf area.

The interaction of pepper accessions and intercropping distance showed significant interaction for only leaf area.

For the second trial, the interaction of tomato accessions showed significant interactions for only growth parameters which are the number of leaf and plant height.

The interaction of pepper accessions and intercropping distance showed significant interaction for only leaf area.

Reddi *et al.* (2015) who studied vegetables as intercrops in juvenile oil palm plantation and its economics reported that among the different vegetables tomatoes and okra recorded higher yield than other vegetables. They attributed these observations to ample scope for intercropping in oil palm plantation during initial years of planting since the canopy was not yet fully developed. They reported that the pooled data of two years indicated that, the vegetable okra intercropped with oil palm recorded higher fruit yield per plant and fruit yield per hectare. They also reported

that okra intercropped recorded higher net return. However, this study revealed that eggplant and tomato produced the highest fruit yield per hectare.

5.4 Effect of intercropping on growth of intercropped and non-intercropped oil palm

During the first trial, intercropped juvenile oil palms recorded higher canopy spread, number of fronds, length of fronds, number of leaflets, trunk length and canopy height. However, at the end of 16 weeks after intercropping, there was no statistical significant in the mean values of the parameter examined except canopy height. This observation indicates that intercropping juvenile oil palm with fruit vegetables does not have detrimental effect on the oil palm, rather it helped to improve the growth.

Ogwuche *et al.* (2012) worked on the economies of intercropping natural rubber with arable crops as a panacea for poverty alleviation of rubber farmers. He reported that a higher annual increase in girth of rubber intercropped compared to the sole rubber plantation. He examined the impact of intercropping on the girth of rubber plants and pointed out that at the end of every year during the intercrop, the girth of the rubber plants on both intercropped and non-intercropped plots increased; and was higher in the intercropped tree crops than the non-intercropped tree crops. This is in agreement with this study that intercropping of tree crop and arable crop such as vegetable crop would lead to an increase in growth of the juvenile oil palm. They attributed this to an increase in organic matter content as a result of residues from the intercropped plants after harvest which promote soil aeration and possible increase in soil nutrients required for the rubber growth and development. Reduction in weed competition may also be responsible.

More so, it could also be due to complementary of species interaction as opined by Esekhaide (2003). He also indicated that intercropping tree crop with arable crops is profitable and can serve as a means of poverty alleviation among the rubber farmers if practiced. Similar report was

also submitted by Giroh *et al.* (2010) who worked on efficiency and cost of production among gum Arabic farmers; that intercropping of food crops and tree crops is profitable. This report is in agreement with findings of this study that intercropping of vegetable crop and juvenile oil palms was profitable and simultaneously improved growth of the tree crop.

According to Oladokun (1990), among many tree crops that could be intercropped with food crops, most farmers prefer oil palm.

Udosen *et al.* (2006) investigated the performance of oil palm and different food crops combinations in four-year sequential intercropping in a rain forest/derived savanna transition zone of Nigeria. They observed that the different crop combinations intercropped with oil palm did not have any significant negative effect on the oil palm growth, number of bunches and fresh fruit bunch yield over the period. This observation is in agreement with findings of this study that intercropped juvenile oil palm did not show negative impact arising from the intercrop; rather it performed even better than the non-intercropped juvenile oil palm. They attributed this observation to the ability of the juvenile oil palm to maximize the available resources in the environment and did not have to compete for sunlight with the food crop which consequently resulted in good performance.

According to Okyere *et al.* (2014) who studied the residual effect of intercropping on the yield and productivity of oil palm, intercropping oil palm and food crop has no adverse effect on the growth, development and yield of the oil palm. He opined that intercropping does not absorb excessive nutrients from the field that would affect the nutrient requirements of the oil palms. He further attributed these findings to decomposition of crops residues after harvesting. More so, he suggested that the regular weeding of intercropped field and its eventual decomposition of weeds might have had added advantage to the nutrient availability for the growth of the oil palm even

though that was not significant. Higher canopy height, number and length of frond, number of leaflets, trunk and canopy heights recorded in the intercropped than in the non-intercropped are in agreement with their observations as there was improvement in growth of the intercropped juvenile oil palms than the non-intercropped juvenile oil palm even though it was not significant. This is also in accordance with an earlier work by Nuerter *et al.* (2000) who studied the economies of intercropping food crops in oil palm for small scale farmers that it is profitable to intercrop oil palm with food crops especially for the first two to four years when the oil palms are not fruiting as compared to sole cropping.

Famaye *et al.* (2012) investigated the effects of intercropping of coffee with rice and plantain at early stage of field establishment in Nigeria. They observed high growth performance in the intercrops and concluded that there were no deleterious effects of intercropping of coffee with rice and food crops at early stage of field establishment. This is in agreement with findings of this study as intercropping of vegetable crops with juvenile oil palm has not shown negative effects on the growth of the intercropped and non-intercropped juvenile oil palm.

This finding is also corroborated by earlier works on the beneficial effect of intercropping some food crops with coffee (Okelana, 1982; Famaye, 2000 and 2005), cocoa, oil palm and kola (Adenikinju, 1980; Ofoli and Lucas, 1988; Okpala-Jose and Lucas, 1989; and CTA, 1993).

Famaye *et al.* (2012) reported that the yield obtained for food crops during intercrop of tree crops and food crops were as high as their sole crops. This observation is in agreement with findings of this work that vegetable crop such as pepper (intercropped at 3 m from juvenile oil palm) and eggplant (intercropped at minimum of 2 m from juvenile oil palm) performed well in terms of growth and yield components. This further affirmed that the beneficial impact on food crop production other than better morphological growth due to intercrop earlier pointed out as an

advantage in intercropping (Okigbo and Greenland, 1975; Okigbo, 1977; and Herera and Harwood 1973).

Putra *et al.* (2012) who investigated the effect of intercropping on growth of one year-old oil palms reported that the food crops intercropped with the juvenile oil palms did not inhibit the growth rate and performance of the juvenile oil palms which were the main crop. This is in agreement with the findings of this study in which the intercropped juvenile oils were found to produce a better performance than the non-intercropped juvenile oil palms by recording higher canopy and trunk heights, canopy spread, and number and length of fronds. Similarly, this earlier report is also in accordance with the findings of this study that though the intercropped juvenile oil palms had better growth performances than the non-intercropped palm during the second- and third-year of field establishment, the differences were largely not significant.

This better performance recorded in the intercropped juvenile oil palms may be attributed to more regular weeding carried out in the juvenile oil palm-vegetable intercrop plots. Furthermore, the initial minimum of 1 m space left fallow before planting the fruit vegetables reduced the competition between the juvenile oil palm and the fruit vegetables for nutrients in the soil. Similar result were obtained during the second trial, there was no significant difference between the intercropped and non-intercropped juvenile oil palms at the end of 16 weeks after intercropping. However, the non-intercropped juvenile oil palm recorded better performance in number and length of fronds.

5.5 Weed species distribution

The reduction observed in number of weed species at 3 through to 6 WAI and after harvesting of fruits may be due to the shading effect of the intercropped oil palm and also the canopy shade cast by the fruit vegetables.

Considerably high numbers of broadleaf weeds were recorded in most of the intercropped plots as compared to grasses and this observation may be due to abundance of seeds and propagules of these species in soil seed bank of shaded or partly shaded soil in tropical rainforest zone- where the experimental juvenile oil palm plantation used in this study is located. More so, abundance of broadleaf weeds observed in this study was previously reported by Olorunmaiye *et al.* (2011) who reported high concentration of broad leaf weeds under the canopies of mature citrus trees.

Also members of the family Asteraceae and Euphorbiaceae were observed to have higher numbers of members. This observation is in agreement with an earlier report by Olorunmaiye *et al.* (2011) who reported high colonizing power of these two families, readily brought about by the high fruit production and the efficient dispersal of fruits and seeds. This is further supported by a report by Oluwatobi and Olorunmaiye (2014) who reported high light requirement, aggressive growth, short life cycle, large seed production with potent explosive seed dispersal mechanisms were identified as attributes that may be responsible for the high relative weed density observed in members of Euphorbiaceae.

Some weed species such as *Mariscus alternifolius*, *Borreria ocymoides*, *Ageratum conizoides* and *Euphorbia heterophylla* were found to be present in most of the plots sampled. This may be because these weeds are predominant in juvenile oil palm fields. This finding is in line with previous study by Yakubu *et al.* (2006) who reported site specificity in both crops and weeds.

Closely related finding was also opined by Karaye *et al.* (2007) who reported that some weeds and crops are site specific, while others will thrive over a wide range of habitat.

High value of weed species distribution recorded at pepper (NGB 01641) – juvenile oil palm intercrop plot at 3 WAI may be due to fertility of the soil and distribution of weed seeds. However the higher weed species distribution recorded in the control plot may be due to absence of additional shade from the intercropped juvenile oil palm which could suppress the growth of weeds. The control plots recorded lower weed species diversity as shown by the Simpson's Index values at the end of harvesting, however; at 3 and 6 WAI, the juvenile oil palm –okra (NGB 01184) intercrop and juvenile oil palm – tomato (NGB 01665) intercrop plots recorded the lowest Simpson's Index of diversity values (0.384 and 0.734) respectively. This observation confirms earlier report by Obadoni *et al.* (2009) who reported that shade effect from trees did not encourage undergrowth regeneration or establishment of weed.

High weed density and above ground biomass, and low smothering efficiency were recorded in the control plot when compared with the fruit vegetables–juvenile oil palm intercropped plots. These findings are in line with earlier report Yakubu *et al.* (2006) who reported site specificity in both crops and weeds. More importantly, this shows that intercropping helps to reduce weed density and biomass and it is in accordance with earlier reports by Egbe (2010), Karkanis *et al.*, (2011) and Oluwatobi and Olorunmaiye (2014) who reported high efficiency of weed elimination in intercropped fields. Chipomho *et al.* (2015) also reported that weed density and weed biomass were affected negatively by intercropping. They reported that weed density and biomass were attributed to sparse canopies observed in non-intercropped fields; hence promote weed growth and development.

Higher smothering efficiency recorded in this study also agree with an earlier report by Henrik *et al.* (2003) who opined that intercropping reduce weed density and biomass when compared to sole cropping probably due to ability to smother weeds by denying them light. This finding is also in accordance with an earlier report by Iqbal *et al.* (2013), that soyabean-sesame and sorghum-cotton intercropped significantly decreased weed density and biomass by intercepting to radiation.

The reduced weed biomass observed in this study is in line with an earlier report by Orluchukwu and Udensi (2013) who reported that weed biomass was significantly lowered during the two years of study in the intercrop compared to the sole cropping. They concluded that intercropping pattern has a great potential in reducing weed infestation in intercropping system especially in farming system with low external input.

This study has been able to demonstrate that intercropping fruit vegetables with juvenile oil palm could help to significantly reduce weed density and weed biomass thereby ultimately increasing productivity by increasing yield of component crops. It has also been able to show the weed species diversity and their abundance in the study area.

CONCLUSION

The responses of the fruit vegetables to intercropping with juvenile oil palms during the second and third year of establishment of the oil palm plantation can be successfully practiced to help reduce weed infestation and increase land productivity of the fallow alley during the initial stage of field establishment before oil palm canopy closure. Oil palm which is the main crop did not show any deleterious effects as a result of the intercrop; rather, intercropping encouraged its growth and development.

This study established that fruit vegetables namely tomato, pepper, okra, and eggplant can successfully be intercropped with juvenile oil palm intercrops during the second and third year of field establishment of the oil palm. This success in intercrop was achieved by planting the fruit vegetables at a minimum of 2 m away from the juvenile oil palm.

However, it was found that intercropping these fruit vegetables at 1 m from the juvenile oil palms depressed the performance of all the fruit vegetables. This low performance recorded by all the fruit vegetables at this distance was probably because light transmission through the juvenile oil palm fronds at this distance was very inadequate to support the growth and yield of the component fruit vegetable crops. Pepper, okra and eggplant intercropped with juvenile oil palm performed best at 3 m from the juvenile oil palms. However, the eggplant (NGB 01737) and tomato (NG/AA/SEP/09/053) were particularly observed to perform well in terms of growth and yield at 2 m from juvenile oil palm probably because of its morphology, leaf arrangement and shade tolerance ability; assisting the crop to smother weeds and maximize the available solar radiation under the canopy of the juvenile oil palm.

It was also revealed that there was reduction in the yield of the fruit vegetable crops from second year to the third year which could be attributed to increase in the canopy spread of the juvenile oil palm.

This study was able to establish that the yield of the vegetable crops were higher the farther away they were from the juvenile oil palm. However, tomato (NG/AA/SEP/09/053) and eggplant (NGB 01737) produce the best performance in terms of growth and yield due to its growth dynamism and its morphology helping the crop to suppress weeds.

Weed species abundance and richness increase with exposure to sunlight; and indicate that shading leads to reduction in weed species abundance and richness. Reduction in weed species abundance and richness could lead to increase in growth parameters and yield components. However, exposure to sunlight could increase weed species abundance, richness, growth parameter and yield components simultaneously in some cases as observed in tomato (NG/AA/SEP/09/053) in this study. Eggplant intercropped with juvenile oil palm indicated ability to smother weeds and gave better yield when intercropped compared to sole cropping. A reduction in weed species richness and abundance was observed in the intercropped plots from 3 weeks after intercropping to after harvesting of fruits. This may be due to the shading effect of the intercropped juvenile oil palm and also the canopy architecture of the fruit vegetable crops.

This study has been able to demonstrate that intercropping fruit vegetables with juvenile oil palm could help to significantly reduce weed density and weed biomass thereby ultimately increasing productivity by increasing yield of component crops. It has also been able to show the weed species diversity and their abundance in the study area.

The biological and economic indices of the fruit vegetable revealed that intercropping of juvenile oil palm with fruit vegetable crops during the establishment stage of second and third year was more profitable than when the oil palms were not intercropped.

RECOMMENDATION

From the results obtained from these studies the following recommendations are made:

1. Intercropping of fruit vegetable crops with juvenile oil palm at a minimum of 2 m from the juvenile oil palm was found to have no adverse effects on the growth and development of the juvenile oil palm. More so, the intercropping did not result in drastic reduction in the fertility of the soil in the study area. Hence, it is recommended that intercropping of juvenile oil palm with fruit vegetable crops should be practiced at the specified distance of 2 m from the juvenile oil palm.
2. Eggplant intercropped with the juvenile oil palms performed well in terms of growth and yield when intercropped at minimum of 2 m from the juvenile oil palm. Therefore, farmers are advised to intercrop this fruit vegetable with juvenile oil palm at second and third year of establishment at the specified distance of 2 m from the juvenile oil palm. Its shade tolerance growth dynamism and weed smothering ability made it a competitive economic crop to intercrop with the juvenile oil palm during initial field establishment.
3. Intercropping of tomato (NGB 01665 and NG/AA/SEP/09/053) with juvenile oil palm at distances less than 3 m from the juvenile oil palm resulted in poor performance. It is therefore recommended to farmers to intercrop these tomato accessions at not less than 3 m from the juvenile oil palm. Tomato (NG/AA/SEP/09/053) is recommended to be intercropped with juvenile oil palm at 3 m from juvenile oil palm during second and third

year of field establishment giving its interaction advantage over tomato (NGB 01665) in terms of its yield and better ability to smother weeds.

4. Pepper (NGB 01312 and NGB 01641) and okra (NGB 01184) are recommended to be intercropped with juvenile oil palm during their second and third year of field establishment at a minimum of 3 m from the juvenile oil palm to obtain good performance in terms of growth and yield.
5. Government agencies such as the Ministry of Agriculture, Forestry and research institutions through their extension programme would find these results useful in educating farmers (smallholders, medium- and large-scale plantation owner) on intercropping fruit vegetables with juvenile oil palm at the early stages of field establishment.
6. It is also hoped that investors, farm managers, agroservice companies would find this result useful in taking decisions on establishing and managing a productive and weed free oil palm plantation; especially at the initial years of plantation establishment when the oil palm are yet to be productive.

CONTRIBUTION TO KNOWLEDGE

The results of this study have contributed to the existing knowledge or literature on the responses of fruit vegetable crops to intercropping with juvenile oil palm as it has been able to:

- Reveal the growth and yield responses of fruit vegetables when intercropped with juvenile oil palm at different intercropping distances in Ala agricultural community, Akure-North Local Government of Ondo State.

- Identify the suitable distance or space allowance when intercropping with juvenile oil fruit vegetables with juvenile oil palm to avoid negative effects on the growth and development of the oil palm.
- Indicate the most suitable fruit vegetable crops to be intercropped with juvenile oil palm during the second and third year of field establishment.
- Identify the weed flora and species distribution in the experimental area and thus reveal the suitable fruit vegetable crop that can be best suppress and compete with weeds in fruit vegetable-juvenile oil palm intercrop in Ala agricultural community; a South-West agro-ecological zone of Nigeria.
- Reveal the economic returns of fruit vegetable crop-juvenile oil palm intercrops during the second and third year of field establishment in Ala agricultural community; a South-West agro-ecological zone of Nigeria.

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