Study of the Efficacy of Oberon 240SC (Spiromesifen) and D-C-Tron Plus on the Red Spider Mite (*Tetranychus* spp) on Tomatoes (*Lycopersicon esculentum*) (Mill) and their Effect on Predatory Mite (*Phytoseiulus persimilis*) (Athias Henriot).

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Thesis submitted to the University of Nairobi, Plant Science and Crop Protection Department, in partial fulfilment of the requirements for the award of Masters of Science in Crop Protection

2005

DECLARATION

I Justin Mabeya Machini hereby declare that this thesis is my original work and has not been presented for a degree in any other University.

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DEDICATION

This work is dedicated to my beloved wife Kerubo, my son Maragia and daughters Nyanchoka and Moraa, who were supportive to me in one way or another through out the time of study.

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ABSTRACT

The overall objective of this study was to establish a cost effective and environmentally friendly control strategy of the red spider mites, *Tetranychus* spp, in tomatoes using Oberon 240SC and D-C-Tron Plus mineral oil. The efficacy of the two products, their mixture and a rotation was tested against the red spider mites (*T. evansi,* Baker and Pritchard) in the laboratory, green house and field conditions. The effect of the treatments on the beneficial capacity of the predatory mite (*Phytoseiulus persimilis* Athias Henriot) was also assessed in the laboratory and the mite species associated with the damage and loss on tomatoes in major tomato growing areas in Kenya were identified.

The ovicidal effect of Oberon 240 SC on the red spider mite (*T. evansi*) was 100%. The product however did not have acute toxicity on the motile stages of the mites, but completely deterred the adult females from laying eggs. D-C-Tron Plus caused mortality to the motile stages and reduced the percentage of eggs that hatched. The results for the mixture and the rotation were similar to those of Oberon 240SC alone. All the treatments were incompatible with the *P. persimilis*. Both in the green house and the field Oberon 240 SC, its rotation and mixture with D-C-Tron Plus showed very high ability to reduce the mite population and the results compared well with Dynamec 1.8EC a standard acaricide. The effect on fecundity of the mites and the ovicidal activity of Oberon 240SC lowered the mite population drastically in the field conditions.

The mites species associated with damage on tomatoes in Loitokitok, Kimana, Rombo and Maili Tatu areas of Kajiado District were a mixed population of *T. evansi* and *T. urticae* (Koch), while in Mwea, in Kirinyaga District *T. urticae* was found. In Subukia and Bahati of Nakuru District *T. evansi* was identified.

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CHAPTER ONE

1: INTRODUCTION

1.1: Origin, cultivation and constraints of tomato production in Kenya

The horticulture industry in Kenya has expanded rapidly in the last one decade to be the third highest foreign income earner in Kenya behind tea and transportation (EPC, 2000). Locally horticulture serves as a source of food, income and employment to many people.

Tomato, *Lycopersicon esculentum* (Mill.), originated in South America in the Peru / Equador region. It was not cultivated in the tropics until the 20th century, but it is now cultivated widely in the world. Tomato is grown for its fruit, which contains vitamins A and C when it is ripe. The fruit is used raw or cooked, made into soup, sauce, juice, ketchup, paste, puree or powder, canned, and used unripe in chutneys (Hill, 1994). In Kenya it is grown for domestic consumption as fresh or as processed products. Tomatoes also earn this country some foreign income (KRA, 2000) though this income is meagre, having been reduced from KShs.15,156,925.00 in 1994 to KShs.125,746.00 in the year 2000. These exports are mainly to Djibouti and Saudi Arabia (Anonymous, 2000).

Tomatoes are grown in all the provinces of Kenya (MOARD, 2001). The hectarage and production of tomatoes have not changed much over the last 10 years (Table 1).

Table 1: Tomato Production Statistics 1995-2004 (FAO, 2004)

Items	Year									
	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Hectarage	13,000	13,000	14,000	15,000	16,338	15,048	16,246	15,800	16,000	16,000
Production (Mt)	200,000	220,000	240,000	250,000	260,037	256,770	271,151	259,340	260,000	260,000

There are many limitations to the cultivation of tomatoes in the tropics (Villareal, 1980). Some of these constraints are diseases and pests. Some of the major diseases in Kenya are late blight (*Phytophthora infestans* (Mont.) de Bary), early blight (*Alternaria solani* Ell. and Martin), septoria leaf spot (*Septoria lycopersici* Spegazzini), bacterial canker caused by *Clavibacter michiganense* (Smith) Jensen and bacterial wilt caused by *Ralstonia solanacearum* (Smith). In Kenya a number of pests have been identified. These include, aphids (*Myzus persicae* Sulzer), African bollworm (*Helicoverpa amigera* Hübner), tobacco white fly (*Bemisia tabaci* Gennadius), the red spider mites (*Tetranychus* spp) russet mite (*Aculops lycorpersci* Massee), cutworm (*Agrotis segetum* Denis and Schiffermuller) and the root knot nematodes (*Meloidogyne javanica* Treub and *M. incognita* Kofoid and White) (MOARD, 2001)

There are a number of species of the red spider mites (*Tetranychus* spp) that have been associated with the red spider mite attack in Kenya. These include *T. cinnabarinus* (Boisduval), *T. lombardini* (Baker and Pritchard). *T. urticae* (Koch) and *T. evansi* (Baker and Pritchard) (Varela *et al.*, 2003), which was introduced to Africa from South America (Knapp, 2002). Kamau (1977) reported that the red spider mites (*Tetranychus* spp) is one of the serious pest of tomato wherever it is grown in semi-arid areas under irrigation and in other areas where the crop experiences periods of warm dry spells.

1.2: Problem Statement

The need for environmentally friendly pesticides and pest control practices is becoming stronger by the day. While there is ample information of the effect of acaricides on spider mites, there are very few detailed studies focussing on natural enemies. This work encompasses the management of red spider mites using Oberon 240SC (a new pesticide in the market) and D-C-Tron Plus, a mineral oil, and their effect on the predatory mite *Phytoseiulus persimilis* (Athias Henriot).

1.3: Justification

The use of pesticides in crop protection has attracted and continues to attract a lot of attention from consumers in and outside of Kenya. This is because of the residues associated with the use of pesticides on crops. Certification of the required maximum residue levels (MRLs) is now a major conditionality for fresh produce exports to the European market, the most important export destination for cut flowers and vegetables from Kenya. This being the case there is urgent need for use of pesticides whose MRLs level is already set. Further these products need to be those that would be applied at low volumes per unit area and yet effective against the target. These requirements fit the description of Oberon 240SC.

There are many examples in literature of the use of pesticides without any regard to their effects on the ecosystem or the development of resistance to pesticides. Information is required on the impact of pesticides on the natural enemies in order to use products with least effects on them, in integrated pest management (IPM) systems (Kumar, 1990). The use of mineral oils in agriculture is supported by its synergist mode of action. Its use has been known to increase the effectiveness of otherwise less effective chemicals by increasing their toxicity against the target pests (Rae, 2000). Its use in a pesticide mixture will enable use of chemicals at low concentrations, which will be more environmentally friendly and at the same time reduce possible residues in a crop by the time of harvest. This will most probably lower the cost of pesticide use.

Oil works as a pesticide by suffocating the target pests. It can therefore be used in the management of a large number of pests. Mineral oils at the same time are known to have less negative environmental effect in the area of use in agriculture than many synthetic pesticides (Rae 2000). Combined use of mineral oils with a pesticide in this case Oberon 240SC and D-C-Tron Plus will be more environmentally friendly especially with reduced rates of the acaricide than the use of individual synthetic pesticides. This combination in a rotation is expected to preserve a number of natural enemies.

One positive impact of this control measure will be reduced possible resistance by the red spider mites to Oberon 240SC. As a result the mites will continue to show a cycle of high susceptibility to Oberon 240SC. Secondly it will reduce the possibility of pests resurgence associated with high use of pesticides. By eliminating unnecessary insecticide application, this system reduces production costs. Thirdly, there will be an increase of the population of natural enemies resulting from reduced use of synthetic pesticides in pest control (Herren, 1990).

Fowden (1990) reported that there has been manifested in the developing countries pesticide misuse, which usually leads to resistance. Use of mineral oil, which is not known to lead to pest resistance and which at the same time is less hazardous than many pesticides, will go a long way in reducing these problems associated with the use of synthetic pesticides.

In Kenya there is a taxonomic problem with the red spider mites. Identification of the specific species of the genus *Tetranychus* responsible for the damage in tomato is vague. For the purposes of this work, unless where indicated the red spider mites will be referred to by its genera name, *Tetranychus* spp.

1.4: Objectives

1.4.1: Broad Objective

To establish a cost effective and environmentally friendly control strategy of the red spider mites, *Tetranychus* spp, in tomatoes.

1.4.2: Specific Objectives

1. To identify the species of red spider mites causing damage and losses in tomatoes in parts of Kirinyaga, Kajiado and Nakuru districts.
2. To determine the effect of Oberon 240SC, D-C-Tron Plus and their mixture on the red spider mites (*T. evansi*) under laboratory conditions.
3. To determine the efficacy of the Oberon 240SC, D-C-Tron Plus, their mixture and rotation, in the control of red spider mites (*Tetranychus* spp) in greenhouse and field conditions.

4. To determine the effect of Oberon 240SC, D-C-Tron Plus and their mixture on the predatory mite *P. persimilis* in laboratory conditions

1.5: Hypotheses

1. Use of Oberon 240SC will have minimum effect on the natural enemies and yet control the red spider mites, *Tetranychus* spp on tomatoes.
2. The use of D-C-Tron Plus and Oberon 240SC as a mixture or in rotation will control the red spider mites and have minimum effect on the natural enemies.
3. There exists a relationship between the concentration of Oberon 240SC used per unit area in the control of red spider mites and the number of natural enemies in such a field while other factors are held constant.

1.6: References

Anonymous, (2000). Horticultural Crops Development Authority statistics of figures of fresh fruits, vegetables and cut flowers by air from Kenya to various destinations. EPC, (2000). Export Promotion Council, economic survey. Values of major Kenya exports: 1990-2000.

FAO, (2004). Food and Agriculture Organization of the United Nations, tomato production statistics in Kenya available online at: http://faostat.fao.org/.

Fowden, G. M., (1990). Integrated pest management: Considerations for success in the developing countries. In: Hahn. S. K. and Caveness F. E. (Eds), Integrated Pest Management for Tropical Root and Tuber Crops. International Institute of Tropical Agriculture, pp. 9-13.

Herren, H. R., (1990). The Africa wide biological control programme. In: Hahn, S. K. and Caveness F. E. (Eds), Integrated Pest Management for Tropical Root and Tuber Crops. International Institute of Tropical Agriculture, pp. 33-41.

Hill, D. S., Waller J. M., (1994). Pests and diseases of tropical crops. Field handbook. Longman Scientific and Technology, Harlow, pp 358-363.

Kamau, A. W., (1977). Effect of Eriophyd mite *Aculops lycopersci* (Massee) (Acarina: Eriophidae) on tomato in Kenya. Kenya Entomologists Newsletter, No.5 pp 4.

Knapp, M. (2002). Important mite crop pests in Africa. Abstracts, XI International Congress of Acarology, Meride, Mexico. pp. 120.

KRA, (2000). Kenya Revenue Authority, Customs Department. Kenya's trade in tomatoes (chilled or fresh) 1994-2000. Report compiled by Centre for Business Information (CBIK), Export Promotion Council, Nairobi.

Kumar, R., (1990). Principles and philosophy of integrated pest management. In: Hahn, S. K. and Caveness F. E. (Eds), Integrated Pest Management for Tropical Root and Tuber Crops. International Institute of Tropical Agriculture, pp 14-17.

MOARD, (2001). Ministry of Agriculture and Rural Development provincial annual reports.

Rae, D. J., (2000). Use of spray oils with synthetic insecticides, acaricides and fungicides. Centre for Horticulture and Plant Sciences, University of Western Sydney, Locked Bag 1797, South Penrith Distribution Centre, New South Wales 1797, Australia. Available online on; http://sprayoils.uws.edu.au//rae.shtml.

Varela, A. M., Seif, A. A. and Löhr, B., (2003). A guide to IPM in tomato production in Eastern and Southern Africa. ICIPE Science Press, Nairobi, pp 21-26.

Villareal, R. L., (1980). Tomatoes in the tropics. Westview Press, Boulder Colorado, pp 109-110.

CHAPTER TWO

2: LITERATURE REVIEW

2.1: Species of mites

Mites of importance in crop protection mainly fall in the families Eriophydae and Tetranychidae. The russet mite, *Aculops lycorpersci* (Massee) (Acarina: Eriophydae) can be the most serious pest of tomatoes grown during the dry season (Kamau, 1977). The red spider mite *Tetranychus* spp is also a major constraint to obtaining high yields of tomatoes. These two mites have been reported as major pests of tomato in Central Province (Anonymous, 1975, 1976).

Two species of *Tetranychus* are commonly found in Eastern and Southern Africa. These include *T. evansi* mainly in Southern Africa and *T. urticae* in Eastern Africa. *T. evansi* is known to cause more damage on tomatoes than *T. urticae* (Lohr *et al.*, 1998). *T. evansi* is wide spread in Southern Africa and is now found in Kenya (Knapp, 2002a). *T. evansi* is regarded as one of the key arthropod pests of tomato in Zimbabwe (Sibanda, *et al.*, 2000) causing yield losses of up to 90% in small holder production. In contrast, even though *T. urticae* is a common pest of vegetables in southern and eastern Africa, it is usually not a major problem on tomato (Knapp *et al.*, 2003). The temperature range within which *T. evansi* can develop that is from 10°C to more than 36°C is very broad. This could corroborate the high adaptability of this phytophagous mite to various environmental conditions and explain their wide distribution (Bonato, 1999).

2.2: The Red Spider Mites (*Tetranychus* spp)

2.2.1: Anatomy

When it is young the red spider mite is almost colourless or may be slightly beige in colour. As it begins to feed on the green sap of the leaves two spots develop. These are the spider mite guts, which can be seen filling up with the dark green sap (Labouchagne, 1999). The adults of the different spider mites show different colours. *T. cinnabarinus* (red spider mite) and *T. urticae* (two spotted spider mite) are yellow green to brownish red with two spots on the side of the body. In a very dark specimen these spots are very difficult to see. *T. evansi* (tobacco spider mite) on the other hand is orange red with an indistinct dark blotch on each side of the body and reddish legs (Varela *et al.*, 2003).

The spider mites measure up to 0.80 mm in length. They are oval shaped with the males smaller than the females and have a narrow portion towards the rear. The spider mites receive their name from their ability to spin a fine web over the leaves of the plant where they feed and at times the entire plant may be covered by this webbing (Baker and Wharton, 1952).

2.2.2: Symptoms of Attack on Tomato Plants and Related Losses.

Normally the spider mites come in with the wind from adjacent infested fields (Labouchagne, 1999). The mites suck the contents of the cells, and produce a characteristic mottling on the upper surface of the leaves. Webs appear with heavy infestations (Plate 1) and if left uncontrolled the leaves go completely brown and drop off and the plant may die (Baker and Wharton, 1952).

Plate 1: Webbing due to heavy mites infestation, (Knapp, 2002b)

Once the damage has been done it does not go away. It remains as a historical evidence of spider mite presence. Excessive webbing will provide some protection from agrochemical sprays. However the predatory mite, *P. persimilis* is able to move under the webbing to feed on the spider mites (Labouchagne, 1999).

According to Kamau (1985), the red spider mites, *Tetranychus* spp infest and cause heavy damage to tomato plants of about 25% in Kirinyaga and 10% in Kajiado districts. The percentage of farms infested with *Tetranychus* spp in Nakuru, Kiambu, Kajiado, and Kirinyaga in 1985 was about 25%, 20%, 45% and 65% respectively. Percentage yield losses caused by *Tetranychus* spp in the same districts ranged from 40 to 50%. *T evansi* first reported in Kenya in 2001 (Knapp, 2002a) can cause yield loss of up to 90% in smallholder production systems in Zimbabwe (Knapp *et al.*, 2003). Its spread in Kenya has however not been established.

2.2.3: Pest Populations

Spider mites reproduce very fast in hot weather. as they are able to reproduce very rapidly, when environmental conditions are favourable. Female spider mites can lay up to 150 eggs during their lifetime at a rate of 5-6 eggs per day. The time between egg and adult reduces with temperature increase but it may vary from 6 – 12 or more days depending on species, temperature, host plant, humidity and other factors (Crooker, 1985; Bonato, 1999) (Plate 2). *T. evansi* displays a higher rate of increase within a broad range of temperature when compared to other species of the same family (Bonato, 1999).

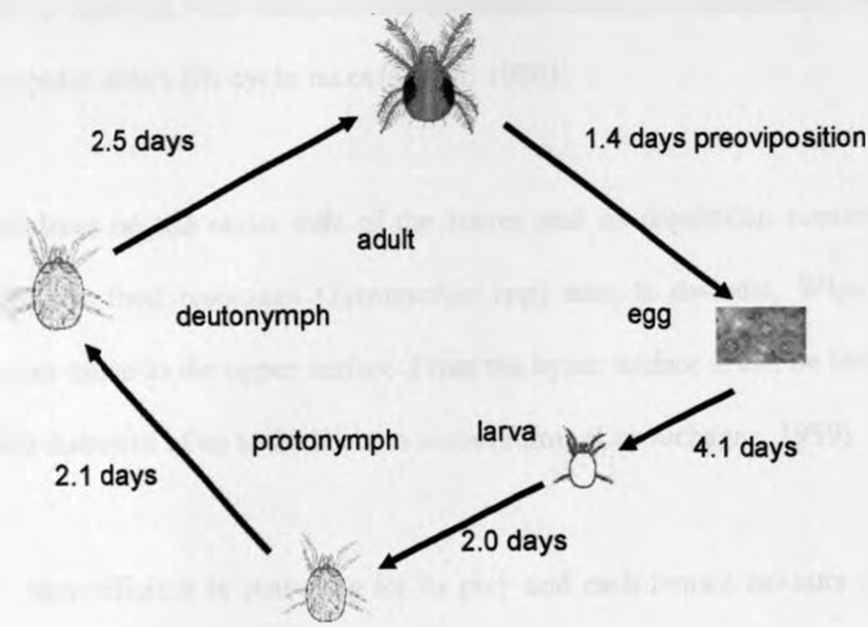

Plate 2: Life cycle of *T. evansi*. Source: Bonato, 1999

The optimum temperature for most rapid development for many tetranychids is from 24 to 29°C (Boudreaux, 1963). Daily fecundity of *T. evansi* increases according to temperature up to a maximum of 31°C and starts to decrease thereafter (Bonato, 1999). In case of deteriorating food supply *Tetranychus* spp abandon their host in search of new plants on which to feed (Jeppson *et al.*, 1975).

2.3: Predatory Mite (*P. persimilis*)

This is a predatory mite and as such will move much faster on the leaves than the spider mites. It has a red pear shaped body with a glossy appearance and is slightly larger than the spider mite (Labouchagne, 1999). An adult lays 50-60 eggs at 20°C at the rate of 3 - 4 per day, which hatch in 2 - 3 days. The eggs of *P. persimilis* are light red to pinkish orange. The immature forms (1 larval and 2 nymphal stages) are greyish white to light red. The complete life cycle takes about 7 days, almost half the duration the spider mite's life cycle takes (Meyer, 1996).

The predator lives on the under side of the leaves and its population continues to increase until the food resources (*Tetranychus* spp) start to dwindle. When fully exhausted, they move to the upper surface. From the upper surface it can be blown by wind for long distances of up to 20 hectares across farms (Labouchagne, 1999).

The mite is very efficient in searching for its prey and each female devours up to 5 adults, or 30 eggs and young spider mites per day. It does not feed on plant parts and its survival depends on the maintenance of a low level of spider mites population. However, experience has shown that some individuals will survive for at least 3 weeks after their prey had been eliminated (Meyer, 1996).

2.4: Surveys done in Kenya on the red spider mites (*Tetranychus* spp)

A survey done in Kenya in 1998 (Lohr. *et al.*, 1998) reports that *T. urticae* the species with worldwide distribution and a wider host range was the predominant species. This explains the higher severity of mite attack in southern Africa compared to Kenya. The report also indicates that red spider mites were only a problem in areas where farmers treated their crops frequently with broad spectrum insecticides. A survey on tomato growing practices, red spider mites composition and natural enemies (ICIPE, 2003), showed *T. urticae* as being the predominant mite species in Kenya and that infestations were only found in areas with intensive horticultural production, mainly for export, which are associated with higher pesticides use, than the others. The report also indicates that this situation was expected to change since *T. evansi* was detected in Kenya in May 2001. Kamau (1977), also reported that the red spider mites (*Tetranychus* spp) is one of the serious pest of tomato wherever it is grown in semi-arid areas under irrigation and in other areas where the crop experiences periods of warm dry spells.

2.5: Control of Red Spider Mites, *Tetranychus* spp

2.5.1: General Methods of Control

Mites prefer dry and hot conditions. Influencing the microclimate by reducing the spacing and applying overhead irrigation has been said to suppress the mite populations. However, this could also enhance fungal diseases, so care should be taken. Water and nutrient stress should be avoided since this has been proven to increase mite populations. Applying mulch and incorporating organic matter into the soil can improve the water holding capacity and reduce evaporation, thus avoid water stress (Keizer and Zuurbier, 1998).

Chemical pesticides are the most frequently used and the most effective pest control tools. Biological control that is, control with the use of natural enemies is cheap, effective, permanent, and non-disruptive of the ecosystem. Unfortunately it is the factor that is likely to be disturbed by the employment of other pest control tactics especially after the use of pesticides (Flint and van den Bosch, 1981).

Varietal resistance is a major element in integrated control of spider mites; it is the least expensive and the easiest technique for plant protection. It has been tried in beans, cucumber, tomato and strawberry. (Impe and Van Hance, 1993).

2.5.2: Use of the Predatory Mite, *P. persimilis* and others in the Control of Red Spider Mites, *Tetranychus* spp.

P. persimilis preys exclusively on phytophagous mites such as *Tetranychus* spp, and it is used in controlling *T. urticae*. This use has increased considerably since the first trials by Bravenboer and Dosse (1962). On *T. evansi* the oviposition rate of *P. persimilis* has been observed to be 4 to 6 times lower than when preying on *T. urticae*. The phytoseiid has also shown lower survivorship when fed on *T. evansi* than *T. urticae*. This indicates that *T. evansi*, which is quickly spreading in Kenya, is an unfavourable prey for *P. persimilis* (Moraes and McMurtry, 1985).

As a biological agent it is used more and more in several countries for the control of red spider mites (*T. urticae*) in green houses (Van Zon and Wysoki, 1978). It has also been used on outdoor crops in the USA and in Israel. It is susceptible to many chemical insecticides (Van Zon and Wysoki, 1978), which complicates its use in integrated control programmes.

Studies by Takafuji and Chant (1976) showed that *P. persimilis* distributes itself over the webs where it places its eggs. Sabelis (1985) also showed that *P. persimilis* does better in webbed mites. In fact, *T. urticae* webs attract *P. persimilis* more than the prey eggs (Schmidt, 1976)

Use of natural enemies to control pests of tomato in Switzerland in glasshouses resulted in reduction of pesticide use by 40%. This allowed for spontaneous development of the indigenous natural enemies such as *Aphidius matricariae* (Haliday) and *Aphidoletes aphidimyza* (Rond.). Release of *P. persimilis* against *T. urticae* was moderately successful (Granges and Leger, 1998).

Only a few species of predatory mites have been reported to be associated with *T. evansi*. Among these are the phytoseiids *Amblyseius caudatus* (Berlese), in the Mauritius Island (Moutia, 1958) and several species in Brazil, including *Ambyseius idaeus* (Denmark and Muma), *Euseius citrifolius* (Denmark and Muma), *Euseius sibelius* (Deleon), *Phytoseius quianensis* (Deleon) and *Phytoseius pemambiucanus* (Moraes and McMurtry) (Moraes and McMurtry, 1983). The effect of these phytoseiids on the population of *T. evansi* is unknown (Moraes and McMurtry, 1985).

2.5.3: Use of Pesticides

There are a number of pesticides registered in Kenya for the control of red spider mites. These are either synthetics like Kelthane 18.5 EC and botanicals like Neemroc. Oberon 240SC and D-C-Tron Plus are synthetics (PCPB, 2002)

The potential of using petroleum-derived oils to control plant pests was recognised as early as the first century AD when Pliny the Elder recorded the use of crude oils, which are among the oldest known organic pesticides (Johnson 1982, Agnello *et al.*, 2000). The control of *Tetranychus urticae* using 1% mineral oil treatment has been shown to be significantly better than other conventional pesticide treatment. At the same time the comparison of pesticide and oil application costs indicated that the oil based pest and disease management programme would be cheaper than the pesticide programme (Singh *et al.*, 2000).

Oils have three principal advantages over contact acaricides (Chapman, 1967). First they have been determined to pose a small human health hazard and thus they are exempted from requirement of tolerance. A second advantage of oils is the apparent inability of the insects and mites to develop resistance to them, most probably because of the oils' presumed smothering mode of action. Predatory mites populations are not as likely to be severely affected by these sprays (Lienk *et al.*, 1980). Oils pose few risks to people or to most desirable species, including natural enemies of insect pests. This allows oils to integrate well with biological control. Toxicity is minimal at least compared to alternative pesticides, and oils quickly dissipate through the evaporation, leaving little residue. The main limitation of oils is their small but real potential to cause plant injury (phytotoxicity) in some situations. (Cranshaw and Bexandale, 2000).

Probably most important, oils demonstrate reliable efficacy at relatively low cost. It is apparent that, the oil recommendations for mite control are based on the assumption that, mortality is generally confined to eggs and motile forms are generally able to survive oil applications. However this assumption has not been investigated systematically (Welty *et al.*, 1988, 1989).

In Kenya a few mineral oils are registered as pest control products. D-C-Tron Plus which is 98.8% mineral oil is registered for the control of a number of pests including the red spider mites, *Tetranychus* spp. (PCPB, 2002). D-C-Tron Plus as an insecticide / acaricide works by suffocation, desiccation, interference with insect metabolic functions, deterrence on oviposition and deterrence on feeding activity. Deterrence experimental work on the two-spotted mite (*Tetranychus* spp) showed that the number of eggs deposited was decreased by 81% in 0.5% D-C-Tron Plus treatment after 6 days. The relationship between the number of eggs deposited and the concentration is a negative exponential relationship. D-C-Tron Plus is compatible with predatory mites, *P. persimilis* (Thwaite, *et al.*, 2000).

Trials conducted in Kenya to evaluate the efficacy D-C-Tron Plus against the red spider mites (*Tetranychus* spp) on tomatoes revealed that, the test product is of high potential in the management of the pest. The trials revealed that D-C-Tron Plus at the rate of 5.0 ml per litre of water was the most cost effective rate of all the rates tested

(Kambo, 2000). Reports from elsewhere also indicate that farmers achieve reasonable control of mite infestation with the use of D-C-Tron Plus on its own or even as a mixture with other synthetic pesticides (Sonoiya, 2002).

Spiromesifen (Oberon 240SC) a derivative of tetronic acid is representative of the Bayer Crop Science own new chemical class of ketoenols. This is an insecticide against whiteflies (*Bemisia* spp. and *Trialeurodes* spp.) with acaricidal activity against *Tetranychus*. It is a non-systemic compound, which is active against all development stages. For its mode of action there is strong evidence that the product interferes with the insect development probably interfering with lipid biosynthesis in insects and mites. Otherwise this subject is still under investigation. Oberon 240SC active ingredient provides a long lasting control of mites and is particularly active against the juvenile stages of the mites but it also reduces fecundity of the adults. The product also displays ovicidal activity on mites (Anonymous, 2002).

Tests on whiteflies (*Bemisia* spp. and *Trialeurodes* spp.) have shown no cross-resistance with organophosphates, carbamates or pyrethroids. Oberon 240SC has very low acute oral toxicity (LD50: >2500 mg/kg body weight) in male and female rats (Anonymous, 2002).

Webs developed by the mites may act as protective canopy against synthetic pesticide particles holding spray droplets and dust grains from the mites. Davis (1952) and Linke (1953) urgently advocated the destruction of webs during chemical control procedures.

Some pesticides induced *T. urticae* to let itself down from sprayed leaves by a thread behaviour termed 'spindown' by Gemrich *et al.*, (1976). Penman and Chapman (1983) identified the spindown of *T. urticae* with avoidance and repellence by the synthetic pyrethroid Fenvalerate. Chemical residues induced spindown of many mites from treated leaves. Mites spinning down from treated plants in the field would be disseminated by wind. This is probably one of the mechanisms contributing to pyrethroid induced spider mite outbreaks.

2.6: References

Agnello, A., Beattie, G. A. C., Watson, D. M., Stevens, M. and Rae, D. J., (Eds), (2000). Petroleum-derived spray oils: chemistry, history, refining and formulation. In: Spray Oils Beyond 2000 – Sustainable Pest and Disease

Anonymous, (1975). Annual reports Ministry of Agriculture, Central Province, Kenya pp. 41.

Anonymous, (1976). Annual reports Ministry of Agriculture, Central Province, Kenya pp. 25.

Anonymous, (2002). Bayer East Africa Ltd. BSN 2060 (Spiromesifen). Summary of the biological activity of the product. 22 April, 2002, pp8 (Unpublished).

Baker, E. W and Wharton, G. W., (1952). An introduction to acarology, Macmillan, New York, pp 211-213.

Bonato, O. (1999). The effect of temperature on life history parameters of *Tetranychus evansi* (Acari: Tetranychidae).Exp. Appl. Acarol. 23: 11-19.

Boudreaux, H. B., (1963). Biological aspects of some phytophagous mites. Annu. Rev. Entomol., 8: 137-154.

Bravenboer, L. and Dosse, G., (1962). *Phytoseiulus riegelli* als Pradator einiger Schadmilben aus der *Tetranychus urticae* Gruppe. Entomologia exp. Appli. 5: 291-304.

Chapman, P. J., (1967). Petroleum oils for the control of orchard pests. New York State Experiment Station. Bulletin 814: 1-24

Cranshaw, W. S. and Bexandale, B., (2000). Insect control: Horticultural oils. No. 5.569. Available online http://www.ext.colostate.edu/pups/insect/05569.html

Crooker, A., (1985). Embryonic and juvenile development. In: Spider mites, their biology, natural enemies and control. World Crop Pests. Vol. 1A. pp.149-154.

Davis, D. W., (1952). Influence on population density in *Tetranychus multisetis*. J. Econ. Entomol., 49: 624-627.

Flint, M. R., van den Bosch, R., (1981). Introduction to integrated pest management, Plenum Press. New York, pp. 121-179.

Gemrich, E. G. II, Lamar Lee, B., Tripp, T. L. and Van de Streek, E., (1976). Relationship between formamidine structure and insecticidal, miticidal and ovicidal activity. J. Econ. Entomol. 69: 301-306.

Granges, A. and Leger, A., (1998). Biological control in glasshouse against tomato and cucumber pests. Evaluation of studies and observations over 10 years at Centre des Fougeres, Rev de Suisse de Viticult. Arboricult Horticult. 30: 65-71.

ICIPE, (2003). Development of environmentally friendly management methods for red spider mites in small-holder tomato production systems in eastern and southern Africa. Final project report (phase 1). pp 187.

Impe, G., Van Hance T., (1993). A technique for testing for Varietal susceptibility to the mite, *Tetranychus urticae* (Acari: Tetranychidae), Application to bean, cucumber, tomato and strawberry. Agronomie, 13: 739-749.

Jeppson, R. L., Keifer, H. H. and Baker, W. E., (1975). Mites injurious to economic plants. University of California Press, Berkeley and Los Angeles, CA, xxiv +614 pp 64.

Johnson, W. T., (1982) Horticultural spray oils for tree pest control. Weeds, Trees and Turf. May: 36-40.

Kamau, A. W., (1977). Effect of Eriophyd mite *Aculops lycopersci* (Massee)

(Acarina: Eriophidae) on tomato in Kenya. Kenya Entomologists Newsletter, No.5 pp 4.

Kamau. A. W., (1985). The biology and control of tomato russet mite, *Aculops lycopersci* (Massee) (Acarina: Eriophyidae) in Kenya, PhD thesis, University of Nairobi, pp. 24-26.

Kambo, C. M., (2000). Efficacy of D-C-Tron Plus against some major pests of orange, kale, tomato and French beans in Kenya. D-C-Tron Workshop held at Grand Regency Hotel, Nairobi on 24th March 2000.

Keizer, M., Zuurbier, J., (1998). Integrated Pest Management for Horticultural crops in Namibia, Proceedings of the National Annual Agricultural Research Reporting Conference, MAWRD September 1998.

Knapp, M. (2002a). Important mite crop pests in Africa. Abstracts, XI International Congress of Acarology, Meride, Mexico. pp. 120.

Knapp, M. (2002b). Heavily infested tomato branch: Picture taken at a field experimental plot at field station in Upper Kabete Campus at the University of Nairobi.

Knapp, M., Wagener, B. and Navajas, M. (2003). Molecular discrimination between the spider mite *Tetranychus evansi* (Baker and Pritchard), an important pest to tomatoes in Southern Africa, and the closely related species *T. urticae* (Koch). African Entomology, 11: 300-304.

Labouchagne, L., (1999). Identification of and life cycle of pests, Dudutech (Unpublished)

Lienk, S. E., Watie C. M., Wieres R. W., (1980). Phytophagous and predacious mites in New York. Search 6 (Geneva): 1-14

Linke, W., (1953). Investigation of the biology and epidemiology of the common spider mite *Tetranychus althaeae* v. Hanst. With particular consideration of the hop as the host. Hoefchen – Briefe (Engl. Ed.), 6: 181-232.

Lohr, B., Knapp, M., Sarr, I., Nzuma, I., (1998). Development of environmentally friendly management methods for red spider mites in smallholder tomato production systems. 1998-1999 ICIPE Scientific Report, pp. 88 – 91, ICIPE, Nairobi.

Meyer, M. K. P. S., (1996). Mite pests and their predators on cultivated plants in Southern Africa. Vegetables and berries. Biosystematics Division, Agricultural Research Council, Pretoria, pp. 64 – 69.

Moraes, G. J. and McMurtry, J. A., (1983). Phytoseiid mites (Acarina) of North Eastern Brazil with descriptions of new species. Int. J. Acorol. 9, 131-148

Moraes, G. J. and McMurtry, J. A., (1985). Comparison of *T. evansi* and *T. urticae* (Acari: Tetranychidae) as prey for eight species of phytoseiid mites. Entomophaga 30 (4), 393-397.

Moutia, L. A., (1958). Contribution to the study of some phytophagous Acarina an their predators in Mauritius. Bull. Entomol. Res. 49: 59-75.

PCPB, (2002). Pest Control Products Board. List of registered pest control products in Kenya.

Penman, D. R. and Chapman, R. B., (1983). Fenveralerate – induced distributional imbalances of two spotted spider mites on bean plants. Entomol. Exp. Appl., 33: 71-78.

Sabelis, M. W., (1985). Development. In: Helle, W. and Sabelis M. W. (Eds); Spider mites. Their biology, natural enemies and control. World Crop Pests, Vol. 1B, Elsevier Amsterdam pp.43-53.

Schmidt, G., (1976). Der Einfluss der von den Beutetieren hinterlassenen Spuren auf Suchverhalten und Sucherfolg von *Phytoseiulus persimilis* A.H. (Acarina: Phytoseiidae). Z. Angew. Entomol. 82: 216-218.

Sibanda, T., Dobson, H. M., Cooper, J. F., Manyangarirwa, W. and Chiimba, W., (2000). Pest management challenges for smallholder farmers in Zimbabwe. Crop Protection 19: 807-815.

Singh, P., Beattie G. A. C., Clift, A. D., Watson, D. M., Furness, G. O., Tesoriero, L., Rajakurendran V., Parkes R.A., Scones M., (2000). Petroleum spray oils and tomato integrated pest and disease management in Southern Australia. General and Applied Entomology, 29: 69 – 93.

Sonoiya, (2002). Personal communication with Mr Bernard Sonoiya, Murphy Chemicals E.A. Ltd

Takafuji, A., Chant D. A., (1976). Comparative study of two species of predacious phytoseiid mites (Acarina: Phytoseiidae) with special reference to their responses to the density of their prey. Res. Ecol. 17: 255-310.

Thwaite, G. W., Eslick, M. A. and Nicol, H. I., (2000). Evaluation of petroleum derived spray oils for integrated pest and disease management in apple orchards. NSW Agriculture, Orange Agricultural Institute, Forest Road, Orange, New South Wales 2800, Australia. Available online on: http://sprayoils.uws.edu.au//rae.shtml.

Varela, A. M., Seif, A. A. and Löhr, B., (2003). A guide to IPM in tomato production in Eastern and Southern Africa. ICIPE Science Press, Nairobi, pp 21-26.

Van Zon, Q. A., Wysoki, M., (1978). The effect of some fungicides on *Phytoseiulus* *persimilis* (Acarina: Phytoseiidae). Entomophaga. 23:371-378.

Welty, C., Reisigg, W. H., Dennehy, T. J., Weires. R. W., (1988). Susceptibility to hexythiozox of eggs of European red mite (Acari: Tetranychidae). J. Econ. Entomol. 81: 586-592.

Welty, C., Reisigg, W. H., Dennehy, T. J., Weires, R. W., (1989). Activity of clofentezine against European red mite (Acari:Tetranychidae). J. Econ. Entomol. 82: 197-203.

CHAPTER THREE

3: GENERAL MATERIALS AND METHODS

3.1: Experimental Sites

Three sets of experiments were conducted in the laboratory, greenhouse and field. The laboratory experiments were conducted at the International Centre of Insect Physiology and Ecology (ICIPE) in Nairobi while the greenhouse experiments were conducted at the Jomo Kenyatta University of Agriculture and Technology (JKUAT) in Juja. The field experiments were conducted at the University of Nairobi farm at the College of Agriculture and Veterinary Services (Upper Kabete) situated in the Kenyan capital, Nairobi 05° 13.12° South, 036° 09.04° East (GPS System). A field survey was also conducted in some parts of Kajiado, Kirinyaga and Nakuru Districts.

3.2: Experimental Materials

Certified tomato seed (Cal-J variety) was purchased from a registered farm inputs outlet store in Nairobi. The variety was chosen because it is the most popular cultivated variety in Kenya accounting for about 80% of the tomato production in the country. The variety was used for laboratory, greenhouse and field experiments. Genuine pesticides were sourced from the respective local Registrants (Agents). Oberon 240SC (Spiromesifen) was sourced from Bayer East Africa Ltd, Crop Science Division, the mineral oil (D-C-Tron Plus) from Murphy Chemicals Ltd. and abamectin (Dynamec 1.8EC) from Syngenta East Africa Ltd (PCPB, 2002). ICIPE provided the laboratory equipment like petri dishes, fridges and microscopes and also the necessary materials for the greenhouse like the pots.

Discs measuring 25mm were cut out from fresh tomato leaves taken from plants that were yet to flower, grown under green house conditions. These were taken every time they were needed for an experiment. For the field and greenhouse experiments the seeds were sown in the nursery and maintained there for a period of about four weeks after which they were transplanted into pots or into the field. In the nursery the crop was sprayed with mancozeb 80% (Dithane M-45) to protect it from *P. infestans* (late blight). This was done as often as need arose. In the field the seedlings were planted at a spacing of 45cm intra-row and 60cm inter-row.

3.3: Experimental Layout and Maintenance of the Tomato Crop

The laboratory and greenhouse experiments were laid in a complete randomised design (CRD), with four replications while the field experiments were laid in randomised complete block design (RCBD) with four replications. Before sowing of the seeds, the nursery was well prepared and the pot mixture worked at a ratio of 2:1:1, by weight for the topsoil, sand and manure. During transplanting to the field Diammonium Phosphate (DAP) (46% P_2O_5) was mixed well with the soil at the rate of 200kg per hectare (MOARD, 2003). Top dressing was applied in two splits of Calcium Ammonium Nitrate (CAN) (26% N) fertilizer at the rate of 100kg per hectare two and four weeks after transplanting just before flowering when the plant is approximately 25 cm high (MOARD, 2003). After transplanting the pots and the field were kept weed free manually. In the field weeding was done in the second, fourth and sixth week after transplanting. During the first two weeks after transplanting irrigation was by sprinkler method and thereafter manually under the plant canopy using watering cans. Manual watering was done in order to ensure that the mites

(*Tetranychus* spp) were not washed away by the irrigation water. Late blight outbreaks in the field were managed by spraying with Milraz 70 WP (Propineb 70% and Cymoxanil 6%) at a rate of 2kg per hectare which is equivalent to 40g per 20 litres of water (PCPB, 2002) with the sprayer calibrated at 4bars psi. Two field experiments were conducted, one greenhouse experiment and fourteen laboratory bioassays. The first field experiment was planted in the nursery on 25th October 2002, transplanted on 3rd December 2002 and terminated on 17th March 2003. The second field experiment was planted in the nursery on 22nd June 2003, transplanted on 20th July 2003 and terminated on 5th December 2003.

3.4: Data Analysis

Raw data from all the experiments was keyed in using the Microsoft Excel computer package. The data was subjected to analysis of variance (ANOVA) (Appendices 2-16) using the SAS computer package (SAS, 1990).

3.5: References

MOARD, (2003). Ministry of Agriculture and Rural Development. Fruits and vegetables technical handbook. Printed by Agricultural Information Centre, Waiyaki Way, Nairobi, pp 81-87.

PCPB, (2002). Pest Control Products Board. List of registered pest control products in Kenya.

SAS Institute (1990). SAS users' guide. Cary North Carolina USA.

CHAPTER FOUR

SPECIES DISTRIBUTION OF THE RED SPIDER MITES (*Tetranychus* spp) IN MAJOR TOMATO GROWING AREAS OF KIRINYAGA, NAKURU AND KAJIADO DISTRICTS OF KENYA.

4.1: Abstract

A preliminary survey was conducted in some of the major tomato growing areas in Kenya, including Kirinyaga, Nakuru and Kajiado districts to sample and identify the red spider mite (*Tetranychus* spp) species associated with infestations in those areas. The purpose for this survey was to establish the extent of spread of the different mite species that attack tomatoes. A total of 30 farms were sampled in all the areas, with 18 in Maili Tatu, Rombo and Kimana areas of Kajiado district, six in Subukia and Bahati areas of Nakuru district and six in Mwea of Kirinyaga district. In each area samples were taken from farms within a kilometre from each other, or the immediate farm after the kilometre. The results indicate that the major species of the red spider mites associated with the tomatoes in Mwea and Kajiado was *T. urticae*, while in Nakuru it was *T. evansi*.

4.2: Introduction

A number of species have been associated with the red spider mites (Acari: Tetranychidae) (*Tetranychus* spp) attack in Kenya. These include *T. cinnabarinus, T. lombardini, T. urticae* (Varela, *et al.*, 2003) and *T. evansi*, which was introduced to Africa from South America (Knapp, 2002). Effective control of agricultural pests requires understanding of the kind of pests even to species level. Identification of the *Tetranychus* species can be done using the differences in the morphological characteristics, mainly the shape of the terminal knob of the aedugus (a part of the male genitalia (Knapp *et al*, 2003). Reports attributed to farmers from the high tomato growing areas in Kenya indicate increased mite problems in the areas some of which they are unable to manage using the common pesticides at their disposal. This scenario reflects a possibility of entry of new species of mites into the country. *T evansi* first reported in Kenya in 2001 (Knapp, 2002) can cause yield loss of up to 90% in smallholder production systems in Zimbabwe (Knapp *et al.*, 2003). Its spread in Kenya has however not been established.

4.3: Materials and Methods

4.3.1: Sampling and Collection

Three districts, Kirinyaga, Nakuru and Kajiado are some of the highest tomato producing areas in Kenya. Samples of tomato plants and other plants (weeds included) with mites in and around the tomato fields of randomly selected farmers' fields were taken from high tomato growing areas from each of the districts. Mwea area was selected in Kirinyaga, Bahati – Subukia area in Nakuru District and Kimana–Loitokitok–Rombo area in Kajiado District. Samples were collected from Mwea on 16th October 2002 while those from Kimana–Loitokitok–Rombo area were collected on 23rd and 24th of October 2002 and those from Bahati – Subukia were collected on 14th March 2003.

The samples were taken randomly by picking branches of plants from tomato farms within a kilometre from each other or the immediate next one in cases where there was no tomato field in any specific kilometre interval. The samples were put into paper bags and labelled. The information on the label included the date, the name of the plant and the field number. A separate sheet of paper was filled with respect to each field. On the sheet was the date of collection, the collector's name, the name of the farmer, the administrative district and location, the tomato variety and the associated vegetation and the geographical location of the plot. The Geographical Positioning System (GPS) was used to give the exact location of the plot with regard to latitude and longitude and also the altitude of the place.

Once the samples were put into the bags they were immediately put in a cool box, which was connected to the power supply of the vehicle. This ensured that the mites were immobilised at the low temperatures of the box. Upon completion of the sampling from each specific area the mites were transported at the low temperatures to ICIPE laboratories in Nairobi for identification.

In the laboratory the male mites were collected from the plant material, under a stereomicroscope, with a brush and transferred into small vials containing 70% alcohol where they stayed for ten days for the purpose of clearing them before mounting in order to identify them (Anonymous, 1998).

4.3.2: Mounting

The mites were mounted on polyvinyl alcohol (PVA) for purposes of identification. A small drop of PVA medium was put in the middle of a clean slide. A mite was transferred from the small glass container using a hairbrush to the medium and the mite manoeuvred so that it lay in the middle of the PVA drop ventrally. A cover slip was then placed first touching the edge of the PVA and then gently lowered onto the drop containing the specimen.

After mounting the mites the slides were allowed to dry in an oven at 30 – 35 ^{0}C for 24 hours. After drying the slides were ringed with clear nail polish to make them permanent (Anonymous, 1998).

4.3.3: Identification

Under a high power magnification of the microscope the specimens were examined and identified to species level. The male aedugus, which is protrusible and variously shaped, was used for identification of the species. (Anonymous, 1998).

4.4: Results

Table 2, gives a break down of the mites collected and identified. The results indicate that the predominant mite species in the parts of Kajiado District was *T. urticae*. *T. evansi* was identified only in Kimana on *Solanum nigrum*, *Datura stramonium* and maize. In all the places visited in Nakuru District only *T. evansi* was identified, while in Mwea only *T. urticae* was identified. The altitude of the places visited ranged from 1289 to 1679 metres above sea level. There were no observable differences in the species distribution with regard to altitude. Figure 1 shows the location of the areas where the various species of mites were identified.

Table 2: Mite species from important tomato growing areas in Kenya

District	*Area*	*Plant/crop*	*GPS position*	*Altitude (metres asl*²)*	*Mites Identity*
Kajiado	Maili Tatu	Tomato	03 05.45 S 037 44.43 E	1515	*T. Urticae*
	Maili Tatu	Tomato	03 015.15 S 037 44.12 E	1515	*T. Urticae*
	Maili Tatu	Tomato	03 05.72 S 037 44.17 E	1515	*T. Urticae*
	Maili Tatu	Tomato	03 04.25 S 037 43.38 E	1443	*T. Urticae*
	Rombo	Tomato	03 04.04 S 037 4.76 E	1415	*T. Urticae*
	Rombo	Tomato	03 04.04 S 037 42.70 E	1328	*T. Urticae*
	Rombo	Tomato	03 03.40 S 037 42.70 E	1305	*T. Urticae*
	Rombo	*Euphorbia*	03 04.04 S 037 42.70 E	1328	*T. Urticae*
	Rombo	Black jack	03 04.04 S 037 42.70 E	1328	*T. Urticae*
	Rombo	*Datura stramonium*	03 04.04 S 037 4.76 E	1415	*T. Urticae*
	Kimana	Tomato	02 49.62 S 037 31.42 E	1322	*T. Urticae*
	Kimana	Tomato	02 49.24 S 037 31.53 E	1335	*T. Urticae*
	Kimana	Tomato	02 47.38 S 037 32.04 E	1323	*T. Urticae*
	Kimana	Tomato	02 47.03 S 037 32.07 E	1289	*T. Urticae*
	Kimana	Tomato	02 49.99 S 037 31.32 E	1273	*T. Urticae*
	Kimana	Black jack	02 49.62 S 037 31.42 E	1322	*T. Urticae*
	Kimana	*Solanum nigrum*	02 49.24 S 037 31.53 E	1335	*T. evansi*
	Kimana	*Datura stramonium*	02 47.38 S 037 32.04 E	1323	*T. evansi*
	Kimana	*Amaranthus*	02 47.03 S 037 32.07 E	1289	*T. urticae*
	Kimana	Maize	02 47.03 S 037 32.07 E	1289	*T. evansi*
Nakuru	Subukia	Tomato	01 128.1 S 036 485 3 E	-	*T. evansi*
	Subukia	Tomato	01 128.1 S 036 485 3 E	-	*T. evansi*
	Subukia	Tomato	00 01.16 S 036 13.81 E	-	*T. evansi*
	Subukia	Tomato	00 0.08 N 036 15.5 E	1309	*T. evansi*
	Bahati	Tomato	00 0.08 N 036 15.51 E	1663	*T. evansi*
	Bahati	Tomato	00 10.49 S 036 08.27.E	1679	*T. evansi*
Kirinyaga	Mwea	Tomato	00 38.17 S 037 21.57 E	-	*T. urticae*
	Mwea	Tomato	00 38.29 S 037 22.25 E	-	*T. urticae*
	Mwea	Tomato	00 38.10 S 037 22.16 E	-	*T. urticae*
	Mwea	Tomato	00 37.14 S 037 22.01 E	-	*T. urticae*
	Mwea	Tomato	00 38.35 S 037.22.26 E	-	*T. urticae*

*²asl- Above sea level

- Not able to get the altitude because of a faulty GPS equipment

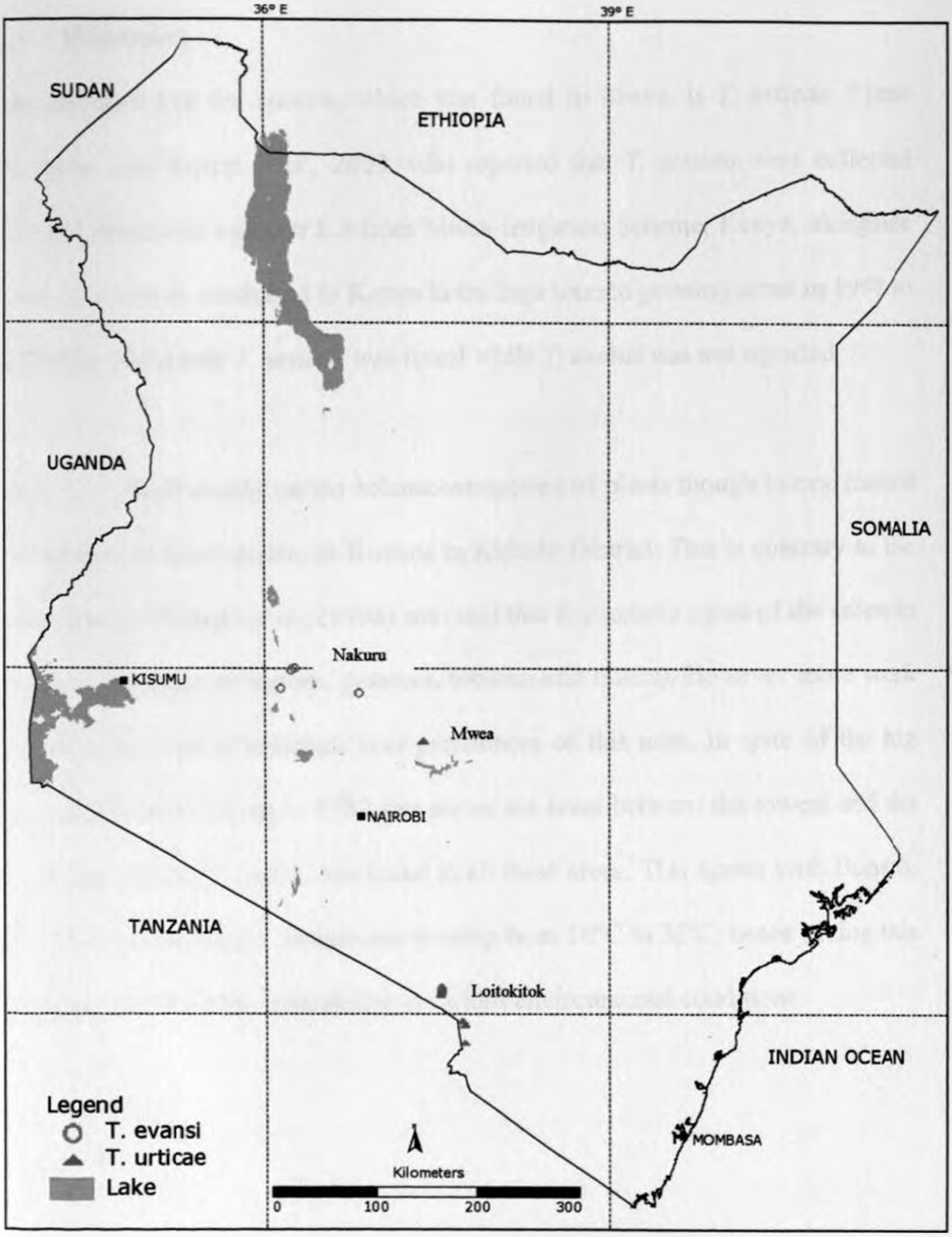

Figure 1: Mite species location in some parts of Kenya

4.5: Discussion

The results show that the species, which was found in Mwea, is *T. urticae*. These results agree with Knapp *et al.*, 2003, who reported that *T. urticae* were collected from beans, *Phaseolus vulgaris* L.) from Mwea Irrigation Scheme, Kenya, alongside *T. evansi*. In a survey conducted in Kenya in the high tomato growing areas in 1998 to 2000 (ICIPE, 2003) only *T. urticae* was found while *T. evansi* was not reported.

T. evansi was found mainly on the solanaceae species of plants though in one instant it was reported to be on maize, in Kimana in Kajiado District. This is contrary to the position taken by Bolland *et al.*, (1998) who said that *T. evansi* is a pest of the crops in the family Solanaceae (tomatoes, potatoes, tobacco and others). However more work may need to be done to establish host preferences of this mite. In spite of the big differences in altitude of up to 1287 feet above sea level between the lowest and the highest point visited, *T. evansi* was found in all these areas. This agrees with Bonato, (1999) who observed that *T. evansi* can develop from 10°C to 36°C, hence giving this phytophagous mite a wide adaptability to various environmental conditions.

4.6: References

Anonymous, (1998). Mites on tomatoes. Collecting, preserving, identification and control. A manual for a practical course in Acarology by The National Collection of Arachnida Biosystematics Division ARC – Plant Protection Research Institute Pretoria, South Africa, pp 85.

Bolland, H. R., Gutierrez, J. and Flechtmann, C. H. W., (1998). World catalogue of the spider mite family (Acari: Tetranychidae). Brill Leiden, pp 380.

Bonato, O. (1999). The effect of temperature on life history parameters of *Tetranychus evansi* (Acari: Tetranychidae).Exp. Appl. Acarol. 23: 11-19.

ICIPE, (2003). Development of environmentally friendly management methods for red spider mites in small-holder tomato production systems in eastern and southern Africa. Final project report (phase 1). pp 187.

Knapp, M. (2002). Important mite crop pests in Africa. Abstracts, XI International Congress of Acarology, Meride, Mexico. pp. 120.

Knapp, M., Wagener, B. and Navajas, M. (2003). Molecular discrimination between the spider mite *Tetranychus evansi* (Baker and Pritchard), an important pest to tomatoes in Southern Africa, and the closely related species *T. urticae* (Koch) (Acarina: Tetranychidae). African Entomology 11: 300-304.

Varela, A. M., Seif, A. A. and Löhr, B., (2003). A guide to IPM in tomato production in Eastern and Southern Africa. ICIPE Science Press, Nairobi, pp 21-26.

CHAPTER FIVE

LABORATORY EVALUATION OF THE EFFECT OF OBERON 240SC (SPIROMESIFEN) AND D-C-TRON PLUS ON THE OF RED SPIDER MITES (*T. evansi*) IN TOMATOES.

5.1: Abstract

Laboratory experiments were conducted to compare the efficacy of the Oberon 240SC and D-C-Tron Plus on red spider mites (*T. evansi*). Different rates of the individual chemicals were evaluated and their appropriate rates and a mixture (at half rates for both chemicals) compared with abamectin (Dynamec 1.8EC), a standard acaricide. The results indicated that the two products are effective as ovicides. There was 100% hatch for the control against 0% for Oberon 240SC treatments while for D-C-Tron Plus 74% hatch was achieved for the control and less than 7% of those treated with D-C-Tron Plus.

5.2: Introduction

Two species of *Tetranychus* are commonly found in eastern and southern Africa. These include *T. evansi* mainly in southern Africa and *T. urticae* in eastern Africa. *T. evansi* is known to cause more damage on tomatoes than *T. urticae* (Lohr *et al.*, 1998). *T. evansi* is wide spread in southern Africa and is now found in Kenya (Knapp, 2002). *T. evansi* is regarded as one of the key arthropod pests of tomato in Zimbabwe (Sibanda, *et al.*, 2000) causing yield losses of up to 90% in small holder production.

In contrast, even though *T. urticae* is a common pest of vegetables in southern and eastern Africa, it is usually not a major problem on tomato (Knapp *et al.*, 2003).

Management of the red spider mites (*Tetranychus* spp) across the country has depended mainly on the use of a number of acaricides many of which are broad spectrum and kill both the pest and the beneficial organisms. Use of acaricdes by the tomato farmers in Kenya has continued to rely mainly on how effective the products are at eliminating the pest and leaving a clean crop. This tendency has been supported by lack of a Government policy, which encourages integrated pest management (Mabeya *et al.*, 2002). Instead, for a long time pesticides have been used more or less as a panacea in pest management. Emerging issues in pest management in crop production like the declaration of maximum residue levels (MRLs) in fresh produce for export should be a consideration on what product to use and how to use it.

To alleviate these possible problems alternative strategies in the use of pesticides in management of mites have been tried for some time now world over. A good example is the use of spray oils with synthetic miticides (Rae, 2000), which achieves high efficacy, and at the same time delays resistance development probably because of the smothering action of the oil (Lienk, *et al.*, 1980). Elsewhere an alternative control strategy that combines "soft pesticides" (like petroleum oils) with biological control of citrus mites has been developed (Childers, 2000). Acaricides from various chemical groups that have been found effective against different stages of the red spider mites have provided ingredients for an acaricide rotation scheme to reduce selection pressure for resistance (Blair, 1989). This work reports on the potential of using a combination of D-C-Tron Plus (a mineral oil) and Oberon 240SC (spiromesifen) (a new low volume acaricide) as mixture, rotation or singly in the management of the red spider mites (*T. evansi*).

5.3: Materials and Methods

5.3.1: Ovicidal tests

Two experiments, one for Oberon 240SC and another for D-C-Tron Plus were conducted to test the contact by immersion effect of the products on the eggs of the red spider mites. The following dilutions (treatments) were used for D-C-Tron Plus tests; 0ml/liter (plain water), 2.0ml/liter, 4.0ml/liter, 6.0ml/liter, 8.0ml/liter and 10.0ml/liter. Treatments for Oberon 240SC were; 0ml/liter (plain water), 0.2ml/liter, 0.4ml/liter, 0.6ml/liter, 0.8ml/liter and 1.0ml/liter and the experimental design was complete randomised design (CRD) with four replications. In both experiments leaf discs measuring 25 mm in diameter of tomato plants (Cal-J variety) were used.

Fifteen adult females were transferred to the leaf discs placed underside up in petridishes lined with moistened cotton wool, and allowed 24 hours to lay eggs. The total number of eggs laid per disc was established. The eggs were then subjected to the treatments by dipping the discs gently for five seconds into each treatment and the number of eggs that hatched counted after every 24 hours for period of six days (Modified after Agnello *et al.*, 1994; Osman, 1997).

5.3.2: Larvicidal tests

A total of four experiments were conducted to test the effect of Oberon 240SC and D-C-Tron Plus through contact by immersion and contact to dry residues on larvae of the red spider mites. The experiment included two for each method of test, for each product. The following dilutions (treatments) were used. D-C-Tron Plus tests had 0ml/liter (plain water), 2.0ml/liter, 4.0ml/liter, 6.0ml/liter, 8.0ml/liter and 10.0ml/liter. Oberon 240SC had 0ml/liter (plain water), 0.2ml/liter, 0.4ml/liter, 0.6ml/liter, 0.8ml/liter and 1.0ml/liter and the experimental design was complete randomised design (CRD) with four replications. In all the experiments leaf discs measuring 25 mm in diameter of tomato plants (Cal-J variety) were used.

Fifteen adult females were transferred to the leaf discs placed underside up in petri dishes lined with moistened cotton wool, and allowed 24 hours to lay eggs. The eggs were then placed in an incubator at a temperature of 25°C and 70% relative humidity for three days to hatch. For contact by immersion tests 15 larvae were transferred to fresh discs which were then dipped into the treatments gently for five seconds and mortality count taken after every 24 hours for a period of six days (Modified after Agnello *et al.*, 1994). For the contact by dry residues test 15 larvae were transferred onto discs that had been dipped into the treatments an hour prior to the transfer of the larvae and mortality count, done every 24 hours for six days.

5.3.3: Adulticidal tests

A total of five experiments were conducted to test the effect of Oberon 240SC and D-C-Tron Plus through contact by immersion and contact to dry residues on adults of the red spider mites. These experiments included one contact by immersion test and contact by dry residues test for each product dilutions and one contact by immersion test using appropriate rates of the two products.

The following dilutions were used. D-C-Tron Plus tests had 0ml/liter (plain water), 2.0ml/liter, 4.0ml/liter, 6.0ml/liter, 8.0ml/liter and 10.0ml/liter. Oberon 240SC had 0ml/liter (plain water), 0.2ml/liter, 0.4ml/liter, 0.6ml/liter, 0.8ml/liter and 1.0ml/liter. The following appropriate dilutions were compared with the standard acaricide on their effect on adult mites: 0.2ml/liter of Oberon 240SC, 5.0ml/liter of D-C-Tron Plus, a mixture of the two at a ratio of 1:1 (at half rate of 0.1ml/liter of Oberon 240SC and 2.5ml/liter of D-C-Tron Plus), plain water (as a control) and 0.25ml/liter of Dynamec 1.8EC (abamectin). The experimental design was complete randomised design (CRD) with four replications. In all the experiments leaf discs measuring 25 mm in diameter of tomato plants (Cal-J variety) were used.

For contact by immersion tests 15 adult mites were transferred to the discs set on moistened cotton in petridishes, with the underside up. The cotton wool was used to prevent the mites from escaping. The mites were then dipped gently into the different treatments for five seconds and then observed for mortality after every 24 hours for a period of six days (Modified after Agnello *et al.*, 1994; Osman, 1997). For contact by dry residues tests, the discs were first dipped into the various treatments for five seconds and then placed underside up on petridishes lined with moistened cotton wool. The discs were allowed to dry for one hour in the open air after which 15 adult mites were transferred to them and mortality count done after every 24 hours for period of six days (Modified after Agnello *et al.*, 1994; Osman, 1997).

5.3.4: Fecundity tests

Three experiments were conducted to test the effect of Oberon 240SC on the fecundity of the red spider mites. A contact by immersion test and a contact by dry residues test using deutonymphs and a contact by immersion test using young adults were compared. These experiments were set using complete randomised design (CRD) with 12 replications. There were three treatments which included two extreme concentrations of Oberon 240SC (0.2ml/lit and 1.0ml/lit) and a control of plain water. The leaf discs were placed underside up on petridishes lined with moistened cotton wool to prevent escape of mites.

For the contact by immersion test using deutonymphs, one quiescent deutonymph was transferred to each disc placed on petridishes with moistened cotton wool, underside up. The discs were dipped gently into the chemical dilutions for five seconds. Two males were then transferred to each disc to simulate natural situation. The deutonymphs were allowed 24 hours to moult into young adults and then observed for fecundity every 24 hours for a period of 7 days (Modified after Agnello *et al.*, 1994; Osman, 1997). The leaf discs were changed every four days to ensure fresh discs for nutrition.

For the contact by dry residues test using deutonymphs the same design, treatments and replications used for contact experiment were used. However the leaf discs were dipped into the chemical dilutions before one quiescent deutonymph was transferred to each disc together with two males. The deutonymphs were allowed 24 hours to moult into young adults and then observed for fecundity every 24 hours for a period of 7 days. The leaf discs were changed every four days to ensure fresh discs for nutrition (Modified after Agnello *et al.*, 1994; Osman, 1997).

For young adults the deutonymphs were allowed 24 hours on the discs in the incubator set at 25°C and 70% humidity to moult into young adults before dipping them into the different dilutions. The mites were then observed for fecundity for a period of 7 days with discs being changed every four days to ensure fresh supply of food (Modified after Agnello *et al.*, 1994; Osman, 1997).

5.4: Results

Laboratory results showed that only up to 7% of the eggs treated with D-C-Tron Plus hatched compared with a mean of 74.4% of the control (treated with plain water). Contact by immersion tests using D-C-Tron Plus achieved 100% mortality on both the larvae and adults (Table 3).

Table 3: The contact by immersion effect of different concentrations of D-C-Tron Plus on eggs, larvae and adults of the red spider mites (*T. evansi*) after six days.

Treatment (ml/litre)	Eggs (% hatchability) ± SE	Larvae (% mortality) ± SE	Adults (% mortality) ± SE
Control (water)	74.3 ± 9.7 a	0.0 ± 0.0 b	0.0 ± 0.0 b
D-C-Tron Plus (2.0ml/litre)	4.5 ± 1.6 b	100.0 ± 0.0 a	100.0 ± 0.0 a
D-C-Tron Plus (4.0ml/litre)	7.0 ± 3.6 b	100.0 ± 0.0 a	100.0 ± 0.0 a
D-C-Tron Plus (6.0ml/litre)	0.0 ± 0.0 b	100.0 ± 0.0 a	100.0 ± 0.0 a
D-C-Tron Plus (8.0ml/litre)	3.8 ± 1.1 b	100.0 ± 0.0 a	100.0 ± 0.0 a
D-C-Tron Plus (10ml/litre)	1.3 ± 0.8 b	100.0 ± 0.0 a	100.0 ± 0.0 a
F – Value	45.85	Infinity	Infinity

Within columns means followed with the same letter are not significantly different at P=0.05 (Student-Newman-Keuls Test).

Contact by dry residues tests of D-C-Tron Plus showed no significant difference between treatments on the larvae but there were some differences on adults. However, percentage mortality for both the larvae and the adults increased with concentration of the treatment. Mortality was much less than that which was due to the contact by immersion effect (Table 4).

Table 4: The effect of contact by dry residues of different concentrations of D-C-Tron Plus on larvae and adults of the red spider mites (*T. evansi*) after six days.

Treatment (ml/litre)	Larvae (% mortality) ± SE	Adults (% mortality) ± SE
Control (Water)	17.3 ± 9.1 a	0.0 ± 0.0 b
D-C-Tron Plus (2.0ml/litre)	21.8 ± 7.8 a	21.8 ± 14.3 a b
D-C-Tron Plus (4.0ml/litre)	28.5 ± 8.3 a	26.0 ± 2.9 a b
D-C-Tron Plus (6.0ml/litre)	16.8 ± 10.0 a	14.3 ± 6.3 a b
D-C-Tron Plus (8.0ml/litre)	55.0 ± 14.1 a	33.3 ± 16.7 a b
D-C-Tron Plus (10ml/litre)	49.0 ± 10.1 a	51.0 ± 14.9 a
F – Value	2.68	2.61

Within columns means followed with the same letter are not significantly different at P=0.05 (Student-Newman-Keuls Test).

Contact by immersion treatment on the eggs resulted in 0% hatch. There was however little or no larvicidal and adulticidal effect for both contact by immersion and by dry residues tests. There was no significant difference in these tests (Table 5 and 6). During the experiments with Oberon 240SC some mites were observed to have escaped into the cotton wool where they were trapped and died.

Table 5: The contact by immersion effect of different concentrations of Oberon 240SC on eggs, larvae and adults of the red spider mites (*T. evansi*) after six days.

Treatment (ml/litre)	Eggs (% hatchability) ± SE	Larvae (% mortality) ± SE	Adults (% mortality) ± SE
Control (water)	100.0 ± 0.0 a	5.0 ± 3.1 a	0.0 ± 0.0 a
Oberon 240SC (0.2ml/litre)	0.0 ± 0.0 b	8.5 ± 3.2 a	1.8 ± 1.8 a
Oberon 240SC (0.4ml/litre)	0.0 ± 0.0 b	5.0 ± 3.1 a	6.3 ± 4.1 a
Oberon 240SC (0.6ml/litre)	0.0 ± 0.0 b	12.3 ± 1.8 a	2. 0 ± 2.0 a
Oberon 240SC (0.8ml/litre)	0.0 ± 0.0 b	3.5 ± 2.0 a	8.3 ± 3.5 a
Oberon 240SC (1.0ml/litre)	0.0 ± 0.0 b	9.5 ± 3.7 a	10.0 ± 6.4 a
F – Value	Infinity	1.32	1.26

Within columns means followed with the same letter are not significantly different at P=0.05 (Student-Newman-Keuls Test).

Table 6: The effect of contact by dry residues of different concentrations of Oberon 240SC on larvae and adults of the red spider mites (*T. evansi*) after six days.

Treatment (ml/litre)	Larvae (% mortality) ± SE	Adults (% mortality) ± SE
Control (0ml/liter)	3.5 ± 2.0 a	0.0 ± 0.0 a
Oberon 240SC (0.2ml/litre)	13.5 ± 5.5 a	1.8 ± 1.8 a
Oberon 240SC (0.4ml/litre)	6.8± 2.7 a	2.0 ± 2.0 a
Oberon 240SC (0.6ml/litre)	3.5 ± 2.0 a	3.5 ± 3.5 a
Oberon 240SC (0.8ml/litre)	10.0 ± 4.3 a	2.0 ± 2.0 a
Oberon 240SC (1.0ml/litre)	11.8 ± 5.7 a	0.0 ± 0.0 a
F – Value	1.12	0.47

Within columns means followed with the same letter are not significantly different at P=0.05 (Student-Newman-Keuls Test).

When the appropriate dilutions were compared there was significant difference between D-C-Tron Plus, Dynamec and Oberon 240SC / D-C-Tron Plus mixture on one hand and Oberon 240SC and the control on the other (Table 7). This proves that unlike Dynamec 1.8 EC, Oberon 240SC does not exhibit acute toxicity. For Dynamec and Oberon 240SC / D-C-Tron Plus mixture, the mortality occurred in the first 24 hours of application of the treatments.

Table 7: The contact by immersion effect of appropriate dilutions of various chemicals on the red spider mite adults (*T. evansi*) after six days.

Treatment (ml/litre)	Percentage adult mortality ± SE
Control (Water)	3.8 ± 2.2 b
Oberon 240 SC (0.2ml/iter)	3.5 ± 2.0 b
DC-Tron Plus (5.0ml/liter)	100.0 ± 0.0 a
Dynamec 1.8 EC (0.25ml/liter)	100.0 ± 0.0 a
Oberon 240SC & D-C-Tron Plus (0.1ml/liter & 2.5ml/liter)	100.0 ± 0.0 a
F – Value	1580.96

Within columns means followed with the same letter are not significantly different at P=0.05 (Student-Newman-Keuls Test).

Fecundity tests using deutonymphs and young adults showed that Oberon 240SC completely deterred mites from laying eggs. Mites treated with Oberon 240SC did not lay eggs at all even after seven days, while there were eggs laid in the control treatments (Table 8).

Table 8: Contact by immersion and dry residues effects of Oberon 240SC on fecundity of the red spider mites (*T. evansi*) using deutonymphs and young adults.

Stage	Treatment	Number of eggs per female after the specified hours ± SE							
		After 24 hours	After 48 hours	After 72 hours	After 96 hours	After 120 hours	After 144 hours	After 168 hours	Mean Total
Deutonymphs (Dry residues)	Control	0.17 ± 0.11 a	0.17 ± 0.11 a	1.08 ± 0.40 a	3.83 ± 0.88 a	3.50 ± 0.93 a	5.92 ± 1.40 a	8.58 ± 2.33 a	23.25 ± 5.20 a
	Oberon (0.2ml/l)	0.00 ± 0.00 a	0.00 ± 0.00 b	0.00 ± 0.00 b	0.00 ± 0.00 b	0.00 ± 0.00 b	0.00 ± 0.00 b	0.00 ± 0.00 b	0.00 ± 0.00 b
	Oberon (1.0ml/l)	0.00 ± 0.00 a	0.00 ± 0.00 b	0.00 ± 0.00 b	0.00 ± 0.00 b	0.00 ± 0.00 b	0.00 ± 0.00 a	0.00 ± 0.00 b	0.00 ± 0.00 b
	F – Value	2.44	2.44	8.38	16.52	23.62	9.67	14.88	20.29
Deutonymphs (Immersion)	Control	0.17 ± 0.11 a	0.17 ± 0.11 a	1.58 ± 0.45 a	3.00 ± 0.78 a	3.08 ± 0.80 a	5.08 ± 1.33 a	7.92 ± 1.44	21.00 ± 5.54 a
	Oberon (0.2ml/l)	0.00 ± 0.00 a	0.00 ± 0.00 a	0.00 ± 0.00 b	0.00 ± 0.00 b	0.00 ± 0.00 b	0.00 ± 0.00 b	0.00 ± 0.00 b	0.00 ± 0.00 b
	Oberon (1.0ml/l)	0.00 ± 0.00 a	0.00 ± 0.00 a	0.00 ± 0.00 b	0.00 ± 0.00 b	0.00 ± 0.00 b	0.00 ± 0.00 a	0.00 ± 0.00 b	0.00 ± 0.00 b
	F – Value	4.60	4.60	25.71	31.05	30.90	30.36	22.04	30.05
Young adults (Immersion)	Control	0.17 ± 0.1 a	0.08 ± 0.11 a	1.25 ± 0.39 a	3.66 ± 0.59 a	2.91 ± 0.56 a	5.67 ± 1.16 a	7.25 ± 2.03 a	21.0 ± 4.31 a
	Oberon (0.2ml/l)	0.00 ± 0.00 a	0.00 ± 0.00 a	0.00 ± 0.00 b	0.00 ± 0.00 b	0.00 ± 0.00 b	0.00 ± 0.00 b	0.00 ± 0.00 b	0.00 ± 0.00 b
	Oberon (1.0ml/l)	0.00 ± 0.00 a	0.00 ± 0.00 a	0.00 ± 0.00 b	0.00 ± 0.00 b	0.00 ± 0.00 b	0.00 ± 0.00 a	0.00 ± 0.00 b	0.00 ± 0.00 b
	F – Value	2.20	1.00	10.19	38.09	27.44	23.46	12.75	23.70

Within columns means followed with the same letter within each treatment are not significantly different at P=0.05 (Student-Newman-Keuls Test).
SE – Standard error

5.5: Discussion

The results indicate that Oberon 240SC works well as an ovicide but not as an adulticide. This agrees with the manufacturer's experimental data, which says that the product does not seem to affect the adults but deters hatching of eggs. The results however indicate that the product does not work well as a larvicide, contrary to the manufacturer's data (Anonymous, 2002).

Observations also indicated that Oberon 240SC does not have a knock down effect on the spider mites. However, the number of mites that seemed to escape from the discs showed that there could be some repellence effect by the product. This is in agreement with Jones and Parella (1984) who mentioned that some pesticides might have sub-lethal effects on mites, which may lead to increased dispersal and walk off.

The mixture of D-C-Tron Plus and Oberon 240SC achieved high efficacy against larvae and adults inspite of the fact that the rates were half that of individual chemical treatments. The results compared well with those of Dynamec 1.8EC. These results are corroborated by Rae (2000) who indicated that in some cases pesticides and oil mixtures exhibit enhanced performance against target pests. This may be attributed to increased canopy penetration and coverage on the plant surface, assisted passage of the active ingredient into plant tissues, and protection against abiotic factors, resulting in longer residual activity. Oils can also result in greater pick up of the active ingredient by the target pest and enhance cuticular penetration. D-C-Tron Plus and Oberon 240SC rotation in the green house achieved equally comparable results. D-C-Tron Plus is also known to smother eggs, larvae and adults of red spider mites.

The mortality of mites due to residues of D-C-Tron Plus reported here agrees with that by Cen *et al*. (2000) who reported that adult females maintained on the oil – treated leaves had significantly shorter longevity, than the females maintained on the water-treated leaves. Similarly, the survival rate of larvae and nymphs were reduced on the 0.25% oil treated leaves. The oil achieved 100% mortality on the larvae and adults. Agnello *et al*. (1994) reported that 100% mortality was achieved when larvae and adults were dipped in 0.25% oil. The same is also true about eggs. D-C-Tron Plus when applied on eggs of the red spider mites reduces significantly the ability of the eggs to hatch. In this light Cen *et al*. (2000) observed that when the red mite eggs were sprayed with the increasing rates of oil, the hatching rates decreased significantly.

5.6: References

Agnello, A. M., Reissig, W.H., Harris, T., (1994). Management of summer populations of European red mite (Acari: Tetranychidae) on apple with horticultural oil. J. Econ. Entomol. 87: 148 – 161.

Anonymous, (2002). Bayer East Africa Ltd BSN 2060 (Spiromesifen). Summary of the biological activity of the product. 22 April, 2002, pp8 (Unpublished).

Blair, B. W., (1989). Laboratory screening of acaricides against *Tetranychus evansi* Baker and Pritchard. Crop Protection 8: 217-222.

Cen, Y. J., Tian, M. Y., Pang, X. F. and Rae D. J., (2000). Repellence, anti-feeding effect and toxicity of horticultural mineral oil against citrus red mite (*Panonychus citri*) (McGregor) [Acari: Tetranychidae]. Available online on http://sprayoils.uws.edu.au//rae.shtml.

Childers, C. C., (2000). Practical use of horticultural mineral oils in integrated pest and disease management programmes and their impact on natural enemies. Citrus Research and Education Centre, university of Florida, 700 Experiment Station Road, Lake Alfred, Florida 33850, United States of America. Available online on http://sprayoils.uws.edu.au//rae.shtml.

Jones, V. P., Parella, M. P., (1984). The sub-lethal effects of selected insecticides on lifetable parameters of *Panonychus citri* (Acari: Tetranychidae). The Canadian Entomologist 116: 1033 – 1040.

Knapp, M. (2002). Important mite crop pests in Africa. Abstracts, XI International Congress of Acarology, Meride, Mexico. pp. 120.

Knapp, M., Wagener, B. and Navajas, M. (2003). Molecular discrimination between the spider mite *Tetranychus evansi* (Baker and Pritchard), an important pest to tomatoes in Southern Africa, and the closely related species *T. urticae* (Koch)

Lienk, S. E., Watie C. M., Wieres R. W., (1980). Phytophagous and predacious mites in New York. Search 6 (Geneva): 1-14

Lohr, B., Knapp, M., Sarr, I., Nzuma, I., (1998). Development of environmentally friendly management methods for red spider mites in smallholder tomato production systems. 1998-1999 ICIPE Scientific Report, pp. 88 – 91, ICIPE, Nairobi.

Mabeya, J. M., Nderitu, J. H., Wambua, E. W., (2002). Pesticides use and implications on horticultural export crops in Kenya. Proceedings of Horticultural Workshop held at Jomo Kenyatta University of Agriculture and Technology August 6th to 10th 2002.

Osman, M.S., (1997). Petroleum oils as a component of integrated pest management of phytophagous mites. Arab Gulf J. Scient. Res., 15: 125-135.

Rae, D. J., (2000). Use of spray oils with synthetic insecticides, acaricides and fungicides. Centre for Horticulture and Plant Sciences, University of Western Sydney, Locked Bag 1797, South Penrith Distribution Centre, New South Wales 1797, Australia. Available online on; http://sprayoils.uws.edu.au//rae.shtml

Sibanda, T., Dobson, H. M., Cooper, J. F., Manyangarirwa, W. and Chiimba, W., (2000). Pest management challenges for smallholder farmers in Zimbabwe. Crop Protection 19: 807-815.

CHAPTER SIX

COMPARATIVE EFFICACY OF OBERON 240SC (SPIROMESIFEN) AND D-C-TRON PLUS ON THE RED SPIDER MITES (*Tetranychus* spp) ON TOMATOES (*L. esculentum*) UNDER GREEN HOUSE AND FIELD CONDITIONS.

6.1: Abstract

One greenhouse and two field experiments were conducted to compare the efficacy of Oberon 240SC and D-C-Tron Plus. The treatments which were applied included Oberon 240SC, D-C-Tron Plus (98% mineral oil), a mixture of Oberon 240SC and D-C-Tron Plus at 1:1 ratio (at half rates for both), a rotation of Oberon 240SC and D-C-Tron Plus beginning with Oberon 240SC, a standard chemical, abamectin (Dynamec 1.8EC) and a control (plain water). The results showed that Oberon 240SC, its rotation and mixture with D-C-Tron Plus have very high ability to reduce the mite population and the results compared very well with that of the Dynamec 1.8EC. Similarly the damage score was significantly different for the treatments. Oberon 240SC achieved effective control of the mites in the field as shown by a relatively longer harvest time compared to the control and D-C-Tron Plus treatments. There was however no significant difference between the treatments with regard to yields of tomatoes in both sets of experiments.

6.2: Introduction

A number of acaricides have been widely used for the control of spider mites in tomatoes. Synthetic pesticides commonly used include diazinon, dicofol, fenpropathrin, malathion, dimethote (Bohlen, 1978). In Kenya like other parts of the world, the use of synthetic pesticides is facing opposition because of toxic residues that the pesticides leave on the crops. Continued use of synthetic pesticides leads to development of resistance by pests to the pesticides (Blair 1989; Whalon and Mota-Sanchez, 2000). This has therefore resulted in the need to look for alternative control measures that are safe and environmentally friendly. One such available alternative is the use of spray mineral oils.

Mineral oil is lethal to or affects the behaviour of insects if brought into intimate contact with them. The generally accepted theories of the mode of action are that, the oil film creates a physical barrier between the plant and pests, acting as a physical control measure. It clogs the insect's oxygen intake system, interfering with normal respiration and so suffocating it or at least disrupting the respiratory system; and the components of the oil or its derivatives act with direct toxicity on the insect (oil interacts with the insect's fatty acids and interferes with metabolism). Mineral oil is also known to have repellent effect on certain insects such as white-fly. As an ovicide, an oil film enveloping the egg may well suffocate the embryo, providing that the film persists for a long enough period. (Anonymous, 2005). Elsewhere an alternative control strategy that combines "soft pesticides" (like petroleum oils) with biological control of citrus mites has been developed (Childers, 2000).

6.3: Materials and Methods

6.3.1: Greenhouse Experiment

One green house experiment was set at Jomo Kenyatta University where potted plants were subjected to six treatments. These included, Oberon 240SC (0.2ml/liter), D-C-Tron Plus (5.0ml/liter), Dynamec 1.8EC (0.25ml/liter), plain water (as a control), a rotation of Oberon 240SC with D-C-Tron Plus, (starting with Oberon 240SC at the same rates given above) and a mixture of Oberon 240SC and D-C-Tron Plus at 1:1 ratio, (using half rates that is 0.1ml/liter of Oberon 240SC and 2.5ml/liter of D-C-Tron Plus).

The potted plants were arranged in a complete randomised design (CRD) with four replications and four plants in each experimental unit. The mite population was established by artificial infestation. Mites were taken from the laboratory and applied on each plant using a hairbrush. Treatments were applied three weeks after infestation at which time the damage was about 20% based on the damage score average on a visual density scale of 1 – 5 (Plate 3) (Modified after Meyer, 1996).

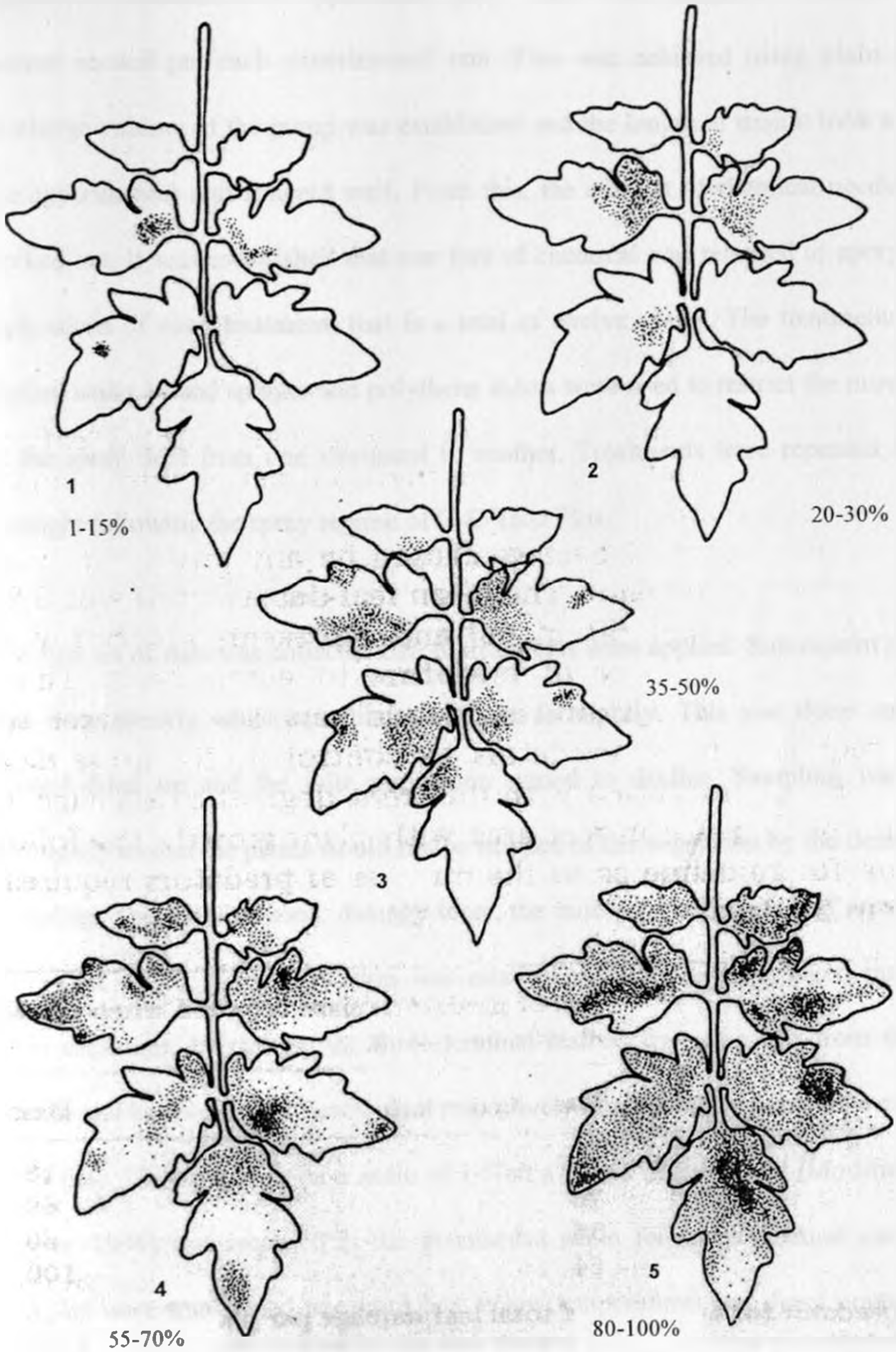

Plate 3: Damage score on a scale of 1 - 5

Before the treatments were applied the spray volume was calibrated to establish the amount needed per each experimental unit. This was achieved using plain water. Discharge volume of the pump was established and the length of time it took to have one experimental unit sprayed well. From this, the amount of chemical needed was worked out. It was established that one litre of chemical was required to spray three replications of each treatment, that is a total of twelve plants. The treatments were applied using a hand sprayer and polythene sheets were used to restrict the movement of the spray drift from one treatment to another. Treatments were repeated after a fortnight following the spray regime of D-C-Tron Plus.

The first set of data was collected before treatments were applied. Subsequent scoring was done weekly while sampling was done fortnightly. This was done until the control dried up and the mite population started to decline. Sampling was done fortnightly so that the plants would not be stripped of the vegetation by the destructive sampling. The data included, damage score, the mite population and leaf area of the leaves on which mites population was established. Samples were taken randomly from each unit, by picking the three terminal leaflets from one leaf from the top, middle and bottom strata of each plant respectively. Two plants per unit were sampled each time. Damage score on a scale of 1-5 on a visual density scale (Modified after Meyer, 1996) was recorded in the greenhouse while for the population count, the samples were transported in a cool box at low temperatures and direct count of all motile stages done in the laboratory at the International Centre for Insect Physiology and Ecology (ICIPE) in Nairobi. The populations were statistically compared using Student-Newman-Keuls (SNK) test (SAS, 1990)

The tomato fruits were harvested as soon as they started to ripen. This was spread for a total of about two months. Harvesting continued until the crop stopped yielding any marketable fruits. The yields were cumulated at the end of the trial and compared using Student-Newman-Keuls (SNK) test (SAS, 1990)

6.3.2: Field Experiments

Two experiments were laid at the College of Agriculture and Veterinary Services (Upper Kabete Campus) of the University of Nairobi using randomised complete block design (RCBD). The first field experiment was planted in the nursery on 25th October 2002, transplanted on 3rd December 2002 and terminated on 17th March 2003. The second field experiment was planted in the nursery on 22nd June 2003, transplanted on 20th July 2003 and terminated on 5th December 2003. Six treatments were applied, which included Oberon 240SC (0.2ml/liter), abamectin (Dynamec 1.8EC), the standard miticide (0.25ml/liter), D-C-Tron Plus (5.0ml/liter), mixture of Oberon 240SC and DC-Tron Plus (at 1:1 ratio, that is 0.1ml/liter of Oberon 240SC with 2.5ml/liter of D-C-Tron Plus) and a rotation of the two (starting with Oberon 240 SC) and a control (plain water). The experimental plot size was 3m by 5m and the plants were spaced at 60cm inter-row by 45cm intra-row giving a plant population of 60 per experimental plot. The path width between the plots was one meter. The spacing was sufficient to minimize mutual shading and avoid the plants touching and so preventing the lateral movement of mites.

The plants were allowed to have natural mite infestation before subjecting them to the treatments. Both in the first and second experiment there was delayed mite infestation. This was because of heavy rains averaging 157.2 mm and 230.9 mm per month for the months of November and December 2002 respectively and low ambient temperatures and short sunshine time per day in August and early September 2003. The mean maximum and minimum temperature in August 2003 was of 21.1°C and 11.5°C, which was close to that of July, which was 20.6°C and 11.3°C the coldest month in the year. The mean sunshine time per day for August was 4 compared to 3.5 hours for July 2003 (Table 9) (Anonymous, 2003).

Table 9: Weather report during the two field experiments at the University of Nairobi Upper Kabete Campus

1st Experiment	***Month***	***Mean maximum temperature (°C)***	***Mean minimum temperature (°C)***	***Total rainfall (mm)***	***Mean sunshine (days)***	***Relative humidity (%)***
	October '03	24.3	14.1	59.1	7.7	50
	November '02	23.0	14.8	157.7	6.9	59
	December '02	22.9	14.3	230.9	6.5	62
	January '03	24.3	13.6	28.4	9.8	49
	February '03	26.7	13.6	12	9.4	41
	March '03	26.4	14.5	61.6	8.9	41
2nd Experiment	July '03	20.6	11.3	3.1	3.5	63.0
	August '03	21.1	11.5	54.3	4	66.6
	September '03	23.0	12.6	27.8	5.8	56.6
	October '03	24.3	13.4	54.7	-	52
	November '03	22.8	14.4	117.1	7.3	60.0
	December '03	23.8	13.3	14.1	-	51

Because of the delayed natural mite infestation the plants were artificially infested. Leaves from solanaceae plants with mites from the surrounding fields were picked and then placed on every tomato plant in the field in the first experiment. In the second experiment leaves of solanaceae plants with mites were collected from Mwea area of Kirinyaga District and Gilgil and Bahati areas of Nakuru District and then placed on every tomato plant. Damage score was taken over a scale of 1-5 on a visual density scale (Modified after Meyer, 1996) as a way of monitoring the population build-up. This was done weekly up to the end of the experiment, a total of nine times (weeks) for the first experiment and seven for the second. Sampling of the plants commenced when the score reached 2 (that is about 20-30% leaf damage) and continued for the subsequent seven weeks in case of the first experiment. In the second experiment the sampling and scoring started simultaneously because of the delayed mite infestation. Both scoring and sampling were randomly done on the plants in the middle rows consisting of 30 plants.

Scoring was done on the top, middle and bottom leaf samples of five and three randomly selected plants per experimental unit in the first and second experiments respectively. Samples from three terminal leaflets from one leaf at each level were randomly taken from three plants in the middle excluding guard rows for both experiments. The damage score was recorded in the field while the leaf samples for population count were put in a cool box and carried to the laboratory in ICIPE where they were put in a fridge at a low temperature to immobilise the mites and therefore retain the numbers. In the laboratory mite population was determined by direct count of all the motile stages under a stereo microscope. Sampling continued until the control plots dried up and the mite population started to decline.

Treatments were applied when the damage score reached at least two (approximately 20 – 30% damage). Before actual application of the chemicals calibration of the knapsack sprayer was done using water. The discharge rate of the pump was determined. The pump was then filled with water and sprayed on an experimental plot sufficiently as to cover the crop thoroughly. The time taken to do this was recorded and then the spray volume of the chemical calculated. Upon doing this it was established that for every plot seven litres of the chemical were required. The treatments were applied based on the recommended spray regime of D-C-Tron Plus that is fourteen days interval and this was done twice.

The tomato fruits were harvested as soon as they started to ripen. This was spread for a total of four weeks in the first experiment and five for the second. The yields were cumulated at the end of the trial. Two grades of the fruits were recorded which included the marketable and unmarketable grades. The unmarketable fruits were very small and damaged and/or diseased. Harvesting continued until the crop stopped yielding any marketable fruits. In total both trials lasted about five months each.

6.4: Results

6.4.1: Green House Experiment

One week after treatments the scores showed some small increase for all the treatments, which started to decline in the second week except for the control, which continued to increase (Table 10). By the fifth week the score for all the treatments except the control was 1 and below. This was two weeks after the application of the second treatments. At this time the score for the control was 3.3 and it continued to increase up to the maximum by the ninth week. From the sixth week onwards the score for D-C-Tron Plus, Oberon 240SC/D-C-Tron Plus rotation, Oberon 240SC & D-C-Tron Plus mixture and Oberon 240SC increased steadily to the last week while that of Dynamec 1.8EC remained low until the last week when it showed some increase. By the end of the experiment Dynamec 1.8EC treated plots had the lowest score followed by Oberon 240SC, Oberon 240SC/D-C-Tron Plus rotation, Oberon 240SC & D-C-Tron Plus mixture, D-C-Tron Plus and lastly the control. From the fifth week onwards to the end of the experiments there were significant differences between the control and other treatments.

Table 10: The effect of various treatments on the red spider mites (*T. evansi*) damage score on tomatoes in the greenhouse in Jomo Kenyatta University

	Damage score for 11 weeks + SE										
Treatment	1	2	3	4	5	6	7	8	9	10	11
Control (Water)	1.3 ± 0.3 a	1.3 ± 0.3 a	1.8 ± 0.3 a	2.3 ± 0.8 a	3.3 ± 0.8 a	4.4 ± 0.5 a	4.4 ± 0.6 a	4.7 ± 0.3 a	5.0 ± 0.0 a	5.0 ± 0.0 a	5.0 ± 0.0 a
D-C-Tron Plus (5.0 ml/lit)	1.6 ± 0.5 a	1.3 ± 0.1 a	1.5 ± 0.7 a	1.4 ± 0.5 a	1.0 ± 0.6 b	1.2 ± 0.6 b	1.9 ± 0.3 b	3.0 ± 0.8 ab	3.1 ± 1.2 ab	4.2 ± 0.6 a	4.6 ± 0.3 a
Oberon 240SC (0.2 ml/lit)	2.1 ± 0.6 a	2.7 ± 0.7 a	2.1 ± 0.2 a	1.8 ± 0.5 a	0.5 ± 0.3 b	0.7 ± 0.3 b	0.9 ± 0.1 b	1.0 ± 0.1 bc	0.9 ± 0.3 bc	1.2 ± 0.5 b	2.8 ± 0.2 a
Oberon 240SC (0.2ml/lit) & D-C-Tron (5.0 ml/lit) Plus rotation	1.5 ± 0.7 a	1.9 ± 0.1 a	1.7 ± 0.4 a	1.3 ± 0.6 a	0.7 ± 03 b	0.4 ± 0.3 b	1.1 ± 0.2 b	1.0 ± 0.7 bc	1.3 ± 0.5 bc	2.2 ± 0.7 ab	3.5 ± 0.8 a
Oberon 240SC (0.1ml/lit) & D-C-Tron Plus (2.5 ml/lit) Mixture	1.3 ± 0.2 a	1.3 ± 0.3 a	1.1 ± 0.7 a	1.0 ± 0.3 a	0.7 ± 0.2 b	0.4 ± 0.2 b	1.3 ± 0.7 b	1.5 ± 0.6 bc	1.8 ± 0.4 abc	2.8 ± 0.5 ab	3.2 ± 0.5 a
Dynamec 1.8EC (0.25ml/lit)	0.6 ± 0.1 a	1.2 ± 0.1 a	1.5 ± 0.3 a	0.9 ± 0.4 a	0.7 ± 0.4 b	0.5 ± 0.3 b	0.4 ± 0.3 b	0.5 ± 0.3 c	0.1 ± 0.1 c	0.2 ± 0.2 c	1.1 ± 0.3 b
F – value	1.48	2.25	1.29	2.81	6.59	10.72	8.13	6.05	6.05	9.90	8.39

Within columns means followed with the same letter are not significantly different at P=0.05 (Student-Newman-Keuls Test).
SE - Standard error

The mite population in the control slowly but steadily rose from 0.9 mites per cm^2 to a maximum of 15.6 mites per cm^2 by the ninth week, six weeks after application of the second treatments. This was followed by a sharp drop, to 2.6 mites per cm^2 by the end of the experiment (Table 11). All the other treatments showed some decline in numbers after treatments followed by some rise towards the end of the experiment though not significant. By the end of the experiment the average population per cm^2 for control was significantly different from the other treatments. There was no significant difference between Oberon 240SC, the rotation, the mixture and Dynamec 1.8EC. Regarding total yields there was no significant difference between the treatments (Table 12).

Table11: The effect of various treatments on the population of red spider mites (*T. evansi*) in a green house in Jomo Kenyatta University

Treatments	**Mite population (mites/cm^2) taken fortnightly for 11 weeks + SE**					
	1	3	5	7	9	11
Control (Water)	0.9 ± 0.5 a	0.3 ± 0.2 a	3.8 ± 1.0 a	7.7 ± 1.6 a	15.6 ± 1.6 a	2.6 ± 0.6 a
D-C-Tron Plus (5.0 ml/lit)	1.2 ± 0.7 a	0.1 ± 0.1 a	0.1 ± 0.1 b	0.3 ± 0.2 b	5.3 ± 2.1 b	3.2 ± 0.9 a
Oberon 240SC (0.2 ml/lit)	1.2 ± 0.5 a	0.0 ± 0.0 a	0.0 ± 0.0 b	0.0 ± 0.0 b	0.3 ± 0.2 c	0.6 ± 0.2 b
Oberon 240SC (0.2ml/lit) & D-C-Tron (5.0 ml/lit) Plus rotation	0.6 ± 0.2 a	0.0 ± 0.0 a	0.0 ± 0.0 b	0.1 ± 0.1 b	0.1 ± 0.1 c	1.2 ± 0.6 b
Oberon 240SC (0.1ml/lit) & D-C-Tron Plus (2.5 ml/lit) Mixture	0.6 ± 0.2 a	0.0 ± 0.0 b	0.0 ± 0.0 b	0.2 ± 0.2 b	0.4 ± 0.2 c	1.0 ± 0.6 b
Dynamec 1.8EC (0.25ml/lit)	0.3 ± 0.2 a	0.1 ± 0.1 a	0.0 ± 0.0 b	0.0 ± 0.0 b	0.2 ± 0.2 c	0.0 ± 0.0 b
F – value	0.75	1.93	13.65	21.05	27.52	4.72

Within columns means followed with the same letter are not significantly different at P=0.05 (Student-Newman-Keuls Test).
SE - Standard error

Table 12: The effect of various treatments on the red spider mites (*T. evansi*) on the yield of tomatoes in the green house experiment at the Jomo Kenyatta University.

Treatments	***Total yield / plant in g*** + SE
Control (Plain water)	210.4 ± 24.8 a
D-C-Tron Plus	249.4 ± 46.2 a
Oberon 240SC	262.3 ± 48.8 a
Oberon 240SC & D-C-Tron Plus rotation	233.2 ± 51.4 a
Oberon 240SC & D-C-Tron Plus mixture	236.7 ± 60.4 a
Dynamec 1.8EC	181.7 ± 46.0 a
F – Value	1.16

Within columns means followed with the same letter are not significantly different at P=0.05 (Student-Newman-Keuls Test).
SE - Standard error

6.4.2: Field Experiments

In the first experiment the damage score for control and D-C-Tron Plus showed an increase up to the maximum (score 5), by the sixth and seventh week respectively (Table 13). This was four and five weeks after application of the first treatment respectively. This remained so up to the end of the experiment. While the score was more or less the same for all the plots just before treatments, that is about 2, plots treated with Oberon 240SC, Oberon 240SC/D-C-Tron Plus rotation, Oberon 240SC and D-C-Tron Plus mixture and Dynamec 1.8EC showed reduced rate of increase in damage score and the score never reached the maximum.

Table 13: The effect of various treatments on the red spider mites (*Tetranyyshus* spp) damage score on tomatoes in the first field experiment at the University of Nairobi Upper Kabete Campus

	Damage score for 9 weeks +SE								
Treatment	1	2	3	4	5	6	7	8	9
Control (Water)	0.2 ± 0.0 a	1.1 ± 0.2 a	2.3 ± 0.2 a	4.0 ± 0.2 a	4.8 ± 0.1 a	5.0 ± 0.0 a	5.0 ± 0.0 a	5.0 ± 0.0 a	5.0 ± 0.0 a
D-C-Tron Plus (5.0 ml/lit)	0.1 ± 0.0 bc	0.2 ± 0.1 a	2.0 ± 0.2 a	1.8 ± 0.2 b	4.4 ± 0.1 a	4.7 ± 0.1 a	5.0 ± 0.0 a	5.0 ± 0.0 a	5.0 ± 0.0 a
Oberon 240SC (0.2 ml/lit)	0.2 ± 0.1 bc	03 ± 0.1 a	2.2 ± 0.2 a	1.8 ± 0.2 b	2.4 ± 0.2 cd	2.4 ± 0.2 b	2.9 ± 0.2 d	3.3 ± 0.2 b	4.0 ± 0.1 c
Oberon 240SC (0.2ml/lit) & D-C-Tron (5.0 ml/lit) Plus rotation	0.2 ± 0.1 bc	0.2 ± 0.1 a	2.0 ± 0.2 a	2.3 ± 0.2 b	2.6 ± 0.2 c	2.7 ± 0.2 b	3.6 ± 0.2 bc	4.3 ± 0.1 a	4.6 ± 0.1 ab
Oberon 240SC (0.1ml/lit) & D-C-Tron Plus (2.5 ml/lit) Mixture	0.3 ± 0.1 b	0.6 ± 0.1 a	1.9 ± 0.2 a	2.4 ± 0.2 b	3.3 ± 0.2 b	2.8 ± 0.2 b	3.7 ± 0.2 b	4.4 ± 0.1 a	4.3 ± 0.2 bc
Dynamec 1.8EC (0.25ml/lit)	0.0 ± 0.0 c	0.2 ± 0.1 a	2.2 ± 0.2 a	2.3 ± 0.2 b	2.1 ± 0.2 a	2.3 ± 0.2 b	3.0 ± 0.2 cd	2.7 ± 0.2 c	3.2 ± 0.2 d
F – value	3.26	13.75	3.64	10.22	26.60	32.53	23.50	27.64	22.07

Within columns means followed with the same letter are not significantly different at P=0.05 (Student-Newman-Keuls Test).
SE - Standard error

In the second field experiment the score for the control rose up to 4.9 by the end of the experiment up from 1.6 (Table 14). The score for the D-C-Tron Plus plots showed an increase up to 3.4 by the 4th week from 0.9. A drop to 2.1 probably occasioned by the second application of treatments followed this. The rise thereafter was minimal ending at 2.7 by the end of the experiment. The other treatments showed minimal changes through out the period of the experiment. This situation could be attributed to the application of treatments in the first and the third week. In the sixth and seventh weeks there was some rise in score probably because of increase in the mite population and senescence.

Table 14: The effect of various treatments on the red spider mites (*T. evansi*) damage score on tomatoes in the second field experiment at the University of Nairobi Upper Kabete Campus

	Damage score for 7 weeks +SE						
Treatment	1	2	3	4	5	6	7
Control (Water)	2.0 ± 0.1 a	1.6 ± 0.2 a	2.4 ± 0.2 a	4.3 ± 0.1 a	4.5 ± 0.1 a	4.9 ± 0.1 a	4.9 ± 0.1 a
D-C-Tron Plus (5.0 ml/lit)	2.0 ± 0.1 a	0.9 ± 0.1 a	2.0 ± 0.3 ab	3.0 ± 0.3 b	3.4 ± 0.2 b	2.1 ± 0.2 b	2.7 ± 0.2 b
Oberon 240SC (0.2 ml/lit)	2.0 ± 0.1 a	1.4 ± 0.2 a	1.4 ± 0.3 b	1.6 ± 0.2 c	1.9 ± 0.2 c	1.0 ± 0.1 d	1.0 ± 0.2 e
Oberon 240SC (0.2ml/lit) & D-C-Tron (5.0 ml/lit) Plus rotation	2.0 ± 0.1 a	1.5 ± 0.2 a	1.1 ± 0.2 b	2.4 ± 0.2 b	2.1 ± 0.2 c	1.6 ± 0.2 c	1.6 ± 0.2 cd
Oberon 240SC (0.1ml/lit) & D-C-Tron Plus (2.5 ml/lit) Mixture	2.0 ± 0.1 a	1.7 ± 0.3 a	1.6 ± 0.2 ab	1.6 ± 0.2 c	2.3 ± 0.2 c	1.4 ± 0.1 cd	1.7 ± 0.1 c
Dynamec 1.8EC (0.25ml/lit)	2.0 ± 0.1 a	1.5 ± 0.3 a	1.2 ± 0.2 b	1.6 ± 0.2 c	1.8 ± 0.3 c	1.3 ± 0.2 cd	1.2 ± 0.2 de
F – value	0.0	1.75	2.89	18.79	15.54	57.86	62.31

Within columns means followed with the same letter are not significantly different at P=0.05 (Student-Newman-Keuls Test).
SE - Standard error

The mite populations showed significant differences between treatments for both the first and second field experiments (Tables 15 and 16). The effects of the different populations were visible in the field (Plates 4 – 9).

Table 15: The effect of various treatments on the red spider mites (*Tetranychus* spp) population (number of mites per three leaflets) on tomatoes in the first field experiment at the University of Nairobi Upper Kabete Campus

	Mite population (mites / three leaflets) in the specified time (weeks) + SE						
Treatment	3	4	5	6	7	8	9
Control (Water)	36.9 ± 17.0 a	264.3 ± 5.5 a	221.2 ± 30.2 a	408.5 ± 73.3 a	522.0 ± 77.4 a	31.6 ± 37.6 b	0.0 ± 0.0 c
D-C-Tron Plus (5.0 ml/lit)	39.3 ± 7.3 a	71.6 ± 12.2 b	223.1 ± 50.7 a	138.8 ± 42.4 b	173.3 ± 41.5 b	188.3 ± 40.7 a	174.6 ± 45.3
Oberon 240SC (0.2 ml/lit)	36.2 ± 8.7 a	6.3 ± 0.7 c	7.8 ± 1.5 b	3.4 ± 1.0 c	2.8 ± 0.6 d	2.2 ± 0.8 b	2.7 ± 1.7 b
Oberon 240SC (0.2ml/lit) & D-C-Tron (5.0 ml/lit) Plus rotation	36.8 ± 10.5 a	15.0 ± 3.2 c	7.0 ± 2.0 b	8.8 ± 3.1 c	5.8 ± 2.1 cd	17.8 ± 7.0 b	44.8 ± 13.8 b
Oberon 240SC (0.1ml/lit) & D-C-Tron Plus (2.5 ml/lit) Mixture	33.3 ± 6.2 a	11.3 ± 3.1 c	5.3 ± 1.0 b	2.2 ± 0.8 c	8.5 ± 1.6 c	9.5 ± 3.6 b	34.2 ± 11.7 b
Dynamec 1.8EC (0.25ml/lit)	23.6 ± 8.8 a	17.8 ± 4.3 c	17.6 ± 6.1 b	1.8 ± 1.5 c	2.9 ± 1.1 d	1.0 ± 0.5 b	0.8 ± 0.3 c
F – value	0.78	13.87	12.86	14.78	22.88	6.23	7.19

Within columns means followed with the same letter are not significantly different at P=0.05 (Student-Newman-Keuls Test).
SE - Standard error

Table 16: The effect of various treatments on the red spider mites (*Tetranychus* spp) population (number of mites per three leaflets) on tomatoes in the second field experiment at the University of Nairobi Upper Kabete Campus

	Mite population (mites / three leaflets) in the specified time (weeks) + SE						
Treatment	1	2	3	4	5	6	7
Control (Water)	23.8 ± 5.0 a	27.6 ± 5.9 b	117.0 ± 16.0 a	391.8 ± 54.8 a	579.8 ± 46.5 a	340.9 ± 68.1 a	119.8 ± 28.4 a
D-C-Tron Plus (5.0 ml/lit)	27.9 ± 9.3 a	51.7 ± 18.2 a	64.7 ± 18.2 b	41.7 ± 14.8 b	42.5 ± 18.6 b	30.7 ± 10.0 b	36.8 ± 7.0 b
Oberon 240SC (0.2 ml/lit)	19.2 ± 4.0 a	2.1 ± 0.5 c	2.9 ± 1.0 d	1.9 ± 0.5 c	0.5 ± 0.1 c	2.2 ± 0.9 cd	7.5 ± 3.7 cd
Oberon 240SC (0.2ml/lit) & D-C-Tron (5.0 ml/lit) Plus rotation	19.3 ± 5.1 a	1.1 ± 0.6 c	4.3 ± 2.2 d	3.5 ± 2.1 c	0.9 ± 0.3 c	1.7 ± 0.8 cd	6.0 ± 2.4 cd
Oberon 240SC (0.1ml/lit) & D-C-Tron Plus (2.5 ml/lit) Mixture	13.8 ± 2.7 a	2.1 ± 0.5 c	3.1 ± 1.3 d	1.9 ± 0.7 c	0.5 ± 0.2 c	3.8 ± 1.3 c	9.8 ± 3.3 d
Dynamec 1.8EC (0.25ml/lit)	19.7 ± 4.7 a	19.0 ± 3.9 b	10.7 ± 2.5 c	6.2 ± 2.7 c	1.0 ± 0.5 c	0.3 ± 0.1 d	2.0 ± 0.6 d
F – value	1.60	9.60	16.57	29.01	87.72	16.38	9.87

Within columns means followed with the same letter are not significantly different at P=0.05 (Student-Newman-Keuls Test).
SE - Standard error

Plate 4: Control treatment in the field

Plate 5: D-C-Tron Plus treatment in the field

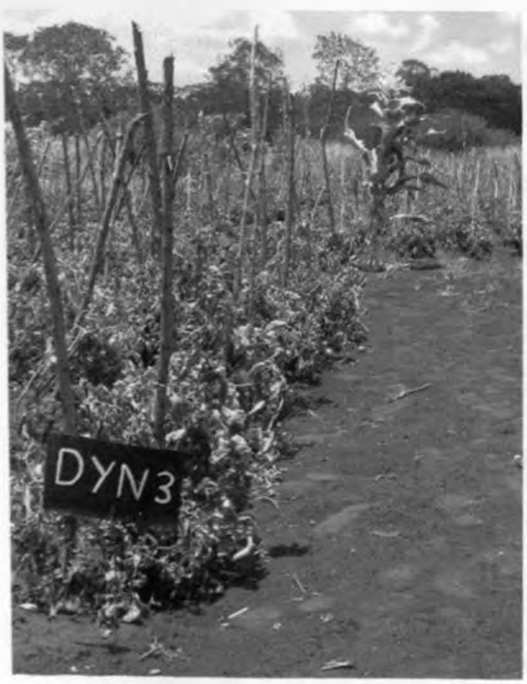

Plate 6: Dynamec 1.8 EC Treatment in the field

Plate 7: Oberon 240 SC treatment in the field

Plate 8: Oberon 240 SC and D-C-Tron Plus mixture treatment in field

Plate 9: Oberon 240SC/D-C-Tron Plus rotation treatment in field

In the first experiment the population increased rapidly for the control up to a maximum of 522.2 per three leaflets by the seventh week (the fifth after the first treatments) up from 36.9 mites per three leaflets just before the treatments (Table 15), and then dropped sharply to zero by the ninth week (the seventh after the first treatment) when the plants were completely dry. D-C-Tron Plus treated plots showed a significant increase in population up to a maximum of 223.1 per three leaflets by the fifth week (the third after the first treatment) and then declined a little but remained stable even up to the ninth week when the population was 174.6 per three leaflets. Plots treated by Oberon 240SC, Dynamec 1.8EC, the mixture of Oberon 240SC and D-C-Tron Plus and the rotation of the two showed a decline in population from a mean of 36.2, 23.6, 36.8 and 33.3 mites per three leaflets to 6.3, 17.8, 15.0 and 11.3 mites per three leaflets respectively following the first treatment. The population remained low all through up to the seventh week, at which time the populations started to increase somewhat for the mixture and the rotation, but remained low for Oberon 240SC and Dynamec right up to the ninth week.

In the second experiment there was a clear-cut increase in population of the control up to 579.8 mites per three leaflets by the fifth week up from 23.8 mites per three leaflets (Table 15). A sharp drop followed this to 119.8 mites per three leaflets by the seventh week. D-C-Tron Plus only showed a mild increase from 27.9 to 64.7 mites per three leaflets by the third week. This population did not change much because of the high rains in the month of November 2003 (Table 9). For the other treatments the population showed a decline after the first treatments and remained less than 11 mites per three leaflets even up to the end of the experiment.

The results on yield recorded no significant differences between treatments, though there were small differences in average yields per hectare for the total yields, the marketable yields and unmarketable yields (Table 17).

Table 17: Yield of tomatoes with different treatments of chemicals on the red spider mites (*Tetranychus* spp) at the University of Nairobi Upper Kabete Campus.

Treatment	***Total yield (tonnes / ha) ± SE***	***Marketable yield (tonnes / ha) ± SE***	***Unmarketable yield (tonnes /ha) ± SE***
1st Field Experiment			
Control	22.5 ± 1.6 a	19.9 ± 1.3 a	2.6 ± 0.5 a
D-C-Tron Plus	25.4 ± 1.4 a	21.4 ± 1.3 a	4.0 ± 0.4 a
Oberon 240SC	26.0 ± 2.7 a	22.8 ± 2.5 a	3.2 ± 0.3 a
Oberon 240SC and D-C-Tron Plus rotation	25.7 ± 3.0 a	22.2 ± 2.4 a	3.5 ± 0.8 a
Oberon 240SC and D-C-Tron Plus mixture	27.9 ± 2.7 a	23.9 ± 2.6 a	4.0 ± 0.4 a
Dynamec 1.8EC	27.5 ± 1.9 a	24.6 ± 1.4 a	3.0 ± 0.6 a
F-Value	1.91	2.12	1.25
2nd Field Experiment			
Control	23.4 ± 5.3 a	20.5 ± 4.6 a	2.8 ± 0.7 a
D-C-Tron Plus	30.4 ± 3.5 a	26.0 ± 3.0 a	4.4 ± 0.5 a
Oberon 240SC	34.7 ± 6.4 a	31.2 ± 6.0 a	3.6 ± 0.4 a
Oberon 240SC and D-C-Tron Plus rotation	26.2 ± 2.8 a	22.9 ± 2.8 a	3.3 ± 0.1 a
Oberon 240SC and D-C-Tron Plus mixture	27.5 ± 5.7 a	23.2 ± 4.8 a	4.2 ± 1.0 a
Dynamec 1.8EC	33.8 ± 5.3 a	30.4 ± 4.2 a	3.4 ± 1.1 a
F-Value	1.34	1.54	0.84

Within columns means followed with the same letter are not significantly different at P=0.05 (Student-Newman-Keuls Test).

6.5: Discussion

These results indicate that Oberon 240SC was effective in the management of the red spider mites. The results agree with the manufacturer's assertions (Anonymous, 2002). The results also show that Oberon 240SC has long lasting residual control of the mites of up to two months after spraying. This fits in well with the recommendation of 1 to 2 applications on the red spider mites by the manufacturer.

The mixture of D-C-Tron Plus and Oberon 240SC achieved high control inspite of the fact that the rates were half that of the individual chemical treatments. This compared well with Oberon 240SC and Dynamec 1.8EC. These results are corroborated by Rae

(2000) who indicated that in some cases pesticides and oil mixtures exhibit enhanced performance against target pests. This may be attributed to increased canopy penetration and coverage on the plant surface, assisted passage of the active ingredient into plant tissues, and protection against abiotic factors, resulting in longer residual activity. Oils can also result in greater pick up of the active ingredient by the target pest and enhance cuticular penetration. The use of D-C-Tron Plus and Oberon 240SC rotation in the field achieved equally comparable results. The rotation therefore can be used to control the mites successfully and it will help go along way in reducing the chances of increasing levels of tolerance or of true resistance (Blair, 1989).

D-C-Tron Plus on its own did not achieve as much control of the mites as the standard acaricide (Dynamec 1.8EC). This is probably because the application of the treatments was done at a time when there was high mite population in the field. This agrees with Nicetic *et al*., (2001) who found out that D-C-Tron plus gave excellent protection against *T. urticae* infestation in roses, when applied fortnightly to roses when the mite population has not established. However, when applied when roses were infested with *T. urticae* above the economic threshold it only stabilized the population without reducing them below that threshold. Agnello *et al*. (1994) obtained similar results using petroleum spray oils against European red mite *Panonychus ulmi* (Koch) (Acarina: Tetranychidae) on apples.

The results also indicate that the yields did not show any significant difference between the treatments because sufficient mite population established after the fruits had set. It took along time for the mites to establish because of the high rainfalls in December 2002 and low ambient temperatures in August and early September 2003

(Table 8). Stacey (1985) reporting on the work done with leaf miners says that attack on leaves immediately surrounding the truss at the time of early fruit swelling apparently caused the ensuing loss. His work with tomatoes also showed that the top 12 leaves were the most important in causing the loss of a number of fruits. These are the leaves surrounding the truss at around the time of fruit set. This is consistent with the position held by Lohr, *et al.* (1998) who found that the spatial and temporal dynamics of *T. urticae* in tomato fields in Kenya show that mite densities are highest in the lower part of the plants. Stacey (1985) also showed that there is a delay of 5 – 6 weeks between the establishment of red spider mites damage and the response of diminished yield and that there is little indication that late damage even if severe causes serious additional yield loss.

6.6: References

Agnello, A. M., Reissig, W.H., Harris, T., (1994). Management of summer populations of European red mite (Acari: Tetranychidae) on apple with horticultural oil. J. Econ. Entomol. 87: 148 – 161.

Anonymous, (2002). Bayer East Africa Ltd BSN 2060 (Spiromesifen). Summary of the biological activity of the product. 22 April, 2002, pp8 (Unpublished).

Anonymous, (2003). Kenya Meteorological Department, Kabete Station. Computation sheet for the monthly weather summary 2002 and 2003.

Anonymous, (2005). Agriculture technical development; Application of mineral oils in plant pests and diseases. http://www.afcd.gov.hk/agriculture/eng/pso_e.htm

Blair, B. W., (1989). Laboratory screening of acaricides against *Tetranychus evansi* Baker and Pritchard. Crop Protection 8: 217-222.

Bohlen, E., (1978). Crop pests in Tanzania and their control. Verlag Paul Parley Berlin, Germany, pp 142.

Childers, C. C., (2000). Practical use of horticultural mineral oils in integrated pest and disease management programmes and their impact on natural enemies. Citrus Research and Education Centre, university of Florida, 700 Experiment Station Road, Lake Alfred, Florida 33850, United States of America. Available online on http://sprayoils.uws.edu.au//rae.shtml.

Lohr, B., Knapp, M., Sarr, I., Nzuma, I., (1998). Development of environmentally friendly management methods for red spider mites in smallholder tomato production systems. 1998-1999 ICIPE Scientific Report. pp. 88 – 91, ICIPE, Nairobi.

Meyer, M. K. P. S., (1996). Mite pests and their predators on cultivated plants in

Southern Africa. Vegetables and berries. Biosystematics Division, Agricultural Research Council, Pretoria, pp. 64 – 69.

Nicetic, O., Beattie, G. A. C., Meats, A. and Zheng, J (2001). Integrated pest management of two spotted mite *T. urticae* on greenhouse roses using PSO and the predatory mite *P. persimilis*. Exp. and Appl. Acarol. 25: 37-53.

Rae, D. J., (2000). Use of spray oils with synthetic insecticides, acaricides and fungicides. Centre for Horticulture and Plant Sciences, University of Western Sydney, Locked Bag 1797, South Penrith Distribution Centre, New South Wales 1797, Australia. Available online on; http://sprayoils.uws.edu.au//rae.shtml.

SAS Institute (1990). SAS users' guide. Cary North Carolina USA.

Stacey, D. L., Wyatt, I. J. and Chambers, R. J., (1985). The effect of glasshouse redspider mite damage on yield of tomatoes. Journal of Horticultural Science 60: 517-523.

Thwaite, G. W., Eslick, M. A. and Nicol, H. I., (2000). Evaluation of petroleum derived spray oils for integrated pest and disease management in apple orchards. NSW Agriculture, Orange Agricultural Institute, Forest Road, Orange, New South Wales 2800, Australia. Available online on: http://sprayoils.uws.edu.au//rae.shtml

Whalon, M. E. and Mota-Sanchez, D., (2000). Database of arthropod resistance to pesticdes. Michigan State University, centre for integrated Plant Systems; http://www.cips.msu.edu/resistance/rmdb/index.hmtl.

CHAPTER SEVEN

THE EFFECT OF OBERON 240SC (SPIROMESIFEN) AND D-C-TRON PLUS ON THE PREDATORY MITE (*P. persimilis*).

7.1: Abstract

A laboratory experiment was conducted to test the effect of Spiromesifen (Oberon 240SC) and D-C-Tron Plus on the predatory mite (*P. persimilis*). The experiment was laid using complete randomised design (CRD), with six treatments and four replications. The treatments included Oberon 240SC (0.2 ml/litre), D-C-Tron Plus (5.0 ml/litre), a mixture of the two at a ratio of 1:1 (that is 0.1ml/liter Oberon 240SC mixed with 2.5 ml/litre D-C Tron Plus), abamectin (Dynamec 1.8EC) (0.25 ml/litre) to act as standard miticide and plain water to act as control. The predators were fed on mites (*T. Urticae*), which had been treated with the various treatments above and observed for mortality for eight days. The methodology was developed based on guidelines of IOBC/WPRS Working Group "Pesticides and Beneficial Organisms" (Oomen, 1988). The total effect of all the treatments besides the control was 100%. This means that the products were not compatible with the *P. persimilis*.

7.2: Introduction

Due to different reasons (like reduction of adverse effects of pesticides on the environment and delay of resistance development of pests to pesticides), the use of beneficial organisms has to be combined with the application of insecticides, acaricides and fungicides. Often more than one pest species occur in the green houses or fields, so that pests like aphids and thrips cannot be controlled satisfactorily by their antagonists (Zhang and Sanderson, 1990), because of the use of harmful pesticides against other pests. This is the reason why the use of pesticides in an integrated pest management programme will only be successful if the biological control agent is left unharmed or at least not affected seriously. This is especially important when dealing with a new chemical product in the market. Global development in the pesticides market encourages less and less use of pesticides and use of more environmentally friendly techniques like integrated pest management.

The predatory mite *P. persimilis* is used for the biological control of the two spotted spider mite *T. urticae* in glass houses (Oomen, 1988), and is one of the most frequently used beneficial in green house crops. *P. persimilis* is not an effective predator for *T. evansi*. The reason for the unsuitability of *T. evansi* for the phytoseiid predator is not known (Moraes and McMurtry (1986). It is said to exert remarkable control of *T. urticae* on bean plants in green houses (Chant, 1961) though this efficiency decreases when the prey density exceeds a certain density because of the disturbance of *P. persimilis* by the motile prey adults at high densities (Mori and Chant, 1966). At present two specific guidelines can be used to test the residual effect of pesticides on *P. persimilis* in the laboratory as published by the IOBC Working Group "Pesticides and Beneficial Organisms" (Oomen, 1988, Bakker *et al.*, 1992).

The test described by Oomen (1988) is performed on detached leaves, whereas the test described by Bakker *et al* (1992) is performed in ventilated glass cages. A disadvantage of the Oomen's (1988) test is that predators may escape from the treated leaf surfaces thus introducing two sources of inaccuracy. First, if predators return to the test arena their exposure time differs from the other test organisms. Second, if they do not return it is unclear whether they should be omitted from the analysis all together or whether they should be denoted as dead or alive. The problem was recognized by Samsoe-Petersen (1983) and Oomen (1988), but the authors did not offer a satisfactory solution (Blümel *et al.*, 1993). Mortality of the predators escaping into the barrier has been referred to as "runoff", and is considered to be a behavioural response to the chemical residue (Penman *et al.*, 1986; Riedl and Hoying, 1983). Some investigators have ignored runoff (Flexner *et al.*, 1988), while others have included it in their calculations (Fischer and Wrensch, 1986). In this study Oomen's (1988) test is used, using juvenile stages which are more easily arrested by moist cotton wool than adults. This study was conducted to determine the effect of Oberon 240SC, D-C-Tron Plus and their mixture on the predatory mite *P. persimilis*. The results of the work would establish the predatory capacity of *P. persimilis* when used in integrated management of the red spider mites (*T. urticae*) in tomatoes.

7.3: Materials and Methods

Appropriate dilutions of acaricides were prepared, which included, Oberon 240SC (0.2 ml/litre), D-C-Tron Plus (5.0 ml/litre), a mixture of the two at a ratio of 1:1 (that is 0.1ml/litre Oberon 240SC mixed with 2.5 ml/litre D-C Tron Plus), abamectin (Dynamec 1.8EC) (0.25 ml/litre) to act as standard acaricide and plain water to act as control. The experiment was arranged in complete randomised design (CRD) with four replications. The experiments conducted were residual toxicity studies and they targeted the juvenile stages of the predator mite, which is the most susceptible stage. Young dark green bean (*Phaseolus vulgaris* L.) leaves were detached from the plants and a total of 20 discs measuring 25 mm made from the leaves and placed underside up on petri dishes with moistened cotton wool. The discs were dipped in the different treatments and allowed to drip for about 15 minutes before transferring about 30 mites (*T. urticae*) to the discs as prey to the predators. Using a wet hairbrush and a binocular microscope 15 *P. persimilis* juveniles were transferred to each disc, immediately after the transfer of the mites. More *T. urticae* were added every 2 to 3 days in the subsequent times to ensure a continuous supply of living prey to the predators. The treatments were then monitored daily for a period of 8 days for mortality of the predators and oviposition in case the predator reached maturity.

In the first three days the numbers of dead and surviving predators per disc were counted and recorded. By day four the predators had reached maturity and some had started ovipositing and so the number of eggs per disc was taken and the eggs removed. At the same time the number of males and females still alive at this time was taken. This was continued up to the eighth day when the experiment was terminated and the total effect (E) of the pesticides per treatment calculated using the formula below.

$$E = 100\% - \frac{(100\% - Mt)}{(100\% - Mc)} \frac{Rt}{Rc}$$

Where;

Mt = % juvenile mortality of the treated group,

Mc = % juvenile mortality of the control group.

Rt = average egg production per treated female,

Rc = average egg production per female of the control group.

The Rt and Rc values are calculated per female present at the start of the adult stage, i.e. from day 4 onwards unless the females escape during the adult stage. This methodology was adopted from guidelines of IOBC/WPRS Working Group "Pesticides and Beneficial Organisms" (Oomen, 1988)

7.4: Results

The analysis was done with the escaped predators (those that died in the cotton wool barrier) being considered as either dead or alive. In both cases there was no significant difference between the treatments, but there was a significant difference between the treatments and the control. The total effect of the individual treatments on the beneficial capacity of the predator was 100 % (Table 18).

Table 18: The effect of various treatments on the beneficial capacity of the predator mite, *P. persimilis* after eight days.

Treatment	*Percentage mortality (inclusive of the escaped) ± SE*	*Percentage mortality (exclusive of the escaped) ± SE*	*Total effect (E) as a %*
Control	5.5 ± 3.6 b	6.9 ± 4.7 b	-
D-C-Tron Plus	55.0 ± 16.6 a	93.8 ± 6.3 a	100
Oberon 240SC	46.7 ± 9.4 a	100.0 ± 0.0 a	100
Oberon 240SC and D-C-Tron Plus mixture	75.0 ± 12.6 a	100.0 ± 0.0 a	100
Dynamec 1.8EC	81.7 ± 10.7 a	93.8 ± 6.4 a	100
F-Value	6.92	81.07	-

Within columns means followed with the same letter are not significantly different at P=0.05 (Student-Newman-Keuls Test).
SE – Standard Error

7.5: Discussion

The total effect on adult reproduction was 100%. This means that all the products tested were harmful. This is in agreement with (Oomen *et al.*, 1991 and Blümel *et al*, 1993) who observed that at 100% effect on adult reproduction it allows the pesticide to be classified as harmful without further testing because the effect is greater than 99%. Oomen (1988) also indicated that experience had shown that no product so classed by this test is classed otherwise in field tests. This test protocol has shown 83% efficiency (Oomen *et al.*, 1991). Toxicity test warrants that a persistence test be conducted when the effect is less than 30% in the laboratory conditions (Bakker, *et al*. 1992, Oomen, 1988). The results of the persistence test will allow the prediction of the introduction intervals of the phytoseiid after pesticide treatment with regard to harmful effects of the population development and the control effect of *P. persimilis.*

D-C-Tron Plus effect on the *P. persimilis* in the laboratory toxicity test was 100 % meaning that it may be incompatible in an integrated pest management with *P. persimilis* as a biological control agent. This is contrary to a finding by Thwaite *et al.*, (2000), who showed that horticultural mineral oils (HMOs) are compatible with integrated pest and disease management (IPDM) since there was no obvious disruption to the beneficial mites. Davidson *et al*., (1991) also observed the same but at the same time observed that predators and parasites may be killed on contact when the petroleum spray oil is sprayed directly on them. In this work a number of predators were trapped by the oil films and because they were juveniles may have either suffocated or starved to death. This probably explains the reason behind the death of the *P. persimilis* in this work. Otherwise Nicetic *et al* (2001) has indicated that D-C-Tron Plus can be combined with *P. persimilis* and achieve equally effective control of *Tetranychus* spp as synthetic miticides. The survival of beneficial arthropods can be further improved if a part of the canopy is not treated with pesticides and functions as a refuge (Davidson *et al.*, 1991; Zhang and Sanderson, 1995) for instance the application of petroleum spray oils to the top canopy.

7.6: References

Bakker, F. M., Groove, A., Blümel, S., Calis, J. N. M. and Oomen. P. A.,(1992). Side effect tests for phytoseiids and their rearing methods. Bulletin IOBC/WPRS. 992/XV: 61 – 81.

Blümel, S., Bakker, F. and Grove, A., (1993). Evaluation of different methods to assess the side effects of pesticides on *Phytoseiulus persimilis* A-H. Exp. Appl. Acarol., 17: 161 – 169.

Chant, D. A., (1961). An experiment in biological control of *Tetranychus telarius* (L) (Acarina: Tetranychidae) in green house using the predacious mite *P. persimilis* Athias – Henriot (Phytoseiidae). Can. Entomologist, 93: 437 – 443.

Davidson, N. A., Dibble, J. E., Flint, M. L., Marer, P. J. and Guye, A. (1991). Managing insects and mites with spray oils. University of California Special Publications. pp. 3347.

Fisher S. W. and Wrensch, D. L., (1986). Quantification of biological effectiveness for pesticides against *Tetranychus urticae* (Acari: Tetranychidae). J. Econ. Entomol., 79: 1472-1476.

Flexner J. L., Westgard, P. J. and Croft.B. A., (1988). Field reversion of organotin resistance in the two-spotted spider mite (Acari: Tetranychidae) following relaxation of selection pressure. J. Econ. Entomol., 81: 1516-1520.

Moraes, G. J. and McMurtry, J. A., (1986). Suitability of the spider mite *Tetranychus evansi* as prey for *Phytoseiulus persimilis*. Entomol. Exp. Appl. 40, 109-115.

Mori, H. and Chant, D. A., (1966). The influence of prey density, relative humidity and starvation on the predacious behaviour of *Phytoseiulus persimilis* (Athias-Henriot) (Acarina: Phytoseiidae). Can. J. Zool., 44: 483-491.

Nicetic, O., Beattie, G. A. C., Meats, A. and Zheng, J (2001). Integrated pest management of two spotted mite *T. urticae* on greenhouse roses using PSO and the predatory mite *P. persimilis*. Exp. and Appl. Acarol. 25: 37-53.

Oomen, P. A., (1988). Guidelines for the evaluation of side – effects of pesticides on *P. persimilis* A.H. IOBC/WPRS – Bulletin, 1988/XI/4: 51 – 64.

Oomen, P. A., Romeijn, G. and Weigers, G. L., (1991). Side effects of 100 pesticides on the predatory mite *Phytoseiulus persimilis*, collected and evaluated according to the EPPO guidelines. Bulletin OEPP/EPPO Bulletin 21: 701-712.

Penman, D. R., Chapman, R. B. and Bowie, M. H., (1986). Direct toxicity and repellent activity of pyrethroids against *Tetranychus urticae* (Acari: Tetranychidae). J. Econ. Entomol., 79: 1183-1187.

Riedl, H., and Hoying, S. A., (1983). Toxicity and residual activity of fenvalerate to *Typhlodromus occidentalis* (Acari: Phytoseiidae) and its prey *Tetranychus urticae* (Acari: Tetranychidae) on pear. Can. Entomol., 115: 807-813.

Samsoe-Petersen, L., (1983). Laboratory method of testing side effects of pesticides on juvenile stages of predatory mite *Phytoseiulus persimilis* A.H. (Acarina: Phytoseiidae). Based on detached bean leaves. Entomophaga, 28: 167-178.

Thwaite, G. W., Eslick, M. A. and Nicol, H. I., (2000). Evaluation of petroleum derived spray oils for integrated pest and disease management in apple orchards. NSW Agriculture, Orange Agricultural Institute, Forest Road, Orange, New South Wales 2800, Australia. Available online on: http://sprayoils.uws.edu.au//rae.shtml.

Zhang, G. Z. and Sanderson, J. P., (1990). Relative toxicity of abamectin to the predatory mite *Phytoseiulus persimilis* (Acari: Phytoseiidae) and two spotted mite (Acari: Tetranychidae). J. Econ. Entomol. 83: pp 1783-1790.

Zhang, Z. Q. and Sanderson, J. P., (1995). Two spotted spider mite (Acari: Tetranychidae) and *Phytoseiulus persimilis* (Acari: Phytoseiidae) on greenhouse roses: spatial distribution and predator efficacy. J. Econ. Entomol. 88: 352-357.

CHAPTER 8

GENERAL DISCUSSIONS, CONCLUSIONS AND RECOMMENDATIONS

In the survey carried out, there were mixed populations of the red spider mites in Kimana, Loitokitok, Maili Tatu and Rombo areas of Kajiado District. However the predominant species was *T. urticae*. The population of *T. evansi* in these areas can be described as minor. In Kimana *T. evansi* was identified on maize, besides being found on solanaceae plants. This means the mite may not be just a solanaceae pest. However more work on the host range needs to be done in order to determine with certainty the preferred hosts of *T. evansi*. In Mwea the species found on the tomato varieties was *T. urticae*. In Nakuru (Bahati – Subukia area) only *T. evansi* was found in all the solanaceae plants that were sampled. Considering the difference in altitudes and the geographical locations of the sample areas, it is clear that the new species of mite in Kenya has been able to and continues to spread widely, attacking both the solanaceae and non-solanaceae plants. This could explain the reason behind the increased losses in tomato production attributed to the red spider mites in the recent past in a number of areas. However, since this survey was basically on selected spot areas, the actual mites identification and distribution in Kenya is not fully known and therefore there is need to undertake a more comprehensive survey.

The laboratory, green house and field experiments show that, D-C-Tron Plus may be used as a contact pesticide against all the stages of the red spider mites (*T. evansi*), that is the eggs, the juveniles and the adults. The residual effect is only beneficial if it is an after effect of contact treatment. This use is especially practical in the green house where application may be much thorough than in the open field. Very low populations of the red spider mites however can only be achieved with more frequent application of the product of at least once a week so that the population does not reach threshold levels. Otherwise after that further application of D-C-Tron Plus won't achieve sufficient reduction of mite populations.

Oberon 240SC can be used as an acaricide against the red spider mites. The time of application of this product should be such that it limits development of the mite population, which may otherwise be difficult to manage and hence cause damage and crop loss. Hence the best time of application would be immediately the mites are sighted. At this time the population will be reduced or kept low because the eggs will not hatch and the adult mites will not lay fresh eggs. This is assured both by the contact and residual effect of the product. The residual effect of the product of about one month, confirms the fact that the product should be applied at most twice. If so done later infestations will not build populations, which will negatively affect the crop. The low rate of use of Oberon 240SC (0.2 ml / litre) once or twice in each growing season has been confirmed in this experiment. If so practiced it will reduce the possible adverse side effects of high volume spray of synthetic pesticides, like the mortality of natural enemies and pest resistance build up. As a result it will ensure environmental safeguard and cycles of susceptibility of the pest to the chemical over a long time.

The use of Oberon and D-C-Tron Plus mixture or rotation should be encouraged. One reason is that their use achieves as much and effective control of the mites as use of

Oberon 240SC singly. Besides such use will not only be economical but also environmentally friendly and will most certainly delay possibility of development of resistance to the synthetics. This will be because of less use of the synthetic chemical.

The application of D-C-Tron Plus singly at an interval of a fortnight is not effective in the management of the mites in the field conditions. A shorter interval will probably be more useful. However, application of Oberon 240SC at the rate of 0.2ml/liter (1000 litres of water per hectare) once or twice in a growing season is able to effectively manage the mites in the same conditions. For this reason, Oberon 240SC should therefore be registered by the Pest Control Products Board as a pest control product against the red spider mites in field conditions at the above-specified rate.

The effect of the use of Oberon 240SC and D-C-Tron Plus on the yield of tomatoes is likely to be higher, where the weather conditions favour fast build up of mite population so as to reach damage thresholds before the fruits set. These are areas like the low altitudes and green houses where the ambient temperatures are high. Without such considerations the use of these products will not be necessary since they will not cause any yield difference. For this reason, more work needs to be done in areas where earlier infestations are expected, so as to be able to assess the effect of the treatments on yields.

D-C-Tron Plus and Oberon 240SC and their combinations (a rotation or a mixture) are not compatible with the phytoseiid *P. persimilis*. This is especially so when both are used in the same site as pest control agents in an integrated pest control scheme. Since the effect of Oberon 240SC and D-C-Tron Plus and their mixture is 100%, there is no need to carry out further persistence tests in the field. This is because the effect is more than 30%. In this respect therefore all the treatments are harmful to the predator.