USE OF MULCHES TO MANAGE SPIDER MITES AND WHITEFLIES IN OPEN FIELD AND GREENHOUSE TOMATOES

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DECLARATION

This thesis is my original work and has not been presented for the award of a degree in this or other university

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DEDICATION

To the Almighty God for His everlasting love, guidance, protection and provision throughout the period of this study.

To my husband James Kihoro and son Onesmus Kariithi who supported me wholeheartedly during the study period.

To parents, relatives, and friends who may have contributed in one way or another to the completion of this study.

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LIST OF ABBREVIATIONS AND ACRONYMS

AEZ	Agro ecological zones
ANOVA	Analysis of variance
ERA	Economic Review of Agriculture
FAO	Food and Agriculture Organization
HA	Hectares
HCD	Horticultural crops Development authority
ICIPE	International Center for Insect physiology and Ecology
IPM	Integrate pest Management
KSH	Kenya shillings
KHDP	Kenya Horticultural Development Programme
LH	Lower highlands
LM	Lower midland
LSD	Least significance difference
MOA	Ministry of Agriculture
MDP	Ministry of Devolution and Planning
MRL	Maximum residue level
MT	Metric tones
UM	Upper midland

ABSTRACT

Tomato *(Lycopersium esculentum*) is one of the widely consumed vegetables in Kenya grown by both small holders and large commercial producers .A study consisting of a survey and field experiment was undertaken in Laikipia County to determine the occurrence, severity of spider mites and whiteflies infestation, and the farmer's management practices. The survey included 79 farmers, where 49 were open field tomato farmers while 30 were greenhouse tomato farmers. Simple random sampling technique was used to collect information on the occurrence and severity of spider mites and whiteflies on tomatoes, the farmers management practices, and the control measures applied by the tomato farmers in Laikipia County. Field experiments were carried out over two growing seasons at Nanyuki children's home in Laikipia County between August 2012 and June 2013. Experiments were conducted both inside the greenhouse and in the open field. Five treatments were administered as follows: Reflective mulch, no mulch, wheat straw mulch, black mulch, and chemical control. Chemical was applied as a positive control and no mulch plot provided negative control

The survey results indicated that majority (90%) of the respondents in the open field had spider mites infestation in their tomato crops, while 63% in greenhouse had similar problem. All the respondents (100%) in the greenhouse and open field had whiteflies infestation on their tomato farms. About 80 % of the open field production system had a high to very high infestation level (51-100%) of mites and whiteflies while in the greenhouse production system majority of the respondents (42% and 30%) reported low infestation level of 0-25% of mites and whiteflies respectively. A total of 79% of the greenhouse farmers who were interviewed had low to medium infestation level (0-50%) of mites and whiteflies, respectively.

Very high infestation level (76-100%) by spider mites and whiteflies was reported in the Upper midland 5 by 67% and 57% of the respondents respectively. High infestation level was noted in the Agro-ecological zone lower highland 4 (LH4) with a severity of 68% for spider mites and 60% for whiteflies. Similarly, medium infestation of 26-50% was noted at lower highland 5 (LH5) for the spider mites at 66.7% and 63.5% for whiteflies. The severity of infestation by spider mites was low in the UH2 and no respondent was noted with medium to high infestation 26-100%.

Chemical control was the most effective method for mites and whiteflies control in the open field and greenhouse tomato production systems .However, the three mulches reduced the number of mites and white flies on the tomatoes compared to the control. The mean number of mites over six weeks period was highest in the green house as compared to the open field production during both seasons. In the present study the mite numbers in the green house, when compared with the control were reduced by 37%, 51% and 44% by black, wheat straw and white mulch respectively. In the open field the numbers of mites were reduced as follows; 10.8%, 25%, 37% by black, wheat straw and white mulch respectively. The whiteflies numbers in the green house, when compared with the control were reduced by 27%, 48% and 45% by black, wheat straw and white mulch respectively. In the open field the numbers of whiteflies were reduced as follows; 37%, 51% and 64% by black, wheat straw and white mulch respectively. Among the three mulches the white mulch worked better in the control of mites and whiteflies in the open field than in the greenhouse environment. The wheat straw mulch reduced the pests population best in the greenhouse environment.

CHAPTER ONE: INTRODUCTION

1.1 Background information.

Tomato is one of the world's most popular vegetables grown both in home gardens and commercially in large scale farms (Kumar, 2010). An annual world production of 110 million metric tons was achieved in the year 2003 (FAO, 2004). Tomatoes are a good source of vitamins A and C and can be used to alleviate deficiencies of these vitamins in many developing countries. In Kenya, tomato is an important vegetable whose fruits are used in salads, cooked as a vegetable, processed into tomato paste, sauce and puree (MOA, 2009). Tomatoes are grown for fresh domestic market, processing and for export (Prasad and Kumar, 2010). Tomato production offers gainful employment for the Kenyan population because of the high gross margins that farmers can achieve through good management of the crop (MOA, 2009).

The most common varieties grown by small scale farmers are open pollinated and determinate such as Roma and the indeterminate variety like Money Maker (Dobson *et al*. 2001). While the indeterminate varieties are usually trellised and pruned to two to three shoots per plant to achieve better plant health and quality tomatoes, the determinate varieties are usually left untrellised (Saunyama and Knap, 2003). The changing climatic conditions have brought very unpredictable rainfall patterns, which have frustrated many farmers who depend on rain fed agriculture. Green house farming is therefore becoming a popular enterprise among many farmers in Kenya (Prasad and Kumar, 2010) and it involves growing of crops in a controlled environment which can either be from local or from commercially made materials glass covers, or green covers (Nelson, 1985).

1.2 Problem statement and justification

Tomatoes are utilized almost daily in most households and the demand is high (MOA, 2011). Low tomato production in Laikipia County does not meet the demand for consumption and marketing. Low productivity is a result of poor rainfall distribution, pests and diseases affecting the crop (MOA, 2010). The pests include spider mites, whiteflies and thrips. In order to control the pests, growers mainly use chemicals, thereby creating a problem of the presence of pesticide residues in and on the produce. Chemicals are also toxic, expensive and leave residues in the environment (HCDA, 2011). Tomato consumers are enlightened on pesticide residue effects on their health, and therefore, increasingly demand for clean and quality produce. In addition, tomato farmers have constantly pointed out the existing challenge of whiteflies and spider mites resistance to chemicals already in use. As tomato growing is very adaptable and grows well in warm conditions, pests and diseases should be controlled to minimize crop losses (Prasad and Kumar, 2010). Greenhouse tomato production is a good management practice aimed at increasing tomato production and minimizing losses from the adverse weather conditions. There is also need for further research to come up with alternative pest management methods to attain higher tomato yield.

1.3 Objectives of the study

The broad objective was to increase tomato production by reducing loses caused due to infestation by spider mites and whiteflies through alternative management strategies.

The specific objectives were:

i. To determine the occurrence and severity of spider mites and whiteflies in open field and greenhouse tomatoes in Laikipia County.

ii. To evaluate the effectiveness of mulches in managing spider mites and whiteflies in tomatoes.

CHAPTER TWO: LITERATURE REVIEW

2.1 Origin and cultivation of tomato

Tomatoes, *Lycopersicon esculentum* (Mill), belong to the family *Solanaceae*. It originated in tropical Central and South America and was first domesticated in Mexico. Its popularity increased in the tropics and the subtropics at the end of the nineteenth century (COPR, 1983).

Tomato growing is fairly adaptable and grows well in warm condition with optimum temperatures of 20–25 °C during the day and 15 – 17 °C at night (Prasad and Kumar, 2010). High humidity and temperatures reduces fruit set and yields while very low temperatures delay colour formation and ripening. Tomatoes prefer medium rainfall. In hot areas, water application at 3 – 5 days interval is essential. Wet conditions increase disease incidence and fruits fail to ripen. The soils should be well drained, light loam with high content of organic matter and pH of 5 – 7.5 (Nelson, 1985).

2.2 Tomato production in Kenya

Tomatoes are grown almost everywhere in Kenya up to about 2,000 Meters above sea level. Areas with high rainfall are unsuitable because tomatoes are highly susceptible to fungal diseases such as late and early blight. Most suitable areas include Central, Cost, Nyanza, Rift Valley, and Eastern Kenya. These are Meru, Embu, Oloitoktok, Nauru, Nyeri, Mwea, Muranga, Busia, Bungoma, kakamega, Kisumu, Taita taveta, among others (HCDA,2012). In Kenya, tomatoes are grown mainly in open field production system and recently in tunnel greenhouses (Prasad and Kumar 2010). Watering systems include rain fed, and irrigation. The main irrigation forms practiced are furrow, sprinkler irrigation and most recent drip irrigation.

Table 1.1 Area under tomato, production and estimated value in Kenya for the period 2009-2011.

Year	Area (Ha)	Production (MT)	Value (Ksh)
2009	17,230	354,356	8,549,178,482
2010	17,529	378,756	10,441,561,004
2011	18,178	407,374	12,353,653,058

Source: Economic Review of Agriculture 2012.

2.3 Greenhouse tomato production

There are two types of tomatoes which include the determinates and the indeterminates. The determinates are short varieties that do not require support for example the Roma, Cal J, Onex, and Monyala F1. The indeterminate varieties grow endlessly and require support system and are commonly grown in greemhouses. These varieties include Anna f1, Monset F1,,Tylka F,1Bravo F1, Riogrande, Kenton F1,amomg others(Odame.2009).

The Kenya Horticultural Development Programme (KHDP), the Agricultural inputs suppliers; Seminis Seeds and Osho Chemical industries have been promoting greenhouse tomato production to ensure supply of tomatoes throughout the year. To achieve this, they provide a demonstration kit comprising a 500 litre water tank, irrigation drip lines, plastic sheet, and chemicals all valued at one hundred and fifty thousand shillings to individual farmers in the project. Tomatoes grown under greenhouse technology are believed to have less disease and pest infestations than the open field production (Syngenta, 2010). According to KARI (2009) introduction and use of disease resistant cultivars coupled with other management practices may be instrumental in alleviating disease constraints in the production of tomatoes in Kenya.

Table 2: Tomato production figures and values in Laikipia County for the period 2009-2011.

Year	Area (HA)	Quantity (MT)	Value (KSH)
2009	345	4777	112,470,000
2010	563	8740	198,340,000
2011	420	7654	174,967,500

Source: Economic Review of Agriculture (2012)

Harvesting and yields depend on market requirements. For distant markets, fruit clusters are cut when the fruits start turning red or pink color depending on the cultivar (HCDA, 2010.) Firm red ripe fruits are required for the domestic market. Yields vary depending on the cultivar. On the whole, a marketable yield of 20 tons/ha and above is considered a good yield. Yields of up to 60 tons/ha have been obtained under experimental conditions at Thika (KARI, 2010). Kenya has also embraced greenhouse tomato production for increased productivity and to ensure supply throughout the year.

2.4 Constraints in tomato production

Tomato production limitations experienced by farmers include pests and diseases, high cost of inputs, poor quality seed, and adverse weather conditions (HCDA, 2011). Other constraints include uncoordinated and unorganized marketing, exploitation by middle men and poor production planning leading to over- supply in some months thus very low prices (MOA, 2011). Pest problems facing tomato production in Kenya are diverse, with the most important being whiteflies and red spider mites.

The major diseases which affect tomatoes include; late bright (*Phytophthora infestans Mont De Bary),* early blight (*Alternaria solani* Ell &Martin), bacterial canker *(Clavibacter michiganense subsp*. *michiganense* (Smith, Jensen), *Fusarium* wilt (*Fusarium oxysporum* f.sp *lycopersici* Synder & Hansen), leaf spot (*Septorial lycopersia* Lycopersici Synder & Hansen) and nematodes (*Meloidogyne spp*) (Varela et al., 2003). The physiological disorders in tomato include, Blossom end rot, which is as a result of calcium deficiency. The arthropod pests of importance include the red spider mites, *Tetranychus* spp, African bollworm (*Helicoverpa* armigera *Hubner*), whitefly (*Bemisia tabaci* Gennadius), Leaf hoppers *Empoasca spp*) and aphids (*Aphid macrosiphum, Aphids gossypil*) (Gleason & Brook, 2006).These pests and diseases are also a serious problem in tomatoes in other parts of Africa (Varela et al., 2003)

2.4.1 Red spider mites

The minute, spider like animals are barely visible with the naked eye and feed on sap from the underside of the leaves. Spider mites are of different species, the adult have eight legs, mostly dark red pale or two dotted at the back .The males are always paler in color, are more slender and shorter 0.3 to 0.35mm than the broad elliptical females approximately 0.5mm.(Nelson, 1985). They cause specking and tarnishing of the leaves turning yellowish to whitish. Severe infestation causes stunted growth, the leaves dries up and falls off, resulting to yield reduction. (Varela et al, 2003).

Mite infestation is more acute in dry areas or the irrigated tomato crop. The pest has a wide host range which include wild and cultivated plants such as tomatoes tea and pears (Takafuji et al. 2000). Tomato spider mite, *Tetranychus evansi* Baker & Pritchard, is a relatively new pest of tomato in Africa, accidentally introduced into Southern Africa around 1980 (Saunyama and Knapp, 2003). Since then, the species has spread and was recorded for the first time in Kenya in 2001.

The effects of pruning and trellising on red spider mite incidents and control, as well as damage and yield of tomatoes were investigated in two important tomatoes production areas of Zimbabwe (Saunyama and Knapp, 2003).The number of mites was lower in the pruned and trellised plots than in the non-pruned and non-trellised. (Saunyama and Knapp, 2003)
According to Kamau (1985), red spider mites infest and cause heavy damage to tomato plants with infestation level of about 25% in Kirinyaga and 10% in Kajiado districts. The percentage of farms infested with the mites 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 disticts ranges from 40 to 50%. (Kamau, 1985). Mites of agricultural importance include *Tetranychus urticae* (Koch), *Tetranychus evansi* (Baker and Pritchard) and *Panonychuscitri (*McGregor). *T. urticae (Koch)* causes most damage on horticultural crops (Saunyama and Knapp, 2003). T.evansi (Baker and Pritchard) is the major pest of tomatoes.

2.4.2. Management strategies of spider mites

Farmers use various methods to reduce spider mites population. These integrated methods include, removal and burning of infested plants during the early stages of infestation when they concentrate on a few plants (Pfadt,1985). Water and nutrient stress have proved to increase spider mite population. According to Pfadt (1985) influencing the microclimate by reducing the spacing and applying overhead irrigation does suppress the mites population. Chemical application when mite numbers increase is recommended (Varela *et al*. 2003). All plant parts should be thoroughly covered, especially the underside of the leaf where most spider mite life stages are located (Schuster *et al*. 2007).

2.5 Whiteflies

Whiteflies are small insects (about 2 mm long) (Nelson,1985) and are covered with white waxy powder and they fly short distances when plant foliage is disturbed .They are found mainly on the underside of young leaves. The host plant range is broad and it includes tomatoes; French beans; but they are mostly troublesome on tomatoes (Nelson, 1985). Whiteflies feed through a piercing sucking mouthpart, sometimes causing yellow stripping of leaves. They excrete honey dew which supports growth of black sooty mould (Fenemore and Prakash, 2006).

The adult whitefly lays a few eggs (20 eggs) often in a circle up to 250 eggs are laid by each female in her lifetime and each egg is attached to the leaf in an upright fashion by a thick stalk (Anderson, 2005).The eggs are creamy at first but eventually become dark, newly hatched crawlers emerge from the eggs in five to ten days and seek a feeding place. They insert their mouth into the leaf tissue and remain stationary for three weeks or so undergoing three moults. During these stages they are flat, scale, like insects and are transparent to greenish yellow in color (Evans, 2007). At the end of this period, they transform into non feeding pupa with two conspicuous eyes. A week later the winged adults emerge' and Females begin laying eggs two to seven days later. Depending on prevailing temperatures, the whole life cycle can take four to five weeks (Nelson, 1985). There are many whiteflies species. *Bemisia species* of whiteflies transmit *Gemini viruses* such as tomato yellow leaf curl virus (Valera *et al.*, 2003)

2.5.1 Management of whiteflies

An integrated pest management program for whiteflies include good cultural practices such as host free periods, conserving cultural enemies, routinely monitoring fields for any trouble spots and using pesticides only when necessary (Schuster, 2007). Parasitic wasps have been used successfully to control greenhouse whiteflies in protected crop situations elsewhere in the world where tomatoes are more commonly grown (Varela *et a*l 2003). These wasps include: *Encarcia formasa,* a parasitoid that lays its eggs in whiteflies nymphs and destroys it within 1-2 weeks. *Eretmocers eremicus* is also a parasitoid that is commercially available and provides better whiteflies control. *Delphastus catalinae* is a tiny predatory beetle that consumes whiteflies eggs and nymphs. Biological control is generally more expensive than chemical control and will not provide complete elimination of pests. However biological control has no residue effects on crops and the environment. (Fenemore and Prakash, 2006)

In Florida, pesticides have been the primary tactic for managing whiteflies and the viral diseases they transmit in tomatoes (Schuster *et al*. 2007). However, this method has not sufficiently controlled the spread of the non-persistently transmitted aphid-borne viruses in cucurbits (Webb *et al.*, 1993) and may not be effective for managing the whitefly-transmitted viruses. In addition, heavy reliance on insecticides increases the selection pressure and potential for resistance in whitefly populations (Dittrich *et al*, 1990). Several control methods have been reviewed for the control of viral diseases in cucurbits. They include border crops (Damicone et al. 2007), intercrops (Liburd *et al*. 2001), living mulches (Hooks et al, 1998; Frank and Liburd, 2005), floating row covers (Webb & Linda 1992), and reflective mulches (Alderz & Everett 1968);

(Wolfenbarger and Moore 1968); (Greenough et al, 1990); (Kring and Schuster 1992); (Summers and Stapliton, 2002); (Summers *et a*l. 2004); (Frank and Liburd, 2005).

2.6 Use of mulches in insect control

Mulches can either be organic or inorganic. Organic mulches include dry leaves, straw, wood chips, and grass chippings (Summers *et al.* 2003). Inorganic mulches include a thin layer of plastics that come in a range of colors like white, black, red and yellow (Summers *et al.* 2000). Plastic mulches have been used commercially on vegetables since the early 1960s. Plastic mulches directly impact on the microclimate around the plant by modifying the radiation budget (absorptivity verses reflectivity) of the surface and decreasing the soil water loss.

The color of the mulch largely determines the energy radiating behavior and its influence on the microclimate around a vegetable plant. Black plastic mulch absorbs most UV visible and infrared wavelenghs of the incoming solar radiation and re-radiates absorbed energy in the form of thermal radiation which can be transferred to the soil if the contact between the soil and the polythene is good(http:www.hort.uconn.edu/ipm /veg /htms /colrmmlch.htm accessed on second April 2012. White plastic mulch absorbs little solar radiation but transmits 85% to 95% with relative transmission depending on the thickness and degree of opacity of the polythene. This light reflectivity affects not only the crop growth but also the insect response to the plants grown on the mulch. Colours of mulches that attracts pests population include; Red, blue and yellow. White plastic mulches and reflective mulches reflect ultra violet light to the lower branches of tomatoes and can increase production, and have an effect on pests (Summers et.al 2002). Adult silver leaf whiteflies are repelled by silver or aluminum colored mulches. (Summers *et al*. 2000).

An integrated approach involving the use of a living or reflective mulch with a reduced-risk insecticide may provide a more sustainable approach for whitefly and disease management (Liburd and Nyoike, 2008).

Synthetic UV-reflective mulch has been reported to successfully protect various vegetable crops against insect pests and to reduce the incidence of viral diseases (Csizinszky *et al*., 1997; Smith *et al.,* 2000; Stapleton and Summers, 2002; Reitz et al., 2003; Summers *et al*., 2004). These mulches protect the crop during the early growing period from insect herbivores and delay the onset of insect-vectored viruses. Alternatively, living mulches have also been shown to reduce the possibility of whiteflies from locating their hosts and subsequently reduce transmission of viruses (Hooks *et al.,* 1998; Frank and Liburd, 2005). Living mulches provide food resources (honey and pollen) and shelter for natural enemies that could contribute to the reduction of pest populations (Root, 1973). (Hilje and Stansly 2008) reported a reduction in the number of adult whiteflies and the incidence of Tomato yellow mottle virus (TYMV) in Costa Rica when tomatoes were grown with living ground covers. Buckwheat (*Fagopyrum esculentum* Moench) is a living mulch shown to reduce insect pests and the spread of aphid-transmitted viruses in zucchini crops (Hooks et al., 1998; Frank and Liburd, 2005). 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, 2000).

CHAPTER THREE

OCCURRENCE OF SPIDER MITES AND WHITEFLIES IN TOMATO FARMS IN LAIKIPIA COUNTY

3.0 Abstract

A study consisting of a survey was undertaken in Laikipia County to determine the occurrence, severity of spider mites and whiteflies infesting tomatoes, and the farmer's management practices. The survey included 79 farmers, where 49 were open field tomato farmers while 30 were greenhouse tomato farmers. Simple random sampling technique was used to collect information on the occurrence and severity of spider mites and whiteflies on tomatoes, the farmer's management practices, and the control measures applied by the tomato farmers in Laikipia County. The results of the study indicated that majority (90%) of the respondents in the open field had spider mites infestation in their tomato crops, while 63% in greenhouse had similar problem. All the respondents (100%) in the greenhouse and open field had whiteflies infestation on their tomato farms. About 80 % of the open field production system had a high to very high infestation level (51-100%) of mites and whiteflies while in the greenhouse production system majority of the respondents reported low infestation level of 0-25% of mites and whiteflies respectively. Very high infestation level (76-100%) by spider mites and whiteflies was reported in the Upper midland 5 by 67% and 57% of the respondents respectively. The severity of infestation by spider mites and whiteflies was low in the Upper highland 2 (UH2).

3.1 Introduction

Tomato *(Lycopersium esculentum*) is one of the widely grown and consumed vegetables in Kenya. It is an important source of nutrition and income for both small holders and large commercial producers (Prasad and Kumar, 2010). Tomatoes are grown almost everywhere in Kenya up to about 2000m above sea level (MOA, 2009). Areas with high rainfall are unsuitable because tomatoes are highly susceptible to fungal diseases such as late and early blight. Most suitable areas include Meru, Nakuru, Nyeri, Embu, Oloitoktok, Garisa, Kisumu, among others (Syngenta, 2011).

In Kenya, tomatoes are grown either under irrigation, rain fed, and of late in tunnel greenhouses. High incidence of pests and disease infestation, lack of quality seeds and inadequate knowledge and skills on agricultural practices are among the major pointers to low yields in tomato production in Kenya (MOA, 2010). In Laikipia tomatoes are grown by both small and large scale farmers either under irrigation, rain-fed or in tunnel greenhouses.

Laikipia County has high agricultural potential as characterized by the potential farming lands in the South Western parts of the county (MOA, 2011). Over 60 % of households, derive their livelihood from agricultural activities. In 2011, Laikipia County had a total of 420 Ha of tomatoes with a production of about 7,654MT of tomatoes valued at Ksh.175 Million (ERA, 2012). A survey was undertaken to gain information on tomato production in the county and in particular the occurrence and severity of whiteflies and spider mites infesting tomato.

3.2 Materials and methods

3.2.1 Description of the study area

Laikipia County covers an area of 9,462Km$^{2.}$ With altitude varying between 1,500M to a maximum of 2,611M above sea level. The County consists mainly of a plateau bordered by the Great Rift Valley to the West, the Aberdares to the South and Mt. Kenya massifs to the South East all of which have significant effects on the climatic conditions of the County. The level plateau and the entire County drainage is dominated by the Ewaso Nyiro North basin with its tributaries which have their sources in the slopes of the Aberdares and Mt. Kenya and flow from South to north (MDP, 2013). The County experiences a relief type of rainfall due to its altitude and location. The annual rainfall varies from 400mm and 750mm though higher annual rainfalls are observed in the areas bordering the slops of Mt. Kenya and the Abardare ranges. The annual mean temperature of the County ranges between 16˚C and 26˚C (Emeritus, *et al.* 2009)

3.2.2 Determination of tomato production practices

A formal survey was carried out in Laikipia County between the months of May and June 2013. The area was stratified according to the selected agro-ecological zones which include Upper Highland 2 (UH2,) Lower Highland 4 (LH4,) Lower highland 5 (LH5), and upper midland 5 (UM5). Twenty five small scale tomato farmers were selected from the Agro ecological Zones throughout the County with the assistance of the respective Agricultural extension officers. Simple random sampling method was used. Ten greenhouse tomato farmers and fifteen open field tomato farmers were randomly selected in every Agro-ecological zone. Questionnaires Appendix 1 and 2 were administered to selected greenhouse and open field tomato farmers.

Multistage sampling technique was used. The first stage involved the selection of agro ecological zones where tomatoes were grown, and the second stage involved the selection of tomato farmers within those agro ecological zones. In each area farmers were randomly selected from the list of tomato farmers provided by the agriculture assistants in the respective areas. The questionnaires were intended to reveal information on tomato varieties grown by farmers, acreage, pest challenges, and the level of infestation with whiteflies and spider mites, management practices for both green house and open- field tomato pests. Samples of spider mites and whiteflies from each agro-ecological zone were collected for identification in the laboratory.

3.2.3 Determination of the population of mites and white flies

The questionnaires (Appendix 1&2) were administered with the assistance of the respective agriculture officers who directed me to where the tomato farmers were located. This was after a briefing meeting on the modalities to be followed when selecting the farmers and accessing the pests population. Three compound leaves per tomato plant which were randomly selected were picked from lower, middle, and top levels of the plant and pest infestation rated as in the questionnaire. The severity of infestation by spider mites and whiteflies was accessed using the rages of 0-25%, 26-50%, 51-75% and76-100% in open field and greenhouse production systems. The structured questionnaire was also intended to reveal information on occurrence, varieties grown, management practices and the control measures of spider mites and whiteflies in tomato farms in Laikipia County.

3.2.4 Data analysis

Statistical analysis was carried out using SPSS. Data on occurrence and severity of spider miter and whiteflies, tomato varieties grown, and the management practices were analyzed for frequencies. Excel was used for data entry while the percentages were calculated manually. The data was then presented in tables and figures using Excel.

3.3 Results.

3.3.1 Tomato production practices in Laikipia County

The results of the study show that majority (80%) of the tomato farmers interviewed in both open field and greenhouse production system were males while the rest (20%) were females. Males are equally involved in open field and greenhouse production systems while more females are involved in greenhouse production (Figure 3.1).

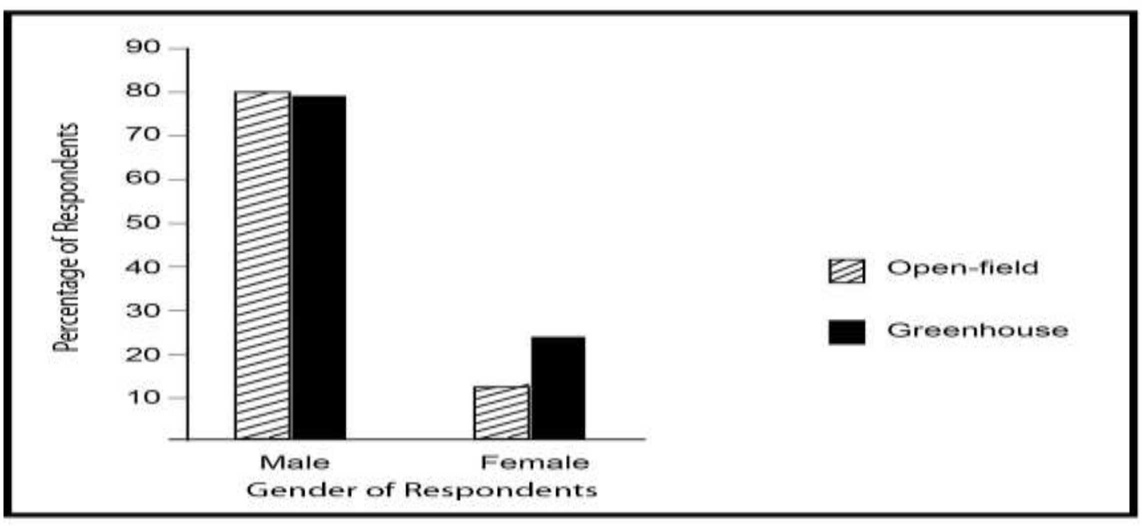

Figure 3.1 Percentage gender of respondents practising different tomato production systems in Laikipia

The age group between 51-60 years had majority of the respondents 30% both in open field and in greenhouse production. Majority (80%) of the respondents in open field and greenhouse were aged between 31-60 years (Figure3.2). This is because tomato production is labour and capital intensive and young farmers may not have the capital and the will to start the venture. Greenhouse tomato production also calls for skilled labour and is highly capital intensive.

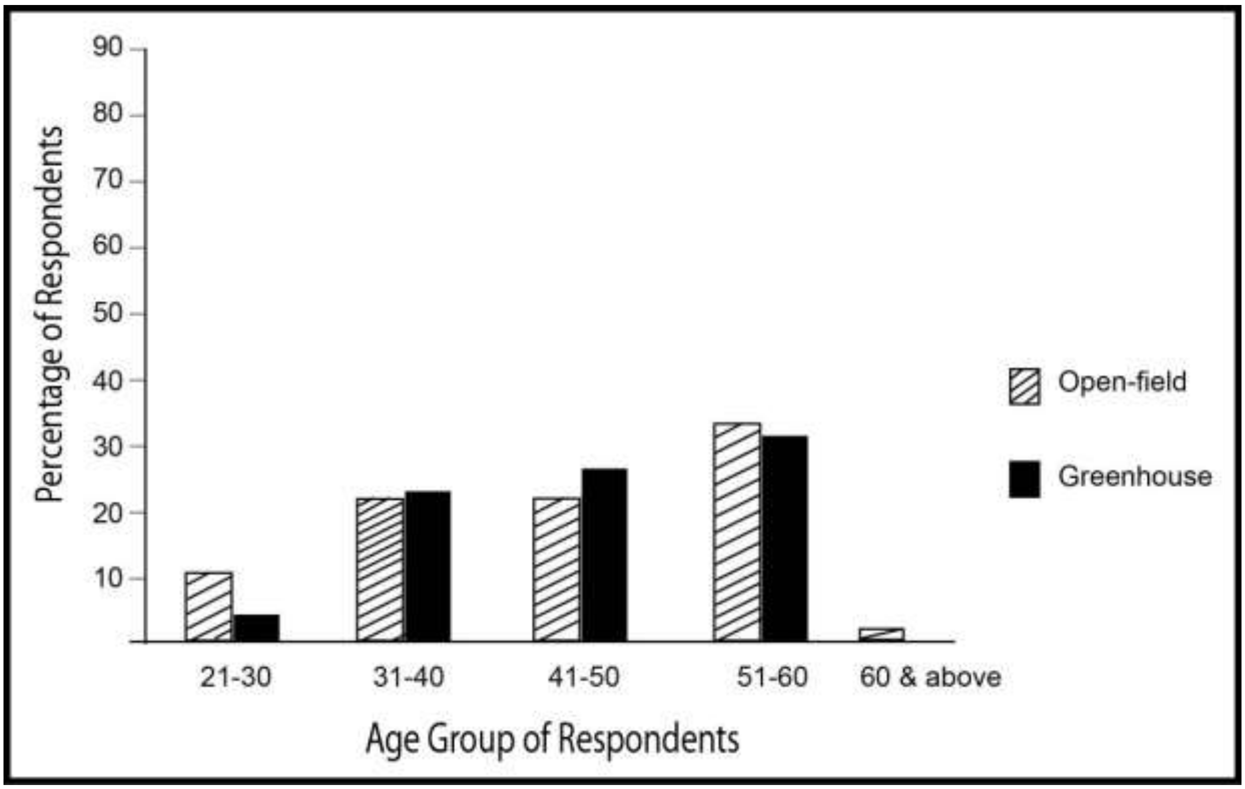

Figure 3.2 Percentage age of respondents practicing open field and greenhouse tomato production.

3.3.1.1 Total farm size and acreage under tomatoes in openfield and greenhouse production systems in Laikipia County

About 47% of the open field farmers interviewed had farms ranging between one and two acres in size and about 33 % had more than 2 acres while the rest had less than 1 acre. Forty four per cent of the greenhouse farmers had more than two acres of land, 36% had 1-2 acres and the rest had less than 1 acre (Table 3.1). For both categories of farmers interviewed, 20% had less than one acre. The majority of greenhouse tomato farmers (96.4%) had less than one acre of land under tomatoes while 79% of open field farmers had the same acreage under tomatoes. However 21% of open field tomato farmers had more than one acre of land under tomatoes (Table3.1).

Table 3.1 Percentage of farmers with different land sizes under tomato production systems in Laikipia County.

Acres	Total farm size		Acreage under tomatoes	
	Open field	Greenhouse	Open field	Greenhouse
< 1	20	20	79.2	96.4
1-2	46.9	36	18.2	0.0
>2	32.7	44	3.3	3.6

3.3.1.2 Tomato varieties grown in Laikipia County

In Laikipia, different cultivars of tomato are grown in the open field and green houses. Majority of the respondents about 85.5% of the farmers in the open field grew the popular tomato varieties Cal J, Rio-Grande and Onex in that order of preference as pure stands, mixed stands or alternately. Only about 15% of the farmers grow other cultivars such as Safari, Bravo and Money maker (table 3.2). In the greenhouse production the most popular varieties were the hybrids, Anna f1 and Tylka f1 grown by about 58 % farmers. The rest 36% grew Bingwa f1, Kenton f1 and Bravo f1 (table 3.2).The greenhouse varieties were different from the open-field varieties, although very little of Anna f1 (1%) was grown in the open field.

Table 3.2 Percentage of farmers growing different tomato varieties in openfield and greenhouse production systems in Laikipia County.

Varieties	Openfield	Greenhouse
Cal J	15.2	0
Rio-grade	12.5	0
Onex	11.2	0
cal ,Riograde&Onex	22.6	0
Onex & Cal J	10.4	0
Cal J &Riograde	12.5	0
Safari & Bravo	6.8	0
money maker	4.2	0
Anna F1	1.2	30.8
TylkaF1	0	26.7
Bigwa F1	0	16.3
Kenton F1	0	10.6
Bravo F1	0	9.4
Others	4	6.3

3.3.1.3 Farmers using different watering systems in open field and in greenhouse tomato production systems in Laikipia County

Laikipia County is generally arid and semi- arid land with low and unreliable annual rainfall of about 400-800mm.(MDP, 2013).This rainfall is not adequate for tomatoes production and. The majority (81.6%) of the open field tomato farmers used irrigation to grow their tomatoes while only 18.4% in the open field used rain fed production.

The level plateau and the entire County drainage is dominated by the Ewaso Nyiro North basin with its tributaries which have their sources in the slopes of the Abardares and Mt Kenya and flow from south to the North. These are the major sources of water for irrigation. The two major swamps in the County, Marura and Ewaso Narok swamps also provide enough water for irrigation (Emeritus et al. 2009).

3.3.1.4. Time period taken by farmers to harvest tomatoes in openfield and in greenhouse productin systems

Majority of the greenhouse farmers (81.5%) harvest their tomatoes for more than four months while the open field tomato farmers (74.5%) harvest for one to two months (figure 3.4). This is mainly due to the different varieties grown in open field and greenhouse production system. Majority of greenhouse varieties perform well and give about ten months of good production achieving a length of fifteen meters. Open field varieties are mostly short and bushy (Determinates). They produce stems that end up with a flower sluster and are easier to harvest. They mature early and have a more concentrated fruit maturity period.

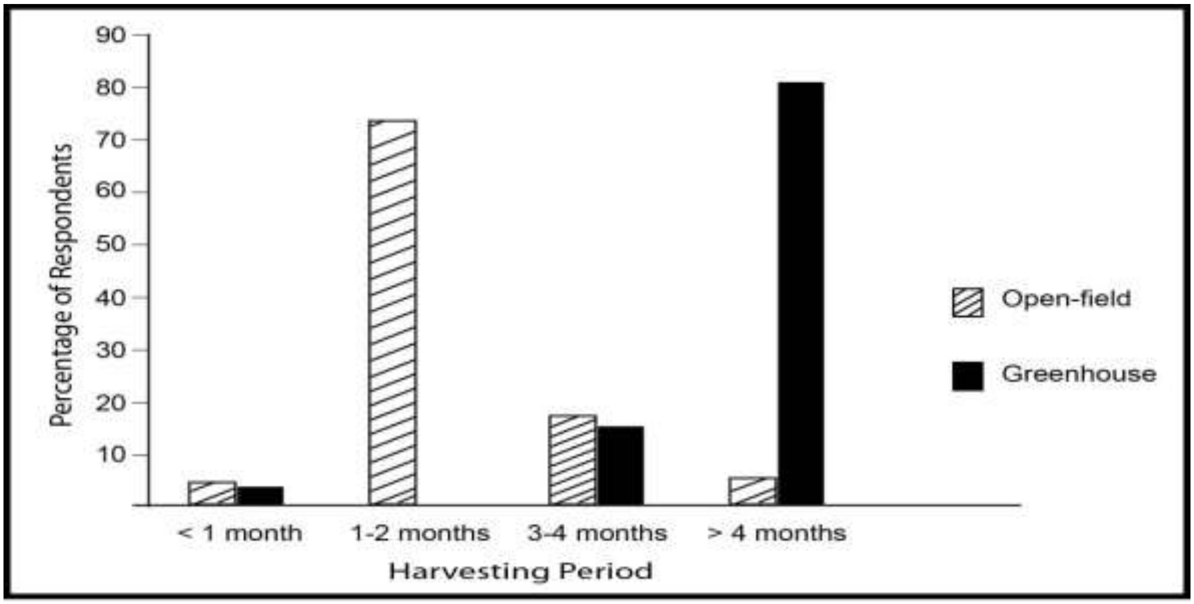

Figure 3.3 Time period taken by farmers to harvest tomatoes in production systems in Laikipia County.

3.3.2 Occurrence and severity of infestation by mites and whiteflies in Laikipia county

Farmers in Laikipia identified mites, whiteflies, aphids, thrips and leafminers as some of the pests which they found in tomato production systems. Open field tomato production system had a higher pest infestation (71%) as compared to the greenhouse production system. (50%). The greenhouse structure, therefore, seems to provide protection against pest infestation .Spider mites, whiteflies, and aphids had the highest infestation levels in greenhouse production (33.3%) compared to open field production (26.6%). Thrips and leaf miner had the lowest infestation level of 2.2% and 0.5% in the open field and in the greenhouse production respectively.

Ninety per cent of the respondents in open field had spider mites infestation in their tomato farms, while 63% respondents in greenhouse tomato production had similar problem. All the respondents (100%) in the greenhouse and the open field had whiteflies infestation on their tomato farms. This implies that spider mites and whiteflies are a major problem in tomato farms in Laikipia County. About 68/70% of the farmers reported a high infestation level (51-75%) of mites and whiteflies, in their farms. Slightly more than 10% farmers practicing open field tomato production reported very high infestation levels (76-100%) of the mites and whiteflies. About 80 % of the open field production system had a high to very high infestation levels of mites and whiteflies (Table 3.3). In the greenhouse production system 42% and 30% of the respondents reported low infestation level of 0-25% of the mites and whiteflies respectively. A total of 79% and 56% had low to medium infestation level (0-50%) of mites and whiteflies, respectively. A fifth of the respondents had high to very high infestation of mites while about half of the respondents reported high to very high infestation of whiteflies (Table 3.3). Forty two percent of the respondents reported having noticed mites infestation in their greenhouses compared to 30% who noticed significant whitefly infestation.

Table 3.3 Percentage of farmers with different severity levels of mites and whiteflies in tomato production systems in Laikipia.

Severity	Openfield		Greenhouse	
	Mites	Whiteflies	Mites	Whiteflies
0-25	8.3	7.89	42.1	29.6
26-50	11.1	13.2	36.8	25.9
51-75	66.7	68.4	10.5	33.3
76-100	13.9	10.5	10.5	11.1

Very high infestation level of 76-100% by spider mites and whiteflies were reported in the Upper midland 5 by 67% and 57% of the respondents respectively (Table 3.4). High infestation level (51-75) was noted in the Agro-ecological zone lower highland 4 (LH4) with severity of 68% for spider mites and 60% for whiteflies. Similarly medium infestation of 26-50% was noted at the lower highland 5 (LH5) for the spider mites at 66.7% and 63.5% for the whiteflies.

The severity of infestation by spider mites was very low in the upper highland2 at 0-25% and no respondent was noted with medium to high infestation 26-100% (Table 3.4).

Table 3.4 Percentage Severity of Infestation by Spider mites and Whiteflies in different Agro-Ecological Zones in Laikipia County**.**

Agro-ecol.	**Spider mites severity**				**Whiteflies severity**			
Zones	0-25	26-50	51-75	76-100	0-25	26-50	51-75	76-100
UH2	44.4	0.0	0.0	0.0	54.5	9.1	6.7	0.0
LH4	33.3	38.3	68	16.7	36.6	0.0	60	4.2
LH5	11.3	66.7	24	16.7	9.1	63.5	26.7	7.1
U M5	11.3	0.0	8.0	66.7	0.0	27.3	10	57.1

3.3.3. Farmers management practices for spider mites and whiteflies in Laikipia County.

Majority (95.5%) of the respondents use chemicals for spider mites and whiteflies control, and only 4.5% of the farmers who used other cultural methods like crop rotation burning of infected crop residues and general field sanitation for pest control in open-field tomato production. In the greenhouse production all the farmers interviewed used chemicals to control tomato pests

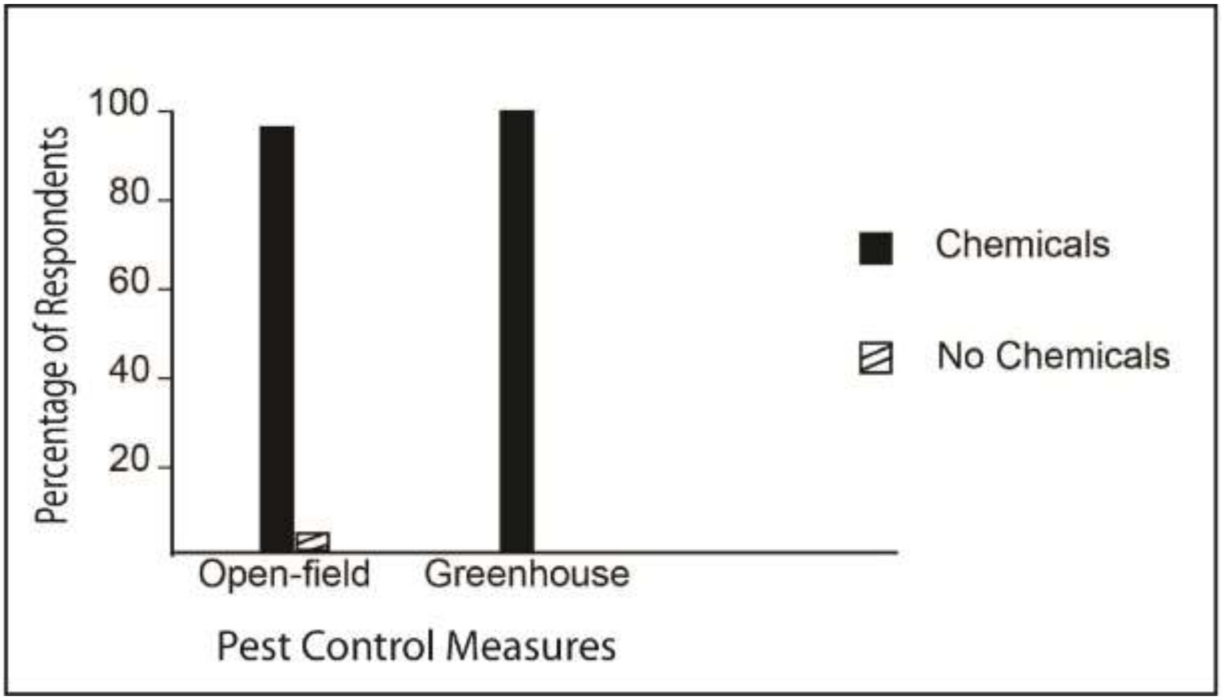

Figure 3.4 Percentage of farmers using different measures to control spider mites and whiteflies in tomato farms in Laikipia County.

For the spider mite control, about 20% of the open field farmers applied Dynamic and another 20% applied Karate and Dimethoate combined, followed by Polytrin and Bestox. In the greenhouse production 38% of the farmers applied Dynamic while 21% applied Polytrin, for the mites control (Table 3.5). Most popular chemical which was used in the control of whiteflies in open field production was Alpha tata followed by Dynamic and Thunder with 16.2%. In the greenhouse production majority of the respondents used Polytrin and Actara for whiteflies control.

Table 3.5 Percentage of chemicals applied to control spider mites and whiteflies in open field and greenhouse production systems in Laikipia County.

Chemical Used	Mites		Whiteflies	
	Open field	Greenhouse	Open field	Greenhouse
Bestox	9.3	0	0	0
Dynamic	18.6	36.8	18.9	6.25
Polytrin	11.6	21.3	8.1	37.5
Alpha-tata	4.6	0	32.4	12.5
Bulldock	0	0	8.1	6.25
Thunder	0	0	16.2	0
Actara	0	0	10.8	37.5
Cyclone	3.3	0	0	0
Almatic/ Karate	6.98	0	0	0
Dimethoate	18.6	5.3	0	0
Ortiva	0	0	5.4	0
Others	27.9	36.8	0	0

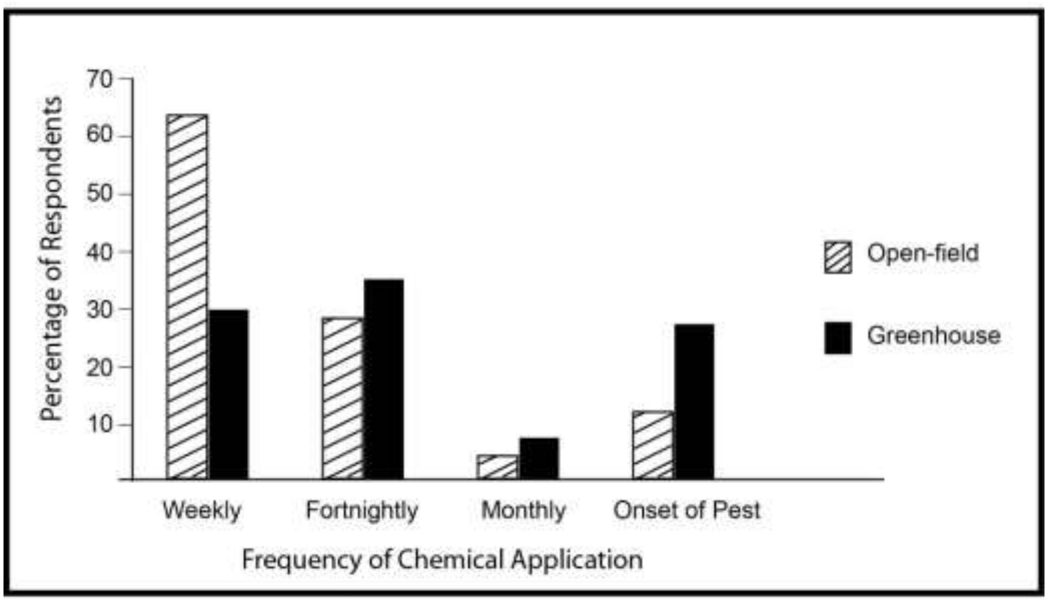

Figure 3.5 Percentage respondents frequency of chemicals application for both spider mites and whiteflies control in tomato production systems in Laikipia County.

The majority of open field respondents applied chemicals weekly while in the greenhouse production only 30% applied weekly. It is noteworthy that about a quarter of the farmers (25%) apply chemicals at the onset of the pest infestation (Figure 3.6). This implies that most of the open field tomato farmers applies chemicals more frequently and therefore have a higher risk of chemical residuals.

3.4 DISCUSSION

The results of the study show that majority of the tomato farmers in Laikipia both in the open field and greenhouse production systems were males whose age ranges between 31-60 years. This could be because tomato production is labour intensive and is also a commercial venture which brings in income for the family (Prasad and Kumar, 2010). Greenhouse varieties are quite different from open-field varieties. Most popular open field varieties in Laikipia included Cal J, Riogrande and Onex in that order of preference as pure stands. All these varieties are high yielding hybrids with resistance *to Fusarium* and *Veticulum* wilt, while Riogrande is resistant to Altenaria (Syngenta, 2011). These are important attributes in tomato seed selection. Most popular greenhouse varieties include Anna F1 and Tylka F1 which comprise of 58% while Biwa F1, KentonF1, and BravoF1, contribute 36%. Anna F1 and Tylka F1 are high yielding hybrids with resistance to tomato yellow leaf curl virus, *Fusarium* and *verticilium* wilts, bacterial specks, nematodes and blights(Odame, 2011).

Laikipia County is generally arid and semi- arid land with low and unreliable annual rainfall of about 400-800mm (MDP, 2013). This is not adequate for tomatoes production thus majority

(81%) of open field tomato farmers use irrigation to grow their tomatoes while only 18.4% in the open field used rainfed production system.

Majority of the respondents in open field and greenhouse had spider mites infestation on their tomato farms, and all the respondents in both greenhouse and open field had whiteflies infestation in their tomato farms. This implies that spider mites and whiteflies are a major problem in tomato farms in Laikipia County. About 80 % of the open field production system had a high to very high infestation level of mites and whiteflies while in greenhouse production system majority of the respondents 42% and 30% reported low infestation level of mites and whiteflies respectively. A total of 79% of greenhouse farmers interviewed had low to medium infestation level of mites and whiteflies, respectively. The greenhouse structure therefore seems to provide protection against pest infestation. This agrees with Robb *et al,* 2002 who indicated that physical exclusion can be achieved through use of greenhouse structures.

Very high infestation level of 76-100% by spider mites and whiteflies was noted in the Upper midland 5 by 66.7% and 57% of the respondents respectively. High infestation level (51-75) was noted in the Agro-ecological zone lower highland 4 (LH4) with severity of 68% for spider mites and 60% for whiteflies. Similarly medium infestation of 26-50% was noted at lower highland 5 (LH5) for spider mites at 66.7% and 63.5% for whiteflies. . The severity of infestation by spider mites was low in the upper highland2 and no respondent was noted with medium to high infestation 26-100%. This agrees with the findings of Mware *et al*, 2010 who noted that the altitude above sea level had an effect on the whiteflies population. The higher the altitude the fewer the whiteflies became.

In greenhouse production all the farmers interviewed used chemicals to control tomato pest although pesticides were applied weekly fortnightly, or at the onset of pests. Majority of open field tomato farmers applied chemicals weekly and fortnightly, therefore more chemicals are used. Similar observations were made by Nderitu *et al.* 2008 and Kilalo 2004 who reported that farmers mainly used synthetic pesticides for the control of pests and diseases. This agrees with the findings of Toroitich *et al,* 2014, Kithusi 2005 and Schuster *et al*. 2005 who observed that Dynamic and polytrin were effective in Spider mite control. Majority of the greenhouse farmers used Polytrin and Actara to control whiteflies while the rest used other chemicals.

The findings imply that pests are a major problem in tomato production in Laikipia County both in open field and in greenhouse production. Pesticides are the most popular methods of spider mites and whiteflies control. Pesticides are known to have residue effects on tomato and also to the environment. It is therefore important to source for alternative control methods that are environment friendly.

A combination of control measures is recommended taking into account the economics, the social, cultural, safety, legal and environmental concerns. Techniques that are not detrimental to the environment include cultural, mechanical, physical, biological, and integrated pest management (IPM) (Fenemore and Prakash, 2009).

CHAPTER FOUR

EFFECT OF MULCHES ON MITES AND WHITEFLIES IN GREENHOUSE AND OPEN FIELD TOMATO PRODUCTION

4.0 Abstract

Field experiments were carried out both in the greenhouse and in the open field tomato production systems to determine the effectiveness of mulches in the management of spider mites and whiteflies. Five treatments were administered as follows: Reflective mulch, no mulch, wheat straw mulch, black mulch, and chemical control. Chemical was applied as a positive control and no mulch plot provided negative control. Chemical control was the most effective method for mites and whiteflies control in the open field and greenhouse tomato production systems. However, the three mulches reduced the number of mites and whiteflies on the tomatoes compared to the control.

In the present study the mite numbers in the green house, when compared with the control were reduced by 37%, 51% and 44% by black, wheat straw and white mulch respectively. In the open field the numbers of mites were reduced as follows; 10.8%, 25%, 37% by black, wheat straw and white mulch respectively. The whiteflies numbers in the green house, when compared with the control were reduced by 27%, 48% and 45% by black, wheat straw and white mulch respectively. In the open field the numbers of whiteflies were reduced as follows; 37%, 51% and 64% by black, wheat straw and white mulch respectively. Among the three mulches the white mulch worked better in the control of mites andwhiteflies in the open field than in the greenhouse environment. The wheat straw mulch reduced the pests population best in the greenhouse environment.

4.1 Introduction

Tomato is an important crop grown in Kenya for local consumption and Export market (Prasad and Kumar, 2010). It is produced in Kirinyaga, Kajiado, TaitaTaveta, Meru, Bungoma, Kiambu, Migori, Makueni and Homa Bay counties in Kenya (HCDA, 2012). Production constraints in tomato include pests such as spider mites and whiteflies that cause yield reduction.(MOA, 2013). Chemical control is the main control strategy used to manage these pests (MOA 2012). Pesticides used are reported to increase residues in the tomato fruits causing health problems to the consumers (Syngenta, 2009). Pest resistance to the chemicals used has also been noted by tomato farmers in Laikipia County (MOA, 2011). Chemicals effects on the environment is an important aspect when choosing pest control methods. Use of different mulches to manage spider mites and whiteflies is an important alternative. The study was carried out to determine the effect of different mulches on Spider mites and whiteflies in tomato production in Laikipia County. Two season experiments were carried out from August 2012 to July 2013.

4. 2 Materials and methods

4.2.1 Experimental site

The experiment was established at Nanyuki children's home, Laikipia East constituency in Laikipia County. The home is situated on a three acre farm where vegetables, fruits and livestock farming are carried out. Tomato farming is a major enterprise and four greenhouses have been constructed with the assistance from well-wishers. The Home has a bore- hole that provides continuous supply of water for daily use and for the farm activities. The area lies along the Equator at altitude 1980 meters above sea level within Agro - Ecological Zone LH4 with an annual rainfall of 730-758mm. Rainfall pattern are bimodal with mean maximum temperature of

25^0C and mean minimum of 9^0C. The soils are moderately fertile, well drained, dark reddish brown clay loam.

4.2.2 Experiment layout and design

Tomato (Tylka variety) was raised in the nursery for one month and transplanted in the greenhouse and open fields. Planting was according to recommended spacing of 60cm by 45cm. Drip irrigation was used to supply the tomato seedling with water throughout the growing season. All other agronomic practices were carried out as recommended.

Experiment was conducted both in the greenhouse and in the open field. Two greenhouses of size 8 meters by 15 meters were used and two open fields of equal size just adjacent to the greenhouses. Five treatments were administered as follows: reflective mulches, no mulch, wheat straw mulch, black mulch, and chemical control. Chemical applied in the control plots was polytrin. The experiment was arranged in a randomized complete block design and arranged in a split plot design (green house and open field). The five treatments were administered in open field and greenhouse with four replications. Plot size inside and outside the greenhouse was 2x3 Meters for each treatment with border rows of 0.5 meters.

4.2.3 Assessment of spider mites populations

Five tomato plants were randomly selected from each plot and three leaves (lower middle and top) were picked and examined for the presence of spider mites. Identification and counting was made possible by the use of a magnifying lens. In cases of high infestation spider mites form a web on the underside of the leaves which makes it easy to identify them. Identification was based on adult biology which included length, width, in comparison to the already documented adult identification features. Spider mites are minute animals that feed on sap from the underside of the leaves and they are of different species. Total number of spider mites on the lower, middle, and top of each tomato leave sampled was established and recorded. Data collection was done weekly up to six weeks. Spider mites samples were collected and stored in 70% ethanol solution and transported to kabete Entomology laboratory University of Nairobi for identification to species level.

4.2.4 Assessment of white fly infestation

Sampling for whiteflies was done by counting the nymphs on the underside of the tomato leaves. The nymphs are small transparent, whitish creamy in color and are mostly attached on the underside of the leaves where they remain stationary for three weeks undergoing three molts (Mware et al 2010) Due to their minute size, counting was done by the use of a magnifying lens. Three leaves (lower, middle, and upper) were picked from five randomly sampled plants and the number of nymphs from each leaf recorded. Sampling started three weeks after tomato transplanting when the plant attained a height of thirty centimeters, and was done weekly for six weeks. Adult whiteflies were also collected using the aspirator (suction bottle) whereby small insects can be drawn into the bottle from the net or directly from the leaves to avoid malformation of insects. Adult whiteflies were stored in a cool box and transported to Upper Kabete entomology laboratory, Department of Plant Science and Crop Protection University of Nairobi for identification to species level. Identification was based on whiteflies adult biology, hind and forewing span, width, length, of antennae and body length (head-abdomen) in comparison to the already documented adult whiteflies identification features. Previously reported and documented host ranges in other studies (John et al 2007) were used to list and further helped to identify the whiteflies.

4.2.5 Data analyses

The data obtained from the experiments was subjected to analysis of variance to determine the most effective mulch in the management of mites, using Genstat computer software package. Comparison of means was done using Fischer's' protected least significant difference (LSD) at 95% confidence level.

4.3 RESULTS

4.3.1 Effect of mulches on spider mites in open field and greenhouse tomato production systems

The data obtained from the experiments was subjected to analysis of variance to determine the most effective mulch in the management of mites. The source of variation on production system, the seasons, the treatments and the weeks were highly significant in the experiment (Appendix III). The interactions between the production system and the seasons, and between the production system and the treatments was highly significant while the interaction between weeks, production system, and season were not significant The interaction between the weeks, production system, and treatment were not significant.

The results in this study showed that during both seasons and in open field and greenhouse conditions chemical control was the most effective in controlling mites. Mean of spider mites population in the chemical treated plots was significantly different ($p<0.05$) from the other treatments. The plots where no treatment was applied had the most number of mites across both seasons and in open field and greenhouse (Table 4.2). Among the three mulches the black mulch was the least effective on spider mites because it had the highest total number of mites during both seasons. However during the first season, the total number of mites in the

black mulch was not significantly different from that of wheat and white mulches. The total number of mites in the wheat straw mulch treatment was not significantly different from those in the white mulch. In the greenhouse among the three mulches, the wheat mulch had the least number of mites while in the open field the white mulch had the least number of mites (Table 4.2). Abaut10% of the youth aged between20-30 years are mostly involved in open field tomato production.

The total number of spider mites was highest in the green house as compared to the open field production during both seasons.(Table 4.1). During the first season both in the greenhouse and in the open field more number of mites was recorded compared to the second season. The covariance figure indicated for season two greenhouse experiment is quite high when compared to the other values. This was due to the breakdown of the greenhouse structure in the second season, which warranted for a repeat of the experiment after the greenhouse was repaired.

Table 4.1: Mean number of spider mites per tomato plant grown in the presence of different types of mulches in greenhouse and open field.

Type of mulch	Green house		Open field	
	Season 1	Season 2	Season 1	Season 2
Black	178.1_b	192.7_c	181.1_b	91.5_c
White	228.3_b	100.3b	146.9_b	44.42_b
Wheat	173.0_b	115.8_b	186.0_{bc}	41.7_b
Chemical	49.3_a	48.8_a	44.7_a	16.21_a
No mulch	303.6_c	292.0_d	205.8_c	99.29_c
L.S.D($p<0.05$)	59.24	41.56	42.79	18.72
CV (%)	22.2	57.7	30.7	30.7

Means followed by similar letters within a column are not significantly different

The total number of spider mites was highest in the green house as compared to the open field production during both seasons.(Table 4.1). During the first season both in the greenhouse and in the open field more number of mites was recorded compared to the second season. The covariance figure indicated for season two greenhouse experiment is quite high when compared to the other values (Table 4.2). This was due to the breakdown of the greenhouse structure in the second season, which warranted for a repeat of the experiment after the greenhouse was repaired.

Table 4.2 Percentage reduction of spider mites by the presence of different types of mulches in greenhouse and open field

Type of mulch	Green house			Open field		
	Season 1	Season 2	%Reduction	Season 1	Season 2	%Redution
Black	178.1	192.7	37.8	181.1	91.5	10.9
White	228.3	100.3	44.8	146.9	44.4	37.4
Wheat	173.0	115.8	51.8	186.0	41.7	25.6
Chemical	49.3	48.8	83.7	44.7	16.2	87.8

The mean population of spider spider mites in the open field was high in the control plots while the chemical controlled plot had the least mean mites population throughout the six weeks (Figure 4.1). The white mulch had second least mean spider mite population, while wheat straw mulch performed better than the black mulch. The mean spider mites population was low at week one, which increased gradually in all plots up to week six. The chemical controlled plot had the least mean mites population, white mulch was the second best control method while the wheat straw mulch was third best mulch to control mites in open field tomato production. The black mulch had a high mean mite's population while the plots with no mulch had the highest mean mite's population (Figure 4.1).

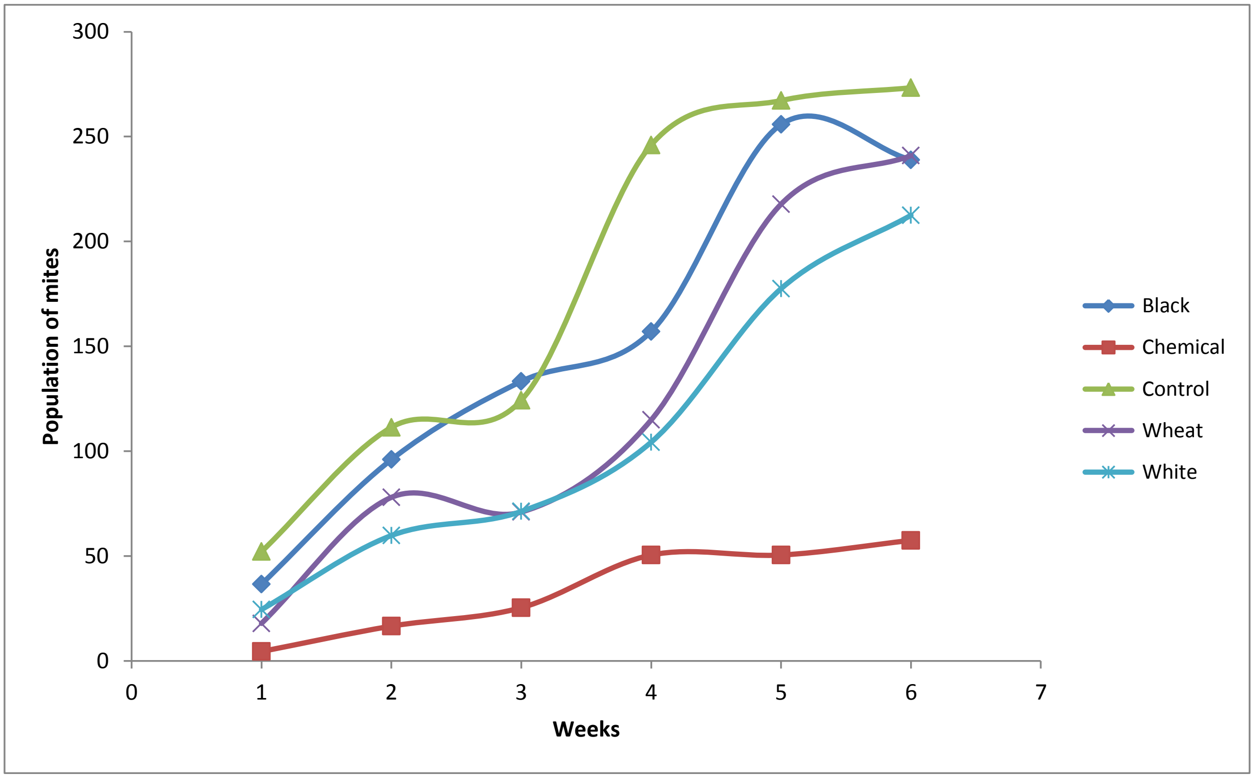

Figure 4.1 Mean mite's population in open field taken over six week's period for season one and two in Laikipia County.

Throughout this study the chemical controlled plots had the least mean number of mites throughout the six weeks. The white mulch had the third least mean population while the wheat straw mulch was second. The plot with no mulch had the highest mean population of mites while the back mulch had a lower population. This implies that the white mulch was better than the wheat straw mulch in the open field plots (Figure 4.2)

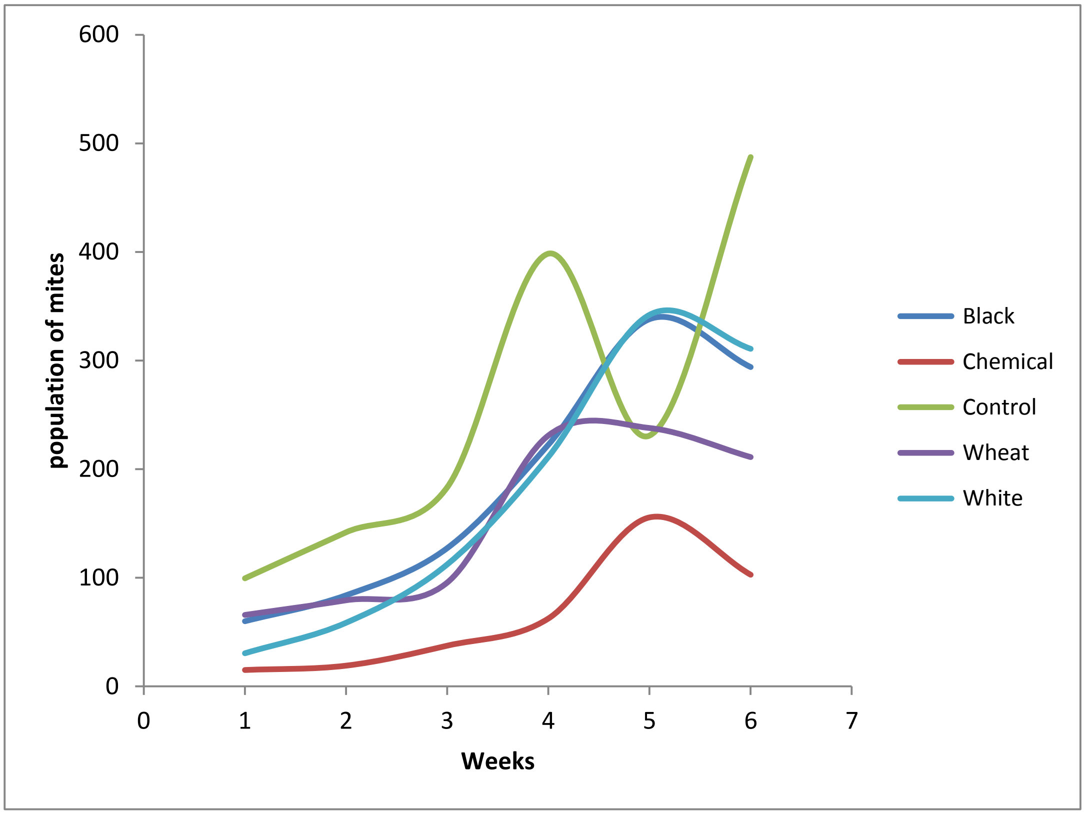

Figure 4.2 Mean populations of spider mites in greenhouse over six week's period for season one and two in Laikipia County.

In the greenhouse production system the total mean number of spider mites was much higher than in the open field production system (Figure 4.2).This is because the rate of multiplication in the greenhouse is much higher than in the open field. The plots where no treatment was applied (control) had the most number of mites in the greenhouse production system (Figure 4.2) Chemical control was the most effective method in mites control. Among the three mulches the black mulch was the least effective on spider mites control because it had the highest total number of mites throughout the six weeks. The wheat straw mulch was the best mulch to control spider mites in the greenhouse production system (Figure 4.2).

4.3.2 Effect of mulches on whiteflies in open field and greenhouse tomato production systems.

The data obtained from the experiments was subjected to analysis of variance to determine the most effective mulch in the management of whiteflies, using Genstat computer software package. Comparison of means was done using Fischer's' protected least significant difference (LSD) at 95% confidence level. The production system, the seasons, the treatments and the weeks were highly significant in the experiment (Appendix IV). The interaction between the weeks and the seasons, weeks and the treatments, and the production system and treatment were highly significant. The interaction between the weeks, season and treatment was not significant.

The plots with no treatment had the highest total number of white flies during both seasons and in open field and greenhouse production system. The numbers of white flies in the control plots were significantly different ($p<0.05$) from the other treatments. Among the three mulches black mulch had the highest number of whiteflies during both seasons and in the two places of production. It was however different from control except in season 1 in the greenhouse. The number of white flies in the wheat and white mulch were not significantly different during both seasons in the green house and during the first season in the open field. In the second season the white polythene reduction in the open field was comparable to that of the standard chemical. The mean number of white flies during both seasons was highest in the green house compared to the open field production (Table 4.3). The plots with no mulch had the highest mean population of whiteflies, while all other treatments reduced the population of whiteflies. Chemical control remained the best control method, while the white mulch reduced the whiteflies population better than the wheat straw mulch. The black mulch was the least effective with the highest mean whiteflies population (Table 4.3).

Table 4.3 Mean number of whiteflies per tomato plant grown in the presence of different types of mulches in greenhouse and open field

	Green house		Open field	
Type of mulch	Season 1	Season 2	Season 1	Season 2
Back	187.6_b	221.1_c	59.8_c	95.6_c
White	177.6_b	128.8_b	46.9_b	41.54_a
Wheat straw	153.4_b	138.3_b	54.3_{bc}	67.0_b
Chemical	65.4_a	70.7_a	22.8_a	27.1_a
No mulch	256.9_c	304.5_d	74.9_d	175.6_d

The whiteflies population increased gradually up to the fifth week but decreased at week six in the four experiments except in the control plots (Figure 4.3). The tomato plots mulched with wheat straw had less mean number of whiteflies compared with those mulched with white mulch. This implies that the wheat straw mulch is better mulch to control whiteflies in the greenhouse than in the open field. The black mulch is the least effective mulch in whiteflies control because it had the highest mean population of whiteflies. Chemical control remained the best whiteflies control method in greenhouse tomato production with 83.7% reduction of whiteflies population after chemical application (Table 4.4). The reduction was calculated over the two seasons and compared with the total population in the control plots. The whiteflies numbers in the green house, when compared with the control were reduced by 27%, 48% and 45% by black, wheat straw and white mulch respectively.

Table 4.4 Percentage reduction of whiteflies by the presence of different types of mulches in greenhouse and open field.

Type of mulch	Green house			Open field		
	Season 1	Season 2	%Reduction	Season 1	Season 2	%Reduction
Back	187.6	221.1	27.0	59.8	95.6	37.0
White	177.6	128.8	45.0	46.9	41.54	64.0
Wheat straw	153.4	138.3	48.0	54.3	67.0	51.0
Chemical	65.4	70.7	83.7	22.8	27.1	80.1

In the open field, chemical control reduced the whiteflies numbers by 80%. The three mulches reduced the whiteflies numbers as follows; 37%, 51% and 64% by black, wheat straw and white mulch respectively (Table.4.4).

In the present study, whiteflies mean population increased from week one to week six in the open field production system (Figure 4.3). Chemical control had the least whiteflies population among the treatments applied while white mulch had the least mean population of whiteflies. Among the three mulches applied the white mulch reduced the population of the whiteflies better than the wheat straw mulch. . Chemical control remained the best control method, while the white mulch reduced the whiteflies population better than the wheat straw mulch. The black mulch was the least effective with the highest mean whiteflies population (Figure.4.3)

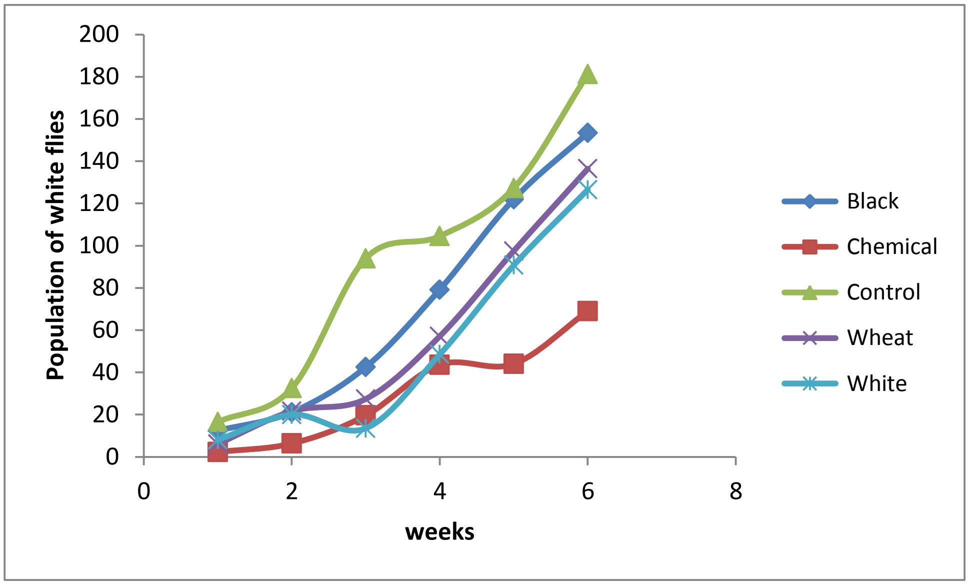

Figure 4.3 Mean of whiteflies population in open field over a six weeks period in Laikipia County.

Results of this study indicate that the number of white flies in open field production increased gradually up to the 6th week for all the plots (Figure 4.3). The plots with no mulch had the highest mean population of whiteflies, while all other treatments reduced the population of whiteflies. Chemical control remained the best control method, while the white mulch reduced the whiteflies population better than the wheat straw mulch. The black mulch was the least effective with the highest mean whiteflies population.(Appendix V)..

In the greenhouse production system, the number of white flies increased up to the 5th week after which they dropped in the 6th week (Figure 4.4). Chemical control remained as best control method. Among the mulches applied, white mulch was better than wheat straw mulch in whiteflies control in the first four weeks .After the fourth week wheat straw mulch performed better than the white mulch in the greenhouse production system. Black mulch was the least effective mulch in the management of whiteflies in the open field (Figure 4.4)

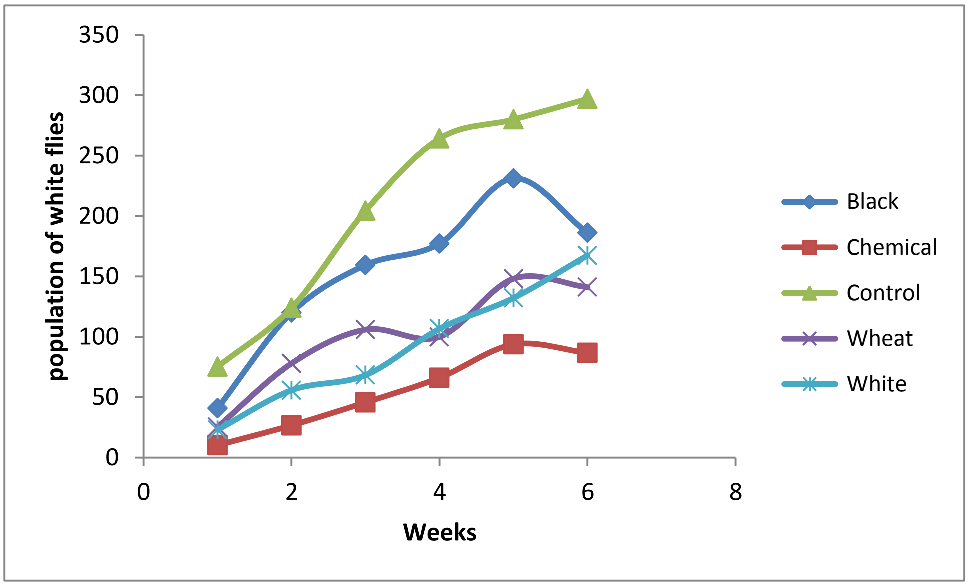

Figure 4.4 Mean Whiteflies Population in Greenhouse over a six weeks period in Laikipia County.

4.3.3 Effect of mulches on both spider mites and whiteflies, and results on identification of pests.

Below is a table to show the comparison between the effect of mulches on spider mites and whiteflies data obtained after the analyses of variance. (Table.4.4). Production system, the seasons, the treatments and the weeks were highly significant in the experiment for both the spider mites and the whiteflies. The interactions between the weeks and the production systems, and the interaction between production system and season were not significant. The interaction between the production system and the treatments was highly significant while the interaction between weeks, production system, and season were not significant The interaction between the weeks, production system, and treatment were not significant.

4.4 DISCUSSION

The analysis of variance tables show that the effects of the weeks, production system, season and the treatments were highly significant on the effects of the population of mites and whiteflies. The interactions between the weeks and the seasons, were highly significant. The numbers of spider mites and whiteflies in the plots where no mulches were applied was significantly different from all the other treatments. This is in agreement with Luko and Philip (2007) who observed that significantly more whitefly adult days were observed on plants in the bare soil treatment compared to any of the other treatments. The three mulches reduced the number of mites and white flies on the tomatoes compared to the plots without any treatment. The whiteflies numbers in the green house, when compared with the control were reduced by 27%, 48% and 45% by black, wheat straw and white mulch respectively. In the open field chemical control reduced the whiteflies numbers by 80%. The three mulches reduced the whiteflies numbers as follows; 37%, 51% and 64% by black, wheat straw and white mulch respectively.This shows that mulching has an effect on the number of insects attacking a crop. This is in agreement with Reitz et al. 2003; Stapleton and Summers 2002; Summers et al. 2004 who observed that reflective mulch alone has successfully reduced whitefly populations, delayed and decreased the spread of viruses transmitted by various insect pests. Living mulch has also been reported to reduce whitefly, spider mites and aphid numbers and the incidence of insect-borne viruses in zucchini squash and tomatoes, respectively (Hooks et al. 1998; Hilje and Stansly 2008). However among the three mulches black mulch had the highest number of mites and whiteflies during both seasons in open field and in greenhouse production. The white mulch had lower mean pests population in the open field than the wheat straw mulched plots. This is because Reflective mulch reflects shortwave light, which repels pests, interfering with their orientation (Zitter & Simons 1980; Csizinszky et al. 1997). The effectiveness of UV reflective mulch in reducing the incidence of Cucurbit Leaf crumple Virus (CuLCrV) is attributed to its ability to repel pests, preventing them from alighting on host plant (Nyoike et.al 2008). Wheat straw mulch in the greenhouse reduced the whiteflies and mites population much better than the white mulch. This may be attributed to the shading effects of the greenhouse coverings that affects the ultraviolet (UV) wavelengths (Stapleton and Summers 2002; and Summers et al 2004).

The result of the research indicates that chemical control remained the most effective method for the control of spider mites and whiteflies. In both seasons and in both places of productions, chemical control was the most effective. This is in agreement with Takafuji et al, 2000 and Toroitich, 2006 who described chemical control as the most practical method for spider mites control. However they pointed out the effects to the environment, the accumulated chemical residuals in the crops and the possibility of resistance by these pests. The plots with no treatment had the highest total number of spider mites and whiteflies during both seasons in open field and in greenhouse. The numbers of mite and whiteflies in the control were significantly different from all the other treatments. During the first season, the total number of mites and whiteflies in the black mulch was not significantly different from the wheat and white mulches. Summers et al, 2004 reported similar findings that the number of alate aphids on foliage was not significantly different among the three mulches: aluminum, white-painted or black plastic mulches. Similarly, the number of leaf miners *Liriomyza spp.* and the number of colonies of *Tetranychus urticae* Koch spider mites were not significantly different among the aluminum, white-painted or black plastic mulches. From this study the results indicate that among the three mulches the black mulch was the least effective spider mite and whiteflies control method. It had the highest total number of pests during both seasons and in both places of production. Schally and Robbins, 1987 however observed fewer aphids and higher yields in tomato plots mulched with aluminum compared to black plastic but also observed more fruit damaged by the tomato pinworm, *Keiferia lycopersicella* (Wals.), and the tomato fruitworm, *Helicoverpa zea* (Boddie). Black plastic film sprayed with aluminum paint reduced the numbers of thrips on tomatoes relative to unpainted plastic although the effects were not consistent (Scott *et al.* 1989).

Black plastic mulch absorbs most UV, visible, and infrared wavelengths of incoming solar radiation and re-radiates absorbed energy in the form of thermal radiation. Much of the energy by black plastic can be transferred to the soil by conduction if contact between mulch and soil surface is good. Soil temperatures under black plastic mulch during the daytime are generally five degrees F higher at two inch depth and three degrees at four inch depth compared to that of bare soil. The increased soil temperature could also provide a conducive environment for pest multiplication (htp:www.hort.uconn.edu/ipm/veg/htms/colmch.htm.accesed on 25th April 2014. In the black plastic mulch weeds are killed in the absence of light, while increased temperatures improves crop yields.(Odame,2009)

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CHAPTER FIVE

GENERAL DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

5.1 General discussion and conclusions

The results of this study indicated that ninety per cent of the respondents in the open field had spider mites infestation in their tomato farms, while 63% respondents in greenhouse tomato production had similar problem. All the respondents (100%) in the greenhouse and open field had whiteflies infestation on their tomato farms. This implies that spider mites and whiteflies are a major problem in tomato farms in Laikipia County. The severity of infestation by spider mites and whiteflies is high in the lowlands and the midlands as compared to the highlands. This is similar to the finding of Mware *et al*.2010 who noted that increase in altitude reduced the population of whiteflies.

The result of the research indicates that chemical control remained the most effective method for the control of spider mites and whiteflies. In both seasons and in both places of productions, chemical control was the most effective pest control method. Majority of the open field tomato farmers applied chemicals weekly and fortnightly while the majority of greenhouse tomato farmers applied chemicals weekly, fortnightly and at the onset of the pests. This implies that more chemicals are applied in the open field tomato production systems. It is also evident that majority of the farmers rely heavily on chemical control with most using weekly and fortnightly sprays. These chemicals are known to have negative effect on the environment and also on the crops residue levels. In addition, heavy reliance on pesticides increases the selection pressure and potential for resistance in whitefly populations (Dittrich et al., 1999.)

About 80 % of the open field production system had a high to very high infestation level (51-100%) of mites and whiteflies while in the greenhouse production system majority of the respondents (42% and 30%) reported low infestation level of 0-25% of mites and whiteflies respectively. A total of 79% of the greenhouse farmers who were interviewed had low to medium infestation level (0-50%) of mites and whiteflies, respectively. The greenhouse structure therefore provided protection against pest infestation. However the data analysis on pests population over the six weeks indicated that the pest population increased rapidly in the greenhouse as compared to the openfield production system.

The results obtained from this study indicate that mulches can successfully be used to minimize mites and whiteflies population in tomato farms in open field and in greenhouse production systems. The mite numbers in the green house, when compared with the control were reduced by 37%, 51% and 44% by black, wheat straw and white mulch respectively. In the open field the numbers of mites were reduced as follows; 10.8%, 25%, 37% by black, wheat straw and white mulch respectively. The whiteflies numbers in the green house, when compared with the control were reduced by 27%, 48% and 45% by black, wheat straw and white mulch respectively. In the open field the numbers of whiteflies were reduced as follows; 37%, 51% and 64% by black, wheat straw and white mulch respectively.

Among the three mulches the white mulch worked better in the control of mites and whiteflies in the open field than in the greenhouse environment. The wheat straw mulch reduced the pests population best in the greenhouse environment. This is in agreement with Reitz et al. 2003; Stapleton & Summers 2002; Summers et al. 2004 who observed that reflective mulch alone successfully reduced whitefly populations, delayed and decreased the spread of viruses transmitted by various insect pests. Living mulch has also been reported to reduce whitefly, spider mites and aphid numbers and the incidence of insect-borne viruses in zucchini squash and tomatoes, respectively (Hooks et al. 1998; Hilje & Stansly 2008, and Liburd &Nyoike.2008).

5.2 Recommendations

From this study the following recommendations can be made;

i. White and wheat mulches can be included in the tomato integrated pest management programs.
ii. Other ways of managing mites and whiteflies such as trap crops and living mulches can be explored to incorporate with these finding.
iii. .Farmers frequency in chemical application can be assessed with the aim of reducing the frequency.
iv. Farmers use a lot of chemicals in tomato production and the residual levels need to be established.

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APPENDIX I: QUESTIONNAIRE (A)

SURVEY QUESTIONNAIRE TO DETERMINE THE OCCURRENCE AND INFESTATION LEVELS OF TOMATO PESTS IN GREEN HOUSE PRODUCTION IN LAIKIPIA COUNTY

<u>Background information</u>

1 Date of sampling______________ 2 .Name of farmer_____________________

3 .Division 4. Location__________________________

5 .Agro-ecological zone _______________ 6. Head of household__________________

7. Respondent: Male_______ Female__________ 8. Age _________years

9. Total Farm size________ (acres) 10.level of education_____________________

Management practices

1. Number of greenhouses under tomatoes……………

2 .Size of each greenhouse in meters (Length)…………. (Width)………………….

3. How many years have you practiced greenhouse tomato production? ....

4. Material used to construct (a) Local ……………… (b) Prefabricated…….……………

5. If pre-fabricated, indicate source (e.g. Amiran) ……………………………………..

6. Which tomato variety/varieties do you grow…………………………………………….

7. Any training on green house tomato management? Yes.................... No....................

8. If yes, who gave training a) Agriculture extension officers…………………..

b) Agrochemical dealer......................... .c) others specify……………………..

9. Duration of training a) days ……………b) Weeks…………c) months……………… d) Others specify………................

10. Growing medium used: a) Soil………b) Special medium (indicate type) ……………………………………………………….

11. Type of irrigation (a) Drip……………. (b)Watering can …………. (c) Farrow…….. d) Others specify…..……………

12. What do you use to fertilize the tomatoes?

a) Farm yard manures ……………………. b) Commercial fertilizers……………

c) Both Manure and fertilizers…………………….d) Foliar sprays…………………….. e) Nothing…………………….

13. Do you practice crop rotation a) Yes…………..b) No……………..

14. Which crops do you rotate with tomatoes?

a) Spinach……………b) capsicum………..c) Strawberry…………

d) Others specify…………

Pest control measures

15. What are the main tomato insect pests affecting your greenhouse tomato? (Rank in importance from1 to 5.)

Not a problem **(1)**	Minor problem **(2)**	Occasionally present **(3)**	Must be controlled **(4)**	Major problem, difficult to control **(5)**

a) Aphids ☐ b) Mites ☐ c) Whiteflies ☐

d) Scales ☐ e) leaf miner ☐ f) Thrips ☐

16. Do you notice spider mites on your tomatoes? Yes…………No…………

17. What is the severity of infestation by these spider mites?

a) 0-25% (Low) (c) 51-75% (High)

b) 26-50% (Medium) (d) 76-100% (Very high)

18. What measures do you use to control spider mites insect pests?

Chemical	Efficacy	Remarks
……………………	………………………	…………………………..
……………………	…………………………..	……………………………….
……………………….	………………………….	………………………….
…………………….	…………………………….	……………………………..

NB: For Efficacy above use terms below-:

1. Effective.
2. Moderately effective.
3. Not effective.

19. Other methods used to control spider mites………………………………………

…………………………………………………………………………………………….

20. Have you noticed whiteflies on your tomato crop? Yes…………No……………

21 What is the severity of whiteflies infestation on your tomatoes?)

a) 0-25 % (Low) (c) 51-75% (high)

b) 26-50% (Medium) (d) 76-100% (Very high)

22. What control measure do you use against whiteflies?

a) Chemicals b) Crop rotation c) Others specify …………….

23. For those that spray, which chemical do you use?

Chemical	Effectiveness	Remarks
………………...………	………….………	…………………
………………...………	………….………	…………………
………………...………	………….………	…………………
………………...………	………….………	…………………

24. What are the major diseases affecting your green house tomato? (Rank in order of importance)

Most damaging (a), to, least damaging (d)

a) ……………………………………… b) …………………………………….

c) ……………………………………… d) …………………………………….

25. What methods do you use to manage the diseases?

Disease	Management
………………………………………..	……………………………………
……………………………………….	………………………………………..
……………………………………………	………………………………………

26. Do you use chemicals to manage the pests and diseases? Yes ….. No………..

If yes, what chemicals do you spray and for what pest/disease?

<u>Chemical</u> <u>Pest/disease</u>

a) ………………………………………… b) ……………………………………

c) ……………………………………….. c) ……………………………………

d) ……………………………………….. e) ……………………………………

27. . How frequent do you apply chemicals?

a) Weekly b) Fortnightly c) Monthly d) When i see pests on tomatoes.

28. Yield (Kg or crates) per month...

29. For how many months do you harvest a crop? …………………………………

30. Interviewer's own assessment of pests/diseases affecting the greenhouse crop:

Pest/disease Infestation level (high, medium, low)

a) ………………………………………… ……………………………………

a) ……………………………………….. ……………………………………

c) ……………………………………….. ……………………………………

d) ………………………………….…… ..…………………………………..

e) ………………………………………. ……………………………………

NB: For each unknown pest, collect samples for identification in the laboratory

Vote of Thanks

Thank the farmer and give advice on how to manage the pests and diseases.

APPENDIX 11: QUESTIONNAIRE (B)

SURVEY QUETIONNNAIRE TO DETERMINE THE OCCURRENCE AND INFESTATION LEVELS OF TOMATO PESTS IN OPEN FIELD PRODUCTION IN LAIKIPIA COUNTY .

Background information

1 Date of sampling______________ 2 .Name of farmer_____________________

3 Division__________________ 4. Location__________________________

5 Agro-ecological zone _________________6. Head of household__________________

7. Respondent: Male_______ Female__________ 8. Age _________years

9. Total Farm size________ acres 10.level of education______________________

Management practices

1. How many years have you practiced open field tomato production? ....

2. Acreage under tomato (acres) a) < 0.25 acres………….. b) 0.25 - 1 acre……………

c) 1 – 2 acres……………………… d) > 2 acres ……………………

3. Varieties grown a)………………… b) ……….………………… c) …………………

4. What type of watering system do you use?

a) Rain fed production ……………….. b) Bucket/ Watering can ………….

c) Farrow irrigation ……………………d) Drip irrigation ………………….

e) Sprinkler irrigation …………………. f) Others specify……

5. What crops were previously grown on the plot before tomato?

a) Last season ………………………… b) Last year ………………………..

c) 2 years ago …………………………... d) 3 years ago ……………………..

6. What do you use to fertilize the tomatoes?

a) Farm yard manures …………….. b) Commercial fertilizers…………………………

c) Both Manure and fertilizers…………………….d) Foliar sprays…………………….. e) Nothing…………………….

7. Do you practice crop rotation a) Yes…………..b) No……………..

8 .Which crops do you plant for rotation after tomatoes a) Spinach……………

b) Capsicum…………c) Strawberry…………d) Others specify……………………..

Pest control measures

1. What are the main tomato insect pests affecting your open field tomato crop? (Rank in importance from1 to 5.

Not a problem **(1)**	Minor problem **(2)**	Occasionally present **(3)**	Must be controlled **(4)**	Major problem, difficult to control **(5)**

a) Aphids ☐ b) Mites ☐ c) Whiteflies ☐

d) Scales ☐ e) leaf minor ☐ f) Thrips ☐

2. Do you notice spider mites on your tomatoes? Yes…………No………….

3. .What is the severity of infestation by these spider mites?

a) 0-25% (low) (c) 51-75% (High)

b) 26-50% (medium) (d) 76-100% (Very high)

4. What measures do you use to control spider mites insect pests

a)Chemicals b)Crop rotation c)burning cop residuals c)others specify………………

…………………………………………………………………………………………………

5. If you use chemical to control spider mites, fill the questions below.

Chemical Efficacy Remarks

……………………	…………………	…………………………..
……………………….	…………………….	……………………………..
……………………	………………………	……………………………
……………………….	………………………	……………………………….

NB: For Efficacy above use terms below

a) Effective.

b) Moderately effective.

c).Not effective.

6. Have you noticed whiteflies on your tomato crops? Yes…………No……………

7. What is the severity of whiteflies on your tomatoes?)

a) 0-25 % (Low) (c) 51-75% (High)

b) 26-50% (Medium) (d) 76-100% (Very high)

8. What control measure do you use against whiteflies?

a) Chemicals …………………… b) Crop rotation……………………

c) Others specify ……………………….

9. .For those that spray, which chemical to you use?

Chemical	Efficacy	Remarks
…………………..	…………………..	…………………………
…………………….	………………………	………………………….
……………………….	……………………	………………………………….
……………………..	……………………….	…………………………….

NB: For Efficacy above use terms below

a) Effective.

b) Moderately effective.

c).Not effective.

10. What are the major diseases affecting your open field tomato crop? (Rank in order of importance)

Most damaging (a), to, least damaging (d)

a) ……………………………………… b) …………………………………….

c) ……………………………………… d) …………………………………….

11. What methods do you use to manage the diseases?

a) ………………………………………… b) ……………………………………

c) ……………………………………….. d) ……………………………………

e) ……………………………………….. f) ……………………………………

12. Do you use chemicals to manage the pests and diseases? Yes ……… No………..

13. If yes, which chemicals do you spray and for what pest/disease?

Pest /disease chemical

a) ……………………………………….. ……………………………………

b)……………………………………… ………………………………………

c) ……………………………………….. ……………………………………

14. How frequent do you apply chemicals?

a) Weekly …………………… b) Fortnightly……………………………..

c) Monthly……………………d) When I see pests on the crop………………

15. Yield in kilograms (kg) per month...

16. For how many months do you harvest a crop? ……………………………………..

17. Interviewer's own assessment of pests/diseases affecting the open field tomato crop:

Pest/disease   Infestation level (high, medium, low)

a) ………………………………………… ……………………………………

a) ……………………………………….. ……………………………………

c) ……………………………………….. ……………………………………

d) ……………………………….…… ..…………………………………..

e) ………………………………………. ……………………………………

NB: For each pest, collect samples for identification in the laboratory

Vote of Thanks

Thank the farmer and give advice on how to manage the pests and diseases.

APPENDIX III

Analysis of variance table for spider mites data taken over six weeks in two seasons in open field and greenhouse tomato production systems.

SOV	d.f.	v.r	F pr.
Weeks	5	66.5	<.001
Production system	1	33.09	<.001
Season	1	38.35	<.001
Treatment	4	42.17	<.001
Weeks. production system	5	2.72	0.02
Weeks. Season	5	37.52	<.001
Production system. Season	1	3.5	0.062
Weeks. Treatment	20	2.96	<.001
Production system. Treatment	4	1.48	0.207
Season. Treatment	4	7.92	<.001
Weeks. Production system. Treatment	5	1.18	0.32
Weeks. Season. Treatment	20	1.4	0.117
Weeks. Season. Treatment .	20	2.97	<.001
Production S. Season.Treat.	4	4.1	0.003
WKs.ps.Season .Treatment	20	1.95	0.009
Residuals	360		
Total	479		

APPENDIX IV

Analysis of variance table for whiteflies data taken over a period of six weeks in two seasons in open field and greenhouse production systems.

SOV	d.f.	v.r.	F pr.
Weeks	5	54.41	<0.001
Production system	1	115.9	<0.001
Season	1	115.91	<0.001
Treatment	4	43.00	<0.001
Weeks. production system	5	2.61	0.02
Weeks. Season	5	2.61	<0.001
Production system. Season	1	56.73	<0.001
Weeks. Treatment	20	1.65	<0.001
Production system. Treatment	4	8.58	<0.001
Season. Treatment	4	8.58	<0.001
Weeks. Production system. Season	5	3.84	0.32
Weeks. Season. Treatment	20	0.44	0.117
Weeks. Season. Treatment .	20	0.44	<0.001
Production S. Season.Treat.	4	4.60	<0.001
WKs.ps.Season .Treatment	20	0.38	0.994
Residuals	360		
Total	479		

APPENDIX V

Analysis of variance for mites and white flies on tomatoes under different production systems.

		white flies		Mites	
Source of variation	**d.f.**	**v.r.**	**F pr.**	**v.r.**	**F pr.**
Weeks	5	54.41	<.001	66.5	<.001
Ps	1	115.9	<.001	33.1	<.001
Season	1	115.9	<.001	38.4	<.001
Treatment	4	43	<.001	42.2	<.001
Weeks. Ps	5	2.61	0.02	2.72	0.02
Weeks. Season	5	2.61	0.02	37.5	<.001
Ps. Season	1	56.73	<.001	3.	0.06
Weeks. Treatment	20	1.65	0.04	2.96	<.001
Ps. Treatment	4	8.58	<.001	1.48	0.21
Season. Treatment	4	8.58	<.001	7.92	<.001
Weeks. Ps. Season	5	3.84	0	1.18	0.32
Weeks .Ps. Treatment	20	0.44	0.98	1.4	0.12
Weeks .Season .Treatment	20	0.44	0.98	2.97	<.001
Ps. Season. Treatment	4	4.6	0	4.1	0
Weeks. Ps. Season. Treatment	20	0.38	0.99	1.95	0.01
Residual	360				
Total	479				