STUDIES ON THE ABUNDANCE, DAMAGE AND CONTROL OF INSECT PESTS ON TWO CULTIVARS OF ROSELLE (*Hibiscus sabdariffa* Linn.) IN YOLA AND JALINGO , NIGERIA

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M.TECH/CPT/17/0939

JANUARY, 2020

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BY

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A THESIS SUBMITTED TO THE DEPARTMENT OF CROP PROTECTION, SCHOOL OF AGRICULTURE AND AGRICULTURAL TECHNOLOGY, MODIBBO ADAMA UNIVERSITY OF TECHNOLOGY YOLA, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD MASTER OF TECHNOLOGY (M.TECH.) DEGREE IN CROP PROTECTION

JANUARY, 2020

DECLARATION

I hereby declare that this thesis titled "Studies on The Abundance, Damage and Control of Insect Pests on Two Cultivars of Roselle (*Hibiscus sabdariffa Linn*.) In Yola and Jalingo, Nigeria" has been written by me and that it is a record of my own research work. It has not been presented before in any previous application for a higher degree.

Akaa, Nguseer Grace	Date

DEDICATION

This work is dedicated to Almighty God (for his magnificent works in my life) and my wonderful sister Hyua Dooshima.

APPROVAL PAGE

This project entitled "Studies on Abundance, Damage and Control of Insect Pests on Two Cultivars of Roselle (*Hibiscus sabdariffa* LIN.) in Yola and Jalingo, Nigeria" meets the regulations governing the award of Master of Technology (M.Tech) Degree in Crop Protection of the Modibbo Adama University of Technology, Yola and is approved for its contribution to knowledge and literary presentation.

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ABSTRACT

Roselle (*Hibiscuss sabdariffa* Linn.) has high susceptibility to insect infestation which negatively affects its growth and yield if not properly managed. This study aimed at providing an effective and more eco-friendly method to curtail the problem through determining the species composition of insects associated with roselle, their damage and the effect of the spray regimes (neem fruit extract mixture100 ml to 3 litres of water and Sherpa plus at 1.65 ml/l) on insect pest control. There were two cultivars of Roselle at the main plot and two insecticidal spray regimes of Neem extract and Sherpa with a control in three replications. The species complex at 16 weeks after sowing was found to be predominantly Coleopterans (45.50 %) followed by Lepidopterans (22.03 %), Homopterans (12.93 %) Orthopterans (11.01%) while Hemipterans (8.62 %) were the lowest which appeared to be same in both varieties at the two locations. Combined analysis showed lower total fruit yield in the control (290.57 g) while a higher fruit yield of 454.03 g and 424.86 g, 488.28 g and 463.90 g was recorded in the samples treated with Neem extract and Sherpa Plus at 4 weeks, Neem extract and Sherpa Plus at 2 weeks respectively. The calyx damage in the control was higher (69.96 g) while the least damage was recorded from Neem extract at 2 weeks (14.93 g), the white cultivar had higher damage (35.15 g) than the red (26.45 g) but no significant difference among the locations. Similar trend was exhibited in most parameters thus neem extract at 2 weeks spray regime could be considered as effective pesticides as equivalent to Sherpa plus at 2 weeks spray regime and is more eco-friendly as it is bio-pesticides, but its effect on the nutritional value roselle should be evaluated and further studies that will determine the group of insects the control is more effective.

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CHAPTER ONE

INTRODUCTION

Roselle [*Hibiscus sabdariffa* (Lin.)] commonly known as Sorrel is one of the major vegetables crops in Nigeria and the world at large. It is an annual herbaceous shrub from family Malvacea which is widely cultivated throughout the world but said to have originated from West Africa (Mehdi *et al*., 2018). The major areas of roselle cultivation include China, Thailand, Benin, Sudan, Ghana, Niger, Burkina Faso and Nigeria. The major growing areas in Nigeria include Kagara and Mokwa (Niger State), southern Jos (Plateau State), and around Ibadan (Oyo State) as the major producing areas. It is also widely grown in Kogi, Kwara, Kebbi, Sokoto, Zamfara, Katsina, Borno, Kaduna, Bauchi, Adamawa, Benue and Kano States while Germany and USA are known to be major importers (Falusi, 2004). It is cultivated in cool and hot weathers, with variable growing cycles. It is an erect and branched annual sub-shrub, (0.5-3m tall) with a tap-root system, its flowers are born on very short peduncle in the axils of the upper leaves, the epicalyxes are made up of 10 linear fleshy bracteoles and the calyx is 8 lobed, becoming large and fleshy after flowering. It is produced annually than any other vegetable of which over 300 different species exist and consist of different colours, textures, leaf shape and size, its yield ranges between 6 to 8 t/ha depending on the variety (Babatunde, 2003). In Nigeria, basically two botanical varieties are recognized, the calyx of the red and the white cultivar. It can tolerate relatively high temperature throughout the growing and fruiting periods with an optimum rainfall of approximately 45-50cm distributed over a 90-120day growing period (Adanlawo and Ajibade, 2006). It has a lot of uses: as vegetables, as feed for livestock, as raw material for industry and as a form of foreign exchange, the leaves and buds of roselle either mature or immature may be consumed in various ways depending on regions or ethnic groups. (FAO, 2007).

Roselle is easy to grow and strives best in the cool part of the year, but with bolt-resistant varieties and a little shade, you can grow roselle in hot season too. It is a short day crop requiring about 11-12 hours day length for flowering and fruiting but the vegetative period can be manipulated through the sowing date. It grows across a range of agro ecological zones, although it is best adopted to well drained sandy loam to silty loam soils rich in organic matters and essential nutrients, can be grown under other diverse conditions as well as from fairly coarse to the heaviest of clay with a minimum soil temperature of 10-

13 ^{0}C, 16-32 ^{0}C atmospheric temperature and pH 5.5-7.5 (Malgwi and Saidu, 2011; Bahaeldeen *et al.,* 2012; Mera *et al.,* 2009).

Roselle is so vulnerable to insect attack at different stages of production and the pest pressures vary geographically. Majority of the pest impacts are due to the direct feeding injury and quality reduction, presence of frass and live or dead insects in the harvested produce will impact marketability of the produce. Insect pests can cause huge damage on roselle and if not well managed, results to field yield losses of about 30-80% by greatly reducing the leaf quality, retard growth or even killing the whole crop. There are several insect pests that attack roselle but the common insect are said to be aphids, white flies, beetles and bugs (Jackie 2018; Mera *et al.,* 2009; Navarra 2017; WAG, 2018; Simon *et al.,* 2017). Minimizing this field yield losses due to insect pest attack include proper hygiene and management, use of botanical products, biological control, insecticidal control, improved cultural practices (early planting and weed control) among others (Alleoni and Ferreira, 2006; Fores, 2017; Oyewole and Mera, 2010).

Insect attack in the field is generally of great economic importance, most especially on vegetable foods such as roselle. The infestation affects greatly the economic and nutritional value of vegetables, the damage caused by the pests to leaves, calyx and seeds if not checked can lead to economic losses hence the need for sort of control and knowledge about the insect species composition, their damage and efficacy of neem seed extract for their control in Yola and Jalingo. The control of these insects is currently done using Synthetic insecticides which are applied directly to the edible leaves and calyx which has raised health concerns due to unacceptable residue levels reported in literatures (Lale, 2001; Siddig and Khalafalla, 2013; Sarah *et al*. 2008; Oparacke, 2007; Malgwi and Hamman, 2013) thus calls for research into safer alternatives of insect pest control on this crop. Therefore this research is aimed at understanding species diversity and an eco friendly method of controlling this great damage to enhance the economic and nutritional returns from the plant.

Therefore the objectives of this study are:

i. to identify the species composition and abundance of insects associated with roselle *H. sabdariffa*.

ii. to determine the damage caused by the insect pests on roselle.

iii. to assess the effect of treatments spray regimes with neem extract and Sherpa plus on insect pest control in two cultivars of roselle.

CHAPTER TWO

LITERATURE REVIEW

2.1 Roselle Production

Roselle [*Hibiscus sabdariffa* (Linn.)] is an important crop in Nigeria not only on the basis of number of farmers that engaged in its cultivation but also in its economic value. It has risen to be a common crop in Nigeria which different industries depend on as raw materials Bahaeldeenat *et al.,* 2012). The increase in demand makes its annual production higher than any other vegetable with approximately 15,000 metric tons entering international trade each year, of which over 300 different species exist and consisting of different colours, textures, leaf shape and size (Babatunde, 2003).

It is a versatile crop which allows it’s cultivation across a range of agro ecological zones, although it is best adopted to well drain sandy loam to silty loam soils. It can be grown under other diverse conditions as well as from fairly coarse to the heaviest of clay rich in organic matters and essential nutrients with a minimum soil temperature of 10-13 ^{0}C, 16-32 ^{0}C atmospheric temperature and pH 4.5-7.5 (Mera *et al.,* 2009). In tropical and subtropical regions, an altitude 3000 ft. (900 m) above sea level is suitable for growing this plant. Annual rainfall between 400 and 500 mm is necessary throughout the roselle growing season. It is a short day crop that is very sensitive to the photoperiod requiring about 11-13 hours day length for flowering and fruiting but the vegetative period can be manipulated through the sowing; in the first 3-4 months of its growth, Flowers would not appear if there would be more than 13 hours of sunlight in a day and it is exceptionally susceptible to frost and mist as growth of the plant ceases at 14ºC but it tolerates floods and heavy winds (Malgwi and Saidu, 2011; Babatunde and Mofoke, 2006, Mehdi *et al*., 2018).

Deen (2018) revealed that roselle sown in mid July has superior vegetative growth of plant height, leaf length, leaf width and highest number of fruits as well as fresh calyx yield as compared to other sowing dates. It is therefore recommended that the mid July sowing date is optimum since it gave the highest calyx yield. Planting of roselle in mid July in Northern Guinea Savanna would result in high calyx yield but at the expense of longer days to flower compared to sowing early August.

Harvesting of *H. sabdariffa* is done from late November onwards. The harvest is timed according to the ripeness of the seed. The fleshy calyces are harvested after the flower has dropped but before the seed pod has dried and opened. The longer the capsule remains on the plant after the seeds begin to ripen, the more susceptible the calyx is to disease and sun cracking. The calyces ripen about three weeks after the start of flowering, which is 100–160 days after the plants are transplanted outdoors. The fruit ripens progressively from the bottom of the plant to the top. Harvesting is carried out by intensive hand labor, the calyces being picked singly at the appropriate stage. The fruit may be harvested when fully grown but still tender, when they can be easily snapped off by hand but later harvesting requires clippers The fruit is easier to break off in the morning than at the end of the day. On average, each fruit yields about 7–10 g of sepals. Drying is the traditional method for preserving foods. Roselle drying is done in one of two ways: by harvesting the fresh fruit and then sun-drying the calyces (the fully developed fleshy calyx is peeled from the fruit by hand and dried naturally), or by leaving the fruit to partially dry on the plants and harvesting the dried fruit, keeping the crop well protected during the process (Bahaeldeen *et al.,* 2012; Babatunde and Mofoke,2006).

2.2 Taxonomy of Roselle

Roselle *Hibiscus sabdariffa* (Linn.) is a plant belonging to the Kingdom Plantae (Plants), Subkingdom Tracheobionta (Vascular plants), Super division Spermatophyta (Seed plants), Division Magnoliophyta (Flowering plants), Class Magnoliopsida (Dicotyledons) Subclass Dilleniidae, Order Malvales, Family Malvaceae (Mallow family), Genus and Species *Hibiscus sabdariffa* Lin.(Deen, 2018)

2.3 Uses of Roselle

All parts of roselle are useful ranging from buds, leaves to stalks. The tender leaves and stalks are also eaten as salad, the stalk used as a substitute to jute and its pulp is suitable for the manufacture of newsprint (Mera *et al.,* 2009). The buds are useful in so many industries as raw materials (beverages, chemical paints, solvents, oils, dyes, soups, insecticides, food, jams, and many more). The stalk and leaves are used as animal feeds and a source of fuel. Roselle leaves are used as staple food (vegetable), spices, beverages among others. The whole plant (or part) maybe also used as a major study plant for many academic disciplines such as genetics, agronomy, medicine, biochemistry, crop protection and others (Puro *et al*., 2015; Bahaeldeen *et al.,* 2012; Babatunde and Mofoke, 2006). Generally, vegetables make up a major portion of the diet of humans in many parts of the world and play significant role in human nutrition, especially as sources of phytonutriceuticals: vitamins (C, A, B1, B6, B9, E), minerals, dietary fiber and phytochemicals (Bahaeldeen *et al.,* 2012; Deen, 2018). Analysis has shown the presence of crude protein and minerals such as iron, phosphorus, calcium, manganese, aluminium, sodium and potassium in the leaves while calcium, mucilage, citrate, ascorbic acid, niacin, riboflavin, gossypetin, hibiscin, and chloride present in calyx (Adam *et al.*, 2017).

Mera *et al.*, (2009) also indicated that Roselle is grown extensively in the Semi-Arid savanna for local consumption and for export to the Middle East and Europe. The red acid succulent calyx are boiled with sugar to produce sorrel drink, they are also made into jellies, sauces, chutneys and preserves. The seeds contain about 17% oil, which is similar in properties to cotton seed oil. The seeds are boiled, fermented and dried for use as condiment for local soup preparations (*Yakuwa* or *Batso* in Hausa) before the arrival of modern substitutes. Mera *et al.*, (2009) further explains that fruit contains approximately 84.5% water, 1.7 % protein, 1.0 % fats and oil, and 12% carbohydrate. Its calyx contains 4 % citric acid. Besides food, the traditional preparations from various parts of the plant such as lowers, leaves, calyx and corolla of the roselle are used as remedy for various illnesses. Relatively little has been reported on the agronomy of roselle in northern Nigeria.

Oyewole and Mera (2010) reported on the response of roselle (*Hibiscus sabdariffa L.*) to rates of inorganic and farmyard fertilizers in the Sudan savanna ecological zone of Nigeria stating the uses of crop as where the red acid succulent calyx is usually boiled with sugar to produce ‘sorrel’ drink, in addition to being made into jellies, sauces and chutneys. Michele *et al.* (2007) Investigated the efficacy and safety of *H. sabdariffa* for treating obesity fourteen herbalists (herb sellers) were interviewed about the popular use of plant with weight loss purpose in Porto Alegre, South Brazil city, all identified species scientific data was reviewed, data collected mainly from animal and invitro studied. Preclinical data indicate the potential role associated with obesity such as hyperlipidemia.

Roselle *Hibiscus sabdariffa* have been found to be rich in vitamins, carbohydrates, proteins, minerals, flavonoids , anisaldehyde, anthocyanins, ascorbic acid, beta sitosterol, tannins, carbohydrates, organic acids, chrysanthemin, citric acid, ergosterol, eugenol, fat,gossypol, hibiscetin, hibiscus acid, hibiscin, hibiscitrin and other antioxidants are useful in different ways including reducing hypertension, serum cholesterol levels, treatment of urinary bladder stones, heart diseases, cough, bronchitis, sores and wounds). Some have also been exported to inhibit the in vitro growth of Staphylococcus epidermidis (Onuorah *et al.,* 2012). Similarly, Bahaeldeen *et al.,* in 2012 investigated the experimental work on root part, the presence of various phytoconstituents like flavonoids, tannins, protein, sterol etc. His studies also reported roots having various diagnostic characters, ash value, extractive value and moisture content determined for quality standard of drugs.

2.4 Constraints to Roselle Production

The production of roselle is greatly being affected by certain factors like traditional inputs, unavailability of farm labour among others. Irrigation problems has been of great concern as the low lying flood plains and other plain lands are fertile during the dry season but lack moisture to be cultivated (David and Tony, 1999). Biological factors like local varieties, diseases and deficiencies have effect on roselle yield as well as poor soil fertility as it is a known constraint to roselle production, this may also be associated with soil erosion where plant roots are exposed by washing away the loose fertile soil. Fertilizer availability is another constraint due to high prices and the unavailability to the local farmers (Mera *et al.,* 2009).

Processing and storage of the products especially the leafy part has been challenging due to the inadequacy or unavailability of standard facilities, most of the harvested vegetable due to their perishable nature are thus wasted (Bahaeldeen *et al.*, 2012). Another great limitation for large scale production of roselle is its rapid rate of deterioration, there are no improved varieties with longer shelf life and also inadequate preserving materials such the fresh calyx easily deteriorates.

Insects pest also constitute a major problem in the production as they either cause loss directly by feeding or indirectly as vectors of plant diseases (Malgwi and Saidu, 2011). The control of the insect thus becomes a great challenge in roselle production; Most of the growers of roselle depend mainly on pesticides as the only tool to minimize the damage caused by pest. The farmers without the required technical supervision conduct Pest control on the fields without knowledge of recommended pesticide that are human and eco friendly, knapsack sprayers and other tools are difficult to purchase and to maintain as such growers use whatever they could purchase from unauthorized dealers and applies it by any means, even by a bunch of herbs (Mohamed, 2000).

There is also a paucity of information concerning improved management practices, such as time and method of sowing, irrigation, fertilizer application, time and method of harvesting and mode of drying and storage of calyces. The crop is still produced by traditional methods under rainfed conditions. The great risks inherent in the traditional sector, chief among which is the uncertainty and fluctuation of rainfall, discourage the adoption of modern production techniques due to the high cost involved. Due to these conditions, roselle yields are still far below the potential of about 6 to 8 t/ha (Babatunde, 2003; Nawal, 2004).

2.5 Some Common Pests of Roselle

Like any other plant, different pest attack roselle at different production stages causing huge damage and if they are not well managed, they greatly reduce the leaf quality or even kill the whole crop. There are several pests that attack roselle and other vegetables but all can be categorized into flies, bugs, mites, worms and mollusks (Fores, 2017; Imam and Makurtar, 2010).

The folial feeders constitute a serious menace to unsprayed plants throughout the growing period of the roselle at anytime of the year. The commonest insects that attack roselle are said to be aphids, white flies, beetles, and bugs (Malgwi and Omuminya, 2004; Susan *et al.,* 2015). Simon *et al.,* (2017) reported a survey on the insect associated with roselle in Benue State, Nigeria; where insect collection and a laboratory enumeration and identification was done, the highest number of insects found were those of Orders Coleoptera, followed by Hemiptera, and Orthoptera in both early and late rainy season but late rainy season had a higher insect infestation (both insect pest and natural enemies) as compared to early rainy season.

2.5.1 *Aphids (Myzus persicae*)

Popularly known as plant lice, Aphids are a diverse group of plant feeding insects belonging to Kingdom Animalia, Phylum Arthropoda, Class Insecta, Order Hemiptera, Suborder: Sternorrhyncha Infraorder Aphidomorpha and Superfamily Aphidoidea predominantly found in temperate climatic zones. There are several species of aphids that attack greens, but the most common ones are peach aphids and potato aphids. The origin is not known but it is found in all warm and tropical part of the world, it strives well throughout warm and humid region around the world (David and Tony, 1999).

These insects are usually small, pear-shaped with long sucking mouth parts and green, pink, orange, or dark red in color. They are sucking pests that feed on the inner tissue fluid of vegetables, causing leaf cupping/curling and stunted plant growth. Displaying tiny, pink or green bodies measuring up to 1/8 inch in length, aphids tend to congregate in large groups on leaf undersides. As a result of their feeding, plant may experience diminished health and cosmetically damaged foliage. As aphids feed, they release a sticky substance called honeydew. This substance collects on plants after dripping from feeding sites. Honeydew attracts ants and also encourages the growth of a black-hued fungus called sooty mold, which may block out essential sunlight. They predispose the plant to other diseases from their activities. Approximately 4000 species of aphids have been described, feeding on over 250 agricultural and horticultural crops throughout the world. Generally, eggs of aphid develop within the mother (female body) and nymphs are born, which mature within few days and population density increases rapidly. In the early stage of infestation, adult have no wings, but as they become crowded, winged forms appear in subsequent generations for dispersal from one plant to another. They are found primarily on the growing points of the host plants, including tips, flowers and developing pods and cover the whole plant at high density. Aphids choose a suitable host plant for feeding, using stylet to probe beyond the epidermis into mesophyll and parenchyma tissues. Stylets are thin, needle like appendages formed by the mandible and maxilla, penetrate the host plant cells intracellularly and route the phloem. Many species of aphids exploit a single host-plant and have to cope with changing environmental conditions, as changes in its population depends on the quality of the host plant(Futuless *et al.*, 2018; PNRC, 2014; Webb *et al.*, 2015).

The symptoms associated with aphid attack are leaf chlorosis, leaf rolling and leaf folding, which are accompanied by plant stunting. Most of the aphid species do not cause physical damage to their host plants, whereas, some cause necrosis on the plant at the site of feeding, resulting in the formation of galls. Some species of aphids also cause indirect damage to plants by acting as a vector of several viruses in the absence of virus transmission; it has been assumed that aphid saliva is the causative agent of damage to plant tissues. Maturing rapidly, females breed profusely so that the number of these insects multiplies quickly. Winged females may develop later in the season, allowing the insects to colonize new plants. In temperate regions, a phase of sexual reproduction occurs in the autumn, with the insects often overwintering as eggs (Futuless *et al.*, 2018; Karnataka, 2012).

Biological pest control as part of an integrated pest management strategy is possible but difficult to achieve except in enclosed environments such as glasshouses. Natural enemies include predatory ladybugs, hoverfly larvae, parasitic wasps, aphid midge larvae, crab spiders, lacewing larvae, and entomopathogenic fungi. Aphids can be controlled by a broad-spectrum pesticide which can be sprayed on the stems and on both sides of the leaves (PNRC, 2014).

2.5.2 *Whiteflies (Bemisia tabaci* (Genn.))

The origin is not known but it is found in all warm and tropical parts of the world, it strive well throughout warm and humid region around the world. They are from Kingdom Animalia, Phylum Arthropoda, Class Insecta as Homoptera- Aleyrodidae, the white flies are known to reproduce bisexually or parthenogenetically, and hence numerous generations can occur during the year (Mohamed, 2000).

Both adults and nymphs suck the plant sap, removing plant nutrients and transmission of a number of viral diseases among different crops such as leaf curl viruses, it produces numerous chlorotic spots on infested leaves. Wilting and shedding of leaves, fruits and branches are associated with very heavy infestation. The honeydew excreted by the juvenile stage cover the leaves. Both result in decrease in yield and quantity. About 200 adult per 10 leaves indicate that spraying using recommended insecticides is required (PNRC, 2014).

Young nymphs overwinter on the leaves of host plants. In adult females deposit 200-400 eggs in circular clusters on the undersides of upper leaves. The eggs hatch in 5-10 days and first instar nymphs, which resemble small mealybugs and are called crawlers, move a short distance from the egg before flattening themselves against the leaf to feed. The remaining nymphal stages (2nd, 3rd and 4th) do not move. A non-feeding pupal stage follows and within a week, young adults emerge to repeat the cycle. There are many generations per year. Whiteflies develop from egg to adult in approximately 25 days at room temperature. All of the immature stages are easily overlooked. They are usually pale, almost translucent, and blend with the color of the leaf to which they are attached. Superficially they are similar to several scale insects. The nymph and adult flies are the only stages that cause physical damage to the host plant. Younger whiteflies will, however, mature into more damaging forms if left unchecked and may live for one to two months. . Adults (1/16 inch long) are moth-like insects with powdery white wings and short antenna. They are easily recognized and often found near the tops of plants or on stem ends. Wingless nymphs are flattened, oval and almost scale-like in appearance. After the first instar, or crawler stage, they settle down and attach themselves to the underside of leaves and begin feeding. Various species including the Silver-leaf, Greenhouse, and Banded-wing whitefly each have a different lifespan (Imam and Makurtar, 2010; PNRC, 2014).

2.5.3 *Spotted boll worm (Earias vittella (Fabricius))*

Spotted boll worm *(E. vittella)* belongs to the lepidoptera Order that is considered as one of largest Orders of the class insect. In the early stage of the crop the larvae enters the terminal buds of shoots and tunnel downward from the growing points. Any outbreak of this insect will lead to economic damage since it will completely destroy at the species of the host plant later on the lower buds and green bolls or fruits (Malgwi and Omuminya, 2004). It is the major pest of cotton and it attacks also few other malvaceous plant such as *Hibiscus*.The closely related species *E. insulana* and *E. capreovridis* attack slightly range of host plants most especially at flowering and fruting stages (PNRC, 2014).

In the early stage of the crop the larvae enters the terminal buds of shoots and tunnels downward from the growing points. The larvae feed on and damage growing vegetative parts developing seed in the cotton bolls, shoots of the main axes, succulent internodes, tops of side branches, young leaves and flower buds. This damage finally leads to flowers and bolls shedding, delayed flower formation, premature opening of the attacked bolls, hollowing of the seeds and weakening and staining of cotton fibers. Eggs are small and bluish green, newly hatched larva is 1-5 mm long; brownish-white has a dark head and prothoracic shield. A well-developed larva has a brown dorsum showing a white median shriek and a pale yellow or green vender. Dark brown Pupa is enclosed in a dirty white to buff colour cocoon. The insect was found to occur in high population during rainy season and its number drop as the temperature increases. The developmental period of different stages prolonged, the longevity fecundity and coloration of the adult also fluctuate with environmental temperature and humidity (Adedire, 2001; PNRC, 2014).

2.5.4 *Beetles (Podagrica puncticollis (Weise)*)

The species of the genus *Podagrica* are widely distributed in the world. In Africa they were found in Sudan, Congo, Uganda, Nigeria, Chad, Somaliland, and Ethiopia. Four stages are recorded during the life history, an egg, larval, pupa and adult stage. Female lays its small yellow eggs into the soil at the base of the host plant and takes 7-13 days to hatch as recorded by Mohamed in 2000, being shortest in August and longest in January. The larvae of this beetle live in the soil and feed on the epidermis tissues of the roots of the plant. The larva is white in color, with dark head, and feeds mainly on the fine roots and root hairs, but sometimes attacks the surface of the main root. The larval stage takes about three to four weeks, followed by a pre-pupa and pupa period of about two weeks. It’s found that the newly hatched larvae of *P. puncticollis* fed for a period of 11-28 days on the rootlets, then pupation takes place in the soil. The pupation period is 10-17 days. The adult is 3-4 mm long. The main host plants of the cotton flea beetle are the members of Malvaceae such as cotton and okra (Alleoni and Ferreira, 2006).

The most serious damage is caused to young seedlings and also cause damage of economic importance by feeding on leaves. The small plants are either badly stunted in growth or destroyed, while a typical (shot-hole) effect is caused on the leaves of older plants. The larvae of *P. puncticollis* feed on the rootless causing damage of economic importance. The adult remains after rain on the host plant for as long as they can find suitable food as they always prefer young growth. Correct timing of sowing can play an important role in reducing flea beetle infestation and damage. Application of insecticides can reduce the damage (Mohamed, 2000).

2.6 Factors Affecting the Development and Control of insects of Roselle

The factors affecting the development and control of insects include Temperature and Relative Humidity which exert considerable drastic effects on insect development and population. Temperatures above 45^0C are eventually fatal to all insects and none survive at temperatures above 50^0C. Low temperatures (below 17^0C) cause negligible insect development and pest status Therefore storage at low temperatures of between 17^0C-5^0C and high temperatures of 40^0C-50^0C is effective in control. However this is applicable in only few cases because of the frost effect as most vegetables do not tolerate frost and similarly too high heat cannot be tolerated by most vegetables. Oxygen requirement for some insect pests for respiration is high hence; gradual reduction of oxygen in the storage atmosphere affects pest development. Rainfall is also another factor affecting the control of insects as soon insects are said to be at their peak during the dry season(Mohamed, 2000).

2.7 Control and Management of Pest in Roselle Farm

Pest control and management is the deliberate action to prevent, reduce or eliminate the harm caused by pest (Malgwi and Saidu, 2011). The general control and management of pests varies from place to place depending on the scale of production, system of storage, the duration of storage, resources available, level of infestation among other factors (Mbah and Okorokwo, 2008).

2.7.1 *Biological Control*

This is the practice whereby survival or presence of pests is reduced through the agency of other living organisms (Ajibade, 2015). These bio-agents are obtained from the concept of "balance of nature" but can be manipulated by man. The use of parasites, predators and pathogens to control and manage pest is another effective way of pest control. There has been a number of biological control agents labeled for this purpose such as *Trichogramma spp, Bacillus thuringiensis, Beauveria bassiana* amongst others. Natural predators of this pest include ladybugs, lacewings, and aphidius which feed on their eggs and the parasite which destroys nymphs and pupae. For best results, make releases when pest levels are low to medium (Usman , 2008).

2.7.2 *Integrated Pest Management*

This is a broad approach that integrates practices for economic control of pests. This approach has become necessary because pests have become resistant to many broad-spectrum insecticides, pesticides and also developed defensive mechanism against natural enemies, so carefully consider all available pest control strategies and subsequent integration of appropriate measures that would suppress pest population below the economic injury level, minimize the risks while making maximum benefits at reduced cost (Ukeh *et al.*, 2008; Wikihow, 2017). Malgwi and Saidu, (2011) reported that integrated pest management emphasizes the need for simple, economically inexpensive and environmentally safe measures for pest control.

Integrated pest control strategies (such as cultural, biological, physical, host plant resistance and chemical pest control) have been proven to be effective in the control of most insect pests with a reduced risk posed by chemicals to human and environment. Proper integrated management is usually of great economic importance as the damage causing pests are controlled leaving the undamaged crop (Malgwi and Saidu, 2011).

2.7.3 *Use of Resistant Cultivars*

Use of resistant or tolerant varieties is a good way of controlling pest especially in the field. Biological control by use of resistant varieties generally retards the increase in infestation and grains damage thereby prolonging the period in which damage remains relatively low (Ukeh *et al.,* 2008).

2.7.4 *Cultural Practices*

There are several practices as recommended: Use proper pre-planting cultural practices to avoid introducing pests into crops like growing pest free transplants and avoid growing vegetable transplants and ornamental plants at the same location, especially if bringing in plant materials from other areas. The removal of the earliest plants with symptoms may be of some value and avoidance of planting new crops near or adjacent to old, infested crops. Management of weeds within crops to minimize interference with spraying and to eliminate weeds that can serve as insect pest and virus hosts thus field hygiene should be a high priority and should be included as an integral part of the overall strategy for managing whitefly populations, incidence of whitefly transmitted viruses, and insecticide resistance (Webb *et al.,* 2015).

Establish a minimum two-month crop free period, preferably from mid-March through mid-June or longer and delay planting new fall crops as long as possible and remove spring crops as early as possible to increase the crop-free period and avoid carryover of disease and pests to the fall crop. Avoid yellow clothing or implements, which will attract whitefly adults as well as aphids. Cover all vents and other openings in the green house (Wiki how, 2017).

Look out for your neighbor’s welfare, ensure your surrounding is clear and advise him also on best practices as any pest infestation on your neighbor’s field may affect your farm too. Covering the ground outside the greenhouse or planthouse, particularly adjacent to greenhouse cooling pads, with UV-reflective mulch can reduce entry of whiteflies, aphids. Use a contact desiccant (burn down) herbicide in conjunction with a heavy application of oil (not less than 3 percent emulsion) and a non-ionic adjuvant to destroy crop plants and to quickly kill whiteflies but do not apply insecticides on weeds on field perimeters. These applications can kill insect natural enemies and interfere with biological control (Wikihow, 2017).

2.7.5 *Chemical Control*

This is the use of synthetic insecticides (chemicals) to reduce or prevent pest damage. This method is widely used and it is effective but could sometimes be disadvantageous because of the side effects of the chemicals. Use selective rather than broad-spectrum control products when possible to conserve bees and natural enemies that enhance biological control. The chemicals could be repellants, killer insecticides, or antifeedal (Lale, 2001; Usman, 2008; Wikihow, 2017). Webb *et al.*, (2015) recommended the use of proper insecticide program to delay development of resistance to insecticides, particularly neonicotinoid insecticides. Many insecticides have limits on the number of applications that can be made in a growing season. Use soil applications of neonicotinoids at planting for longer season crops, such as watermelon, so that there is less chance of affecting bees pollinating the crop. Soil applications of neonicotinoids through the drip irrigation system are generally inefficient and wasteful of product and thus not recommended.

The World Health Organization (WHO) estimates that, every year 200,000 people are killed worldwide as a direct result of pesticide poisoning. In addition, the utilization of such synthetic chemicals has been restricted as they are carcinogenic, teratogenic, and showed high and acute residual toxicity. They can imbalance the hormonal secretion and show spermatotoxicity, long degradation period which resulted in toxic residues in food. In spite of ban over many chemical pesticides, farmers use more than 60 pesticides like DDT, Endosulfan, endrin, Methyl Bromide Monocrotophos, Diazinon Sodium Cyanide Methyl Parathion. Due to the higher utilization of these chemicals, many agricultural pests have already developed resistance towards the synthetic chemicals like, Pyrethroids, Carbomates, 20 organophosphates and chlorinated hydrocarbons Conventional agricultural chemicals used in pesticides, chemical fertilizers, seed and plant growth treatment have been implicated in polluting the soils and waterways. They have caused substantial disruption to the ecosystems and have led to biodiversity loss (Naima *et al* .,2013). Over

98% of sprayed insecticides and 95% of herbicides reach a destination other than their target sites, including non target species, air, water, bottom sediments and food. Over years, chemical pesticides had made a great contribution to the fight against pests and diseases. However, their widespread and long-term use resulted in insecticide resistance and biomagnifications of insecticides, which in turn resulted in restrictions on their export. Problems like soil and water contamination and dramatic increase of the harmful residues in many primary and derived agricultural products arose, which endangered both the general environment and human health. It is estimated that the financial cost of the damage to the environment and social economy is about $ 8.1 billion a year. The use of synthetic organic insecticides in crop pest control programs around the world had caused tremendous damage to the environment, pest resurgence, pest resistance to insecticides, and lethal effects on non-target organisms). Pesticides or chemicals are meant to control harmful pests such as insects, nematodes, diseases, weeds among others however, excessive use of pesticides not only leave residues in soil, water and air but also have adverse effects on the non target organisms such as pollinators, parasitoids, predators and wild animals. This has adversely affected the ecological balance resulting in pest resurgence, development of resistance in the pest species and environmental pollution (Malgwi and Hamman, 2013: Webb *et al.,* 2015).

Sherpa Plus (cypermethrin 12 g + dimethoate 100 g / L) is a systemic and contact action synthesized insecticides commonly available, less costly and said to have less harmful effect on the environment (Oparacke, 2007). Similarly, Malgwi and Hamman, (2013) reported the use of cypermethrin on the control of insect pests stressing the cost effectiveness and less environmental effects as a basis for the choice of the insecticide as such was used in this research too.

2.7.6 *Use of Botanicals*

This is the use of plant materials with insecticidal properties to control pests. Plants are known to possess secondary compounds which are used as part of the plants defense against insects and herbivores. These secondary compounds have known function in photosynthesis, growth or other aspect of plant physiology; confer on plant materials and their extracts some insecticidal activities (Webb *et al.,* 2015). In view of the several disadvantages associated with the unscientific use of pesticides in agriculture; there is an urgent need for minimizing the use of chemical pesticides in the management of insect pests. Growing public concern over potential health hazards of synthetic pesticides and also steep increase in cost of cultivation/low profit making by farmers has led to the exploration of eco-friendly pest management tactics (Mohamed, 2000).

The plant kingdom is recognized as the most efficient producer of chemical compounds, synthesizing many products that are used to defend plants against different pests and "Biopesticides are certain types of pesticides derived from such natural materials as bacteria, plants, animals, and certain minerals". Based on the natural resources from which they are isolated, biopesticides are classified as microbial pesticides, botanical pesticides, zooid pesticides and genetically modified plants. The number of areas in which they were used increased year by year; they were fast becoming the preferred choice for pest control. Biopesticides were usually applied to control rather than to eradicate pests, often incorporating a delay factor; they were also more selective than chemical pesticides. In fact, most biopesticides had the advantage of higher selectivity and non-target biological safety. Moreover, plants have also been used for centuries in the form of crude fumigants where plants were burnt to drive away nuisance mosquitoes and later as oil formulations applied to the skin or clothes which was first recorded in writings by ancient. Pesticides derived from plant and plant materials were widely used until the 1940s, the botanicals were replaced by synthetic pesticides that were easier to handle and lasted longer. Due to the abnormal side effects, alternate method is needed to protect the ecosystem as well as to increase the crop yield (Fores, 2017). The biopesticides characteristics also included low-residue and high-performance, fewer poisonous side effects and good compatibility with the environment. The resistance to biopesticides in target organisms was not easily generated, unlike in many cases of their chemical counterparts. They are fast becoming a new trend in the global pesticide industry (SFGATE, 2018). As an alternative method many researchers preferred and shifted to plant based pesticides. Plants synthesize a diverse array of secondary metabolites either as a part of normal growth and development or as a defense to pest or pest attack. These secondary metabolites can be exploited into biopesticides for combating several agricultural pests. The plant products are environmentally safe, low cost, biodegradable, and indigenous and can provide prophylactic measure for protection against various agricultural pests. The plant materials proved to be a good anti-feedant, inhibiting the further growth of the larva resulting in abnormal growth of the pest larva (Wikihow, 2017).

Webb *et al.*, (2015) reported botanical as insecticides, deterrents, and repellents for insect pest control. He stressed that when conventional insecticides are affordable to growers through government subsidies, limited literacy and a lack of protective equipment give rise to thousands of accidental poisonings annually, botanicals help in preventing the dumping of thousands of tons of pesticides on the earth; they are safer to the user and the environment because they are biodegradable and break down into harmless compounds within hours or days in the presence of sunlight.

Research on natural products is always an interesting target for scientists over decades especially on plants. Historically, plants (fruits, vegetables, medicinal herbs among others) have provided a good source of a wide variety of compounds, such as alkaloids, phenolic compounds, vitamins, terpenoids and steroids, which are rich in valuable bioactivities. The Neem tree is considered as one of the best natural insecticide/ pesticide plant and the quality of pesticide and pharmacological products depend upon the contents of azadirachtin and nimbin in the plant. Azadirachtin, a major compound of the neem has potent antifeedant, growth and reproductive regulating properties. Likewise, nimbin, a limonoid from neem, is also involved in improving pesticide properties (Mohamed, 2000). The neem tree from the different tropical parts of the world is reported to contain high level of polyphenolic compounds, but due to the wide range of geographical distribution, a large variety of morphological and biochemical characteristics have been reported. It has also been reported that phenolic contents of neem can be influenced by geographical locations and other abiotic factors. The alkaloids found in plants are pyrrollizidine alkaloids, solanine (from potato), lupines, morphine, cocaine, nicotine, quinine, and vinblastine. Several of these alkaloids act as insect feeding deterrents. Botanical extracts kill and repel pests, affect insect growth and development, have anti-feedant effects against pests. There are many bioactive compounds from botanicals which can be grouped into five categories: nitrogen compounds (primarily alkaloids), terpenoids, phenolics, proteinase inhibitors, and growth regulators. In developing countries, pesticidal plants offer unique and challenging opportunities for exploration and development of their own botanicals. Recently, the use of microencapsulation has allowed slower release rates of oils to be achieved, thus prolonging protection time. Using gelatin-arabic gum microcapsules maintained the repellency of citronella up to 30 days on treated fabric stored at room temperature (22°C) (Sarah *et al.*, 2008).

Different plant extracts have varying anti-feedal or insecticidal effects on different products with the increasing concern about the use of synthetic insecticides, the need to find alternatives that are readily available, affordable, less poisonous and less detrimental to the environment is apparent. Production of botanical insecticides would remove the high cost of importation in developing countries. Using of technologies for enhancement of the shelf life, the speed of kill, the field efficacy and reliability, and the cost of these natural insecticides are very curtailed for botanicals to be pro-poor and cost-effective and making botanical a more viable option for controlling pests (Siddig, 2017).

So many people have evaluated the insecticidal effect of plant products on weevil. The most studied botanicals are neem, lemon grass, hot pepper, moringa, citrus peels amongst others either as powders or oils (Diaz *et al*., 2015). Fast-acting botanical insecticides should be used as a last resort. Derived from plants which have insecticidal properties, these natural pesticides have fewer harmful side effects than synthetic chemicals and break down more quickly in the environment. The eggs and pupae are able to resist most common insecticides but horticultural oils which work by smothering insects, are very effective on all stages of these pests. The use of chemicals may unwittingly create a strain of pesky super-insects or create a strong chance that the insect will adapt even if they switched out in several-day rotations to keep insect population from adapting as such plant extract are better. Naima *et al., (*2013) reported the action of two plant products and a synthetic insecticide on a major stored-product insect, *Tribolium castaneum* (Herbst) (Coleoptera:Tenebrionidae). The use of *Psidium guajava* (L.) Guava, leaves; Myrtaceae) and *Citrus reticulata* (Kinnow, peel and leaves; Rutaceae) and Methoprene a synthetic insecticide; where results had significant effects pertaining to all variables analyzed however ethanol extract was found to be remarkably more potent than powder form of same plant. Furthermore, leaves and peel of *C. reticulata* did not differ signifiantly pertaining to their toxicity against adult *T. castaneum* but stronger than *P. guajava* whereas, activity of methoprene was comparable to that of botanicals.

Neem trees, which are grown widely in the Nigeria are potential source of natural plant protection agents to minimize the yield losses caused by different pest with minimum impacts on the environment cause by synthetic insecticides. Several biologically active compounds have been isolated from different parts of neem tree (Mohamed, 2000). Several vilasinin derivatives, salanins, salanols, salasnolactomes, vepaol, isovepaol, epoxyazadirachdone, gedunin, 7-deacetylgedunin have been isolated from neem kernels. Azadirachtin is the most potent growth regulator and antifeedant. Crude neem extracts deters settling and reduces feeding as reported by Siddig, (2017).

About 413 different species/subspecies of insect pest have been listed by Mohamed, (2000) found to be susceptible to neem products. The listed species/subspecies belong to different insect orders most of them were Lepidoptera (136) and Coleopteran (79). Siddig and Khalafalla, (2013) examined the Performance of IPM package including neem for the control of potato pests in fields which gave a positive result. Also in 2016, Siddig evaluated neem seed and leaf water extracts and powders for the control of insect pests yielding a positive result.

Sarah *et al*. (2008) compared the effectiveness of three plant-based sprays including neem, garlic and hot pepper to soap and a conventional pesticide, all the treatments gave significant protection against aphids. Weekly applications can prevent insect population explosions and provide protection equal to or better than conventional chemical pesticides. Organic Neem Oil can be sprayed (spray all leaf surfaces including the undersides of leaves until completely wet) on vegetables, fruit trees and flowers to kill eggs, larvae and adults.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Experimental Site

The whole experiment was conducted from January 2018 to February, 2019. The field experiment was conducted at the Experimental Farm of Modibbo Adama University of Technology Yola, Adamawa State and at the Experimental Farm of Collage of Education Jalingo, Taraba State. Yola lies between latitude 8^{o} N and longitude 11.5^{o} E and 13.5^{o} E and at an altitude of 162m above the sea level (Bashir,2000) while Jalingo lies between latitude 8.89^{o} N and longitude 11.35^{o} E and at an altitude of 208m above the sea level (Geodatos, 2019).

3.2 Source of Materials

Seeds of two Roselle cultivars were obtained from local farmers at Vunoklang in Girei LGA Adamawa, the botanical (neem) was sourced within the Modibbo Adama University of Technology, Yola, Adamawa while the synthetic chemical Sherpa Plus (Cypermethrin 12g + dimethoate 100g / L) was purchased from Jimeta Modern Market.

3.3 Treatments and Experimental Design

The experiment was conducted in a Split Plot Design having a total Plot size of approximately 23M by 18M, Experimental units of 3.0M x 3.0 M with 0.5M pathway between units and 1M pathway between blocks (shown in figure 1) as with the case of Karnataka (2012). There were two cultivars of Roselle (red and white calyx) which was at the main plot and two insecticidal spray regimes of Neem extract and Sherpa Plus administered at two weeks and four weeks intervals each with a control assigned to sub-plots in three replications in the sub plots.

REP. I	
V_2	V_1
T_0	T_1
T_1	T_2
T_2	T_3
T_3	T_4
T_4	T_0

REP. II	
V_1	V_2
T_2	T_3
T_3	T_4
T_4	T_0
T_0	T_1
T_1	T_2

REP. III	
V_2	V_1
T_4	T_2
T_0	T_3
T_1	T_4
T_2	T_0
T_3	T_1

Figure1: Treatments and Experimental Layout in a Split Plot Design

Key

T_0= Control

T_1 = Neem extract administered at two weeks interval

T_2 = Neem extract administered at four weeks interval

T_3 = Sherpa Plus administered at two weeks interval

T_4 = Sherpa Plus administered at four weeks interval

V_1 = Cultivar one (white calyx Roselle)

V_2 = Cultivar two (red calyx Roselle)

3.4 Preparation of Experimental Materials

Polythene bags, specimen tubes used to collect insect samples, rearing jars for rearing of immature forms and transferring the insects to the laboratory for identification. Alcohol (70%) was used to preserve them for identification. Hand lens was used for proper viewing and identification keys was used for the insect identification and grouping. Neem fruit extract was made (using mortar and pestle) and mesh size of 500 µm was used to sieve, a solution of 100 ml neem extract to 3litres of water was done as with the case of Malgwi and Hamman, (2013). While Sherpa plus was diluted at 1.65 ml/l of water as 800 ml/ha is the recommended standard. The treatments were separately poured in spray bottles of 1litre capacity each and labeled appropriately for prior use.

3.5 Experimental Procedures

3.5.1 Cultural Practices

Roselle *Hibiscus sabdariffa* L. cultivars (White and red) was cultivated at two different locations in the 2018 cropping season to determine the variation in the insect infestation among the cultivars and the response of the insects to the treatment at those locations. Manual land clearing and tillage was done before planting (Ottia and Mergawi, 2014). The land was then measured and subdivided into experimental units as shown on the experimental layout on figure 1. Four viable seeds per hill were sown to the depth of 2.5 cm at an intra-row spacing of 50 Cm inter-row spacing of 75 Cm that was later thinned to two plants per stand given a plant population of 20 stands per experimental unit. Weeding was done manually at 2 and 6 weeks after sowing using hand hoe.

3.5.2 Treatment Administration

All treatments were applied using spray bottles so as to reduce drift effect and spray force so that it was not strong enough to knock the insect off the leaves (Mera *et al*., 2009). The administering of treatments commenced two weeks after sowing then sprays intervals of 2week and 4weeks of both neem extract and Sherpa Plus was observed till harvest while the control remains unsprayed. The plants were harvested at four months after sowing when the fruits had attained maturity manually using knife and the fruits obtained as freshly harvested for data collection.

3.6 Data collection

Data collection from the field was done around 7am to 8 am by randomly selecting five plants and tagged from the net plot size from each plot while the outer ones were left as discards.

The parameters considered were:

i. **The Insect Species Composition**; the sampling for this was done at 2 weeks after sowing, 10 weeks after sowing and 16 weeks after sowing then careful observing of all the insects sampled, grouping and identifying them through use of identification of keys and comparative method. Morphological identification of the insect pest was done using hand lens, direct comparing and utilizing identification keys then placed into their respective groups as with the case of Ottia and Mergawi (2014) The grouping was done as follows; Order, Family, Scientific name, Common name and Relative abundance then rated in percentage.

ii. **The abundance of the insects in relation to treatments, cultivars and locations;** This was done by randomly selecting 5 plants across the net farm size, and carefully having a quick visual count of the insects on the plants, then capturing all the insects from those plants through the use of transparent polythene bag to cover the whole plants, carefully shaking to collect the insects as described by Malgwi and Onumiya, (2000). Immature forms (eggs, larvae /maggots / nymphs, pupae) and adults were collected from the vegetable crop fields and taken to the laboratory of Crop Protection Laboratory, Modibbo Adama University of Technology Yola. The immature forms were reared in glass/ plastic jars for the emergence of adult pests. During rearing process, the larvae/ Nymphs/ maggots were fed on fresh parts of their host plant roselle. The adult pest specimens were then properly preserved in glass jar and identified. Population size (number of species in their various orders and the relative abundance) of each of the insect species was taken into consideration. Data on the abundance of insects was taken on the sampled plants at two weeks after sowing (seedling stage), 6 weeks and 10 weeks after treatment (vegetative stage) and 14 and 16 weeks after treatment (fruiting stage) respectively as similar to the case of Ottia and Mergawi (2014).

iii. **The plant height**; this was taken monthly by randomly selecting 5 plants across the net plot size, and carefully taking the height of each plant from the plant base to the apex using measuring tape in centimeters at 1, 2,3 and 4 months after sowing and the mean taken.

iv. **The Number of leaves**; The Number of leaves per plant was obtained by counting the number of leaves on five plant sampled at the vegetative stage (4, 6, 8 and 10 weeks after sowing) and the mean estimated.

v. **The Number of leaves damage by the insects**: Five randomly selected plants were tagged and degree of damage was assessed by counting the damaged leaves and the mean obtained. The plant (leave) was considered undamaged if less than 5% of the sampled portion was damaged (considering perforations or distortions on individual leaf as a result of insect attack) otherwise considered as damaged. Damage caused on the sampled plants were recorded two times at vegetative stage (6weeks and 10weeks after sowing) as similar to the case of Ottia and Mergawi (2014) and caution was taken to avoid plant damage during data collection.

vi. **Total Fruit Yield in respect to treatments and cultivars**; The fruit (whole fruit with seeds and calyx) were harvested from five randomly selected plants from each experimental unit and weighed immediately (so as to avoid loss in weight before measurement).

vii. **Calyx Weight (only calyx without the seeds)**; the calyx were removed from freshly harvested fruits and then the weighed in grams and the mean determined.

viii. **The Fruit damage caused by the insects**; Five selected plants were assessed by counting and weighing the damaged fruits and their mean obtained in grams. The calyx was considered undamaged if less than 5% of the sampled portion was damaged (considering perforations or distortions on individual calyx as a result of insect attack) otherwise considered as damaged.

ix. **The dry calyx weight in grams in respect to treatment and cultivar**; this was obtained by carefully removing only the calyx from the 5 randomly harvested plants and air dried for one week and then the mean weight determined in kilogram.

3.7 Data Analysis

Data was subjected to analysis of variance (ANOVA) using Statistical Analysis Software (SAS) version 14 and means separated using Student Newman Keuls (SNK) at 5% level of probability.

CHAPTER FOUR

RESULTS

4.1 The Insect Species Composition at Yola and Jalingo in the 2018 Cropping Season

The insect pest species collected on the experimental farm on both varieties were same with only a slight difference in their abundance in Yola as presented on Table 1, Plate III and Figure 2 shows that, the insect pest species collected on both varieties were same with only a slight difference in their abundance in Yola. At 2 weeks after sowing out of 216 total of insect sampled order Coleoptera had highest mean of 108 (50%) followed by Homoptera with 39 (18%) then Hemiptera with 38 (18%) and Orthoptera having 28 (13%) while Lepidoptera was 2 (1%) as the lowest in number.

At 10 weeks after sowing, a total of 124 insects were observed of which total of insect sampled order Coleoptera had highest mean of 51 (41%) followed by Homoptera with 38 (31) then Orthoptera with 19 (15%) and Hemiptera having 11 (9%) while Lepidoptera was 5 (4%) as the lowest in number.

At 16 weeks after sowing, a total of 95 insects were observed of which total of insect sampled order Coleoptera had highest mean of 39 (41%) followed by Lepidoptera with25 (26%) then Homoptera with 10 (13%) and Orthoptera having 12 (11%) while Hemiptera was 9 (9%) as the lowest mean number.

On the Jalingo experimental Farm presented on Table 1 and Fig. 3 shows that; at 2 weeks after sowing out of 171 total of insect sampled order Coleoptera had highest mean of 79 (46%) followed by Homoptera with 40 (24%) then Orthoptera with 31 (18%) and Hemiptera having 14 (8%) while Lepidoptera was 7 (4%) as the lowest in number.

At 10 weeks after sowing, a total of 151 insects were observed of which total of insect sampled order Coleoptera had highest mean of 65 (43%) followed by Homoptera with 37 (24%) then Orthoptera with 22 (15%) and Hemiptera having 18(12%) while Lepidoptera was 9 (6%) as the lowest in number.

At 16 weeks after sowing, a total of 114 insects were observed of which total of insect sampled order Coleoptera had highest mean of 56 (49%) followed by Lepidoptera with 21 (18%) then Homoptera with 17 (15%) and Orthoptera having 11 (10%) while Hemiptera was 9 (8%) as the lowest in number.

4.2 The Combined Cumulative Insect Species Composition at Yola and Jalingo in the 2018 Cropping Season

The insect pest species collected on the two experimental farm on both varieties as presented on Figure 4 were same with only a slight difference in their abundance in Jalingo, at 2 weeks after sowing out of 193.5 total of insect sampled order Coleoptera had highest mean of 93.5 followed by Homoptera with 39.5 then Orthoptera with 30 and Hemiptera having 28 while Lepidoptera was 4.4 as the lowest in number.

At 10 weeks after sowing, a total of 137.5 insects were observed of which total of insect sampled order Coleoptera had highest mean of 58 followed by Homoptera with 37 then Orthoptera with 20.5 and Hemiptera having 14.5 while Lepidoptera was 7 as the lowest in number.

At 16 weeks after sowing, a total of 104.5 insects were observed of which total of insect sampled order Coleoptera had highest mean of 47.5 followed by Lepidoptera with 23 then Homoptera with 13.5 and Orthoptera having 11.5 while Hemiptera was 9 as the lowest in number.

Plate I: Sample of Roselle

Plate II: Sample of Neem Fruits

Plate III: Sample of Collection of Insect pests on Roselle

Table 1: The Insect Species Composition at Yola and Jalingo Locations in the 2018 Cropping Season

Order /Family	Common Name	Scientific Name	Yola	Jalingo
Coleoptera:Chrysomelidae	Flea Beetle	*Altica himensis*	+	+
Coleoptera: Chrysomelidae	red beetle	*Lilioceris lilii*	+	+
Coleoptera: Chrysomelidae	Leaf beetle	*Podagrica spp.*	+	+
Coleoptera:Coccinellidae	Lady-bird beetles	*Coccinella spp*	+	+
Coleoptera:Meliodae	Blister beetle	*Mylabris spp.*	–	+
Lepidoptera:Nolidae	Bollworm	*Earias insulana*	+	+
Lepidoptera:Noctuidae	Cotton bollworm	*Helicoverpa amigera*	+	+
Hemiptera: pentatomidae	Brown stink bug	*Halyomorpha halys*	–	+
Hemiptera: pyrrhocoridae	Red bug	*Pyrrhocoris spp*	+	+
Hemiptera:Aphididae	Cotton aphid	*Aphis gossypii*	+	+
Orthoptera: Phrgomorphidae	Grasshopper	*Zonocerus variegates*	+	+
Orthoptera:tettigoniidae	Bush cricket	*Tettigonia spp*	+	–
Homoptera:cicadellidae	Leafhopper	*Osbornellus spp.*	+	+

\+ indicates presence of the insect

\- indicates absence of the insect.

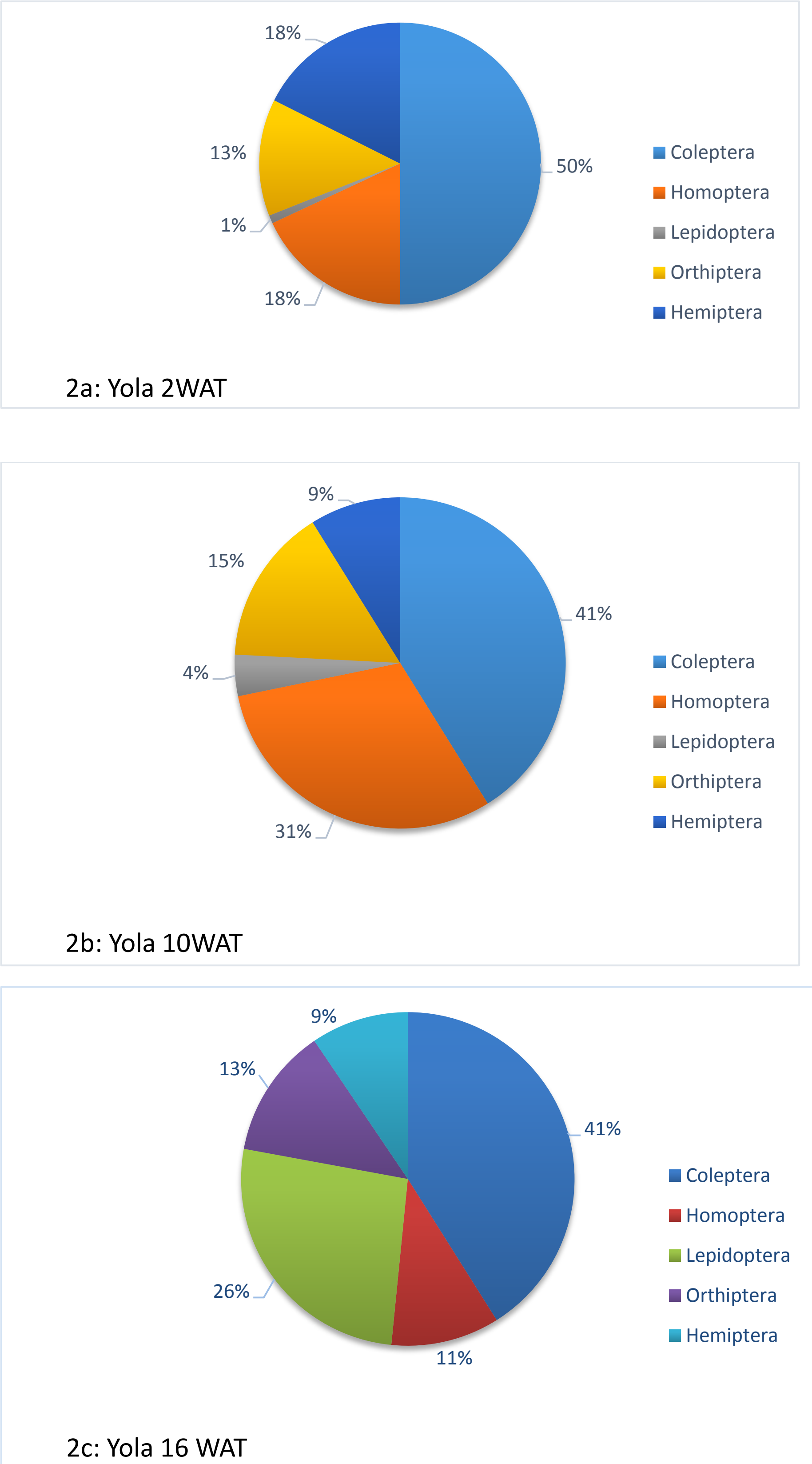


Figure 2: Cumulative Number of Insect Species Composition at Yola in the 2018 Cropping Season

WAT= Weeks after Treatment

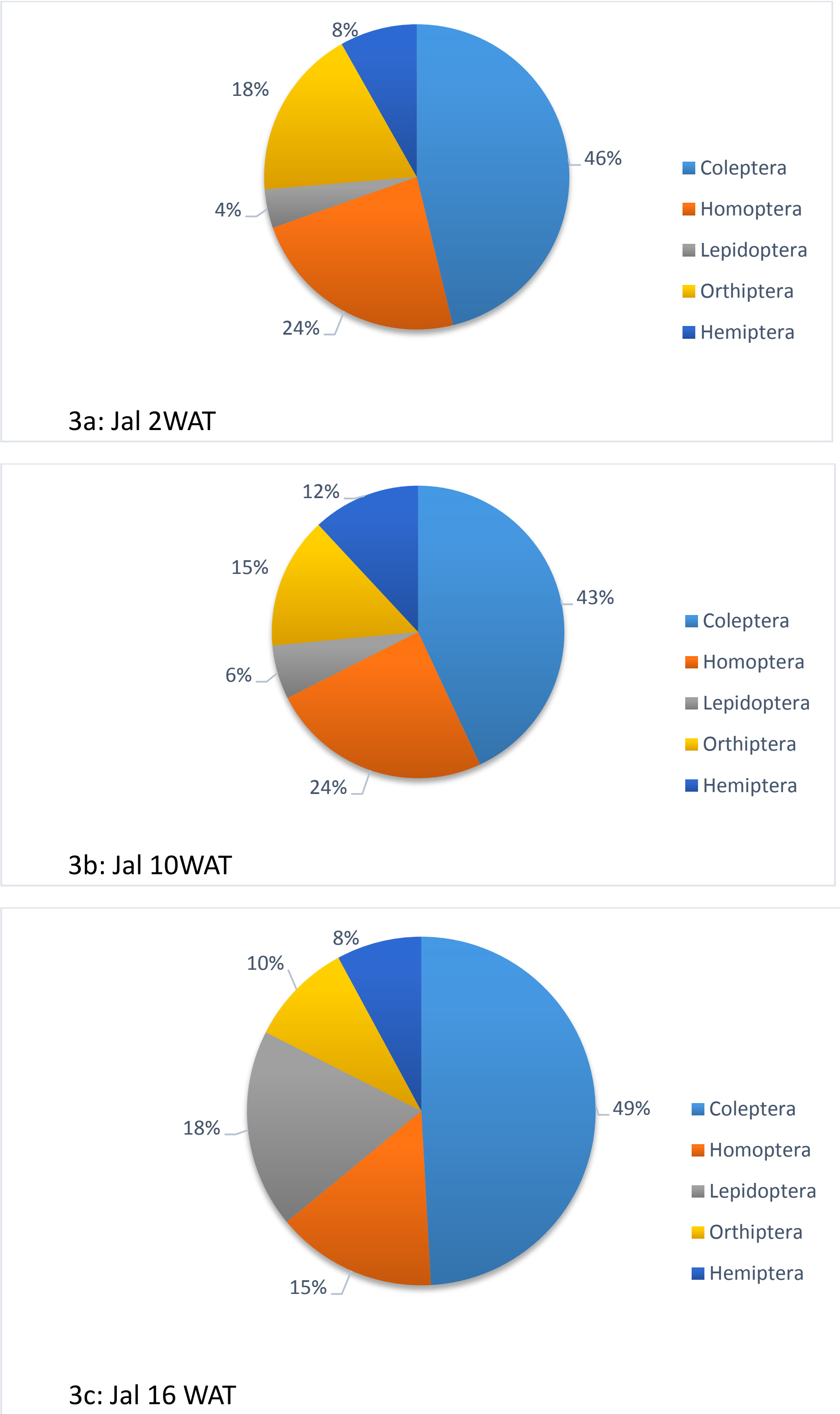


Figure 3: The Cumulative Number of Insect Species Composition at Jalingo in the 2018 Cropping Season

Jal= Jalingo Location, WAT= Weeks after Treatment

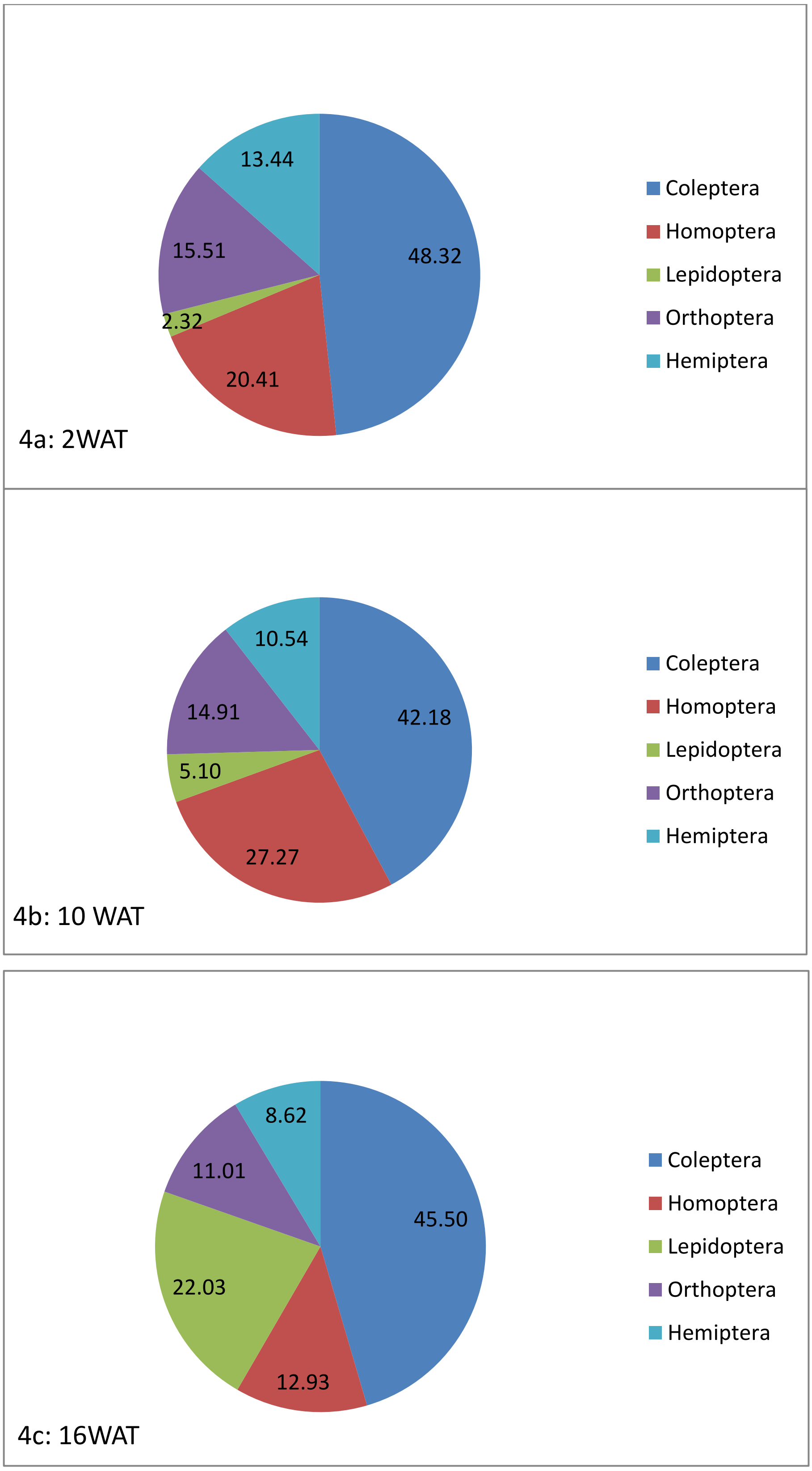


Figure 4: Combined Cumulative Insect Species Composition at Yola and Jalingo in the 2018 Cropping Season

WAT= Weeks after Treatment

4.3 The Effect of Treatments on the Abundance of the Insects at Yola and Jalingo in the 2018 Cropping Season

Table 2 shows the effect of treatments on the abundance of the insects at Yola. Before treatment commenced (two weeks after sowing) there was no significant difference (P>0.05) between the varieties as both white cultivar and red cultivars had mean insect infestation of 7.20 each. Among the treatments, there was no significant difference (P>0.05), those that were to be treated with Sherpa Plus at 2weeks interval had a higher mean number infestation of 7.50 each, lowest mean number of insect infestation of 7.00 each was recorded in Neem extract at 4 weeks interval, Sherpa Plus at 4 weeks interval and the control.

At two weeks after treatment, there was no significant difference (P>0.05) between the varieties as white cultivar and red cultivars had mean insect infestation of 4.07 and 2.07 respectively. There was no significant difference (P>0.05) among the treatments, the control had the highest mean number of insect infestation of 6.00 followed by Sherpa Plus at 4 weeks interval with 4.17 mean then Neem extract at 4 weeks interval having 3.00. Sherpa Plus at 2 weeks interval had low mean 2.00 while Neem extract at 2 weeks interval had the lowest mean of 1.83 insect infestations per sampled plant.

At six weeks after treatment, there was highly significant difference (P<0.01) between the varieties as white cultivar and red cultivars had mean insect infestations of 5.13 and 4.00 respectively. There was significant difference (P<0.05) among the treatments, the Control had the highest mean number of insect infestations of 13.33 followed by Sherpa Plus at 4 weeks interval with 3.50 mean then Sherpa Plus at 2 weeks interval with 2.83 mean, Neem extract at 4 weeks interval which had 1.83. Neem extract at 2 weeks interval had the lowest insect infestation mean of 1.33.

At ten weeks after treatment, there was highly significant difference (P<0.01) among the varieties as white and red cultivars had mean insect infestation of 5.27 and 3.00 respectively. There was significant difference (P<0.01) among the treatments, the Control had the highest mean number of insects infestation of 13.17 followed by Sherpa Plus at 4 weeks interval with 3.33 mean then Neem extract at 4 weeks interval having 2.00, Sherpa Plus at 2weeks interval had lower infestation mean of 1.33 while Neem extract at 2weeks interval had the lowest mean of 0.83.

Table 2: The Effect of Treatments on the Abundance of the Insects at Yola in the 2018 Cropping Season

Treatments	BT	2WAT	6WAT	10WAT	14WAT	16WAT
Varieties						
White cultivar	7.20[a]	4.07[a]	5.13[a]	5.27[a]	5.80[a]	4.13[a]
Red cultivar	7.20 [a]	2.73 [b]	4.00[b]	3.00[b]	5.13[b]	2.20[b]
Mean	7.20	3.400	4.57	4.133	5.47	3.17
P>F	1.0000	0.1405	0.0035	<0.0001	0.0235	<0.0001
Coefficient of Variation%	38.26	69.65	20.25	16.06	13.50	26.28
Treatments						
Control	7.00a	6.00[a]	13.33[a]	13.17[a]	16.50[a]	10.00[a]
Neem extract at 4 weeks interval	7.00[a]	3.00[ab]	1.83d[c]	2.00[c]	2.83[c]	1.17[c]
Sherpa Plus at 4 weeks interval	7.00[a]	4.17[ab]	3.50[b]	3.33[b]	4.00[b]	2.67[b]
Neem extract at 2weeks interval	7.50[a]	1.83[b]	1.33[d]	0.83[d]	1.17[d]	0.50[c]
Sherpa Plus at 2 weeks interval	7.50[a]	2.00[b]	2.83[bc]	1.33[cd]	2.83[c]	1.50[c]
Mean	7.20	3.40	4.57	4.13	5.47	3.17
P>F	0.9929	0.04	<0.0001	<0.0001	<0.0001	<0.0001
Coefficient of Variation%	38.26	69.65	20.25	16.07	13.50	26.28
Interaction						
Variety*Treatment	Ns	Ns	*	**	**	**

Means followed by the same letter(s) in the same column are not significantly using Student Newman Kaul Test of Significance, BT= Before Administering Treatments, WAT=Weeks After Treatment.

At fourteen weeks after treatment, there was significant difference ($P<0.05$) between the varieties as white and red cultivars had mean insect infestation of 5.80 and 5.13 respectively. There was highly significant difference ($P<0.01$) among the treatments, the Control had the highest mean number of insects infestation of 16.50 followed by Sherpa Plus at 4 weeks interval with 4.00 mean, Neem extract at 4 weeks interval and Sherpa Plus at 2 weeks interval had lower infestation mean of 2.83 each while Neem extract at 2weeks interval had the lowest mean of 1.17.

At sixteen weeks after treatment, there was highly significant difference ($P<0.01$) between the varieties as white and red cultivars had mean insect infestation of 4.13 and 2.20 respectively. There was highly significant difference ($P<0.01$) among the treatments, the Control had the highest mean number of insects infestation of 10.00 followed by Sherpa Plus at 4 weeks interval with 2.67 mean, lower insect infestation means of 1.17 and 1.50 was obtained from Neem extract at 4 weeks interval and Sherpa Plus at 2weeks interval respectively while the lowest infestation mean of 0.50 was then obtained in Neem extract at 2weeks interval.

The result of experimental farm in Jalingo is presented on Table 3; there was significant difference in the abundance of insects on the plants treated to the untreated at all sampling periods on the experimental farm in Jalingo. Before treatment (two weeks after sowing) there was no significant difference ($P>0.05$) between the varieties, the white and red cultivars had mean insect infestation of 6.13 and 5.27 respectively. There was significant difference ($P<0.01$) among the treatments, those treated with Sherpa Plus at 2 weeks interval had the highest mean number infestation of 6.67, followed by Sherpa Plus at 2 weeks interval having 6.00 mean, lower mean number of insect infestation of 5.67 and 5.17 each was recorded in Sherpa Plus at 4 weeks interval and Neem extract at 4 weeks interval respectively while the control had the lowest mean of insect infestation before the treatments were administered.

At two weeks after treatment, there was no significant difference ($P>0.5$) between the varieties as white and red cultivars had mean insect infestation of 3.67 and 2.73 respectively. There was no significant difference ($P>0.05$) among the treatments, the Control had the highest mean number of insects infestation of 7.33 followed by Sherpa Plus at 4 weeks interval with 4.00 mean, then Neem extract at 4 weeks interval and Neem extract at 2 weeks interval has 1.83 mean each while the lowest mean of 1.00 was obtained in Sherpa Plus at 2 weeks interval.

At six weeks after treatment, there was highly significant difference (P>0.01) among the varieties as white and red cultivars had mean insect infestation of 4.80 and 3.73 respectively. There was highly significant difference (P<0.01) among the treatments, the Control had the highest mean number of insect infestation of 12.33 followed by Sherpa Plus at 4 weeks interval with 3.50 mean, Sherpa Plus at 2 weeks interval and Neem extract at 4 weeks interval had a lower mean of insect infestation of 2.67 and 2.00 respectively while the lowest insect infestation mean of 0.83 was obtained from Neem extract at 2 weeks interval.

At ten weeks after treatment, there was highly significant difference (P<0.01) between the varieties as white and red cultivars had mean insect infestation of 5.87 and 4.20 respectively. There was highly significant difference (P<0.01) among the treatments, the Control had the highest mean number of insects infestation of 15.00 followed by Sherpa Plus at 2 weeks interval with 3.00 mean, Neem extract at 4 weeks interval and Sherpa Plus at 4 weeks interval had lower infestation mean of 2.83 and 2.50 respectively while Neem extract at 2 weeks interval had the lowest mean of 1.83.

At fourteen weeks after treatment, there was highly significant difference (P<0.01) between the varieties as white and red cultivars had mean insect infestation of 6.73 and 4.73 respectively. There was highly significant difference (P<0.01) among the treatments, the Control had the highest mean number of insects infestation of 16.33 followed by Sherpa Plus at 4 weeks interval, Neem extract at 4 weeks interval and Sherpa Plus at 2 weeks interval which had lower infestation mean 3.83, 3.50 and 3.16 respectively while Neem extract at 2 weeks interval had the lowest mean of 1.83.

At sixteen weeks after treatment, there was significant difference (P<0.05) among the varieties as white and red cultivars had mean insect infestation of 4.06 and 3.06 respectively. There was highly significant difference (P<0.01) among the treatments, the Control had the highest mean number of insects infestation of 9.33 followed by Sherpa Plus at 4 weeks interval with 3.50 mean then Neem extract at 4 weeks interval and Sherpa Plus at 2 weeks interval which had lower infestation mean of 2.67 and 2.33 respectively while Neem extract at 2 weeks interval had the lowest mean 1.17.

Table 3: The Effect of Treatments on the Abundance of the Insects at Jalingo in the 2018 Cropping Season

Treatments	BT	2WAT	6WAT	10WAT	14WAT	16WAT
Varieties						
White cultivar	6.13[a]	3.67[a]	4.80[a]	5.87[a]	6.73[a]	4.067[a]
Red cultivar	5.27[b]	2.73[a]	3.73[b]	4.20[b]	4.73[b]	3.53[b]
Mean	5.70	3.20	4.27	5.033	5.73	3.80
P>F	0.0210	0.0545	0.0022	0.0002	<0.0001	0.0146
Coefficient of Variation%	16.47	38.84	19.19	19.61	12.61	14.23
Treatments						
Control	5.00[b]	7.33[a]	12.33[a]	15.00[a]	16.33[a]	9.33[a]
Neem extract at 4 weeks interval	5.67[ab]	1.83[c]	2.00[c]	2.50[b]	3.50[b]	2.67[c]
Sherpa Plus at 4weeks interval	5.17[ab]	4.00[b]	3.50[b]	2.83[b]	3.83[b]	3.50[b]
Neem extract at 2 weeks interval	6.67[a]	1.83[c]	0.83[d]	1.83[b]	1.83[c]	1.17[d]
Sherpa Plus at 2weeks interval	6.00[ab]	1.00[c]	2.67[bc]	3.00[b]	3.16[b]	2.33[c]
Mean	5.700	3.20	4.27	5.03	5.73	3.80
P>F	0.0434	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Coefficient of Variation%	16.47	38.84	19.19	19.61	12.60	14.23
Interaction						
Variety*Treatment	**	Ns	**	**	**	**

Means followed by the same letter(s) in the same column are not significantly using Student Newman Keuls Test of Significance,
BT= Before Administering Treatments,
WAT=Weeks After Treatment.

4.4 The combined Effect of Treatments on the Abundance of the Insects at Yola and Jalingo in 2018 Cropping Season

Table 4 shows the combined effect of treatments on the abundance of the insects at Yola and Jalingo; Before treatment (two weeks after sowing) there was no significant difference (P>0.05) in the abundance of the insects between the locations; the plants in Yola recorded higher mean number of the insects of 7.20 while the Jalingo location has 5.70 insect infestation per sampled plant. Between the varieties there was no significant difference (P>0.05) as the white recorded 6.67 mean of insect infestation while the red cultivars had mean insect infestation of 6.23 per sampled plant which were significantly same. Among the treatments there was no significant difference (P>0.05) among them, those that were to be treated with Neem extract at 4 weeks interval, Sherpa Plus at 4 weeks interval, Neem extract at 2 weeks interval, Sherpa Plus at 2 weeks interval and the control had insect infestations of 6.33, 6.08, 7.,08, 6.75 and 6.00 respectively.

At two weeks after treatment, there was still no significant difference(P>0.05) in the abundance of the insects between the locations; the plants in Yola recorded mean insect infestation of 3.40 while the Jalingo location was 3.20 insect infestations per sampled plant which were significantly same. Between the varieties there was significant difference (P<0.05) as the white cultivar recorded higher (3.87) mean of insect infestation while the red cultivars had lower mean insect infestation of 2.73 per sampled plant. There was highly significant difference (P<0.01) among the treatments, the Control had the highest mean number of insect infestation of 6.67 followed by Sherpa Plus at 4 weeks interval with 4.08 mean, then Neem extract at 4 weeks interval having 2.42. Sherpa Plus at 2 weeks interval and Neem extract at 2 weeks interval had the lowest mean of 1.83 and 1.50 respectively.

At six weeks after treatment, there was still no significant difference (P>0.05) in the abundance of the insects between the locations; the plants in Yola recorded mean insect infestation of 4.57 while the Jalingo location was 4.27 insect infestations per sampled plant which were significantly same. Between the varieties there was highly significant difference (P<0.01) among the varieties as white cultivar had higher mean insect infestation of 4.87 while the red cultivars had and 3.87. Among the treatments there was highly significant difference (P<0.01) among them, the Control had the highest mean number of insect infestation of 12.83 followed by Sherpa Plus at 4 weeks interval with mean 3.50. Sherpa Plus at 2 weeks interval and Neem extract at 4 weeks interval which had lower insect infestations of 2.75 and 1.92 respectively. Neem extract at 2 weeks interval had the lowest insect infestation mean of 1.08 per sampled plant.

At ten weeks after treatment, there was highly significant difference ($P<0.01$) in the abundance of the insects between the locations; the plants in Jalingo recorded higher mean insect infestation of 5.03 while the Yola location was 4.13 insect infestations per sampled plant. Between the varieties there was still highly significant difference ($P<0.01$) among the varieties as white cultivar had higher mean insect infestation of 5.57 while the red cultivars had and 3.60. Among the treatments there was highly significant difference ($P<0.01$) among them, the Control had the highest mean number of insects infestation of 14.08 followed by Sherpa Plus at 4 weeks interval with 3.08 mean, then Neem extract at 4 weeks interval and Sherpa Plus at 2weeks interval had lower infestation means of 2.25 and 2.17 respectively while Neem extract at 2weeks interval had the lowest mean of 1.33.

At fourteen weeks after treatment, there was no significant difference ($P>0.05$) in the abundance of the insects between the locations; the plants in Yola recorded mean insect infestation of 5.47 while the Jalingo location was 5.73 insect infestations per sampled plant. Between the varieties there was highly significant difference ($P<0.01$) among the cultivars as white cultivar had higher mean insect infestation of 6.27 while the red cultivars had 4.93. There was highly significant difference ($P<0.01$) among the treatments, the Control had the highest mean number of insects infestation of 16.42 followed by Sherpa Plus at 4 weeks interval with 3.92 mean, Neem extract at 4 weeks interval and Sherpa Plus at 2 weeks interval had lower infestation mean of 3.17 and 3.00 respectively while Neem extract at 2 weeks interval had the lowest mean insect infestation of 1.50 per sampled plant.

At sixteen weeks after treatment, there was significant difference ($P<0.05$) in the abundance of the insects between the locations; the plants in Jalingo recorded mean insect infestation of 3.80 while the Yola location was 3.17 insect infestations per sampled plant. There was highly significant difference ($P<0.01$) between the varieties as white cultivar had higher mean insect infestation of 4.10 while the red cultivars had 2.87. There was still highly significant difference ($P<0.01$) among the treatments, the Control had the highest mean number of insects infestation of 9.67 followed by Sherpa Plus at 4 weeks interval with 3.08 mean, Lower insect infestation means of 1.92 each were obtained in Neem extract at 4 weeks interval and Sherpa Plus at 2 weeks interval while the lowest infestation mean of 0.83 was then obtained in Neem extract at 2 weeks interval.

Table 4: Combined Effect of Treatments on the Abundance of the Insects at Yola and Jalingo in the 2018 Cropping Season

Treatments	BT	2WAT	6WAT	10WAT	14WAT	16WAT
Location						
Yola	7.20^{a}	3.40$_{a}$	4.57^{a}	4.13^{b}	5.47^{a}	3.17^{b}
Jalingo	5.70^{b}	3.20^{a}	4.27^{a}	5.03^{a}	5. 73^{a}	3.80^{a}
Mean	6.45	3.30	4.41	4.58	5.60	3.48
P>F	0.0062	0.6778	0.1986	0. 0002	0.1771	0.0013
CV%	31.06	56.05	20.11	18.42	13.41	20.28
Varieties						
White cultivar	6.67^{a}	3.87^{a}	4.97^{a}	5.57^{a}	6.27^{a}	4.10^{a}
Red cultivar	6.23^{a}	2.73^{b}	3.87^{b}	3.60^{b}	4.93^{b}	2.87^{b}
Mean	6.45	3.30	4.41	4.58	5.60	3.48
P>F	0.4075	0.0228	<0.0001	<0.0001	<0.0001	<0.0001
CV%	31.06	56.05	20.11	18.42	13.41	20.28
Treatment						
Control	6.00^{a}	6.67^{a}	12.83^{a}	14.08^{a}	16.42^{a}	9.67^{a}
Neem extract at 4 weeks interval	6.33^{a}	2.42^{c}	1.92^{d}	2.25^{c}	3.17^{c}	1.92^{c}
Sherpa Plus at 4 weeks interval	6.08^{a}	4.08^{b}	3.50^{b}	3.08^{b}	3.92^{b}	3.08^{b}
Neem extract at 2 weeks interval	7.08^{a}	1.83^{c}	1.08^{e}	1.33^{d}	1.50^{d}	0.83^{d}
Sherpa Plus at 2 weeks interval	6.75^{a}	1.50^{c}	2.75^{c}	2.17^{c}	3.00^{c}	1.92^{c}
Mean	6.45	3.30	4.41	4.58	5.60	3.48
P>F	0.6449	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
CV%	31.06	56.05	20.11	18.42	13.41	20.28
Interaction						
Location*Treatment	Ns	Ns	Ns	*	Ns	*
Location*Variety	Ns	Ns	Ns	Ns	**	**
Variety*Treatment	Ns	Ns	**	**	**	**
Location*Variety*Treatment	Ns	Ns	Ns	*	Ns	**

Means followed by the same letter(s) in the same column are not significantly using Student Newman Kaul Test of Significance,
BT= Before Administering Treatments, WAT=Weeks After Treatment.

4.5 Interactive Effect of Treatments on the Abundance of the Insects at Yola and Jalingo in the 2018 Cropping Season

Location and Treatment Interaction result presented on Table 5 shows significant difference (P>0.01) at Ten (10) weeks after treatment, the Control recorded highest (15.00) mean infestation followed by Sherpa plus at 2 weeks spray regime (3.00), Sherpa plus at 4 weeks spray regime (2.83), Neem Extract at 4 weeks spray regime (2.50) while the least was observed from Neem Extract at 2 weeks spray regime (2.50) in Jalingo location. Yola location Control recorded highest (13.66) mean insects infestation followed by Sherpa plus at 4 weeks spray regime (3.33), Neem Extract at 4 weeks spray regime (2.00), Sherpa plus at 2 weeks spray regime (1.33), while the least was observed from Neem Extract at 2 weeks spray regime (0.83).

A similar trend was observed at 16 weeks after treatment showing significant difference (P>0.01) at 6 weeks after treatment, the Control recorded highest (9.33) mean infestation followed by Sherpa plus at 4 weeks spray regime (3.55), Sherpa plus at 2 weeks spray regime (2.33), Neem Extract at 4 weeks spray regime (2.66) while the least was observed from Neem Extract at 2 weeks spray regime (1.16) in Jalingo location. Yola location had the Control recorded highest (10.00) mean infestation followed by Neem Extract at 4 weeks spray regime (2.66), Sherpa plus at 4 weeks spray regime (1.55), Sherpa plus at 2 weeks spray regime (1.165), while the least was observed from Neem Extract at 2 weeks spray regime (0.50).

Variety and Treatment Interaction presented on Table 6 shows that, at 6 weeks after treatment, shows highly significant (P<0.01) the Control recorded highest (14.66) mean infestation followed by Sherpa plus at 4 weeks spray regime (4.16), Sherpa plus at 2 weeks spray regime (2.83), Neem Extract at 4 weeks spray regime (2.16) while the least was observed from Neem Extract at 2 weeks spray regime(1.16) in the white cultivar. The Red cultivar had the Control recorded highest (11.00) mean infestation followed by Sherpa plus at 4 weeks spray regime (2.86), Sherpa plus at 2 weeks spray regime (1.16), while the least was observed from Neem Extract at 2 weeks spray regime (2.66) and Neem Extract at 4 weeks spray regime (2.66).

At Ten (10) after sowing, the interaction shows highly significant (P<0.01) the Control recorded highest (17.83) mean infestation followed by Sherpa plus at 2 weeks spray regime (3.16), Sherpa plus at 4 weeks spray regime (3.00), Neem Extract at 4 weeks spray regime

(2.33) while the least was observed from Neem Extract at 2 weeks spray regime (1.50) in the white cultivar. The Red cultivar had the Control recorded highest (10.00) mean infestation followed by Sherpa plus at 4 weeks spray regime (3.16), Neem Extract at 4 weeks spray regime (2.16), while the least mean (1.16) was observed from Sherpa plus at 2 weeks spray regime and Neem Extract at 2 weeks spray regime each.

A similar trend was observed at 16 weeks after sowing shows highly significant ($P<0.01$), the Control recorded highest (12.00) mean infestation followed by Sherpa plus at 4 weeks spray regime (3.833), Sherpa plus at 2 weeks spray regime (2.00), Neem Extract at 4 weeks spray regime (2.00) while the least was observed from Neem Extract at 2 weeks spray regime (0.66) in the white cultivar. The Red cultivar Control recorded highest (7.33) mean infestation followed by Sherpa plus at 4 weeks spray regime (2.33), Sherpa plus at 2 weeks spray regime (1.83) and Neem Extract at 4 weeks spray regime (1..83), while the least was observed from Neem Extract at 2 weeks spray regime (1.00).

Location and Variety Interaction presented on Table 7 shows highly significant ($P>0.01$) at 14 weeks after treatment, the white recorded higher (6.730) mean infestation while the lower mean was observed from the Red cultivar (4.73) in Jalingo location. The white cultivar was still the highest mean (5.80) and 5.13 was recorded from the Red cultivar at Yola location.

At 16 weeks after sowing there highly significant ($P<0.01$), the white recorded higher (4.06) mean infestation while the lower mean was observed from the Red cultivar (3.53) in Jalingo location. The white cultivar was still the highest mean (4.13) and 2.20 was recorded from the Red cultivar at Yola location.

Location, Variety and Treatment Interaction presented on Table 8. Shows that at 10 weeks after sowing at Jalingo, shows significant difference ($P>0.01$) on the white cultivar, its Control recorded highest (18.66) mean infestation followed by Sherpa plus at 2 weeks spray regime (3.66), Sherpa plus at 4 weeks spray regime (3.00), while the least mean (2.00) was observed from Neem Extract at 4 weeks spray regime and Neem Extract at 2 weeks spray regime each. The Red cultivar Control recorded highest (11.33) mean infestation followed by Sherpa plus at 4 weeks spray regime (3.66), Sherpa plus at 2 weeks spray regime (2.33) and Neem Extract at 4 weeks spray regime (2.00), while the least was observed from Neem Extract at 2 weeks spray regime (1.66). On the Yola experimental farm, shows significant difference (P>0.01) on the white cultivar, the Control recorded highest (17.00) mean infestation followed by Sherpa plus at 4 weeks spray regime (4.00), Sherpa plus at 2 weeks spray regime (2.66), Neem Extract at 4 weeks spray regime (1.66) while the least mean (1.00) was observed Neem Extract at 2 weeks spray regime. The red cultivar Control recorded the highest (9.33) mean infestation followed by Sherpa plus at 4weeks spray regime (2.66), Neem Extract at 4 weeks spray regime (2.33), Neem Extract at 2 weeks spray regime (0.66) while the least mean (0.00) was observed from and Sherpa plus at 2 weeks spray regime at Ten(10) weeks after Sowing.

At Sixteen (16) Jalingo, shows significant (P>0.01) on the White cultivar Control recorded highest (10.00) mean infestation followed Neem Extract at 4 weeks spray regime (4.33), Sherpa plus at 4 weeks spray regime (4.33), Sherpa plus at 2 weeks spray regime (2.00) while the least mean (1.66) was observed from Neem Extract at 2 weeks spray regime. The Red cultivar, its Control recorded highest (8.66) mean infestation followed by Sherpa plus at 4 weeks spray regime (3.33), Sherpa plus at 2 weeks spray regime(2.00) while the least mean(0.66) was observed from Neem Extract at 2 weeks spray regime and Neem Extract at 4 weeks spray regime (2.00) each.

On the Yola experimental farm, shows significant (P>0.01) on the white cultivar, the Control recorded highest (14.00) mean infestation followed by Sherpa plus at 4 weeks spray regime (3.33), Sherpa plus at 2 weeks spray regime (2.66) while the least means (0.66) was observed Neem Extract at 4 weeks spray regime and Neem Extract at 2 weeks spray regime each. The red cultivar had Control recorded as the highest (6.00) mean infestation followed by Sherpa plus at 4weeks spray regime (2.00), Neem Extract at 4 weeks spray regime (1.66), Neem Extract at 2 weeks spray regime (1.00) while the least mean (0.33) was observed from and Sherpa plus at 2 weeks spray regime at 16 weeks after Sowing.

Table 5: Interaction Between Location and Treatment on Cumulative Abundance of Insect at both Yola and Jalingo Locations

	Location	Control	Neem at 4 weeks	Sherpa at 4 weeks	Neem at 2 weeks	Sherpa at 2 weeks
	Jalingo	15.0000	2.5000	2.8333	1.8333	3.0000
10 WAT	Yola	13.1666	2.0000	3.3333	0.8333	1.3333
	P>F	0.0110				
16 WATS	Yola	9.3333	2.6666	3.555	1.1666	2.333
	Jalingo	10.0000	1.1666	2.6666	0.5000	1.5555
	P>F	0.0109				

Table 6: Interaction Between Variety and Treatment on Cumulative Abundance of Insect at both Yola and Jalingo Locations

		Treatment Regimes				
	Variety	Control	Neem at 4 weeks	Sherpa at 4 weeks	Neem at 2 weeks	Sherpa at 2 weeks
	White cultivar	14.6666	2.1666	4.1666	1.0000	2.8333
6 WAT	Red cultivar	11.0000	1.6666	2.8333	1.1666	2.6666
	P>F	<0.0001				
10 WAT	White cultivar	17.8333	2.3333	3.0000	1.5000	3.1666
	Red cultivar	10.3333	2.1666	3.1666	1.1666	1.1666
	P>F	<0.0001				
14 WAT	White cultivar	18.6666	3.6666	4.1666	1.5000	3.3333
	Red cultivar	14.1666	2.6666	3.6666	1.5000	2.6666
	P>F	<0.0001				
16 WAT	White cultivar	12.0000	2.0000	3.8333	0.6666	2.0000
	Red cultivar	7.3333	1.8333	2.3333	1.0000	1.8333
	P>F	<0.0001				

Table 7: Interaction Between Location and Variety on Cumulative Abundance of Insect at both Yola and Jalingo Locations

	14 WATS		16 WATS	
	White cultivar	Red cultivar	White cultivar	Red cultivar
Jalingo	6.7333	4.7333	4.0666	3.5333
Yola	5.8000	5.1333	4.1333	2.2000
P>F	0.0014		0.0005	

Table 8: Interaction Between Location, Variety and Treatment on Cumulative Abundance of Insect at both Yola and Jalingo Locations

	Location	**Variety**	**Treatment Spray Regimes**				
			Control	Neem at 4 weeks	Sherpa at 4 weeks	Neem at 2 weeks	Sherpa at 2 weeks
	Jalingo	White cultivar	18.6666	3.0000	2.0000	2.0000	3.6666
10 WAT		Red cultivar	11.3333	2.0000	3.6666	1.6666	2.3333
	Yola	White cultivar	17.0000	1.6666	4.0000	1.0000	2.6666
		Red cultivar	9.3333	2.3333	2.6666	0.6666	0.0000
		P>F	0.0257				
16 WAT	Jalingo	White cultivar	10.0000	4.3333	4.3333	0.6666	2.0000
		Red cultivar	8.6666	2.0000	2.6666	1.6666	2.6666
	Yola	White cultivar	14.0000	0.6666	3.3333	0.6666	2.0000
		Red cultivar	6.0000	1.6666	2.0000	0.3333	1.0000
		P>F	0.6203				

4.6 The Effect of Treatments on the Plant Height at Yola and Jalingo in the 2018 Cropping Season

Figure 5 shows the result the effect of treatments on the plant height on the experimental farm in Yola; At one month after sowing there was no significant ($P>0.05$) difference in the plant height between the varieties; the white cultivar recorded mean height 29.32cm while the red cultivar had mean of 28.26 cm in height. Among the treatments there was also no significant difference among them, the sample treated with Neem extract at 4 weeks interval, the control and Neem extract at 2 weeks interval had a slightly higher means plant height of 29.95, 29.25 and 29.20 cm respectively followed by Sherpa Plus at 2 weeks interval having 28.10 cm while the lowest height of 27.45cm was observed from Sherpa Plus at 4 weeks interval.

At two month after sowing there was still no significant difference in the plant height between the varieties; the white cultivar recorded mean height 62.16 cm while the red cultivar had a mean plant height of 58.38 cm. Among the treatments there was also no significant difference among them, the sample treated with Neem extract at 2 weeks interval and Sherpa Plus at 2 weeks interval were slightly taller with height of 66.10 and 65.45 cm respectively. Lower means of 58.80, 57.45 and 53.55 cm were obtained from samples treated with Sherpa Plus at 4 weeks interval, Neem extract at 4 weeks interval and the control respectively.

At three month after sowing there was significant difference in the plant height among the varieties; the white recorded mean height of 120.80 cm while the red cultivar had a height of 110.61 cm. Among the treatments there was significant difference among them, the sample treated with Neem extract at 2 weeks interval had the highest height of 130.25cm followed by Sherpa Plus at 2 weeks interval, Neem extract at 4 weeks interval and Sherpa Plus at 4 weeks interval having height of 122.88, 118.85 and 116.80 cm respectively. While the lowest mean plant height of 89.75 was obtained from the control.

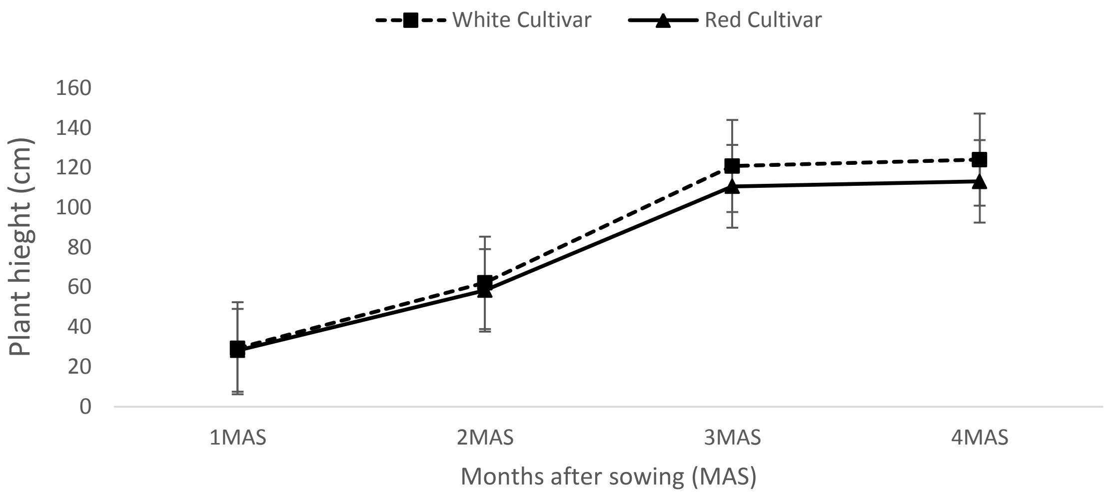
At four months after sowing there was still significant difference ($P<0.05$) in the plant height between the varieties; the white cultivar recorded mean 124.00 cm in height while the red cultivar was 113.10 cm in height. Among the treatments there was highly significant difference, the sample treated with Neem extract at 2 weeks interval was the tallest in height of 133.25 cm followed by Sherpa Plus at 2 weeks interval which was 126.10 cm in height. Lower means of 122.05 and 119.50 cm were observed from Neem extract at 4 weeks interval and Sherpa Plus at 4 weeks interval respectively while the control had the lowest height of 91.85 cm.

Result on the experimental farm in Jalingo presented on Fig.5; at one month after sowing there was no significant ($p>0.05$) difference in the plant height between the varieties; the white recorded mean 23.10 cm in height while the red cultivar was 22.20 cm in height. The sample treated with Neem extract at 2 weeks interval was the tallest in height (25.30) followed by Neem extract at 4 weeks interval having 22.80cm then Sherpa Plus at 4 weeks interval which was 22.50. A lower plant height of 22.00cm was observed in the sample treated with Sherpa Plus at 4 weeks interval while the control which had the lowest plant height recorded 22.00 cm.

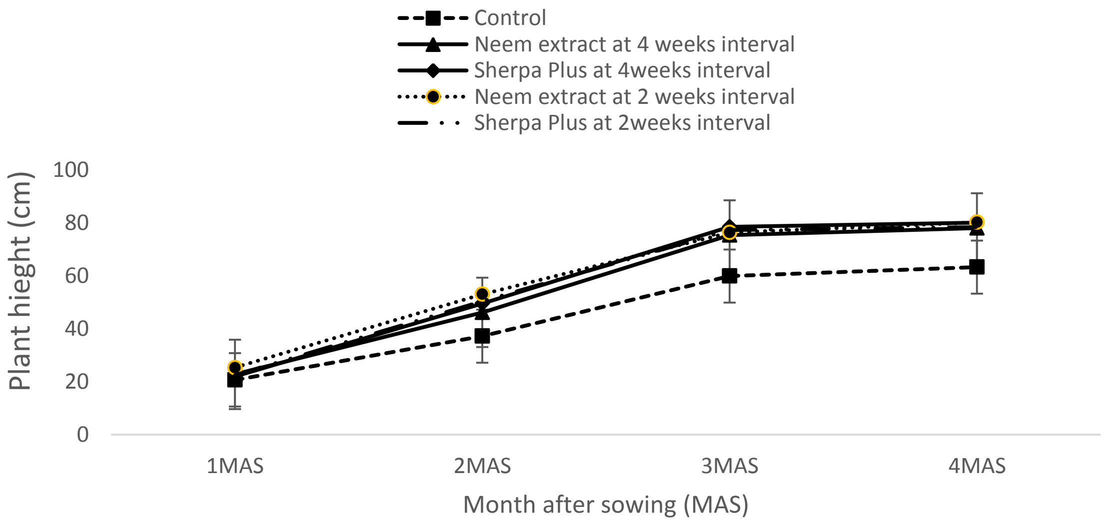
At two months after sowing there was still no significant ($P>0.05$) difference in the plant height between the varieties; the white cultivar recorded a mean plant height of 47.52 cm in height while the red cultivar was 47.00cm in height. Among the treatments, the sample treated with Neem extract at 2 weeks interval had the tallest plant height (53.05 cm) followed by Sherpa Plus at 2 weeks interval having plant height of 50.35 cm then Sherpa Plus at 4 weeks interval which had plant height of 49.55 cm. A lower height of 46.15cm was observed in the sample treated with Neem extract at 4 weeks interval while the control recorded the lowest in height 37.20 cm.

At three months after sowing there was significant difference ($P<0.05$) in the plant height between the varieties; the white cultivar recorded the mean of 76.16 cm in height while the red cultivar had 70.78 cm in height. Among the treatments, the sample treated with Sherpa Plus at 4 weeks interval recorded the tallest in height (78.50 cm) followed by Sherpa Plus at weeks interval which was 77.25 cm in height then Neem extract at 2 weeks interval which was 76.35 cm. A lower height of 75.35 cm was recorded in Neem extract at 2 weeks interval while the control which was the lowest in height recorded 59.90 cm.

At four months after sowing there was no significant difference ($P>0.05$) in the plant height between the varieties; the white cultivar recorded mean of 78.96 cm in height while the red cultivar was 73.02 cm. Among the treatments, the sample treated with Neem extract at 2 weeks interval recorded the tallest plant with height of 80.20 cm followed by Sherpa Plus at 4 weeks interval which had 80.10 cm. Lower heights of 78.35 cm and 78.0 cm was

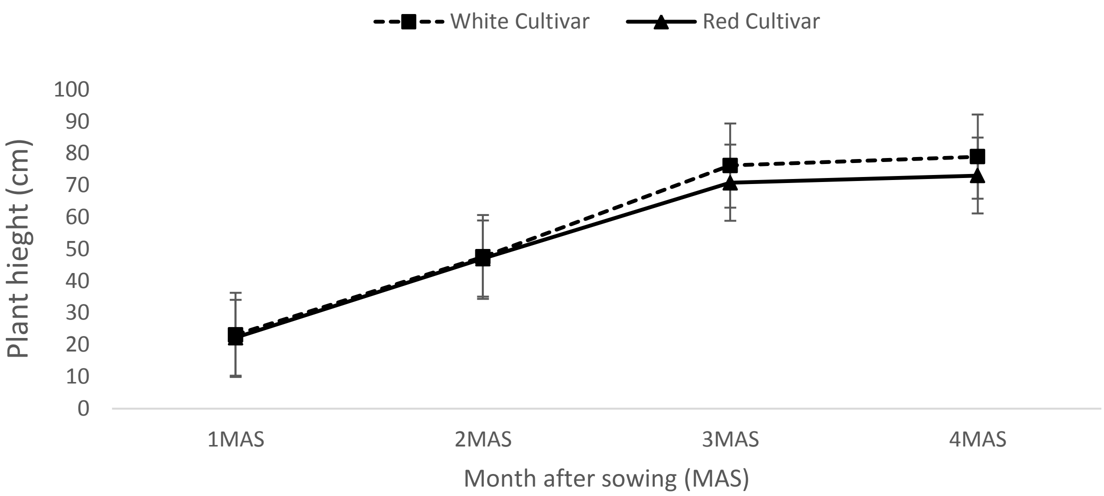


5a: Effect of the Different Cultivars on the Height(cm) of Roselle at Yola in 2018 Cropping Season

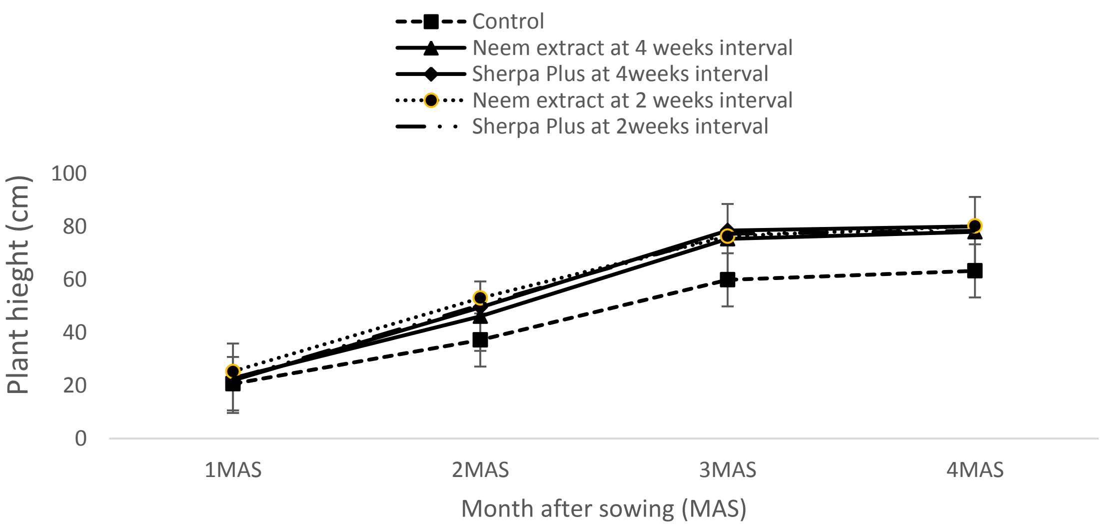


5b: Effect of the Different Treatments on the Height(cm) of Roselle at Yola in 2018 Cropping Season

Figure 5: Effect of the Different Treatments on the Height (cm) of Roselle in the at Yola in 2018 Cropping Season



6a: Effect of the Different Cultivar on the Height(cm) of Roselle at Jalingo in 2018 Cropping Season



6b: Effect of the Different Treatments on the Height(cm) of Roselle at Jalingo in 2018 Cropping Season

Figure 6: Effect of the Different Treatments on the Height (cm) of Roselle at Jalingo in 2018 Cropping Season

Table 9: The Combined Effect of Treatments on the Height of Roselle at Yola and Jalingo in 2018 Cropping Season

Treatments	Plant Height (cm) 1MAS	2MAS	3MAS	4MAS
Location				
Yola	28.79[a]	60.27[a]	115.71[a]	118.55[a]
Jalingo	22.68[b]	47.26[b]	73.47[b]	75.99[b]
Mean	25.73	53.76	94.59	97.27
P>F	<0.0001	<0.0001	<0.0001	<0.0001
CV%	8.46	7.10	4.12	2.95
Varieties				
White cultivar	26.23[a]	54.84[a]	95.79[a]	98.51[a]
Red cultivar	25.24[a]	52.69[b]	93.38[b]	96.03[b]
Mean	25.73	53.76	94.59	97.27
P>F	0.082	0.0354	0.0220	0.0018
CV%	8.46	7.10	4.12	2.95
Treatment				
Control	24.97[a]	45.37[c]	74.82[c]	77.57[c]
Neem extract at 4 weeks interval	26.37[a]	51.80[b]	97.10[b]	100.02[b]
Sherpa Plus at 4 weeks interval	24.75[a]	54.17[b]	97.65[b]	99.80[b]
Neem extract at 2 weeks interval	27.25[a]	59.57[a]	103.30[a]	106.72[a]
Sherpa Plus at 2 weeks interval	25.32[a]	57.90[a]	100.07[b]	102.22[b]
Mean	25.73	53.76	94.59	97.27
P>F	0.036	<0.0001	<0.0001	<0.0001
CV%	8.46	7.10	4.12	2.95
Interaction				
Location*Treatment	Ns	Ns	**	**
Location*Variety	Ns	Ns	**	**
Variety*Treatment	Ns	Ns	*	**
Location*Variety*Treatment	*	Ns	Ns	**

Means followed by the same letter(s) in the same column are not significantly using Student Newman Kaul Test of Significance.
MAS=Months After Sowing.

recorded from Sherpa Plus at 2 weeks interval and Neem extract at 2 weeks interval respectively while the control which was the lowest in height recorded 63.30 cm.

4.7 The Combined Effect of Treatments on the Height of Roselle at Yola and Jalingo in 2018 Cropping Season

Table 9 showed the combined effect of treatments on the plant height on the experimental farm in Yola and Jalingo; At one month after sowing there was highly significant difference ($P<0.01$) in the plant height between the locations; the plants in Yola recorded mean height of 28.79 cm in while the Jalingo location was 22.68 cm in height. Between the cultivars, was no significant difference ($P>0.05$) in the plant height among them; the white recorded mean 26.23 cm in height while the red cultivar was 25.24 cm in height. Among the treatments there was significant difference ($P<0.05$) among them, mean heights of. 27.25 cm, 26.37 cm, 25.32 cm, 24.97 cm and 24.75 cm observed from sample treated with Neem extract at 2 weeks interval, Neem extract at 4 weeks interval, Sherpa Plus at 2 weeks interval, the control and Sherpa Plus at 4 weeks interval respectively.

At two months after sowing there was still highly significant difference ($P<0.01$) in the plant height between the locations; the plants in Yola recorded higher mean height of 60.27 cm in while the Jalingo location had 47.26 cm in height. Between the cultivars, was significant difference ($P<0.05$) in the plant height among them; the white cultivar recorded higher mean of 54.84 cm in height while the red cultivar was 52.69 cm in height. Among the treatments there was highly significant difference ($P<0.01$) among them, highest mean plant heights of 59.57 cm and 57.90 cm were observed from sample treated with Neem extract at 2 weeks interval and Sherpa Plus at 2 weeks interval respectively. Sherpa Plus at 4 weeks interval and Neem extract at 4 weeks interval had mean plant heights of 54.17 cm and 51.80 cm respectively while the control had the lowest height of 45.37 cm.

At three months after sowing there was still highly significant difference ($P<0.01$) in the plant height between the locations; the plants in Yola recorded higher mean plant height of 115.71 cm while the Jalingo location was 73.49 cm in height. Between the cultivars, there was also significant difference ($P<0.05$) in the plant height among them; the white cultivar recorded higher mean plant height of 95.84 cm while the red cultivar had 93.38 cm in height. There was highly significant difference ($P<0.01$) among the treatments, the sample treated with Neem extract at 2 weeks interval recorded the tallest plant height (103.30 cm) followed by Sherpa Plus at 2 weeks interval, Sherpa Plus at 4 weeks interval and Neem extract at 4 weeks interval having mean heights of 100.07, 97.65 and 97.10 cm respectively while the control was the lowest in height which recorded 74.82 cm.

At four months after sowing there was still highly significant difference (P<0.01) in the plant height between the locations; the plants in Yola recorded higher mean height of 118.55 cm in while the Jalingo location was 75.99 cm in height. Between the cultivars, there was also highly significant difference (P<0.01) in the plant height among them; the white cultivar recorded higher mean of 98.51 cm in height while the red cultivar was 96.03 cm in height. treatments there was highly significant difference (P<0.01) among the treatments, the sample treated with Neem extract at 2 weeks interval was the tallest in height (106.72 cm) followed by Sherpa Plus at 2 weeks interval and Neem extract at 2 weeks interval which were 102.22 cm and 100.02 cm respectively. Lower height of 99.80cm observed from Sherpa Plus at 4 weeks interval while the control which was the lowest in height recorded 77.57 cm.

4.8 Interactive Effect of Treatments on the Height (Cm) of Roselle at Yola and Jalingo in the 2018 Cropping Season

Location and Treatment interaction on the Height of Roselle presented in Table 10 shows that there was highly significant difference (P<0.01) among the treatments, at Jalingo farm, the highest height was from samples treated with Sherpa Plus at 4weeks interval (78.50 cm) followed by Sherpa Plus at 2 weeks interval (77.25 cm), Neem extract at 2 weeks interval (76.35 cm), Neem extract at 4 weeks interval (75.35 cm) while the lowest height was obtained from the untreated control (59.90 cm). A similar trend was observed in Yola Location, Neem extract at 2 weeks interval, Sherpa Plus at 2 weeks interval, Sherpa Plus at 4weeks interval, Neem extract at 4 weeks interval, Sherpa Plus at 2weeks interval and the untreated control recorded 130.25, 122.88, 118.85, 116.80 and 89.75 cm respectively.

Location and Variety on the Height of Roselle presented in Table 11 shows that there was highly significant difference (P<0.01) among the treatments, at Jalingo farm the higher height was from record white cultivar (76.16 cm) than the white cultivar (70.78 cm) at three months after sowing while Yola location had the white cultivar (120.80 cm) taller than the red cultivar (110.61 cm).

Table 10: Interaction of Location and Treatment on the Height (cm) of Roselle at Yola and Jalingo Locations

	Location	Control	Neem at 4 weeks	Sherpa at 4weeks	Neem at 2 weeks	Sherpa at 2 weeks
	Jalingo	59.9000	75.3500	78.5000	76.3500	77.2500
3 MAS	Yola	89.7500	118.8500	116.8000	130.2500	122.8833
	P>F	<.0001				
4 MAS	Yola	63.3000	78.0000	80.1000	80.2000	78.3500
	Jalingo	91.8500	122.0500	119.5000	133.2500	126.1000
	P>F	<.0001				

Table 11: Interaction of Location and Variety on the Height (cm) of Roselle at Yola and Jalingo Locations

	3MAS		4MAS	
	White cultivar	Red cultivar	White cultivar	Red cultivar
Jalingo	70.78000	76.16000	73.0200	78.9600
Yola	120.8000	110.6133	124.0000	113.1000
P>F	<.0001		<.0001	

Table 12: Interaction of Variety and Treatment on the Height (cm) of Roselle at Yola and Jalingo Locations

		Spray Regimes				
	Variety	Control	Neem at 4 weeks	Sherpa at 4 weeks	Neem at 2 weeks	Sherpa at 2 weeks
	White cultivar	75.6500	99.050	100.50	101.05	102.70
3 MAS	Red cultivar	74.0000	95.150	94.800	105.55	97.433
	P>F	0.0173				
4MAS	White cultivar	78.3000	101.70	102.90	105.00	104.65
	Red cultivar	76.8500	98.350	96.700	108.45	99.800
	P>F	0.0021				

At four months after sowing, there was still highly significant difference ($P<0.01$) among the treatments, at Jalingo farm the higher height was from record red cultivar (78.96) than the white cultivar (124.00 cm) while Yola location had the white cultivar (120.80) taller than the red cultivar (113.10 cm).

Variety and Treatment Interaction on the Height of Roselle presented in Table 12 shows that there was highly significant difference ($P<0.01$) among the treatments, at Jalingo farm, the highest height was from samples treated with Sherpa Plus at 2 weeks interval (102.70 cm) followed by Neem extract at 2 weeks interval (101.05), Sherpa Plus at 4 weeks interval (100.50 cm), Neem extract at 4 weeks interval (99.00) while the lowest height was obtained from the untreated control (75.65) for the white cultivar. The Red cultivar the highest height was from samples treated with by Neem extract at 2 weeks interval (105.70 cm), followed by Sherpa Plus at 2 weeks interval (97.43 cm), Neem extract at 4 weeks interval (95.15 cm), Sherpa Plus at 4 weeks interval (94.80 cm) while the lowest height was obtained from the untreated control (74.00 cm).

A similar trend was observed in Yola Location, Neem extract at 2 weeks interval, Sherpa Plus at 2 weeks interval, Sherpa Plus at 4weeks interval, Neem extract at 4 weeks interval, Sherpa Plus at 2weeks interval and the untreated control recorded 105.00, 104.65, 102.90, 101.70 and 78.30 cm respectively from the white cultivar. The red cultivar recorded Neem extract at 2 weeks interval, Sherpa Plus at 2 weeks interval, Sherpa Plus at 4weeks interval, Neem extract at 4 weeks interval, Sherpa Plus at 2weeks interval and the untreated control recorded 108.45, 99.800 98.350, 96.700, and 76.85 cm respectively from the white cultivar.

4.9 Effect of Treatments on the Total Number of leaves per Planat Yola and Jalingo in the 2018 Cropping Season

The mean number of leaves per plant was observed at four weeks, six, eight and ten weeks after sowing in both Yola and Jalingo locations; at four weeks after sowing on the experimental farm at Yola as presented on Table 13, There was highly significant difference ($P<0.01$) in the mean number of leaves per plant among the varieties, the white cultivar had higher mean number (12.00) of leaves per plant while the red cultivar had 10.93 number leaves per plant. There was highly significant difference ($P<0.01$) among the treatments, those treated with Neem extract at 4 weeks interval (12.50) had the highest number of leaves per samples plant, lower means were obtained from Neem extract at 2 weeks interval, Sherpa Plus at 2 weeks interval, Sherpa Plus at 4 weeks interval and Sherpa

Plus at 2weeks interval having 11.83, 11.50 and 11.17 number of leaves respectively while the control had the lowest mean of mean number (10.33) of leaves per plant.

At six weeks after sowing on the experimental farm at Yola, there was highly significant difference (P<0.01) in the number of leaves per plant among the varieties, the white cultivar had higher mean number (25.27) of leaves per plant while the red cultivar had 24.00 number leaves per plant. There was highly significant difference (P<0.01) among the treatments, higher mean number of leaves per plant was obtained from those treated with Neem extract at 2 weeks interval and Sherpa Plus at 2weeks interval recording 27.83 each, followed by Neem extract at 4 weeks interval having 25.83. Lower mean number of leaves was obtained from Sherpa Plus at 4 weeks interval having 22.50 while the control had the lowest mean of mean number (19.17) of leaves per plant.

At eight weeks after sowing on the experimental farm at Yola, there was still highly significant difference (P<0.01) in the number of leaves per plant among the varieties, the white cultivar had higher mean number (46.80) of leaves per plant while the red cultivar had 43.60 mean number leaves per plant. There was highly significant difference (P<0.01) among the treatments, those treated with Neem extract at 2 weeks interval and Neem extract at 4 weeks interval had the highest number of leaves of 49.33 and 49.17 respectively followed by Sherpa Plus at 2 weeks interval having 46.17 then Sherpa Plus at 4 weeks interval having 44.17 mean number of leaves per plant, while the control had the lowest mean of mean number (37.17) of leaves per plant.

At ten weeks after sowing on the experimental farm at Yola, there was highly significant difference (P<0.01) in the number of leaves per plant among the varieties, the white cultivar had higher mean number (89.87) of leaves per plant while the red cultivar had 85.33 number leaves per plant. There was highly significant difference (P<0.01) among the treatments, the highest mean number (95.83) of leaves was obtained from those treated with Neem extract at 2 weeks interval followed 95.17 obtained from Neem extract at 4 weeks interval then Sherpa Plus at 2 weeks interval having 93.83 mean number of leaves while the control had the lowest mean of mean number (64.83) of leaves per plant.

Result on the experimental farm at Jalingo is presented in Table 14; at four weeks after sowing there was highly significant difference (P<0.01) in the mean number of leaves per plant between the varieties, the white cultivar had higher mean number (12.80) of leaves per plant while the red cultivar had 9.20 number leaves per plant. There was significant difference ($P<0.05$) among the treatments, those treated with Neem extract at 4 weeks interval (10.83) had the highest number of leaves followed by Sherpa Plus at 4 weeks interval having 10.33. Those treated with Neem extract at 2 weeks interval and Sherpa Plus at 2 weeks interval had a lower mean number of 9.83 each while the control had the lowest mean of mean number (9.17) of leaves per plant.

At six weeks after sowing, there was highly significant difference ($P<0.01$) in the number of leaves per plant between the varieties; the white cultivar had higher mean number (24.07) of leaves per plant while the red cultivar had 21.80 number leaves per plant. There was highly significant difference ($P<0.01$) among the treatments, those treated with Sherpa Plus at 2weeks interval had the highest mean number (27.17) of leaves per plant followed those treated with Neem extract at 2 weeks interval by recording having 26.50. Neem extract at 4 weeks interval and Sherpa Plus at 4 weeks interval had a lower mean of 24.33 and 22.00 respectively while the control had the lowest mean of mean number (14.67) of leaves per plant.

At eight weeks after sowing, there was highly significant difference ($P<0.01$) in the number of leaves per plant between the varieties; the white had higher mean number (40.40) of leaves per plant while the red cultivar had 39.27 number leaves per plant. There was highly significant difference ($P<0.01$) among the treatments, higher mean number of leaves per plant was obtained from the sample treated with Neem extract at 2 weeks interval having mean of 43.83 followed by Neem extract at 4 weeks interval and Sherpa Plus at weeks interval having 42.50 and 41.00 respectively. Lower mean number of leaves was obtained from Sherpa Plus at 4 weeks interval having 39.67 while the control had the lowest mean of mean number (32.17) of leaves per plant.

At ten weeks after sowing, there was no significant difference ($P>0.05$) in the number of leaves per plant between the varieties; the white had higher mean number (86.13) of leaves per plant while the red cultivar had 80.60 number leaves per plant. There was highly significant difference ($P<0.01$) among the treatments, the highest mean number (91.67) of leaves was obtained from those treated with Neem extract at 2 weeks interval followed 91.00 obtained from Neem extract at 4 weeks interval then Sherpa Plus at 2 weeks interval having 89.33 mean number of leaves. A lower mean of 76.67 was obtained from the sample

Table 13: Effect of Treatments on the Total Number of leaves and Number of Damaged Leaves Per Plant at Yola in 2018 Cropping season

	Mean Number of leaves				Mean Number of Damaged Leaves	
Treatments	4WAS	6WAS	8WAS	10WAS	**6** WAS	**10** WAS
Varieties						
White cultivar	12.00[a]	25.27[a]	46.80[a]	89.87[a]	4.07[a]	9.20[a]
Red cultivar	10.93[b]	24.00[a]	43.60[b]	85.33[b]	3.13[b]	8.13[b]
Mean	11.47	24.63	45.20	87.60	3.60	8.67
P>F	0.0005	0.0039	<0.0001	<0.0001	0.0002	0.0005
Coefficient of Variation%	6.075	4.26	1.86	1.01	15.21	8.04
Treatments						
Control	10.33[c]	19.17[a]	37.17[d]	64.83[d]	9.50[a]	26.50[a]
Neem extract at 4 weeks interval	12.50[a]	25.83[b]	49.33[a]	95.17[a]	1.83[c]	4.00[c]
Sherpa Plus at 4weeks interval	11.50[ab]	22.50[c]	44.17[b]	88.33[c]	4.00[b]	5.00[b]
Neem extract at 2 weeks interval	11.83[ab]	27.83[a]	49.17[a]	95.83[a]	1.17[c]	3.67[c]
SherpaPlus at 2weeks interval	11.17[cb]	27.83[a]	46.17[b]	93.83[b]	1.50[c]	4.17b[c]
Mean	11.47	24.63	45.20	87.60	3.60	8.67
P>F	0.0007	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Coefficient of Variation%	6.075	4.26	1.86	1.01	15.21	8.04
Interaction						
Variety*Treatment	Ns	*	**	**	Ns	**

Means followed by the same letter(s) in the same column are not significantly using Student Newman Kaul Test of Significance,
WAS=Weeks After Sowing.

Table 14: Effect of Treatments on the Total Number of leaves and Number of Damaged Leaves Per Plant at Jalingo in 2018 Cropping season

	Total Number of leaves				Number of Damaged Leaves	
Treatments	4WAS	6WAS	8WAS	10WAS	6 WAS	10 WAS
Varieties						
White cultivar	10.80[a]	24.07[a]	40.40[a]	86.13[a]	4.67[a]	9.93[a]
Red cultivar	9.20[b]	21.80[b]	39.27[b]	80.60[a]	3.87[b]	7.93[b]
Mean	10.00	22.93	39.83	83.37	4.27	8.93
P>F	<0.0001	<0.0001	0.0005	0.0683	0.0023	<0.0001
Coefficient of Variation%	7.72	2.64	1.85	9.37	14.48	7.01
Treatments						
Control	9.17[b]	14.67[d]	32.17[e]	68.50[b]	10.83[a]	27.83[a]
Neem extract at 4 weeks interval	10.83[a]	24.33[b]	42.50[b]	91.00[a]	2.17[c]	3.83[cd]
Sherpa Plus at 4 weeks interval	10.33[ab]	22.00[c]	39.67[d]	76.33[b]	4.00[b]	5.67[b]
Neem extract at 2 weeks interval	9.83[ab]	26.50[a]	43.83[a]	91.67[a]	1.83[c]	3.17[d]
Sherpa Plus at 2 weeks interval	9.83[ab]	27.17[a]	41.00[c]	89.33[a]	2.50[c]	4.17[c]
Mean	10.00	22.93	39.83	83.37	4.27	8.93
P>F	0.0186	<0.0001	<0.0001	0.0001	<0.0001	<0.0001
Coefficient of Variation%	7.72	2.64	1.85	9.37	14.48	7.01
Interaction						
Variety*Treatment	*	**	**	Ns	**	**

Means followed by the same letter(s) in the same column are not significantly using Student Newman Kaul Test of Significance,
MAS=Weeks After Sowing.

treated with Sherpa Plus at 2 weeks interval while the control had the lowest mean of mean number (64.83) of leaves per plant.

4.10 The Combined Effect of Treatments on the Total Number of leaves at Yola and Jalingo in 2018 Cropping Season

The mean number of leaves per plant was observed at 4 weeks, six, eight and ten weeks after sowing in both Yola and Jalingo locations presented in Table 13; At four weeks after sowing, there was highly significant difference ($P<0.01$) in the number of leaves between the locations; the plants in Yola recorded highest mean number of leaves (11.47) while the Jalingo location had 10.00 leaves per sampled plant. Between the varieties there was highly significant difference ($P<0.01$) in the mean number of leaves per plant among the varieties, the white had higher mean number (11.40) of leaves per plant while the red cultivar had 10.07 number leaves per plant. Among the treatments, those treated with Neem extract at 4 weeks interval had highest number of leaves (11.67), lower mean number of leaves was obtained from Sherpa Plus at 4 weeks interval, Neem extract at 2 weeks interval and Sherpa Plus at 2weeks interval which had 10.91, 10.83 and 10.50 respectively while the control had the lowest mean of mean number (9.75) of leaves per plant.

At six weeks after sowing on the experimental farm at Yola and Jalingo, there was highly significant difference ($P<0.01$) in the number of leaves between the locations; the plants in Yola recorded highest mean number of leaves (24.63) while the Jalingo location was 22.93 leaves per sampled plant. Between the varieties there was still highly significant difference ($P<0.01$) in the number of leaves per plant among the varieties, the white cultivar had higher mean number (24.67) of leaves per plant while the red cultivar had 22.90 number leaves per plant. There was still highly significant difference ($P<0.01$) among the treatments, highest mean number of leaves per plant was obtained from those treated with Sherpa Plus at 2weeks interval and Neem extract at 2 weeks interval recording 27.50 and 27.17 respectively followed by Neem extract at 4 weeks interval having 25.08. Lower mean number of leaves was obtained from Sherpa Plus at 4 weeks interval having 22.50 while the control had the lowest mean of mean number (16.91) of leaves per plant.

At eight weeks after sowing on the experimental farm at Yola and Jalingo, there was still highly significant difference ($P<0.01$) in the number of leaves between the locations; the plants in Yola recorded highest mean number of leaves (45.20) while the Jalingo location was 39.83 leaves per sampled plant. Between the varieties there was still highly significant difference (P<0.01) in the number of leaves per plant among the varieties, the white cultivar had higher mean number (43.60) of leaves per plant while the red cultivar had 41.43 mean number leaves per plant. There was still highly significant difference (P<0.01) among the treatments, those treated with Neem extract at 2 weeks interval and Neem extract at 4 weeks interval had the highest number of leaves of 46.50 and 45.92 respectively followed by Sherpa Plus at 2 weeks interval having 43.58 then Sherpa Plus at 4 weeks interval having 41.92mean number of leaves per plant, while the control had the lowest mean of mean number (34.67) of leaves per plant.

At ten weeks after sowing on the experimental farm at Yola and Jalingo, there was still highly significant difference (P<0.01) in the number of leaves between the locations; the plants in Yola recorded highest mean number of leaves (87.60) while the Jalingo location was 83.37 leaves per sampled plant. Between the varieties there was still highly significant difference (P<0.01) in the number of leaves per plant, the white cultivar had higher mean number (88.00) of leaves per plant while the red cultivar had 82.97 number leaves per plant. There was still highly significant difference (P<0.01) among the treatments, the highest mean numbers 93.75, 93.08 and 91.58 were obtained from those treated with Neem extract at 2 weeks interval, Neem extract at 4 weeks interval and Sherpa Plus at 2 weeks interval respectively. Lower mean number of leaves was observed from Sherpa Plus at 2 weeks interval having 82.33 while the control had the lowest mean of mean number (66.67) of leaves per plant.

4.11 Effect of Treatments on the Number of Damaged Leaves Per Plant at Yola and Jalingo in 2018 Cropping season

Table 13 shows effect of treatments on the number of damaged leaves per plant; At six weeks after sowing on the experimental farm at Yola, there was highly significant difference (P<0.01) in the mean number of leaves per plant among the varieties, the white cultivar had higher mean number (4.01) of leaves damaged per sample while the red cultivar had 3.13 number leaves per sample. There was highly significant difference (P<0.01) among the treatments, those treated with Neem extract at 2 weeks interval had lowest mean number (1.17) of leaves damaged followed by those treated with Sherpa Plus at 2 weeks interval(1.50) then the sample treated with Neem extract at 4 weeks interval had a mean of 1.83. Higher mean of 4.00 was obtained from sample treated with Sherpa Plus at

4 weeks while the control had the highest mean of mean number (9.50) of leaves damaged per sampled plant.

At ten weeks after sowing there was highly significant difference ($P<0.01$) in the mean number of leaves damaged per plant between the varieties, the white cultivar had higher mean number (9.20) of leaves damaged per sample while the red cultivar had 8.13 number leaves per sample. There was highly significant difference ($P<0.01$) among the treatments, those treated with Neem extract at 2 weeks interval had lowest mean number (3.67) of leaves damaged followed by those treated with Neem extract at 2 weeks interval (4.00) then Sherpa Plus at 2 weeks interval (4.17). Higher mean of 5.00 was obtained from sample treated with Sherpa Plus at 4 weeks interval while the control had the highest mean of mean number (26.50) of leaves damaged per plant.

On the Jalingo experimental farm, the result presented on Table 14 showed that; At six weeks after sowing there was highly significant difference in the mean number of leaves damaged per sample between the varieties, the white had higher mean number (4.67) of leaves damaged per sample while the red cultivar had 3.87 number leaves per sample. There was highly significant difference ($P<0.01$) among the treatments there was highly significant difference, the sample treated with Neem extract at 2 weeks interval had lowest mean number (1.83) of leaves damaged followed by those treated with Neem extract at 4 weeks interval having 2.17 then the sample treated with Sherpa Plus at 2 weeks interval which had a mean of 2.50. Higher mean of 4.00 was obtained from sample treated with Sherpa Plus at 4 weeks while the control had the highest mean of mean number (10.83) of leaves damaged per sampled plant.

At ten weeks after sowing, there was still highly significant difference in the mean number of leaves damaged per sample between the varieties; the white had higher mean number (9.93) of leaves damaged per sample while the red cultivar had 7.93 mean number leaves per sampled plant. There was highly significant difference ($P<0.01$) among the treatments, the sample treated with Neem extract at 2 weeks interval had lowest mean number (3.17) of leaves damaged followed by those treated with Neem extract at 4 weeks interval having 3.38 then the sample treated with Sherpa Plus at 2 weeks interval which had a mean of 4.17. Higher mean of 5.67 was obtained from sample treated with Sherpa Plus at 4 weeks while the control had the highest mean of mean number (27.83) of leaves damaged per sample as shown on table 15.

4.12 The Combined Effect of Treatments on the Number of Damaged Leaves Per Plant at Yola and Jalingo in 2018 Cropping season

Table 15 shows effect of treatments on the number of damaged leaves per plant; At six weeks after sowing there was still highly significant difference (P<0.01) in the number of leaves damaged between the locations; the plants in Yola recorded highest mean number of leaves damaged (4.27) while the Jalingo location was 3.60 leaves damaged per sampled plant. Between the varieties there was highly significant difference (P<0.01) in the mean number of leaves damaged per plant among the varieties, the white cultivar had higher mean number (4.37) of leaves damaged per sample while the red cultivar had 3.50 number leaves per sample. There was still highly significant difference (P<0.01) among the treatments, those treated with Neem extract at 2 weeks interval had lowest mean number (1.50) of leaves damaged followed by those treated with Sherpa Plus at 2 weeks interval and Neem extract at 4 weeks interval having 2.00 mean each. Higher mean of 4.00 was obtained from sample treated with Sherpa Plus at 4 weeks while the control had the highest mean of mean number (10.17) of leaves damaged per sample.

At ten weeks after sowing there was no significant difference (P>0.05) in the number of leaves damaged among the locations; the plants in Yola recorded 8.93 mean number of leaves damaged while the Jalingo location was 8.67 leaves damaged per sampled plant. Among the variety there was highly significant difference in the mean number of leaves damaged per plant, the white cultivar had higher mean number (9.57) of leaves damaged per sample while the red cultivar had 8.03 number leaves per sample. There was highly significant difference (P<0.01) among the treatments, those treated with Neem extract at 2 weeks interval had lowest mean number (3.42) of leaves damaged followed by those treated with Neem extract at 4 weeks interval(3.920) then Sherpa Plus at 2 weeks interval (4.17). Higher mean of 5.33 was obtained from sample treated with Sherpa Plus at 4 weeks interval while the control had the highest mean of mean number (27.17) of leaves damaged per plant.

Table 15: The Combined Effect of Treatments on the Total Number of leaves and Number of Damaged Leaves Per Plant at Yola and Jalingo in 2018 Cropping season

	Number of leaves per plant				Number of damaged leaves per plant	
Treatments	4WAS	6WAS	8WAS	10WAS	**6** WAS	**10** WAS
Location						
Yola	11.47^{a}	24.63^{a}	45.20^{a}	87.60^{a}	4.27^{a}	8.93^{a}
Jalingo	10.00^{b}	22.93^{b}	39.83^{b}	83.37^{b}	3.60^{b}	8.67^{a}
Mean	10.73	23.78	42. 51	85.48	3.93	8.80
P>F	<0.0001	<0.0001	<0.0001	0.0059	<0.0001	0.1290
CV%	6.69	3.52	1.82	6.57	14.81	7.56
Varieties						
White cultivar	11.40^{a}	24.67^{a}	43.60^{a}	88.00^{a}	4.37^{a}	9.57^{a}
Red cultivar	10.07^{b}	22.90^{b}	41.43^{b}	82.97^{b}	3.50^{b}	8.03^{b}
Mean	10.73	23.78	42. 51	85.48	3.93	8.80
P>F	<0.0001	<0.0001	<0.0001	0.0013	<0.0001	<0.0001
CV%	6.69	3.52	1.82	6.57	14.81	7.56
Treatment						
Control	9.75^{c}	16.91^{d}	34.67^{d}	66.67^{c}	10.17^{a}	27.17^{a}
Neem extract at 4 weeks interval	11.67^{a}	25.08^{b}	45.92^{a}	93.08^{a}	2.00^{c}	3.92^{cd}
Sherpa Plus at 4 weeks interval	10.91^{b}	22.25^{c}	41.92^{c}	82.33^{b}	4.00^{b}	5.33^{b}
Neem extract at 2 weeks interval	10.83^{b}	27.17^{a}	46.50^{a}	93.75^{a}	1.50^{c}	3.42^{d}
Sherpa Plus at 2 weeks interval	10.50^{b}	27.50^{a}	43.58^{b}	91.58^{a}	2.00^{c}	4.17^{c}
Mean	10.73	23.78	42. 51	85.48	3.93	8.80
P>F	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
CV%	6.69	3.52	1.82	6.57	14.81	7.56
Interaction						
Location*Treatment	Ns	**	**	*	Ns	*
Location*Variety	Ns	*	**	Ns	Ns	**
Variety*Treatment	**	**	**	Ns	**	**
Location*Variety*Treatment	Ns	Ns	**	Ns	Ns	Ns

Means followed by the same letter(s) in the same column are not significantly using Student Newman Kaul Test of Significance, WAS=Months After Sowing.

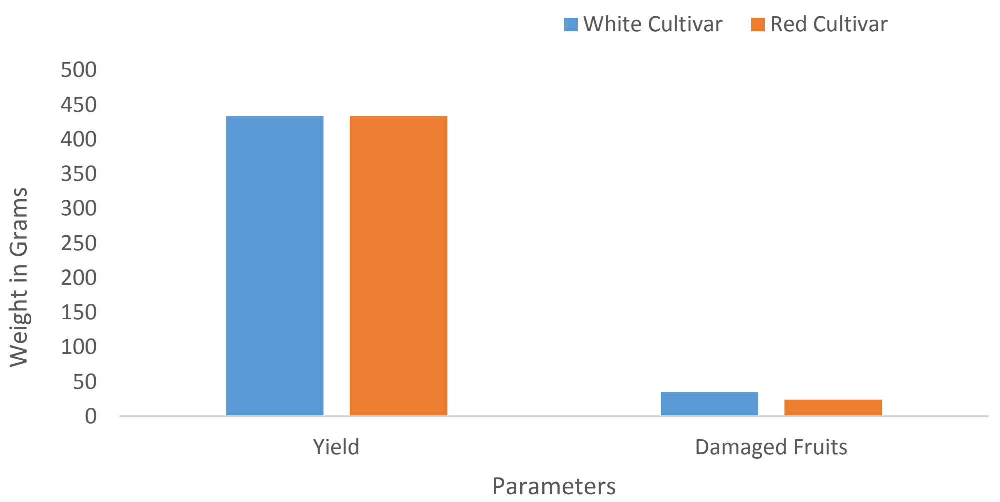
4.13 The Effect of the Different Treatments on Total Yield at Yola and Jalingo in the 2018 Cropping Season

Figure 7a and 7b shows the effect of the different treatments on total yield per plant; there was highly significant difference (P<0.01) in the total yield per plant between the cultivar as both white and red cultivar had weight of (433.72 g) each per sampled plant. There was highly significant difference (P<0.01) among the treatments, plants treated with Neem extract at 2 weeks interval gave the highest yield of 515.15 g. Higher yields of 489.41, 484.62 and 448.05 g were observed from Neem extract at 4 weeks interval, Sherpa Plus at 2 weeks interval and Sherpa Plus at 4 weeks interval respectively while the untreated control gave the lowest mean harvest of 317.65 g per plant.

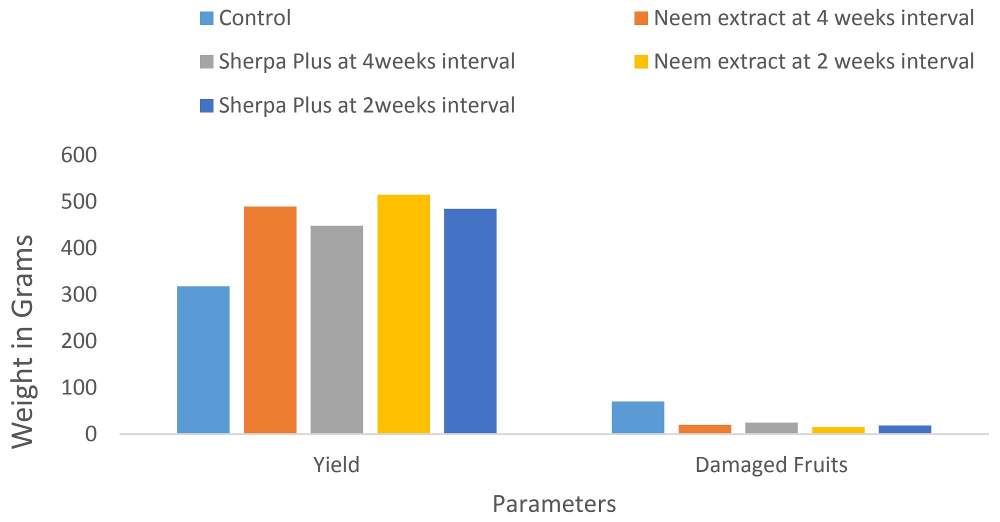
In Jalingo the result (Figure 8a and 8b) shows there was significant difference (P<0.05) in the total yield per plant between the cultivars; the red had higher mean number (412.15 g) of yield per sample plant while the white cultivar was 383.22 g. There was highly significant difference (P<0.01) among the treatments, plants treated with Neem extract at 2 weeks interval gave the highest yield of 461.42 g. Higher yields of 443.48, and 418.66 g were observed from Sherpa Plus at 2 weeks interval and Neem extract at 4 weeks interval respectively followed by Sherpa Plus at 4 weeks interval having and while the untreated control gave the lowest mean harvest of 263.22 g per plant.

4.14 The Combined Effect of the Different Treatments on Total Yield (g) at Yola and Jalingo in the 2018 Cropping Season

Table 19 shows the effect of the different treatments on total yield per plant; on the experimental farm at Yola and Jalingo, there was highly significant difference (P<0.01) in the total yield between the locations; the plants in Yola recorded 450.97g yield as the highest while the Jalingo location had 397.69 g yield per plant. There was highly significant difference (P<0.01) in the total yield per plant among the varieties as red cultivar had higher weight of 440.19 g while the white cultivar was 408.47 g per sampled plant. There was still highly significant difference (P<0.01) among the treatments, plants treated with Neem extract at 2 weeks interval gave the highest yield of 488.28 g. High yields of 463.90 g and 454.03 g were observed from Sherpa Plus at 2 weeks interval and Neem extract at 4 weeks interval respectively followed by Sherpa Plus at 4 weeks interval having 424.86 g while the untreated control gave the lowest mean harvest of 290.57 g.

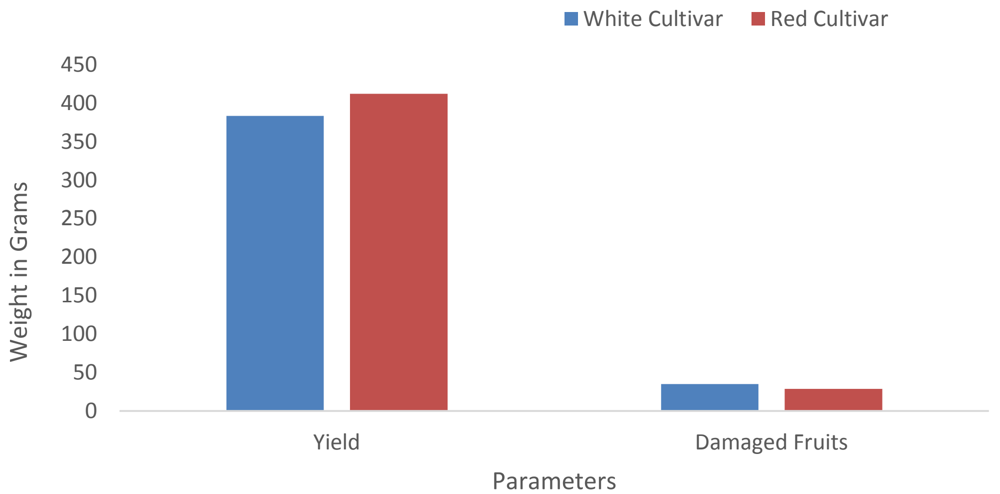


7a: The Effect of the Cultivars on Total Yield and Damaged Fruits at Yola in 2018 Cropping Season

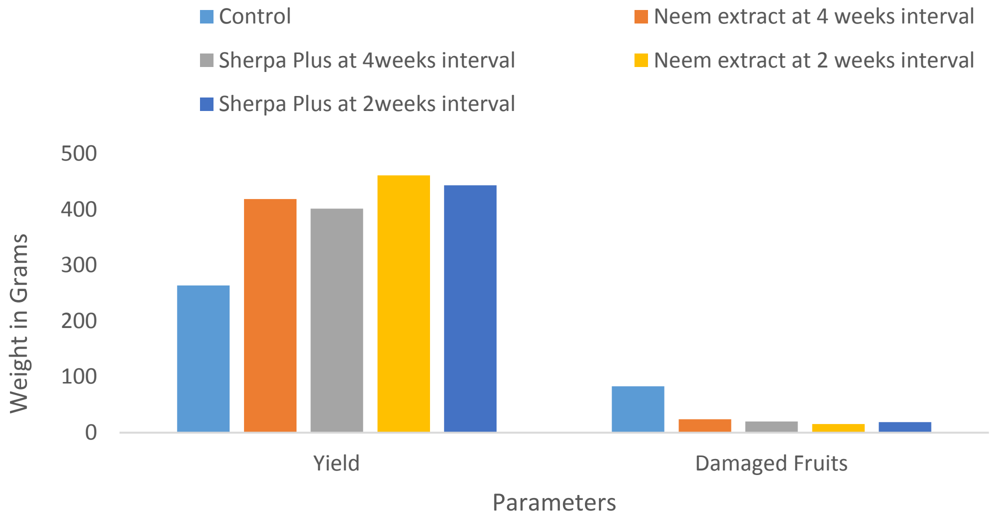


7b: The Effect of the Different Treatments on Total Yield and Damaged Fruits at Yola in 2018 Cropping Season

Figure 7: The Effect of the Different Treatments on Total Yield and Damaged Fruits at Yola in 2018 Cropping Season



8a: The Effect of the Different Cultivars on Total Yield and Damaged Fruits at Jalingo in 2018 Cropping Season



8b: The Effect of the Different Treatments on Total Yield and Damaged Fruits at Jalingo in 2018 Cropping Season

Fig. 8: The Effect of the Different Treatments on Total Yield and Damaged Fruits at Jalingo in 2018 Cropping Season

Table 16: Interaction of Location, Variety and Treatment on the Total Fruits Yield (g) at Yola and Jalingo Locations

	Location	Variety	Spray Regimes				
			Control	Neem at 4 weeks	Sherpa at 4 weeks	Neem at 2 weeks	Sherpa at 2 weeks
4 MAS	Jalingo	White cultivar	143.5600	270.0000	175.4333	262.6666	220.9333
		Red cultivar	194.8333	282.0200	270.7366	294.6666	268.4333
	Yola	White cultivar	185.6333	269.3833	218.8333	288.2000	273.1000
		Red cultivar	199.5333	287.6666	265.9666	295.1666	245.1333
		P>F	0.0194				

4.15 The Effect of the Different Treatments on Calyx Weight (g) at Yola and Jalingo in 2018 Cropping Season

The result of the study in Yola presented on table 17 shows that there was highly significant difference ($P<0.01$) in the mean calyx weight per plant between the varieties; the red cultivar had higher mean calyx weight of 258.69 g per sampled plant while the white cultivar was 247.03 g. Among the treatments there was highly significant difference ($P<0.01$), highest calyx weight of 291.68 g was obtained from the sample treated with neem at 2 weeks interval followed by the sample treated with neem at 4weeks interval having278.52 g. High weights of 259.17 g and 242.40 g were obtained from samples Sherpa Plus at 2 weeks interval and Sherpa Plus at 4weeks interval respectively while the untreated control the lowest calyx weight of 192.58 g per plant.

The result of the study in Jalingo presented on table 18 shows that there was highly significant difference ($P<0.01$) in the mean calyx weight per plant between the varieties; the red had higher mean calyx weight of 262.14 g per sampled plant while the white cultivar was 214.52 g. Among the treatments there was still highly significant difference ($P<0.01$), highest calyx weights of 278.67 g and 278.01 g was obtained from the sample treated with neem extract at 2 weeks interval and neem extract at 4 weeks interval respectively followed by the sample treated with Sherpa Plus at 2 weeks interval having 244.68 g then 223.08 g obtained from samples treated with Sherpa Plus at 4 weeks interval while the untreated control the lowest calyx weight of 169.20 g per plant.

4.16 The Combined Effect of the Different Treatments on Calyx Weight at Yola and Jalingo in 2018 Cropping Season

The result of the study in Yola and Jalingo presented on table 19 shows that there was highly significant difference ($P<0.01$) in the calyx weight between the locations; the plants in Yola recorded 252.86 g calyx weight as the highest while the Jalingo location had 238.33 g. There was highly significant difference ($P<0.01$) in the mean calyx weight per plant between the varieties; the red had higher mean calyx weight of 260.41 g per sampled plant while the white cultivar was 230.77 g. Among the treatments there was highly significant difference ($P<0.01$), highest calyx weight of 285.17 g was obtained from the sample treated with neem at 2 weeks interval followed by the sample treated with neem at 4weeks interval having 277.27 g. High weights of 251.90 g and 232.74 g were obtained from samples Sherpa Plus at 2 weeks interval and Sherpa Plus at 4weeks interval respectively while the untreated control the lowest calyx weight of 180.89 g.

4.17 The Effect of the Different Treatments on Fruit Damaged at Yola and Jalingo in 2018 Cropping Season

The result of the study in Yola presented in Figure 8a and 8b shows that there was highly significant difference (P<0.01) in the mean fruits damaged per plant between the varieties; the white had higher mean weight (35.11 g) of damaged calyx per sampled plant while the red cultivar was 23.98 g. Among the treatments there was highly significant difference (P<0.01) between the control and all treated samples, highest weight of damaged fruits of 69.96 g was observed from the untreated control while lower damages of 24.50 g, 19.83 g, 18.50 g and 14.93 g were observed from neem extract at 4weeks interval, Sherpa Plus at 4weeks Sherpa Plus at 2 weeks interval and neem extract at 2 weeks interval respectively.

The result of the study in Jalingo presented in Figure 8a and 8b shows that there was highly significant difference (P<0.01) in the mean fruits damaged per plant between the cultivar; the white had higher mean weight (35.20 g) of damaged calyx per sampled plant while the red cultivar was 28.92 g. Among the treatments there was highly significant difference (P<0.01) between the control and all treated samples, highest weight of damaged fruits of 82.97 g was obtained from the untreated control while lower means of 23.77 g, 20.06 g, 18.51 g and 15.00 g were obtained from neem extract at 4weeks interval, Sherpa Plus at 4weeks interval, Sherpa Plus at 2 weeks interval and neem extract at 2 weeks interval respectively.

4.18 The Combined Effect of the Different Treatments on Fruit Damaged at Yola and Jalingo in 2018 Cropping Season

The result of the study in Yola and Jalingo presented on Table 19 shows that there was no significant difference (P>0.05) the mean calyx damaged between the locations; the plants in Yola recorded 252.86 g calyx damaged as the highest while the Jalingo location was 238.33 g. Between the there was highly significant difference (P<0.01) in the mean fruits damaged per plant among the cultivars; the white had higher mean weight (35.15 g) of damaged calyx per sampled plant while the red cultivar was 26.45 g. Among the treatments there was highly significant difference (P<0.01) between the control and all treated samples, highest weight of damaged fruits of 76.46 g was observed from the untreated control while lower damages of 22.28 g, 21.80 g, 18.50 g and 14.97 g were observed from Sherpa Plus at 4weeks interval, neem extract at 4weeks interval, Sherpa Plus at 2 weeks interval and neem extract at 2 weeks interval respectively.

Table 17: Effect of the Different Treatments on Calyx Weight and Dried Weight of Calyx sat Yola in 2018 Cropping Season

Treatments	Mean Calyx weight (g)	Dry Weight of Calyx (g)
Varieties		
White cultivar	247.03[b]	47.50[b]
Red cultivar	258.69[a]	50.10[a]
Mean	252.86	48.80
P>F	0.0030	0.0280
Coefficient of Variation%	3.687	6.11
Treatments		
Control	192.58[e]	33.00[c]
Neem extract at 4 weeks interval	278.52[b]	52.95[b]
Sherpa Plus at 4weeks interval	242.40[d]	50.30[b]
Neem extract at 2 weeks interval	291.68[a]	57.60[a]
Sherpa Plus at 2 weeks interval	259.17[c]	50.15[b]
Mean	252.86	48.80
P>F	<0.0001	<0.0001
Coefficient of Variation%	3.687	6.11
Interaction		
Variety*Treatment	**	Ns

Means followed by the same letter(s) in the same column are not significantly using Student Newman Kaul Test of Significance.

Table 18: Effect of the Different Treatments on Calyx Weight and Dried Weight of Calyx at Jalingo in 2018 Cropping Season

Treatments	Mean Calyx weight (g)	Dry Weight of Calyx (g)
Varieties		
White cultivar	214.52[b]	44.47[b]
Red cultivar	262.14[a]	46.75[a]
Mean	238.33	45.61
P>F	<0.0001	0.0002
Coefficient of Variation%	7.67	2.87
Treatments		
Control	169.20[c]	30.00[e]
Neem extract at 4 weeks interval	276.01[a]	51.13[b]
Sherpa Plus at 4 weeks interval	223.08[b]	44.42[d]
Neem extract at 2 weeks interval	278.67[a]	54.35[a]
Sherpa Plus at 2 weeks interval	244.68[b]	48.17[c]
Mean	238.33	45.61
P>F	<0.0001	<0.0001
Coefficient of Variation%	7.67	2.87
Interaction		
Variety*Treatment	*	**

Means followed by the same letter(s) in the same column are not significantly using Student Newman Kauls Test of Significance.

Table 19: The Combined Effect of Treatments on Calyx Weight and Dried Weight of Calyx at Yola and Jalingo in 2018 Cropping Season

Treatments	Total yield(Calyx+ seeds) (g)	Mean Calyx weight(g)	Damaged Fruits(g)	Dry Weigh of Calyx(g)
Location				
Yola	450.97[a]	252.86 [a]	29.54[a]	48.80[a]
Jalingo	397.69[b]	238.33[b]	32.06[a]	45.61[b]
Mean	424.33	245.59	30.80	47.21
P>F	<0.0001	0.0003	0.2377	<0.0001
CV%	4.99	5.80	26.38	4.93
Varieties				
White cultivar	408.47[b]	230.77[b]	35.15[a]	45.99[b]
Red cultivar	440.19[a]	260.41[a]	26.45[b]	48.43[a]
Mean	424.33	245.59	30.80	47.21
P>F	<0.0001	<0.0001	0.0002	0.0002
CV%	4.99	5.80	26.38	4.93
Treatment				
Control	290.57[d]	180.89[d]	76.46[a]	31.50[d]
Neem extract at 4 weeks interval	454.03[b]	277.27[a]	21.80[b]	52.04[b]
Sherpa Plus at 4 weeks interval	424.86[c]	232.74[c]	22.28[b]	47.36[c]
Neem extract at 2 weeks interval	488.28[a]	285.17[a]	14.97[b]	55.97[a]
Sherpa Plus at 2 weeks interval	463.90[b]	251.90[b]	18.50[b]	49.16[c]
Mean	424.33	245.59	30.80	47.21
P>F	<0.0001	<0.0001	<0.0001	<0.0001
CV%	4.99	5.80	26.38	4.93
Interaction				
Location*Treatment	Ns	Ns	Ns	Ns
Location*Variety	Ns	**	Ns	Ns
Variety*Treatment	Ns	**	*	**
Location*Variety*Treatment	**	*	Ns	Ns

Means followed by the same letter(s) in the same column are not significantly using Student Newman Kaul Test of Significance,

4.19 The Effect of the Different Treatments on Dried Weight of Calyx at Yola and Jalingo in 2018 Cropping Season

The result of the study on the effect of the different treatments on dried weight of calyx at Yola in 2018 cropping season presented in Table 17 shows that there was highly significant difference (P<0.01) in the mean calyx weight per plant between the varieties; the red had higher mean dried weight of calyx of 50.10 g per sampled plant while the white cultivar was 47.50 g. Among the treatments there was highly significant difference (P<0.01), highest calyx dried weight of 57.60 g was obtained from the sample treated with neem at 2 weeks interval followed by the sample treated with neem at 4weeks interval having 52.95 g. High weights of 50.30 g and 50.15 g were obtained from samples Sherpa Plus at 2 weeks interval and Sherpa Plus at 4 weeks interval respectively while the untreated control the lowest dried weight of calyx of 33.00 g.

The result of the study on the effect of the different treatments on dried weight of calyx at Jalingo in 2018 cropping season presented in Table 18 shows that there was highly significant difference (P<0.01) in the mean calyx weight per plant between the varieties; the red had higher mean dried weight of calyx of 46.75 g per sampled plant while the white cultivar was 44.47 g. Among the treatments there was highly significant difference (P<0.01), highest calyx dried weight of 54.35 g was obtained from the sample treated with neem at 2 weeks interval followed by the sample treated with neem at 4weeks interval having 51.13 g. High weights of 48.17g and 44.42g were obtained from samples Sherpa Plus at 2 weeks interval and Sherpa Plus at 4weeks interval respectively while the untreated control the lowest dried weight of calyx of 30.00 g.

4.20 The Combined Effect of the Different Treatments on Dried Weight of Calyx at Yola in 2018 Cropping Season

The result of the study on the effect of the different treatments on dried weight of calyx at Yola and Jalingo in 2018 cropping season presented on table 19 shows that that there was highly significant difference (P<0.01) the mean weight of dried calyx between the locations; the plants in Yola recorded 252.86 g dried calyx weight as the highest while the Jalingo location was 45.61 g. Among the treatments there was highly significant difference (P<0.01) in the mean calyx weight per plant among the varieties; the red had higher mean dried weight of calyx of 48.43 g per sampled plant while the white cultivar was 45.99 g.

Among the treatments there was still highly significant difference ($P<0.01$), highest calyx dried weight of 55.97 g was obtained from the sample treated with neem at 2 weeks interval followed by the sample treated with neem at 4weeks interval having 52.04 g. High weights of 49.16 g and 47.36 g were obtained from samples Sherpa Plus at 2 weeks interval and Sherpa Plus at 4weeks interval respectively while the untreated control the lowest dried weight of calyx of 31.50 g.

CHAPTER FIVE

DISCUSSION

5.1 Effect of the Treatments on the Abundance of insect and Insect Species Composition

The species found in the two locations (Yola and Jalingo) were observed to be made up of Coleopterans, Homopterans, Lepidopterans, Orthopterans, Hemipterans which is in conformity with the studies of Jackie (2018) and Simon *et al.* (2017). The insect species on both cultivars (white and red) were the same with only slight differences in their relative abundance. The higher percentage of insect pests recorded from order coleopteran is an indication that insect pests of roselle are dominantly from this order. The pattern of insect was observed to be changing as the experiment progresses even though Coleoptera remained the highest in population throughout the study period proving it is a major group of insect infesting roselle at all growth stages. There seems to be obvious increases from the relative abundance of insects in order Lepidoptera towards the end of the experiment indicating that they majorly attacks the plant at fruiting stage agreeing with the indications by PNRC (2014) that most lepidopterans attack slightly range of host plants at flowering and fruiting stages.

The result also indicated that the results at both locations had a similar trend on the abundance of insects however among the variety the interaction showed general highly significant difference indicating that may have different inherent resistivity levels to insect pest infestation. The lower insect infestation mean in the Red cultivar is an indication that it's more resistant to insect infestation than the white cultivar. The non significant difference at the beginning of the study to highly significant difference observed at the end of the study is an indication that the treatments were all effective for the control of insect pests of roselle. Among the treatments the significance difference between the untreated control and all the treated samples possibly explains the observed significance damage at the untreated samples and the positive effect of the treatments (neem and sherpa plus) in insect pest control conforming to the report of Mohamed, (2000) who reported that Neem trees which are grown widely in Nigeria are potential source of natural plant protection agents to minimize the yield losses caused by different pest with minimum impacts on the environment cause by synthetic insecticides and works of many other researchers (Siddig and Khalafalla, 2013; Mohamed, 2000; Malgwi and Hamman, 2013; Oparacke, 2007) who reported those treatments to have given good insecticidal control.

The finding further indicated that the tested neem spray regime (4 weeks interval and 2 weeks interval) were found to be of significant importance in insect pest control on roselle farm but the later gave a higher protection. Generally the samples treated with neem extract at 2 weeks intervals and the 2 doses of sherpa plus all statistically non different seconding to the findings of Sarah *et al*., 2008 who compared the effectiveness of three plant-based sprays including neem, garlic and hot pepper to soap and a conventional pesticide, all the treatments gave significant protection against aphids and recommended weekly applications to prevent insect population explosions and provide protection equal to or better than conventional chemical pesticides. The application of neem extract as bio-pesticides may thus be consider an alternative for synthetic pesticides since it has adversely affected the ecological balance resulting in pest resurgence, development of resistance in the pest species and environmental pollution as reported by Webb *et al.*, 2015 and Oparacke, 2007.

5.2 The Effect of the Treatment on Height of the Roselle

The effect of the treatment of height of roselle shows a significant difference among them, the lower plant height in the untreated as compared to all the treated samples indicates stunted growth and crop damages due to insect damages since all there was treatments were given similar treatments as pest control measures. The result presented indicated that the significant difference among the treatments increased by the day implying that the effectiveness of the was better at consecutive application, at 2 weeks after sowing when all the samples where untreated there was no significance difference in the height but upon consecutive treatments there as then changes in the level as significance than the untreated control giving a highly significance difference at the 16th week after sowing. The non significance on mean plant height observed in this study at the early vegetative stages when the plants were yet to be treated may be attributed to treatments (pest control measures) as the level of significance increased upon application of insect pest control measures. The highly significant difference between the control and all the treated samples indicated that roselle is highly susceptible to insects pest attack rendering it stunted with other characterized symptoms of damages. This however agrees with the findings

Jackie (2018), Mera *et al., (*2009) and Simon *et al.*, (2017) who reported on the potentials of Insect pests.

5.3 Effect of the Treatments on the Number of Leaves

The result of the experiment at both Yola and Jalingo locations was in a similar trend but Yola location had relatively higher number of leaves per plant which may have being due to some environmental factors or as a result of stunted growth. The significant difference between the control and other treatment was an indication that all the treatment had positive effect on the number of leaves per plant. The sampled plants treated with neem extract 2 weeks interval spray regime and Sherpa plus at 2 weeks interval gave superior effect than those at 4 weeks intervals as such 2 weeks interval spry regimes are more effective. The use of these treatments probably gave positive effect in the number of leaves per plant thus was reliable in handling the devastating pest attack which would have caused economic losses by greatly reducing the leaf quality, retarding growth or even killing the whole crop as reported by many researchers (Mera *et al.,* 2009; Navarra 2017; WAG, 2018). The effects from each of the treatments was significantly different from the untreated control as manifested in the higher number of leave conforming to the indications of Sarah *et al*., (2008), Adedire, (2001) and Siddig (2016) on the effectiveness those treatments in protection of against insect pests.

5.4 Effect of the Treatments on the Number of Leaves Damaged

The result of the study presented showed that there was no significant difference in the number of leaves damaged among the two locations indicating the level of insect infestation was not greatly affected by location. The higher mean number of damaged leaves observed from white cultivar as compared to the red cultivar is an indication that it may be more susceptible to insect attack than the red cultivar. The highest leaves damage observed from the control is an indication that the treatment was effective to have prevented leave damage from the treated samples. This result proves that the use of those treatments could be effective in controlling field damages on roselle farm.

Among the treatments those treated with Sherpa plus at 2 weeks interval had the lowest damage which could be because it was more reliable in handling the devastating pest attack agreeing to the findings by Lale, (2001) of being the most widely used pest control method and effective but could sometimes be disadvantageous because of the side effects of the chemicals. Neem extract at the two spray regimes also had significant difference from the control which indicated that it was also effective protecting the leaves against leaf damages either through repellence, retard feeding knock down effect and/or killing effect as also exhibited in the fewer number of insects found on these samples. Between the two spray regimes, neem extract at 2 weeks interval was superior to neem extract at 4 weeks interval indicating that neem extracts at 2 weeks interval spray regime (frequent sprays) gives better protection. The effectiveness of neem in the control of insect pests of roselle in this study seconds to the findings of many researchers (Adedire, 2001; Mohamed, 2000; Sarah *et al*., 2008) who reported neem to have insecticidal power against insect pests.

5.5 Effect of the Treatments on the Total Yield

The total yield in Yola was slightly higher than that of Jalingo which may be due to location, environmental factors and/or insect pest infestation. The cultivars responded to the treatment but the red cultivar recorded higher total calyx yield which would have been due to high yielding capacity, the inherent resistivity to pest. All the samples treated had higher yields as compared to the untreated control in both cultivars at both locations indicating effectiveness of the treatments. A lower yield was recorded in the untreated control and this agrees with the findings of Jackie 2018; Mera *et al.,* (2009); Navarra, (2017); WAG, (2018); Simon *et al.,* (2017) that insect pests can cause huge damage on roselle and if not well managed, results to field yield losses of about 30-80% by greatly reducing the leaf quality, retard growth or even killing the whole crop. The damages on the plant from leaves, stem, flower, reduction in height among others could be the reflected the lower yield in the control.

The higher mean yield observed from the treated samples is thus an indication of the effectiveness of the treatments conforming to the results of Malgwi and Hamman, (2013); Sarah *et al*., (2008) who elaborated on the use of Neem and Sherpa plus for insect pest control. This study further observed that all the treatments were effective (Sherpa plus at 4 weeks spray regime 424.86, Sherpa plus at 2 weeks spray regime 463.90 g, neem at 4 weeks spray regime 454.57 g) but neem extract at 2 weeks interval spray regime gave the best control as it had the highest (488.28 g) Total yield as could be considered an effective and more eco friendly option for insect pest control on roselle farm which is equivalent to the one achievable in synthetic pesticides.

5.6 Effect of the Treatments on the calyx weight

This result showed that Yola had higher calyx weight than that of Jalingo which would have been as result of Location and other environmental factors such as rainfall, sunshine among others. The higher calyx weight in red cultivar however could be attributed to its high producing capacity as exhibited in the total yield. The red cultivar noticeably had longer and bigger fully fleshed calyx with smaller buds and higher calyx weight. The effect of the treatments on the calyx weight is highly significant as compared to the untreated control, this weight is clear indication that the calyx were protected from damages caused by insect pests of roselle while the lower calyx weight in the in the untreated control is an expression of high damaging potential of insect pest on roselle as reported by many researchers (Jackie 2018; Mera *et al.,* 2009; Navarra 2017; WAG, 2018; Simon *et al.,* 2017). Among the treatments, neem extract at the two spray regimes recorded higher calyx weight (488.28 g) in the combined result against 290.57, 454.03, 424.86 and 463.90 g obtained from the control, Sherpa plus at 4 weeks spray regime, neem extract at weeks spray regime and Sherpa plus at 2 weeks spray regime respectively indicating it can prevent insect population explosions and provide protection equal to or better than conventional chemical pesticides as reported by Sarah *et al*., (2008).

5.7 Effect of the Treatments on the Fruits damaged

The result of the study as presented explains the reduction in yield caused by the insect pests. The effect of the two locations Yola and Jalingo was statistically non significant but the effect of the two variety was significant. The white cultivar recorded higher fruit damages which is a clear indication that it was more susceptible to insect infestation. All the treatments gave significant statically difference when compared to the control. The higher fruit damage from untreated samples explains the high susceptibility of roselle to insect agreeing with the research of some researchers (Jackie 2018; Mera *et al.,* 2009; Navarra 2017; WAG, 2018; Simon *et al.,* 2017) that insect pests can cause huge damage on roselle and if not well managed, results to field yield losses of about 30-80% by greatly reducing the leaf quality, retard growth or even killing the whole crop while the lower mean damages from the treated samples indicates effectiveness of the treatments in the control of insect pests as reported by Malgwi and Hamman, (2013); Sarah *et al*., 2008) elaborating on the use of Neem and Sherpa plus for insect pest control.

The lowest damages were from Sherpa plus treated sample which was not statistically different from the mean of samples treated with neem extracts suggesting their equivalent insecticidal effect on insect pest on roselle farm.

5.8 Effect of the Treatments on the Dry Calyx Weight

The dry weight of the calyx here is greatly dependent on the total weight of the calyx and the composition of the cultivar. The location here had very little effect on the dry weight as Yola had higher weight which was statistical different from the Jalingo Location. The treatment effect on the weight of dry calyx was significant when compared to the control as all treated samples yielded higher dry weights. The samples treated with neem extract at 2 weeks interval gave the highest mean weight followed by samples treated with Sherpa plus at 2 weeks interval spray regime even though both were statistically same at combined analysis indicating their equivalence in the control of insect pests of roselle. This further explains that the higher weight of dry calyx obtained in the treated samples could be attributed to the higher total yield obtained in the treated samples.

CHAPTER SIX

SUMMARY, CONCLUSION AND RECOMMENDATION

6.1 Summary

The study on the Abundance, Damage and Control of Insect Pests of Roselle (*Hibiscus sabdariffa Linn*.) In Yola And Jalingo, Nigeria aimed at to determining the species of insects associated with roselle (*H. sabdariffa*), the damage caused by the insect pests and the effect of the treatments (neem extract and Sherpa plus) on insect pest control on two cultivars laid in a split plot experimental design with two varieties and four insecticidal treatments and a control where establishment count, the plant height, the abundance of the insects, the insect Species , the number of leaves, the number of leaves damage, total fruit yield, the fruit damage and the dry calyx weight were studied.

Roselle had high susceptibility to insect infestation which can affect all growth and yield parameters negatively if not properly managed. This was exhibited in the reduction in growth from the untreated samples. The number of leaves and fruits damages among other damages observed from the untreated samples as also significantly different from all treated samples. All the treatments applied were effective in the control of insect pests as compared to the untreated control as there was lower leave damage, higher yield and higher calyx dry weight in the treated samples which is significantly different from the untreated samples. From the combined analysis neem extract at 2weeks interval and Sherpa plus at 2 weeks interval had superiority over those at 4 weeks spray regimes but since bio pesticides are more eco friendly neem extract maybe considered best option for the pest control.

The species composition was found to be predominately Coleopterans, Homopterans, Lepidopterans, Orthopterans and Hemipterans which appeared to be same in both varieties at the two locations. The species were *Altica himensis, Lilioceris lilii, Podagrica spp., Coccinella spp, Mylabris spp., Pyrrhocoris spp, Aphis gossypii, Zonocerus variegatus, Earias insulana, Helicoverpa armigera, Halyomorpha halys, Tettigonia spp.* and *Osbornellus spp.*.

6.2 Conclusion

Insect pests found at both Yola and Jalingo locations on the two cultivars comprised of Coleopterans, Homopterans, Lepidopterans, Orthopterans and Hemipterans and have been evident to have serious damage potentials on roselle, this was exhibited in the high insect number, high leaves and fruits damage observed from the control. All the treatments were effective in the control of insect pests on roselle as they showed high total yield, high calyx weight, high dry weight, lower insect infestation and lower leave damage as contrary obtained from the control.

The effects of neem fruits extract at two weeks spray regime was equivalent to those of Sherpa plus at all parameters thus no doubt that neem could be used as a reliable, safer and cheaply available pesticide to substitute synthetic pesticides that are highly toxic to man and the environment.

6.3 Recommendations

This study has recommended the following;

I The isolation and formulation of active ingredients responsible for insecticidal action in the neem fruit.

II The effect of neem extract on the nutritional value roselle should be evaluated.

III Further studies that will determine the group of insects the control is best on since there wasn’t 100% protection.

IV The use of Neem extract which could be as bio-insecticide that is effective, readily available and less harmful to human and the environment since they are botanicals from medicinal plant.

REFERENCES

Adanlawo, I.G. and Ajibade V.A. (2006) Nutritive Value of the Two Varieties of Roselle (*Hibiscus sabdariffa*) Calyces Soaked with Wood Ash Pakistan *Journal of Nutrition 5 (6): 555-557, 2006 ISSN 1680-5194.*

Adedire, W. O. (2001) Biology, Ecology and Control of Insect Pest of Stored Cereals and Pulses in Nigeria *Nigeria International Journal of Scientific & Engineering Research, 5(7) 1542 ISSN 2339-5598* IJSER http://www.ijser.org

Ajibade, F. E. (2009) Effect of some Selected Plant Botanicals Against the Cowpea Bruchid in Yola, Adamawa. Unpublished Thesis Submitted To Department Of Crop Protection, Federal University Of Technology Yola, 38.

Alleoni, B. and Ferreira, W. (2006) Control of *Sitophilus zeamais* Mots., 1958 and Sitophilus oryzae (L.,1763) weevils (Coleoptera, Curculionidae) in stored wheat (Triticuma estivum L.) with insecticide pirimiphos methyl (Actellic 500 ce). 9th International Working Conference on Stored Product Protection, 1242PS10-18 – 619384Alleoni and Ferreira, 2006). Stored products pests control. Internet information accessed on 27/2/2018 https://www.semanticscholar.org › D...

Babatunde, F. E. and Mofoke A. L. E. (2006) Performance of Roselle (*Hibiscus sabdariffa* L) as Influenced by Irrigation Schedules *Pakistan Journal of Nutrition 5 (4): 363-367, ISSN 1680-5194.*

Babatunde, F.E., (2003) Intercrop Productivity of Roselle in Nigeria. *African Crop Science Journal, 11: 1-6.*

Bahaeldeen *et al.* B. M., Abdelatif A. S. and Abdelhafiz A. D. (2012) Roselle (*Hibiscus sabdariffa* L.) in Sudan, Cultivation and Their Uses *Bulletin of Environment, Pharmacology and Life Sciences Online ISSN 2277 – 1808* www.bepls.com.

Bashir, A. B. (2000) Water Quality and Outbreak of Diseases in Yola, Adamawa. Unpublished Thesis Submitted To Department Of Geography, Federal University Of Technology Yola: 12.

David, L. K. and Tony T. (1999) Evaluation of New Insecticides for Aphid Control in Green Leaf Lettuce *University of Arizona College of Agriculture VegetableReport,indexathttp://ag.arizona.edu/pubs/crops/az1143/.*

Deen, M. (2018) Effect of Sowing Date on Calyx Yield And Yield Components Of Rosselle (*Hibiscus Sabdariffa L.*) In Northern Guinea Savanna *New York Science Journal 3(11).*

Dennis, P. (2013) Harvest Index, A Prediction of Corn Stover Yield *Michigan State University Newsletter MSUE4MI.*

Diaz, B. D., Villanueva C. A., Dublan G. O., Quintero S. B. and Dominguez L. A. (2015) Assessing release kinetics and dissolution of spray-dried Roselle (*Hibiscus sabdariffa*

L.) extract encapsulated with different carrier agents. *LWTFood Science. Technoogy*, 64 (2): 693-698.

Falusi, O. (2004) Collecting Roselle(*Hibiscus sabdariffa*) Germplasm in Nigeria. *Journal of Arid Agriculture* 14 : 81-83 .

FAO, (2007) Roselle (*Hibiscus sabdariffa*) Production. Internet information accessed on 27/2/2018. Available at http://www.fao.org/ag/AGp/ agpc/doc/services/pbn/pbn-195.htm

Fores, J. S. (2017) Common Pests of Leafy Vegetables: Photes, Prevention, and Control. Dengarden Internet information accessed on 28/4/2018.

Futuless, K. N, Kwaga, Y. M. and Clement, T.(2018) Systematic checklist and species richness of insect pests associated with vegetable crops in Jammu & Kashmir State (India) *Journal of Entomology and Zoology Studies:* https://www.researchgate.net/publication/323639456.

Geodatos, (2019) Geographic Coordinates of Jalingo. Internet information accessed on 28/11/2019. https://www.geodatos>taraba

Imam, T. S., Yusuf A.U. and Mukhtar M. D. (2010) A survey of some insect pests of cultivated vegetables in three selected irrigation areas along Jakara river, Kano, Nigeria *International Journal of Biological Sciences 4(2): 400-406, ISSN 1991-863* **http://ajol.info/index.php/ijbcs**.

Jackie, C. (2018) Common Spinach Problems: Dealing With Spinach Pest and Diseases. GardeningKnowHow: www.gardeningknowhow.com/edible/vegtables/spinach//common-spinach-problems.htm. Internet information accessed on 5/2/2018.

Karnataka, (2012) Bio-efficacy of insecticides against aphid and leaf bug on dodi (*Leptadenia reticulata)* (Retz.) Wight & Aruott. *Journal of Agricultural Science.,25 (1) : (155-157).*

Lale, N E S (2001) The impact of storage insect pests on post-harvest losses and their management in the Nigerian agricultural system. Nigerian Journal Exp. and Applied Biology2: 231-2

Malgwi, A. M and Hamman S. I. (2013) Comparative Efficacy of Three Plants Extracts at possible biopesticides and cypermethrin on insects pest of cowpea and its yield in Yola, Adamawa, paper presentation at Biocion 2013.

Malgwi, A. M and Omumiya J. J. (2004) Survey of Dry season insects pests around Lake Geriyo farms , Yola, Adamawa States of Nigeria. Proceedings of National Conference of Revitalization of Agriculture and Agricultural Technology, Federal University of Technology Yola, 13-16 Nov., 2004.

Malgwi, A. M and Saidu S. S. (2011) Effects of Sherpa Sprays on the Control of Insect Pests on the Growth and Yield of Hibiscus Sabdanriffa L. at Sangere ,Adamawa State, Yola. *Journal of Horticultural Society of Nigeria 16(95):1902 ISSN 1118-2733.*

Mbah and Okoronkw (2008) Effect of the plant product powder on the S. zeamais mortality in stored maize – Academic online Journals www.academicjournals.org

Mehdi, A., Touba E., Zarrin S. and Tahereh E. (2018) An Overview of the Roselle Plant with Particular Reference to Its Cultivation, Diseases and Usages *European Journal of Medicinal Plants 3(1): 135-145.*

Mera, U. M., Singh B .R., Magaji M. D., Singh A., Musa M. and Kilgori M. J .S. (2009) Response of Roselle (*Hibiscus sabdariffa* L.) to Farmyard Manure and Nitrogen-fertilizer in the semi-arid savanna of Nigeria Available online at http://www.ajol.info/browse-journals
Nigerian Journal of Basic and Applied Science, 17(2):246-251.

Michele, L. D., Sella M. K. and Mera R. R. (2007) Plants Popularly Used for Lossing Weight in Porto Alegre, Brazil. Journal of Ethnopharmacoly 109(1)60-71

Mohamed, M. M. (2000) Studies On The Control Of Insect Pests In Vegetables (Okra, Tomato, And Onion) In Sudan With Special Reference To Neem Preparations. *Unpublished MSc. Dissertation University of Göttingen in Faculty of Agriculture Germany Agrarwissenschaften, Ökotrophlogie und Umweltmanagement University of Giessen.* Internet information accesed on 4/4/2018

Naima, I.; Muhammad A. and Naheed A. (2013) Biological Control Evaluation of Botanical and Synthetic Insecticide for the Control of *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae) *Entomológica do Brasil BioAssay: 8:3 Sociedade www.bioassay.org.br.*

Navarra, K. (2017) Guide to Spinach Pest, Weed and Disease Control. Growing magazine Internet information accessed on 1/2/2018.

Nawal, A. B. (2004) Effect of Intercropping On The Growth And Yield Of Roselle Hibiscus sabdariffa var. sabdariffa L.)*Unpublished Thesis Submitted to the Department of Agronomy, Faculty of Agriculture,University of Kordofan . Internet information accesed on 5/4/2018*

Onuorah, S. C.; Akudo; C. A. Okafor N. A.;Obika I .E. and U. C. Okafor (2012) Bacteriological Quality of locally-produced Sorrel Beverage (Zobo) Vended in Awka Campus of Nnamdi *International Journal of Scientific & Engineering Research, 5(7) 1542 ISSN 2229-5518* IJSER http://www.ijser.org.

Oparacke, A. M. (2007) Toxicity and Spraying Schedules of a Biopesticide Prepared from *Piper guineense* Against two Cowpea Pests. Plant Protection Science Journal, 43(3): 103-108.

Ottai, A. A. and Mergawi R. (2014) Effect of variety and location on growth and yield components of Roselle, *Hibiscus Sabdariffa* L. and its infestation with the spiny bollworm *Earias Insulana* (BOISD. Archives of Phytopathology and Plant Protection Journal 27(3) 215- 231: http://www.tandfonline.com/doi/full/10.1080/03235400410001685701?src=recsys

Oyewole, C. I. and Mera M. (2010) Response of roselle (Hibiscus sabdariffa L.) to rates of inorganic and farmyard fertilizers in the Sudan savanna ecological zone of Nigeria African Journal of Agricultural Research Vol.5 (17), pp. 23052309, Available online at http://www.academicjournals.org/AJAR.

PNRC, (2014) Whitefly, Plant Natural Research Center: https://www.planetnatural.com/pest-problem-solver/houseplant-pests/whitefly-control/ Internet information accessed on 25/3/2018.

Puro K., R. Sunjukta, S. Samir, S. Ghatak, I. Shakuntala and A. Sen (2015) Medicinal uses of Roselle plant (*Hibiscus sabdariffa* L.) : a mini review. *Indian Journal of Hill Farming*, 27(1): 81-90.

Sarah, O., Rawleigh and Amy E. B. (2008) Comparison of homemade and conventional sprays as aphid control on lettuce *Journal of the North Carolina Academy of Science, 124(2), 53–57.*

SFGATE, (2018) Which Insect Pest Target Spinach?. Homequides.sfgate.com/insect-pest-target-spinach-5096. Internet information accessed on 19/3/2018

Siddig, S.A. (2016) Evaluation Of Neem Seed And Leaf Water Extracts And Powders For The Control Of Insect Pests In The Sudan. Agric. Res. Crop. Tech. Bulletin. No.6.

Siddig, S.A. (2017) A Proposed Pest Management Program Including Neem Treatments For Combating Potato Pests In The Sudan. Proc. 3rd Int. Neem Conf., Nairobi, 2017 Eschborn: GTZ. 449-459

Siddig, S.A., and Khalafalla, A. (2013) Performance Of IPM Package Including Neem For The Control Of Potato Pests In Fields.World Neem Conf. (Bangalore, India)Abstract: 5

Simon L.D., Ogunwolu E.O. and Okoroafor, E. (2017) Insects Associated with Roselle in Benue State, Nigeria. Book of Abstracts Nigerian Society For Plant Protection Conference Makurdi NSPP/2017/0055.

Ukeh D. A., Gabriel A. A. and Emmanuel I. O. (2008)Toxicity and Oviposition Deterrence of Piper guineense (Piperaceae) and Monodora myristica (Annonaceae) Against Sitophilus zeamais (Motsch.) on Stored Maize Journal of Entomology 5 (4) 295-299

Usman, M. B.(2008) Combating Agricultural pest and Diseases Through Cultural means. *Pest management Practices 68:8-11*

WAG, (2018) Insects pests of Vegetables. Department of Primary industry and Regional Development, Government of Western Australia: www.agric.wa.gov.au/pest-inescts-insect-pests-vegetables. Internet information accessed on 27/2/2018.

Webb, L. Susan E.,, David J. Schuster, Phillip A. Stansly, Jane E. Polston, Scott Adkins, Carlye A. Baker, Pamela R., Oscar E. Liburd, Teresia N., Eugene M., and Alicia W. (2015) Recommendations for Management of Whiteflies, Whitefly-Transmitted Viruses, and Insecticide Resistance for Production of Cucurbit Crops in Florida ENY-478, one of a series of the Entomology and Nematology Department, UF/IFAS Extension. Original publication date July2011. Revised June 2015. http://edis.ifas.ufl.edu Internet information accessed on 19/3/2018.

Wikihow, (2017) How To Get Rid of the Whiteflly: http://www.wikihow.com/get-rid-of-the-whitefly Internet information accessed on 19/1/2018.

APPENDICES

Appendix I: ANOVA Table for the Effect of Treatment on the Mean Number of insects at 2 weeks after sowing at Yola

Source of Variation	Degree of freedom	Total Sum of squares	Mean Sum of Squares	F. cal	F. tab
Replication	2	1.4000	0.7000	0.09	0. 9123
Treatment	4	1.8000	0.4500	0.06	0.9929
Variety	1	0.0000	0.0000	0.00	1.0000
Var*Trt	4	15.000	3.7500	0.49	0.7402

Appendix II: ANOVA Table for the Effect of Treatment on the Mean Number of insects at 2 weeks after sowing at Jalingo

Source of Variation	Degree of freedom	Total Sum of squares	Mean Sum of Squares	F. cal	F. tab
Replication	2	0.8000	0.4000	0.45	0.6423
Treatment	4	10.8000	2.7000	3.06	0.0434
Variety	1	5.6333	5.6333	6.39	0.0210
Var*Trt	4	25.2000	6.3000	7.15	0.0013

Appendix III: ANOVA Table for the Combined the Effect of Treatment on the Mean Number of insects at 2 weeks after sowing

Source of Variation	Degree of freedom	Total Sum of squares	Mean Sum of Squares	F. cal	F. tab
Replication	2	2.1000	1.0500	0.26	0.7713
Location	1	33.7500	33.7500	8.41	0.0062
Treatment	4	10.1000	2.5250	0.63	0.6449
Variety	1	2.8166	2.8166	0.70	0.4075
Location*Trt	4	2.5000	0.6250	0.16	0.9593
Location*Var	1	2.8166	2.8166	0.70	0.4075
Var*Trt	4	5.100	1.2750	0.32	0.8644
Location*Var*Trt	4	35.1000	8.7750	2.19	0.0891

Appendix IV: Harvesting of Roselle for Taking of Final Data

Appendix V: Taking Data on the Effect of the Treatments on Calyx Yield