Sudan University of Science and Technology

College of Graduate Studies

A Survey of Spider Mites *Tetranychus* spp on Eggplant *(Solanum melongena* L.*)* in Different Areas of Khartoum State

مسح لآفة الحلم العنكبوتي على محصول الباذنجان في مناطق مختلفة في ولاية الخرطوم

A Thesis submitted in partial fulfillment of the requirements for the M.Sc. degree in Plant Protection

By

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الآيـة

بسم الله الرحمن الرحيم

قال تعالى:

(مَثَلُ الَّذِينَ اتَّخَذُوا مِنْ دُونِ اللَّهِ أَوْلِيَاءَ كَمَثَلِ الْعَنْكَبُوتِ اتَّخَذَتْ بَيْتًا وَإِنَّ أَوْهَنَ الْبُيُوتِ لَبَيْتُ الْعَنْكَبُوتِ لَوْ كَانُوا يَعْلَمُونَ)

صدق الله العظيم

سورة العنكبوت الآية (41)

Dedication

To Sudan, my beloved country and to my Parents, sister and brothers

To my late friends Abdalla Fadeel and Hamza Abdal Hameed may their souls rest in peace

To all my teachers and colleagues, and finally to all my friends.

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Abstract

The study was carried out at eight different sites in Khartoum state these are, WadRamli, El Fakey Hashim, Elnuba, Shambat and Selait Scheme (North Khartoum), El Gezira Islanj (North Omdurman), Gamoaia Scheme (South Omdurman) and Toti Island (Khartoum). The aim of this study is to determine the host range of the spider mites on vegetables and weeds, in addition to estimating the infestation percentage (%) of this pest on eggplant in 5 sites (WadRamli, Selait scheme, Shambat, Gamoaia scheme, Toti).

The cross method was used to determine the infestation (%) in each site in the period from early April to the end of May, 2016.

A questionnaire was designed and distributed to the farmers to measure their awareness about this pest, types of infested crops, history and date of pest appearance, methods of application, number of sprays per season and number of days between each sprays. Crop loss, and the season of high infestation of spider mites.

The questionnaire was statistically analyzed and the results showed that the highest (%) of infestation was in Toti (100%), and the lowest infestation percentage was reported in Shambat site at (56.7%). Also results revealed that most farmers (92%) known about spider mites, 40% of them saied that (SM) appeared more than two years ago, but in Shambat it was observed and recorded since 1972.

From these results, spider mite was recorded in 22 host plants (such as, Eggplant, Tomato, Potato, Okra, Onion, Chili, Cowpea, Pumpkins, Cucumber, Bean, Peanut, Squash, Cabbage, Cotton, Ushar, Sakran, Gubbien, Nageela, Seida, Defra, SannMakka, Marmeet).

Results showed that farmers were using more than 15 pesticides for controlling (SM), most of them are insecticides and not Acaricides and more than seven sprays per season, the crop loss (%) reached more than 70% in

most sites of the study.

The results also showed that eggplant was highly infested (67%) by spider mites in winter season when compared with other seasons.

Based on the discussions with the farmers, it concluded that there is a shortage of knowledge and deficiency in agricultural extension services in most study areas, therefore our recommendation concentrate on increasing of farmers awareness through an extensive agricultural extension program including (workshops, field days, farmer's schools and etc…).

ملخص البحث

أجريت هذه الدراسة في ثمانية مناطق مختلفة في ولاية الخرطوم , ود رملي، الفكي هاشم، النوبة ، شمبات، مشروع السليت (شمال الخرطوم)، الجزيرة اسلانج (شمال امدرمان)، مشروع الجموعية (جنوب امدرمان) وتوتي (الخرطوم) وذلك بهدف معرفة المدى العوائلي لآفة الحلم العنكبوتي علي محاصيل الخضر والحشائش إضافة لتقدير نسبة الإصابة بحلم العنكبوت علي محصول الباذنجان في 5 من مناطق (ودرملي، مشروع السليت شمبات، مشروع الجموعية، توتي) وتم استخدام طريقة التقاطع (cross method) لتحديد نسب الإصابة في هذه المناطق في الفترة من مطلع ابريل إلى نهاية مايو 2016.

تم عمل استبيان للمزارعين في هذه المناطق حول مدي معرفتهم بالآفة وأنواع المحاصيل التي تصيبها، وأول تاريخ لظهور الآفة، وطرق المكافحة المستخدمة ، عدد الرشات في الموسم ، وعدد الأيام بين الرشات ، ومقدار الفقد في المحصول، إضافة لأكثر فصول السنة إصابة بحلم العنكبوت.

حللت نتائج الإستبيان إحصائيا، وأظهرت النتائج أن اعلي نسبة إصابة كانت في منطقة توتي، حيث بلغت نسبة 100%، واقل نسبة إصابة كانت في منطقة شمبات وبلغت نسبة 56.7%.

إضافة لمعرفة معظم المزارعين بالآفة (نسبة 92% من المزارعين)، كما أوضحت أن نسبة 40% منهم لاحظوا ظهور حلم العنكبوت الأحمر قبل أكثر من عامين، بل أن هنالك من ذكروا أن هذه الآفة لوحظت في منطقة شمبات منذ سنوات عديدة ترجع إلى عام 1972، أيضا أشارت النتائج لتواجد حلم العنكبوت الأحمر علي حوالي 22 نبات من محاصيل الخضر والحشائش شملت (الباذنجان ،الطماطم، البطاطس، البامية ، البصل، الشطة، اللوبيا، القرع، العجور، الفاصولياء ،الفول السوداني، الكوسا، الكرنب، القطن، العشر، السيكران، الجبين، النجيلة السعدة، الدفرة، السنمكة، المرميت).

أوضحت النتائج أن المزارعين يستخدمون 15نوع من المبيدات المختلفة ومعظمها مبيدات حشرية وليست اكاروسية ،كما وصل عدد الرشات في الموسم الواحد إلى أكثر من سبعة رشات ، و نسب الفقد في المحصول إلى أكثر من 70% في معظم مناطق الدراسة.

أوضحت النتائج أيضا الإصابة العالية في محصول الباذنجان بآفة حلم العنكبوت في الموسم الشتوي مقارنة بالمواسم الأخرى حيث بلغت نسبة الإصابة 67%.

من خلال المناقشات التي تمت مع المزارعين وضح أن هناك قصور وإهمال لخدمات الإرشاد الزراعي في معظم مناطق الدراسة. لذلك تمت التوصية بالتركيز علي توعية المزارعين من خلال عمل إرشاد زراعي مكثف يتضمن(ورش عمل , أيام حقلية ,مدارس للمزارعين ...الخ).

CHAPTER ONE

INTRODUCTION

Vegetables are important components in the human diet because they supply nutrients such as vitamins A & C as well as appreciable quantities of the various B vitamins and minerals which are often lacking in most traditional staple foods. Vegetables also provide 'roughage' in the form of cellulose which aids in the digestion of other foods (Peet, 1995).

In 1992, Sudan harvested around 36,000 hectares of vegetables which represent only 0.28% of its total arable land of 12,830,000 ha. (Baudoin, 1994).

Eggplant (*Solanum melongena* L.), also called aubergine or brinjal, is one of the top ten vegetables in the world. Eggplant contains nutrients such as dietary fiber, folate, ascorbic acid, vitamin K, niacin, vitamin B6, pantothenic acid, potassium, iron, magnesium, manganese, phosphorus, and copper (USDA 2009).

Eggplant production is severely constrained by several insect and mite pests. The major pests include eggplant fruit fly and shoot borer, leafhopper, whitefly, thrips, aphid, spotted beetles, leaf roller, stem borer, blister beetle, red spider mite, and little leaf disease. (Gapud and Canapi 1994; Orden *et al*. 1994).

Spider mite (*Tetranychus* spp) belongs to the family *Tetranychidae* of the order Prostigmata. The family *Tetranychidae* is one of the most important families of the Acarina because many species can be serious pests of agricultural crop (Faith *et al*., 2009).

spider mites (Tetranychus spp.) attack many cultivated crops, including maize, tobacco, cotton, beans, eggplant, pepper, tomatoes, cucurbits and many other vegetables (Mau & Kessing, 1992).

Spider mite (*Tetranychus* spp) is one of the most important pests of horticultural crops worldwide. It has been associated with up to 1,200 host

plant species and has become a serious pest on many fruits, vegetables, trees, shrubs, herbs, herbaceous perennials and ornamental plants and many broadleaf weeds in field and protected settings (Khajehali *et al.*, 2009).

Spider mites problem increased when natural enemies are destroyed by applications of broad spectrum insecticides, applied against other pests (Mainul *et al.,* 2010). Spider mites have been rapidly developing resistance to a series of acaricides (Croft and van de Baan, 1988) and have recently assumed a new aspect of multiple resistances (Pree *et al.*, 2002; Van Leeuwen *et al.,* 2004 and Kim *et al.,* 2006).

During the last few decades, only 2 studies were carried out on the biology and ecology of the red spider mites in Sudan El Tingari (1994) and Abbas (1997). At present, there are many records on the infestation and damage of red spider mites on many crops in different area in Sudan; however, no recent studies were recorded on this pest. Accordingly, this study was initiated to point out the spread of this pest and its damage on some vegetables (mainly eggplant) in Khartoum State.

Objectives:

- General survey of the spider mite infestation in different area study sites in Khartoum State.
- Estimation of the percentage of spider mite infestation on eggplant in some study sites.
- Conduction a comprehensive questionnaire to examine farmers knowledge and awareness about the infestation and damage caused by spider mites and what the methods of control which were applied against this pest.

CHAPTER TWO

LITERATURE REVIEW

2.1 Eggplant (*Solanum melongena* L)

2.1. 1Classification

Order: Solanales

Family: Solanaceae

Genus: Solanum

Scientific name: *Solanum melongena L*

Common names: Eggplant, aubergine, brinjal

2.1.2 Description

Eggplant, is one of the top ten vegetable in the world and are kin to the tomato, bell pepper and potato. Eggplants grow in a manner much like tomatoes, hanging from the vines of a plant that grows several feet in height. One of the most popular varieties of eggplant in North America looks like a pear-shaped egg, a characteristic from which its name is derived. The skin is glossy and deep purple in color, while the flesh is cream colored and spongy in consistency. Contained within the flesh are seeds arranged in a conical pattern. (Whitaker and Stommel, 2003)

In addition to this variety, eggplant is also available in a cornucopia of other colors including lavender, jade green, orange, and yellow-white, as well as in sizes and shapes that range from that of a small tomato to a large zucchini.

While the different varieties do vary slightly in taste and texture, one can generally describe the eggplant have a pleasant bitter taste and spongy texture. In many recipes, eggplant fulfills the role of being a complementary ingredient that balances the surrounding flavors of the other more pronounced ingredients. (Whitaker and Stommel, 2003)

2.1.3 Economic importance

Eggplant fruits are low in calories and have mineral composition which is beneficial for human health. They are very rich in potassium, from 200 to 600 mg 100g-1 of fresh matter. The fruits are also a rich source of magnesium, calcium and iron (Lawande and Chavan, 1998, and Kowalski *et al*., 2003).

2.1.4 Important Insect and mite pests on eggplant

In the tropics, eggplant production is severely constrained by several insect and mite pests. The major pests include eggplant fruit and shoot borer, leafhopper, whitefly, thrips, aphid, spotted beetles, leaf roller, stem borer, blister beetle, red spider mite, and little leaf diseases (Gapud and Canapi 1994)

2.2 Spider mites (*Tetranychus* spp)

2.2.1Classification

Class	Arachnida
Sub class	Acarida = Acari
Order	Trombidiformes
Super family	Tetranychoidea
Family	Tetranychidae
Scientific name:	*Tetranychus* spp
Common names:	Spider mites

The three well known species which are *Tetranychus cinnabarinus* (Boisduval), carmine mite; *Tetranychus urticae* Koch, two spotted red spider mite (Bok *et al*., 2006); and the tobacco spider mite, *Tetranychus evansi* Baker & Prichard (Visser, 2005).

2.2.2 Description

Spider mites are soft-bodied, medium-sized mites (about 400 mm for an average adult female). They are often red, green, orange or yellow in colour when alive. The gnathosoma has a capsule-like structure known as the stylophore, which is formed by the fusion of the cheliceral body .The movable digits of the chelicerae are very long, often whip-like and recurved proximally. They are well suited for piercing. A pair of stigmata is located near the base of the chelicerae, where the peritremes arise. The palps are five-segmented (Lindquist, *et al*., 1987). The palpal tarsus and tibia with a distal claw-like seta known as the tibial claw often form a thumb-claw complex. The tarsus often has an enlarged distal eupathidium (spinneret) in the Tetranychinae and this is used to spin webbing in many species. The size and shape of the spinneret is of taxonomic significance. The idiosoma is often covered with a striate cuticle. The pattern of the striation and the shape/density of lobes distributed on the striae are useful diagnostic characters. There are three or four pairs of normal setae in two rows (*v*1-2, *sc*1-2) and two pairs of eyes on the dorsal propodosoma. On the opisthosomal dorsum, there are five rows of setae: *c*, *d*, *e*, *f* and *h*. The number, location, length and structure of dorsal setae are of taxonomic significance. Female genital pores are transverse and are bordered anteriorly by a genital flap and laterally by characteristic cuticular folds.The structures of the paired lateral claws and the medial empodium are of taxonomic importance. The claws may be claw-like or pad-like with tenent hairs, and so is the empodium. Claws may bear dorsal or ventral hairs. The tarsi of legs I and II bear duplex setae (a long solenidion and a short normal tactile seta with their bases joined together; the number of duplex setae and their positions are of taxonomic significance. Wedge-shaped males are smaller than ovoid females and have a tapering opisthosoma. Males have a protrudable aedeagus, the shape of which is very important in species identification (Meyer, 1987).

2.2.3 Distribution

Red spider mites are most probably word-wide in distribution. They have recorded from Europe, Africa and America, the near and Middle East, Indonesia, Japan and numerous other countries.

In the Sudan, Red spider mites proved to be most common in the northern, central and eastern parts of the country (Merowe, El Damer, Khartoum, Wad Medani, Kassala, Gash Delta ect.) (Schmutterer, 1969).

2.2.4 Life cycle

The life cycle of spider mites is temperature-regulated and occurs rapidly at warmer temperatures (Mau and Kessing, 1992). Both *T. cinnabarinus* and *T. urticae* complete their life cycle from egg to adult in about a week or two when temperatures are favourable (Mau and Kessing, 1992 and Bolland and Valla, 2000). Spherical shiny eggs are laid singly by the adult on the underside of the leaf surface or are attached to the silken web span. It takes three days for the eggs to hatch there are three active immature stages (larva, protonymph and deutonymph), each separated by a resting stage before a final moult to the adult (Klubertanz et al., 1991).and the resultant larvae are six legged and pinkish in colour. After a resting phase, the larva moults into a protonymph, which is eight-legged. The protonymph feeds before going into another resting stage. It then changes into the deutonymph before moulting into the adult (Knapp *et al*., 2003). Adult female mites are 0.5 mm long while the males are slightly smaller and wedge-shaped with a black spot on either side of its colourless body. The adult females may live up to 24 days and may lay up to 200 eggs (Meyer, 1987). Thus, at a temperature of between 21 to 31 degrees Celsius in October, 10 spider mites are capable of multiplying so fast as to reach 1000 by November and 100,000 by December (Collyer, 1998).

2.2.5 Host plants

Spider mites attack nearly 1200 cultivated crops, including maize, tobacco, cotton, beans, eggplant, pepper, tomatoes, cucurbits and many other vegetables (Mau and Kessing, 1992). Spider mites are also pests of papaya, passion fruit and are a common pest of many flowers such as carnations, chrysanthemum, cymbidium, gladiolus, marigold and roses (Guo et al., 1998; Tadmor et al., 1999; Bolland & Valla, 2000; Batta, 2003; Knapp etal., 2003). The polyphagous spider mite attacks numerous plant species wherever it occurs. In the Sudan attacks castor, beans (*Phaseolus* spp.), ground nuts, cotton, okra and cucurbits. (Schmutterer1969)

2.2.6 Economic importance and damage

Adult and nymphs of the red spider mites suck sap especially from the mature and older leaves. This causes the upper surface to become stippled with little dots. These dots on the upper surfaces usually indicate the presence of feeding punctures on the underside of the leaf (Goff, 1986 and Lu and Wang, 2005). Continued feeding may result in the collapse of mesophyll cells. The leaves eventually become bleached and discolored. Leaf drop can occur following heavy infestations due to an increase in the mite population especially under hot, dry conditions (Knapp *et al.*, 2003). This drastically reduces the crop yield (Hill, 1983; Visser, 2005 and Bok *et al*., 2006).

During feeding the mites penetrate the plant foliage/leaves with their mouth stylets and suck out the cell contents. On strawberry, low populations of *T. urticae* mainly damage the spongy mesophyll tissue but higher densities increase the area of damage and injury to the palisade parenchyma occurs (Sances *et al*., 1979 and Kielkiewicz and Van de Vrie, 1983). The function of the stomatal apparatus is also affected, so that the stomata remain closed.

The result of this damage to leaf tissue is reduced chlorophyll content and reduced photosynthesis, carbon dioxide assimilation and transpiration. Such effects have been shown for cotton (Bondana *et al*., 1995), tomato (Nihoul *et*

al., 1992), apple and peach (Mobley and Marini, 1990), and strawberry (Sances *et al*., 1982).

Crops yields are diminished as essential plant processes are affected. This has been demonstrated on maize (Archer and Bynum, 1993), strawberry (Oatman *et al*., 1982), pear (McNab and Jerie, 1993), cotton (Wilson, 1993), soyabean (Singh, 1988; Suekane *et al*., 2012) and grapevine (Hluchy and Pospisil, 1992), among others. The mites feed directly on tomato fruit, causing gold fleck (discolouration of the fruit), which could have a negative impact on the marketability of the fruit (Meck *et al*., 2012). Nyoike and Liburd (2013) studied the impact of the mites on the marketable yield of field grown strawberries in Florida and reported that yield reduction in strawberry was detected when plants had 80 mites per leaf in the 2008/2009 growing season, and 50 mites per leaf in the 2009/2010 growing season. Results like this can be used to determine the timing of control programmes, ensuring maximum yields are attained. The timing of mite infestation has also been shown to have an impact. For example, Gore *et al*. (2013) reported that early infestations of *T. urticae* on cotton in mid-southern USA caused the highest impact on yield.

2.2.8 Control measures

In the past the red spider mite was thought to be an insect rather than a mite (Luchen and Mingochi, 1994). This led to the use of insecticides which, paradoxically, resulted in an increase in mite infestation (Dagli and Tunc, 2001). With the proper classification of these pests as mites, a variety of other control measures were developed such as natural control, biological control, chemical miticides and the use of botanical extracts (Greathead *et al*.,1990).

2.2.8.1 Natural control

Since all *Tetranychus* species infestations happen during hot and dry weather, rain helps to reduce spider mite numbers, especially during moulting, by washing them off leaves of the infested plants (Brandenburg

and Kennedy, 1982 and Rosenheim and Corbett, 2003). A number of researchers have reported on crop varieties which are resistant to the red spider mite (Knapp *et al*., 2003). For example, various cucurbits such as melon and water melon are resistant to the carmine spider mite (Mansour *et al.*, 1987; Mansour and Bar-Zur, 1990; Scully *et al*., 1991and Mansour *et al*., 1994).

2.2.8.2 Biological Control

The spider mite has been the subject of some of the most successful examples of biological control. The predator used most often was been the phytoseiid mite *Phytoseiulus persimilis*. This species was first used in glasshouses, on various crops, in the 1960s (Hussey *et al*., 1965), and since then has been used successfully on a wide variety of crops in a range of protected and unprotected environments. Several biological control companies package this predator for distribution on plants by growers. Suitable release rates and timings vary with the crop. In areas where the mite has been established, augmentative releases are required to maintain control.

However, *P. persimilis* is active only under a limited range of conditions (Gorski and Eajfer, 2003), and so other species of phytoseiid mites have also been used against *T. urticae*. For example, *Amblyseius idaeus* and *Phytoseiulus macropilis* have been used on strawberry and cucumber in Brazil (Watanabe *et al.*, 1994). Metwally *et al*. (2005) investigated life table and prey consumption of the predatory mite *Neoseiulus cynodactylon*, and concluded that T. *urticae* was a profitable prey species of this phytoseiid as a facultative predator.

Predators from other insect families have also shown promise as biocontrol agents against red spider mite. For example, the chrysopid *Mallada basalis* has been used on strawberry in Taiwan (Tzeng and Kao, 1996). Yanagita *et a*l. (2014) reported that the predatory thrip *Scolothrips takahashii* could be used as an effective control agent against red spider mite in integrated pest

management programmes for strawberry plants. Other potential predatory biocontrol agents include *Orius minutus* (Fathi, 2013), *Coccinellla septempunctata* (Sirvi and Singh, 2014), *Stethorus gilvifrons* (Ahmad *et al.*, 2010) and *Stethorus punctillum* (Gorski and Eajfer, 2003).

Neoseiulus californicus has shown promise as an agent in conservation biological control of red spider mite; the natural control of the mite in strawberries was used as the basis for developing an integrated management plan, using acaricide only when necessary (Greco *et al*., 2011).

Shivaprakash *et al*. (2004) reported on the natural occurrence of the entomopathogenic fungus *Beauveria bassiana* on *T. urticae* in an okra plot grown without the use of chemicals in Bangalore, Karnataka, India. Laboratory tests using entomopathogens against, the spider mites have also been carried out (e.g. Simova and Draganova, 2003 and Chandler *et al*., 2005).

2.2.8.3 Host-Plant Resistance

Research to find sources of resistance to *Tetranychus* spp has been carried out on a variety of crops, including Impatiens (Al-Abbasi and Weigle, 1982), soyabean (Mohammad and Rodriguez, 1985), Pelargonium (Chang *et al*., 1972), cucumber (de Ponti, 1980), Vigna angularis (Aguilar *et al*., 1996), strawberry (Shanks and Moore, 1995; Easterbrook and Simpson, 1998 and Olbricht *et al*., 2014), watermelon (Lopez *et al*., 2005 and El-Saiedy *et al*., 2011), maize (Mead *et al*., 2010), tomato (Saeidi and Mallik, 2012) and citrus (Agut *et al*., 2014). Several studies have found differences in susceptibility to the mite between different cultivars or selections. However, the resistance may be polygenic in most cases (Easterbrook and Simpson, 1998), and so is difficult to exploit by plant breeders. Even partial resistance is potentially useful in IPM programmes, however, as it slows the rate of population increase of the spider mite, and so makes it easier for predators to gain control. Mechanisms of host-plant resistance to *Tetranychus* spp have been

attributed to flavonoid pathways in citrus (Agut *et al*., 2014), leaf trichomes on Fragaria (Olbricht *et al*., 2014) (shown to entrap mites on tomato [Saeidi and Mallik, 2012]), increased peroxidase and polyphenol oxidase activity in melon (Shoorooei *et al*., 2013), antibiosis and antixenosis in bean (Kamelmanesh *et al*., 2010), phytochemical compounds in watermelon, where El-Saiedy *et al*., (2011) reported a negative relationship between mite infestation and tannins, and nitrogen and protein content in maize leaves (Mead *et al*., 2010).

2.2.8.4 Chemical Control

To date, no acaricides have been recommended in the Sudan against the spider mites in all horticultural and field crops (Ahmed *et al*, 2014).

Tetranychus spp is very difficult to control with acaricides because most populations developed resistance to chemical groups after a few years of use (Cranham and Helle, 1985). In some cases, cross-resistance to other chemical groups has also developed. For example, resistance to the ovicide clofentezine developed quite rapidly, and cross-resistance to hexythiazox also occurred (Thwaite, 1991). Al-Jboory *et al*., (2004) reported that a bromopropylate-resistant strain (R) of *Tetranychus* spp showed strong positive cross-resistance towards dicofol and a mixture of dicofol and tetradifon, moderate positive cross-resistance towards amitraz, and low negative cross-resistance towards chlorpyrifos. No cross-resistance was observed towards abamectin and dinobuton.

Later, control often relied on acaricides from a group that act as inhibitors fenpyroximate, fenazaquin and tebufenpyrad. However, resistance was detected in a relatively short space of time, leading to decreased susceptibility to all the compounds in this group (Bylemans and Meurrens, 1997). This illustrates the importance of anti-resistance strategies, involving restricted acaricide use and rotation of acaricides from different chemical groups, such

as that proposed for fruit crops by the Insecticide Resistance Action Committee (IRAC) (Wege and Leonard, 1994).

2.2.8.5 Alternative methods of control:

Increased resistance to acaricides has led to research into alternative sources for control, such as fatty acid derivatives (Silva-Flores *et al*., 2005), sugar esters (Puterka *et al*., 2003), plant extracts, including essential oils (Kawka and Tomczyk, 2002; Mateeva *et al*., 2003; Aslan *et al*., 2004, 2005; Hou *et al*., 2004 and Kawka, 2004), such as *Elettaria cardamomum* (Fatemikia *et al*., 2014), and botanical insecticides derived from the neem tree (*Azadirachta indica*) (Pavela, 2003). Of various plant extracts tested for acaricidal activity against *T. urticae* in Plovdiv, Bulgaria, Mateeva *et al*., (2003) reported that thornapple (*Datura stramonium*), wormwood (*Artemisia absinthium*) and basil (*Ocimum basilicum*) were toxic to the active stages of this pest. It was stated that extracts of these species could be used to control *Tetranychus* spp on rose in urban areas. Saber (2004) reported that ethanol extracts of sand wormwood *(Artemisia monosperma*) were least effective against females of *Tetranychus* spp compared to petroleum ether, chloroform or ethyl acetate. The acaricidal activity of Australian Lamiaceae extracts has also been tested against *Tetranychus* spp with varying results (Rasikari *et al*., 2005). Extracts from the subfamilies Ajugoideae, Scutellarioideae, Chloanthoideae, Viticoideae and Nepetoideae showed acaricidal activity, and 14 species of Plectranthus showed moderate to high contact toxicity against *Tetranychus* spp. Methanol extracts of *Cinnamomum* species (family: Lauraceae) are potential acaricides (Reddy *et al*., 2014). Commercially available Bionatrol (specified emulsion nano-particle soyabean oil) was shown to reduce populations of *Tetranychus* spp, aphids (*Aphis gossypii*) and whiteflies (*Trialeurodes vaporariorum*) on greenhouse-grown English cucumber (*Cucumis* subsp. kasa) by 88-95% (Lee *et al*., 2005).

2.2.8.6 Integrated Pest Management

Management of *Tetranychus* spp forms an integral part of IPM programmes for many crops. It is important that pesticides used for other pests and diseases are chosen so that they cause minimal disruption to naturally occurring predators or biocontrol agents such as *Phytoseiulus persimilis*. Also, control agents applied against the same pest must also be chosen carefully so that they do not disrupt each other. Thus, even though *P. persimilis* and *B. bassiana* have been shown to be effective in controlling *Tetranychus* spp, when applied together, an increase in handling time by *P. persimilis* was reported, leading to a decrease in the rate of feeding by the predatory mite (Seiedy *et al*., 2012). It may sometimes be necessary to use a selective acaricide to reduce spider mite numbers and maintain a suitable pest/predator ratio. For example, a selective acaricide may be needed to reduce a large overwintered population of *Tetranychus* spp in the spring, before a release of *P. persimilis* later in the year (Easterbrook, 1992). IPM programmes should minimize the use of acaricides, to delay the onset of resistance and prolong their effective life, but even programmes that do not heavily rely on pesticide use need to be cautious when employing different control strategies. For example, hot-water treatment on strawberry discs has been shown to control *Tetranychus* spp (Gotoh *et al*., 2013); however, it was suggested that the natural enemy, *Neoseiulus californicus* would have to be replaced following treatment due to its sensitivity to hot water.

Supplements, such as fertilizers, used in the growing environment must also work synergistically in an IPM programme and several authors have investigated the effect of fertilizer application on pests, such as *Tetranychus* spp. For example, Zhang and Xiang (2007) reported an increase in the number of *Tetranychus* spp (and *Aphis gossypii*) with an increase in organic fertilizer application. In contrast, other studies have shown that application of nitrogen

or phosphorous fertilizers had no effect on numbers or activity of *Tetranychus* spp on soyabeans (Shabalta *et al*., 1992).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study sites

This study was carried out in different eight sites in Khartoum State (WadRamli, El Fakey Hashim, Elnuba, Shambat and Selait Scheme (North Khartoum), El Gezira Islanj (North Omdurman), Gamoaia Scheme (South Omdurman) and Toti Island (Khartoum). (Figure 1).

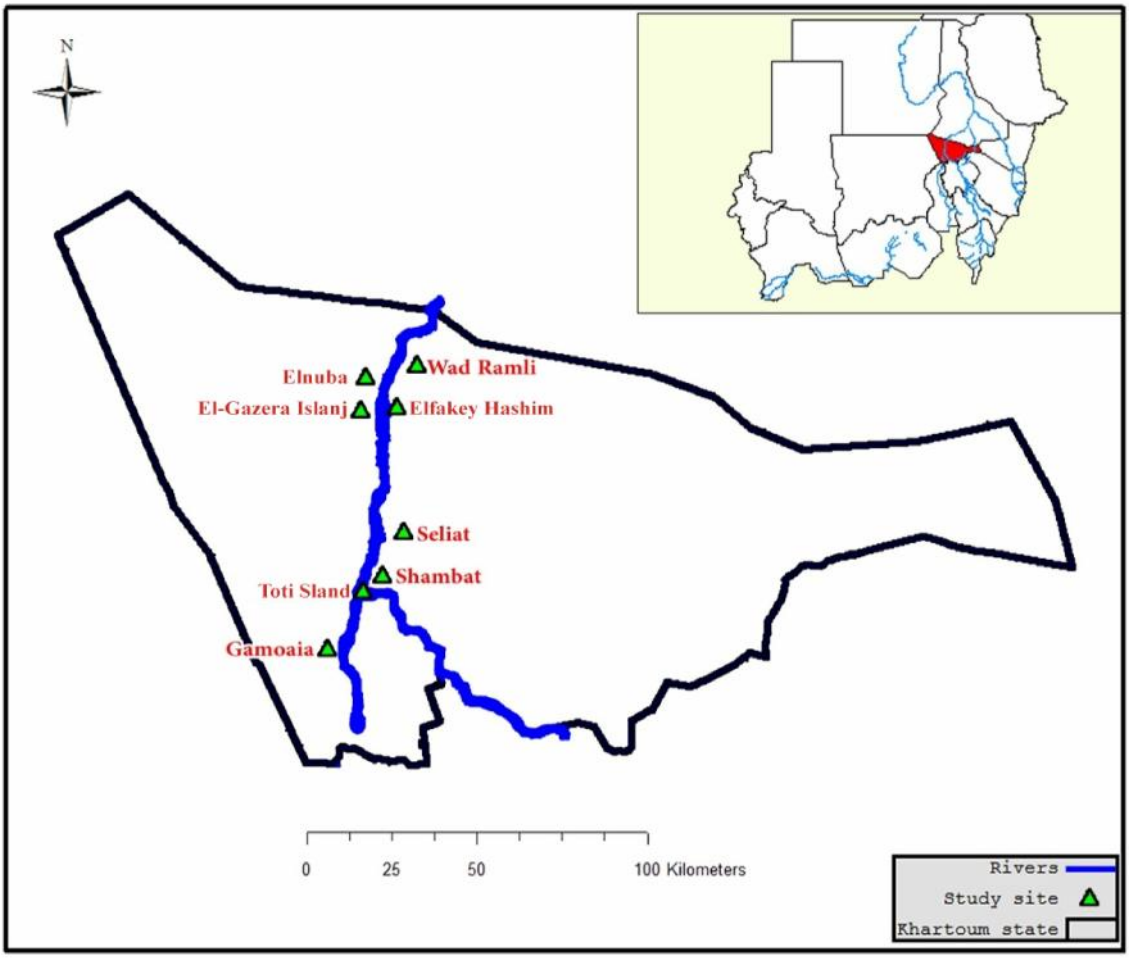

Fig 1. Study Sites of map in Khartoum State

3.2 Methods

3.2.1 General survey

A general survey was carried out in different eight sites in the Khartoum State (Fig.1). The survey was made to investigate the spider mite infestations on the main vegetable crops grown in those areas. In addition of main weeds.

3.2.2 Specific survey

Specific survey was conducted to evaluate the status of the spider mites infestation on eggplant in the study sites in Khartoum State during April/May 2016.

3.2.3 Cross sampling method

Five sites were chosen for the study (e.g. WadRamli, Selait scheme, Shambat, Gamoaia scheme, Toti). In each site, 3 plots, eash10×10m was chosen randomly. In each plot, the cross sampling method was applied, 7-8 plants was chosen randomly along each cross line. In each plant, 3 leaves (one upper, one middle, and one lower) were examined for red spider mite infestation (the presence of 1 mite /leave or /plant was considered an infestation).

3.3 Questionnaire

A standardized questionnaire was distributed to 40 farmers in the study sites to understand the economic importance of the red spider mites and how the farmers deal with the infestation problems. A set of 16 questions was set out to understand: the farmers' knowledge about the pest and its damage, types of crops and weeds affected seasonal abundance and the control measures applied. Regarding chemical control; what types of pesticides applied and the methods of application and annual loss (Appendix 5).

3.4 Statistical analysis

The collected data was subjected to analysis of variance (ANOVA) and the means were separated by the least significant difference test (LSD). M-Stats statistical package and SPSS (version 18.1) (statistic analysis used by descriptive and Frequency statistic) were used for data analysis. And least sig. deferent (LSD) used by statistic8.

Plate 1. Spider mites shape

Plate 2. Spider mites colonies on eggplant leaf

Plate 3. Evaluation of spider mites infestation (Selait Scheme site)

Plate 4. Farmers questionnaire (Toti site)

CHAPTER FOUR

RESULTS

4.1 Abundance of spider mite infestation on the study sites

4.1.1 General Survey

The general survey showed that, the vegetable crops in the study sites were infested by the spider mites, with variable degrees of infestation. The eggplant showed high infestation in all surveyed sites (36%) and the lower infestation was noted in Cotton - *Gossypium hirsutum* (1%) (Table1). In addition, eight weeds from different families showed various degrees of infestation by spider mites during the survey period. The high infestation (30%) of weeds was recorded in Ushar weed *Calotropis procera* and the lower infestation was noted in Indian senna *Cassia senna* and Marmeet *Pergia capensis* (2%) (Table 2).

4.1.2 Specific survey

In this survey, five study sites were chosen and the cross sampling method was applied. Of the five sites, Toti site was the highest infested area with spider mites, with (100%) infestation, followed by WadRamli (93.3%), Gamoaia (86.7%) and Selait (70%). The lowest infestation percentage was reported in Shambat site (56.7%) (Table3 & Fig.2).

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Table 1. Vegetable crops infested by the spider mites in the study sites

No.	Vegetable crops	No. of infested plants	Infestation %
1	Eggplant - *Solanum melongena*	36	36%
2	Tomato - *Lycopersicum esculentum*	21	21%
3	Potato- *Solanum tuberosum*	7	7%
4	Okra- *Hibiscus esculentus*	6	6%
5	Onion- *Allium cepa*	4	4%
6	Chili- *Capsicum frutescens*	3	3%
7	Cowpea- *Vigna sinensis*	3	3%
8	Pumpkins- *Cucurbita maxima*	5	5%
9	Cucumber- *Cucumis sativus*	3	3%
10	Bean- *Phaseolus vulgaris*	2	2%
11	Peanut- *Arachis hypogaea*	4	4%
12	Squash- *Cucurbita pepo*	2	2%
13	Cabbage- *Brassica oleracea*	2	2%
14	Cotton - *Gossypium hirsutum*	1	1%
	SE±		2.5
	Sample Variance		93.763
	SD±		9.6

Table 2. Weeds infested with the spider mites in the Study Sites

No.	Weeds	No. of plants	Infestation %
1	Ushar – *Calotropis procera*	17	30%
2	Sakran – *Datura stramonium*	13	23%
3	Gubbien – *Solanum sativum*	9	16%
4	Nageela – *Cynodon dactylon*	6	11%
5	Seida – *Cyperus rotundus*	4	7%
6	Defra – *Digitaria sangunalis*	4	7%
7	Senn Makka– *Cassia senna*	2	4%
8	Marmeet – *Pergia capensis*	2	4%
	SE±		1.93
	Sample Variance		29.8
	SD±		5.46

Table 3. Spider mite infestation (%) on eggplant at different sites in Khartoum State (April - May 2016).

Site name	Infestation %
Toti	100.0a
WadRamli	93.3 a
Gamoaia	86.7 ab
Selait	70.0 ab
Shambat	56.7 b
C.V (%)	20.3
SE±	7.4
LSD	31.1

Means in the same column with the same letter (s) are not significantly different at $P \leq 0.05$.

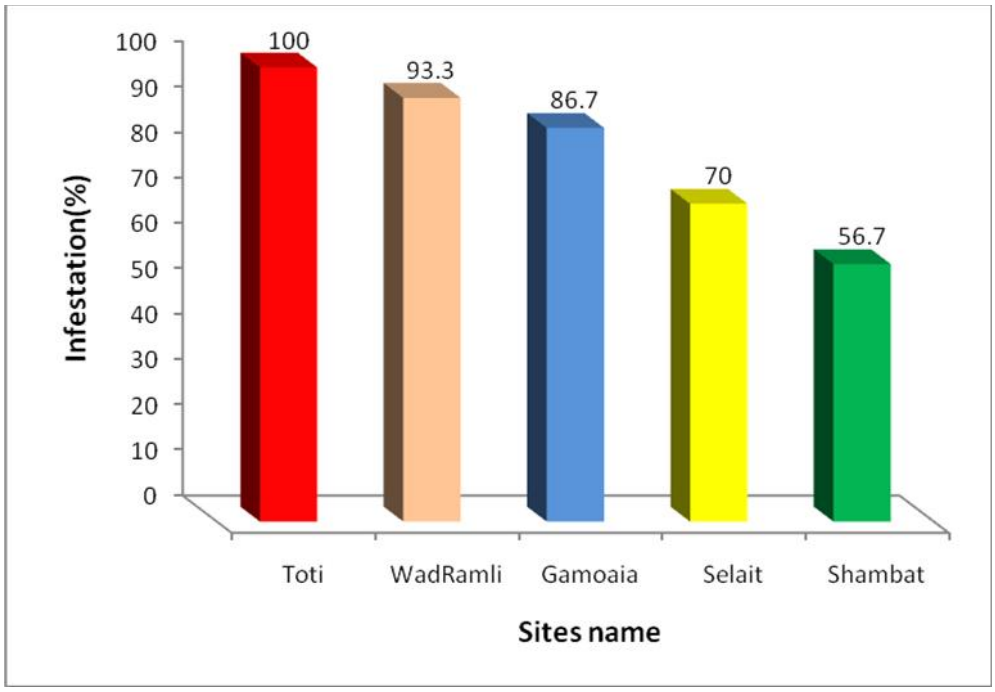

Fig 2. Spider mites infestation (%) on eggplant at different sites in Khartoum State (April - May 2016).

4.2 Questionnaire

4.2.1 Farmers age

A simple questionnaire was distributed to 40 vegetable crops farmers in eight sites. The questioned farmers were between 18 and above 50 years old and the majority of them (60%) were between 26 to 50 years old (Table 4).

4.2.2 Education levels

The majority of farmers were basic educated (57.5%), followed by secondary (25%) and university level (7.5%). A 10 % of farmers were not- educated (Table 5).

4.2.3 Infested crops

All questioned farmers Saied that eggplant was the most susibtable and heavy infested by spider mites among other vegetable crops and then followed by tomatoes, cucumbers and potatoes (Table 6).

Table 4. Farmers age percentage

No.	Age	No. of farmers	Age%
1	18-25	5	12.5
2	26- 50	24	60
3	Above 50	11	27.5
	SE±		5.60
	Sample Variance		94.33
	SD±		9.7

Table 5. Percentage of farmer's different educational level

No.	Educational level	No. of farmers	Education level%
1	Not-educated	4	10
2	Basic	23	57.5
3	Secondary	10	25
4	University level	3	7.5
	SE±		4.6
	Sample Variance		84.6
	SD±		9.20

Table 6. The percentage of the most infested crops

No.	Crops	No. of plants	Infestation %
1	Eggplant	34	41
2	Tomato	26	31
3	Potato	8	10
4	Cucumber	15	18
	SE±		5.76
	Sample Variance		132.9
	SD±		11.5

4.2.4 Farmers awareness and knowledge

The majority of farmers (92%) have a good information and knowledge about the red sider mite and their infestations (Table 7).

4.2.5 Historical records spider mite's

A 40 % of the farmers noticed that spider mite was appeared from more than two years ago, and (27%) mentioned that infestation was recorded only one year ago (Table 8).

Table 7. Farmers awareness and knowledge

Respond	No. of farmers	Percentage
Yes	37	92.5
No	3	7.5
SE±		17
Sample Variance		578
SD±		24.04

Table 8. Historical records spider mite's

No.	Years	No. of farmers	Percentage
1	One year ago	11	27.5±
2	Two years ago	12	30±
3	More than two years	16	40±
4	No response	1	2.5±
	SE±		3.18
	Sample Variance		40.6
	SD±	6.3	

4.2.6 Control measures

The majority of farmers (87.5%) were used chemical control to reduce mite's infestations, a few of them (7.5%) were used agricultural practice reduce mite infestations (Table 9).

4.2.7 Types of pesticides used by the farmers

The present study showed that the farmers used about, 15 different pesticides to control spider mites (Appendix 2). About 35% of them use Acaros (1.8 % EC) alone and 50% of farmers use Acaros 1.8% combined with other pesticides, few of them (7.5%) use other different pesticides to control the spider mites and 7.5% of farmers did not respond (Table 10).

Table 9: Control measures

No.	Control method	No. of farmers	Percentage
1	Chemical control	35	87.5%
2	Agricultural control	3	7.5%
3	No response	2	5%
	SE±		8.35
	Sample Variance		279.33
	SD±		16.7

Table 10: Types of pesticides used by the farmers

Type of Pesticide	No .of Farmers	Percentage
Acaros1.8% EC alone	14	35%
Acaros 1.8%EC+other pesticides	20	50%
Other pesticides	3	7.5%
No response	3	7.5%
Total	40	100%
SE±		4.22
Sample Variance		71.3
SD±		8.4

4.2.8 Numbers of pesticide application per the season

About 45% of farmers stated that they applied pesticides more than seven times during the season, 32.5% of them applied the chemicals between 6 to 7 times per season. A few of them (12.5 % and 2.5 %) applied the pesticides between 2 to 5 times per season (Fig.3).

4.2.9 Intervals between pesticides application

The majority of farmers (65%) mentioned that, the interval between pesticides spray was 7 to 10 days. 10 % of them applied pesticides after 4- 6 days. Few of them (7.5%) applied pesticides at interval of more than10 days (Fig.4).

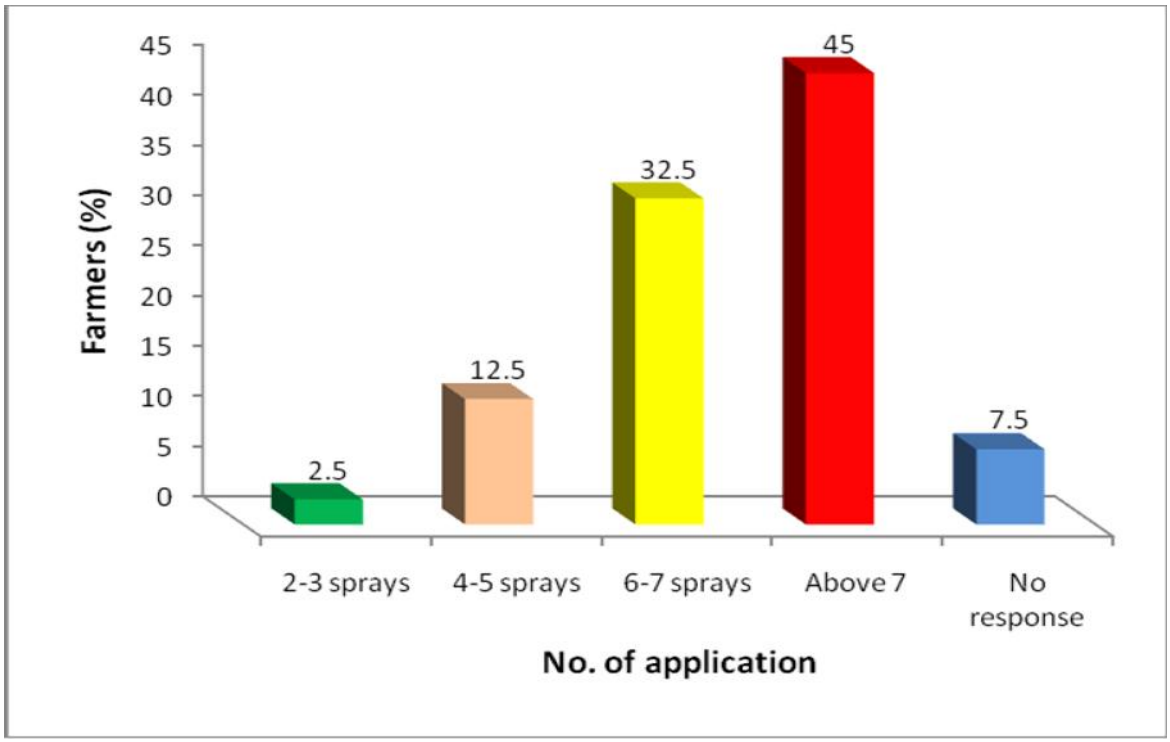

Fig 3. Numbers of pesticide application per the seas

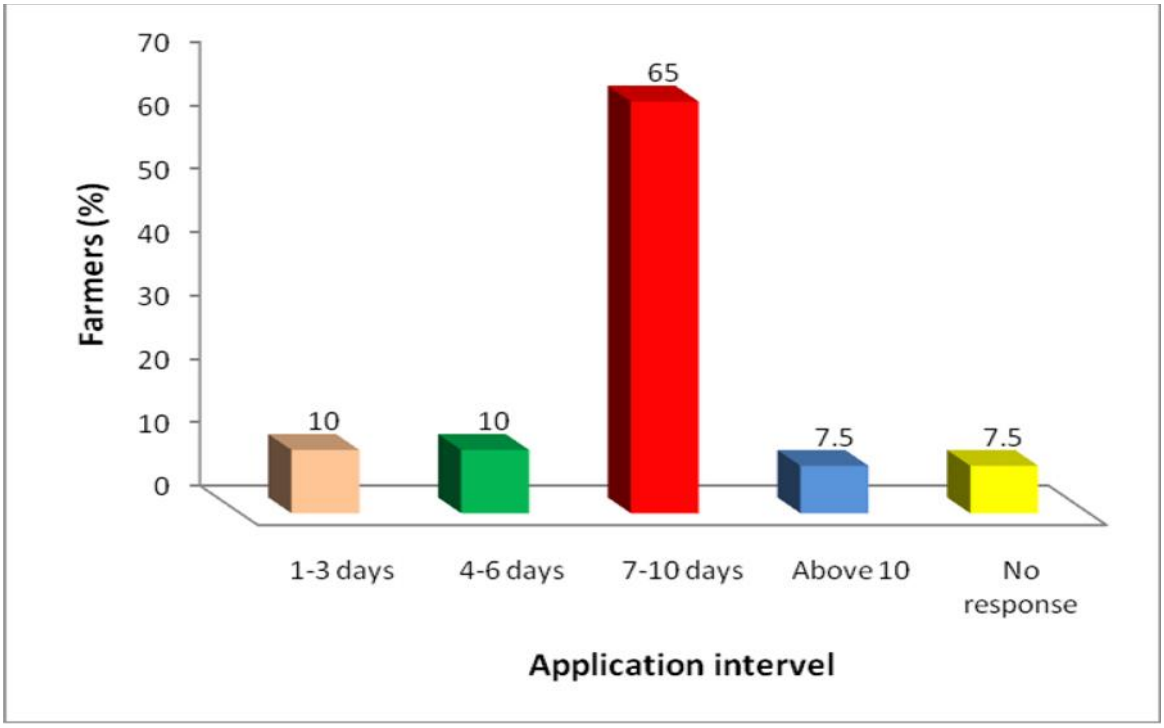

Fig 4. Intervals between pesticides application

4.2.10 Percentage of eggplant loss due to spider mites infestation

About 55% of farmers stated that, the percentage losses of eggplant range from 76% to 100%, a 25% of them said the loss ranged of 51% to 70 %. A few of them (5% and 7.5%) mentioned that the loss of crop range from zero to 50 % (Fig.5).

4.2.11 The season of infestation

The majority of farmers mentioned that, no different of infestation between winter season and summer season, while few farmers (2.5%) mentioned that, eggplant was most infested by spider mites during autumn season (Fig.6).

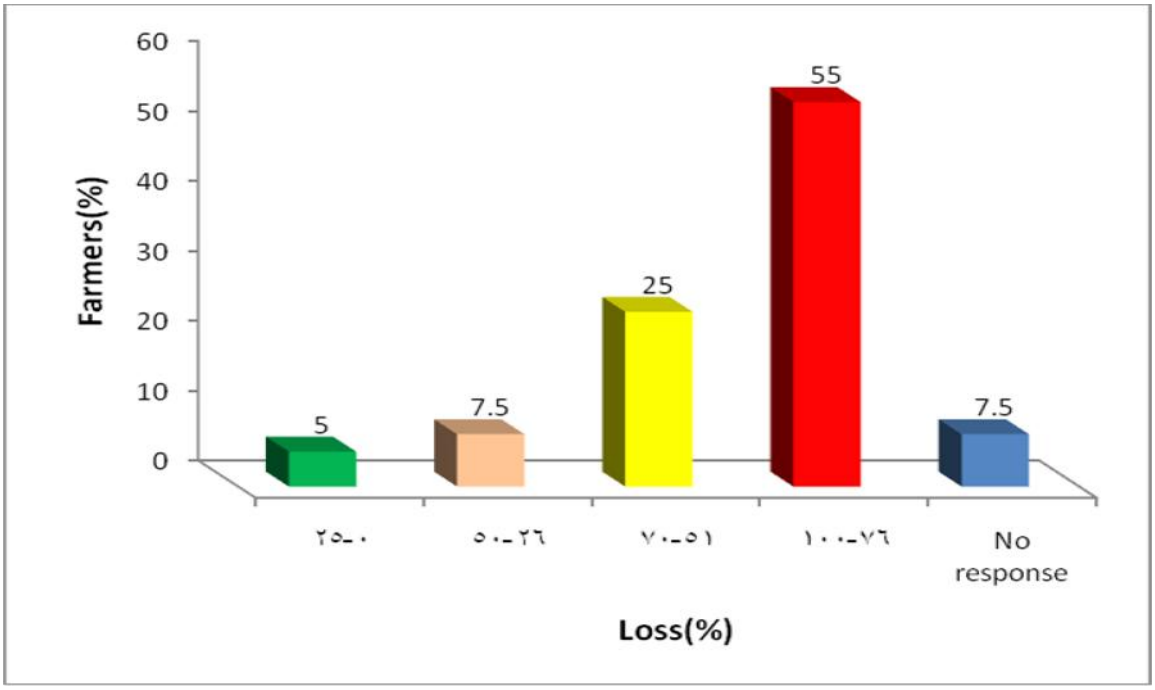

Fig 5. Percentage of eggplant loss due to spider mites infestation

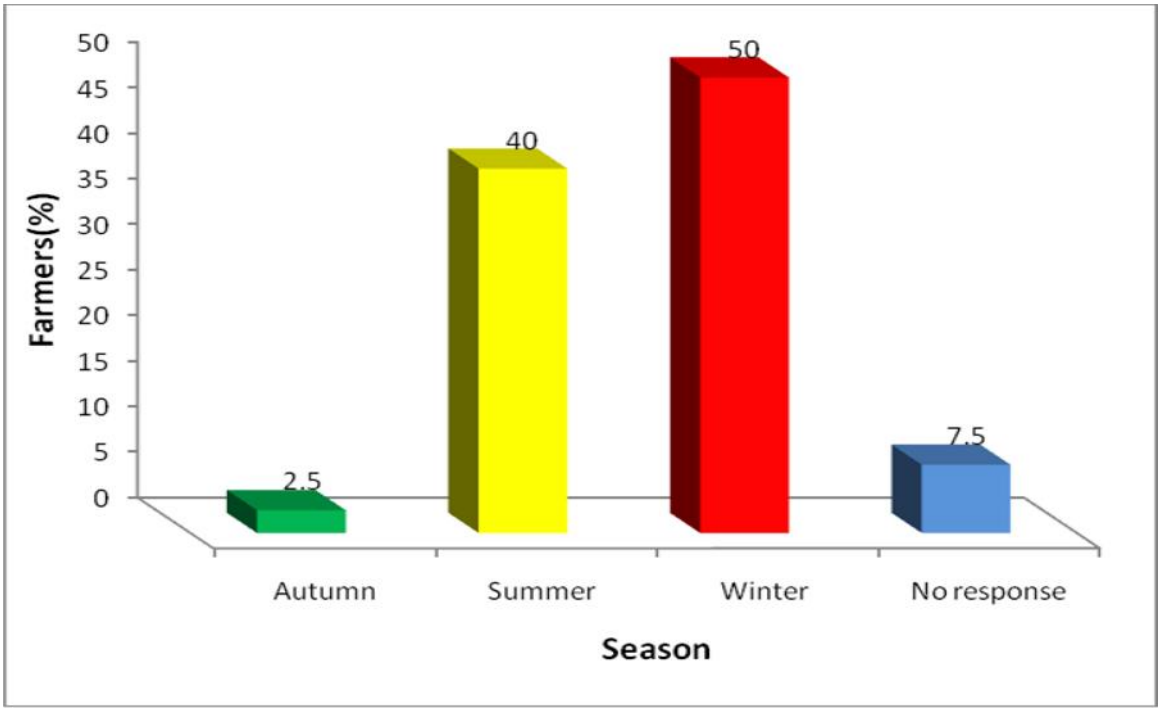

Fig 6. The season of infestation

CHAPTER FIVE

DISCUSSION

During the last decades a number of studies were carried out on the red spider mites (RSM) in some African countries. In South Africa, Mwandlla (2009) carried out a study for controlling the red spider mites which became one of the main pests affecting tomato's production in the country. He applied the extracts of two plants namely, neem (*Azadirachta indica* A. Juss) and syringa (*Melia azedarach* L.) for the control of red spider mites. The overall results of the study indicated that, both Neem and Syringa assays showed that all levels of concentrations and time of exposure had significant effects on mortalities of adult RSM and compared significantly with the commercial acaricides applied.

Also, in Chad the Red spider mite was recorded as one of the main pests attacking a wide range of plants. Accordingly, a survey was conducted by Maina (2014) to gather information about spider mite around the Lake Chad shore area of Nigeria. The aim of the study was to report the status of spider mites on horticultural crops, amount of losses that associated with infestation and to find out the measures taken by farmers in controlling the pests. The results showed that, spider mite (*Tetranychus* spp) recorded to be one of the major pests on eggplant and tomato since the year 2006. More than 50% loss of yield on eggplant has been recorded. To reduce this huge loss of yield, farmers in the area used insecticide spray as their major control measure.

In Egypt, some studies were also carried out on the red spider mites. A study made by Manal *et al* (2007) covered some ecological aspects of the two spotted spider mites *Tetranychus urticae* and its predators. Their final conclusion indicated that, the predators are essential for the biological control of the red spider mites. In Kenya, Faith (2011) made a study to develop a

detailed record of the Tetranychid mites of Kenya and Tanzania and to assess their diversity in East African biodiversity.

A recent study was made by AbdEl Mohsin (2015) on the red spider mites in Egypt. The study covered some approaches (based on genetic mutations) in controlling the red spider mites on Tomato plants.

Here, in Sudan, by comparison, few studies (only 3) were carried out on the red spider mites during that period. An old study was made by Siddig (1969) on some aspects of the taxonomy and biology of the red spider mites. The other two studies were also made on the biology and ecology of the red spider mites in 1990s e.g. El Tingari (1994) and Abbas (1997).

Although those studies showed somewhat high infestations by the red spider mites on many crops in Khartoum State, however; there was no consideration for that infestation by the agricultural authorities in the State.

Khartoum State ranks top among other States in Sudan regarding the production and consumption of vegetables that relates to the higher increase in population growth, income level and nutritional awareness (Mohammed, 2005). Accordingly, this study was also carried out in Khartoum State to highlight the severe damage caused by this neglected pest in the State.

The results of the survey carried out showed that, more than 20 different vegetables and field crops, and weeds, in Khartoum State were infested by red spider mites. The percentage of infestation ranged between 56.7% (Shambat) and 100% (Toti).

The results also showed that, the eggplant was the most affected crop, and was considered as main host plant among all vegetable crops in Khartoum State. The survey showed that, Toti was the most affected area with spider mites with (100%) infestation.

The results of the questionnaire carried out among farmers showed that, most of the farmers lost their crops completely due the high infestation of the red spider mites and some of them lost their money, and also homes as well, because they have debts from banks before cultivation seasons.

From our findings, most of the questioned farmers were using chemical pesticides to control the red spider mites on eggplant. Many of the farmers were using high toxic pesticides to mammals such as Omethoate, Dimethoate and Malathion to control this pest regardless of it is hazard, risk and the adverse effects on the environment that caused by these pesticides (Appendix 2). Some farmers in most of the study sites in Khartoum north (e.g. El Fakey Hashim, Elnuba, Wad Ramli) and Elgezira Islanj (in omdurman) mentioned that, some of their colleagues died and some others were admitted to hospitals as patients, due to the abuse and misapplication of pesticides for many years. The results of questioner indicated that, no role of the agricultural extension services were applied in the study sites during the last few years.

It was clear that the farmers in the study sites need to be informed about other control methods, for example, Cultural practices (such as, Field sanitation, crop rotation…), mechanical control (for example, use of traps, e.g. light traps, sticky traps, use of barriers, etc), and also on biological control tactics (e.g. Manal *etal.*, 2007). Also, the experience on pest control in other countries indicated that, farmers can be trained to apply biobesticides (for ex. Neem –based biobesticides) for plant spraying (e.g. Mwandlla, 2009). In addition, the use of sex pheromone traps is another tactic in eggplant pest control (e.g. Srinivasan, 2009).

As indicated above, it is the duty of the agricultural extension and plant protection workers in Khartoum State to educate the farmers of the State on all these control tactics. That training and educating of the farmers would lead to the implementation of an Integrated Pest control Programme, based on the awareness and understanding of the farmers concerned.

Conclusions and Recommendations

Conclusion

- High infestations of red spider mites have been recorded in the majority of the study areas of Khartoum State, particularly on the eggplant crop. Spider mites has a wide host-range, including various vegetables such as Solanaceae, Cucurbitaceae, Malvaceae, Brassicaceae, Fabaceae and Liliaceae families and weeds Solanaceae, Cyperaceae, Fabaceae, Poaceae, Asclepiadaceae, were recorded in the study areas.
- Forty farmers were questioned in eight study sites in Khartoum State, on the problem of the red spider mites. Most of the farmers mentioned that, losses in Eggplant caused by the red spider mites were above 75%. The infestation increased during both seasons (the winter and summer).
- Shortage of Agricultural Extension service in all study sites .
- Most of the farmers used only the chemical pesticides to control the spider mites, and used more than 15 different pesticide products with more than 7 sprays per season.

Recommendations

1. More studies (especially that concentrate on Biology, Ecology, Identification, control and etc) should be made by specialist in University, Agricultural Research Corporation (ARC) and Plant Protection Directorate – Ministry of Agriculture.
2. More effort and work (survey, inspection, workshops, etc) should be done to increase the knowledge and information about this pest.
3. Farmers should be made aware of the importance of keeping farms free from weeds and other surrounding wild plants, as a good cultural control method.

4. Farmers awareness must be increased by improving the role of agricultural extension services (visits, Farmer's Schools, etc..).
5. Encourage the farmers to use the other alternative and safe methods of control against spider mites, specially Traps, Bio control, such as natural enemas, botanicals, and other biopesticides.
6. More inspection should be done to check the pesticides that are not registered in Plant Protection Directorate.
7. As indicated above, further studies are recommended to identify of mite's species in Sudan that attack a wide range of plants and weeds.
8. Agricultural extension workers and specialists in Khartoum State should do more regular extension work among farmers in all the agricultural areas in the State. This is of prime importance, to know (and to discover) the new pests and new infestations in the different areas in the State in order to apply control measures at the right time.

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APPENDICES

Appendix 1. Spider mite's infestation (%) at the different study sites

Sites	R1	R2	R3	Mean
Shambat	40%	70%	60%	57%
Gamoaia	100%	70%	90%	87%
Seliat	40%	70%	100%	70%
WadRamli	80%	100%	100%	93%
Toti	100%	100%	100%	100%

Appendix 2. Chemical pesticides applied for controlling of spider mites

Pesticide	Common name	Pesticide group
Acaros 1.8% EC	Abamactin	Vermectin
Cypermight 10%EC	Cypermethrin	Pyrethroid
Folimat 80%EC	Omethoate	Organophosphates
Sevin 85%WP	Carbaryl	Carbamates
Bright 25%EC	Carbosulfan	Carbamates
Sicorin 25%EC	Cypermethrin	Pyrethroids
Rogor 32%EC	Dimethoate	Organophosphates
Malathion 57%EC	Malathion	Organophosphates
Sicofidor 30.5%SC	Imidacloprid	Nenicotinoids
Hitcel 44%EC	Profenofos + cypermethrin	Organophosphates + pyrethroid
Decis 0.5%EC	Deltamethrin	Pyrethroids
Karate 5%EC	Lambda-cyhalothrin	Pyrethroids
Tricel 48%EC	Chlorpyrifos	Organophosphates
Zorak 25%EC	Carbusulfan	Carbamates
Sinomate 80%SL	Omethoate	Organophosphates

Appendix 3. The Acaricides (Acaros 1.8 EC) mostly used for controlling spider mites

Appendix 4. Eggplant field infested by spider mites (Shambat site)

Appendix 5. Questionnaire

بسم الله الرحمن الرحيم

جامعة السودان للعلوم والتكنولوجيا

كلية الدراسات العليا

قسم وقاية النبات

استبيان عن الحلم العنكبوتي الأحمر بمناطق (.....)- ولاية الخرطوم

ملحوظة: المعلومات الواردة أدناه تستخدم لغرض الدراسة فقط.

1/ البيانات الشخصية:

- الاسم: .....
- العمر: 18-25 ( ) 26-50 ( ) أكثر من 50 ( )
- النوع: ذكر ( ) أنثى ( )
- المستوى التعليمي: أمي ( ) ابتدائي ( ) أساس ( ) متوسط ( ) ثانوي ( ) جامعي ( ) فوق الجامعي ( )
- عدد أفراد الأسرة:.....

2/ المحاصيل المزروعة: باذنجان ( ) طماطم ( ) بطاطس ( ) عجور ( )

3/ هل يمكنك معرفة العنكبوت الأحمر: نعم ( ) لا ( )

4/ متى كانت أول إصابة؟ منذ عام ( ) منذ عامين ( ) أكثر من عامين ( )

5/ المحاصيل التي تصاب بالعنكبوت الأحمر؟ طماطم ( ) باذنجان ( ) بطاطس ( ) أخرى ( ) حددها.....

6/ هل لاحظت أن الحشائش بالمزرعة تصاب بالعنكبوت؟ نعم ( ) لا ( )

7/ في حالة نعم أذكرها:

1.....2.....

3.....4.....

8/ هل تكافح العنكبوت الأحمر؟ نعم ( ) لا ( )

9/ في حالة نعم ما هو نوع المكافحة؟ كيميائية بالمبيدات ( ) زراعية ( )

10/ في حالة رش المبيدات الكيميائية أذكر المبيدات التي تستخدمها

1.....2.....

3.....4.....

11/ كم عدد رشات المبيد التي تطبقها في العام؟

2-3 ( ) 4-5 ( ) 6-7 ( ) أكثر من 7 ( )

12/ الزمن بين الرشات بالأيام 1-3 ( ) 4-6 ( ) 7-10 ( ) أكثر من 10 ( )

13/ ما هو مقدار الفقد الذي تسببه هذه الآفة؟

0-25% ( ) 26-50% 51-70 ( ) 76-100( )

14/ هل لاحظت أي أصناف مقاومة للعنكبوت؟ نعم ( ) لا ( )

15/ في حالة نعم أذكرها:.....

16/ ما هو أكثر موسم من العام تكثر فيه الإصابة؟

الخريفي ( ) الصيفي ( ) الشتوي ( )