INFLUENCE OF COLOUR OF AGRONET COVER ON PEST INFESTATION AND TOMATO (*Solanum lycopersicum* L.) GROWTH, YIELD AND QUALITY

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DECLARATION AND RECOMMENDATION

Declaration

This thesis is my original work and has not been submitted before in any institution for any other award.

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Recommendation

This thesis has been submitted with our approval as university supervisors.

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DEDICATION

To my husband, my daughter, my son, mum, relatives and friends who have been a great source of motivation and inspiration during my studies.

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ABSTRACT

Tomato (*Solanum lycopersicum* L.) is a nutritious vegetable consumed worldwide. Open field production faces a number of constraints including biotic and abiotic stresses. The general objective of the study was to enhance tomato productivity through provision of an alternative pest control and protected cropping system that is relatively affordable to small scale farmers. The study entailed a field production and laboratory postharvest experiment at the Horticulture Research Field, Egerton University. Cultivar "Rio Grande" was grown under five agronet covers; white, grey, yellow, blue and multi-coloured with open field as the control. Randomized Complete Block Design (RCBD) was used for the field experiment and Completely Randomized Design (CRD) for the laboratory experiment. Data collected were analyzed using analysis of variance (ANOVA) and means separated using Tukey`s Honestly Significant Difference Test (THSD) at $p \leq 0.05$. Net covers modified the crop microclimate with highest increase in temperature, soil moisture and, relative humidity recorded under white (4.5^{o}C), blue (15.6%) and multi-coloured covers (11.4%), respectively compared to the control. Photosynthetically active radiation (PAR) was reduced under covers with the highest reduction of 47.5% recorded under the blue agronet cover. Generally, covered plots recorded lower pest populations than the control treatment throughout the study. Populations of whitefly reduced by 41.6-65.9% under yellow net cover. Regardless of net colour, aphid and mite populations reduced by between 15.1-43.7% and 26.2-52.5%, respectively. Thrips population was lowered under the coloured-colour nets (blue and yellow) by 51.6-61.4%. Growing tomato under agronet covers improved plant height and internode length by between 6.67 – 34.09% and 13.52-23.06%. Tomato under white net cover had higher branching and stem thickness by between 57.4-72.2 and 23.9-40.1% with higher yield of 24.9 t/ha. Covering tomato plants with white cover recorded highest marketable yields of 18t/ha while the lowest marketable yields of 11t/ha was recorded under blue net cover. Fruits obtained from white cover tended to be firmer (23.7-275%) with higher (18.8-38.9%) sugar acid ratio. Longer shelf life of 8-12 days was recorded under agronet covers compared to fruits from open field with fruits obtained from blue cover registering highest lycopene content of 13.4mg/kg. Study findings indicate that use of agronet covers especially the white cover could improve microclimate, protect tomato against insect pests and can be considered a viable strategy for minimizing on the use and cost of pesticide application for enhanced environmental safety and better yields and quality of tomato for smallholder tomato growers.

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LIST OF ABBREVIATIONS AND ACRONYMS

ANOVA	-	Analysis of Variance
CRD	-	Completely Randomized Design
DAH	-	Days after Harvest
DAP	-	Diammonium Phosphate
DAT	-	Days after Transplanting
FAO	-	Food and Agriculture Organization
HCD	-	Horticultural Crops Directorate
HCDA	-	Horticultural Crops Development Authority
KALRO	-	Kenya Agricultural and Livestock Research Organization
LUE	-	Light Use Efficiency
PAR	-	Photosynthetically Active Radiation
R: FR	-	Red to Far Red light
RCBD	-	Randomized Complete Block Design
TA	-	Titratable Acidity
THSDT	-	Tukey`s Honestly Significant Difference Test
TSS	-	Total Soluble Solids
UV	-	Ultraviolet Radiation
VWC	-	Volumetric Water Content
WAT	-	Weeks after Transplanting

CHAPTER ONE
INTRODUCTION

1.1 Background Information

Tomato (*Solanum lycopersicum* L.) is one of the important Solanaceous vegetable crops consumed throughout the world. It has high nutritional value with important vitamins, mineral and antioxidants (Velioglu *et al*., 1998) whose consumption is believed to help the heart among other benefits. Present world production stands at 170,750,767 tonnes produced on 5,023,810 hectares of land (FAO, 2017). In Africa, total production area of tomato increased from 159,593ha in 1961 to 1,214,227 ha in 2014 and production increased from 1,968,812 tonnes in 1961 to 19,253,066 tonnes in 2014 (FAO, 2017). In sub-Saharan Africa including Kenya, tomato is still among the most commonly grown and consumed vegetable crop as it greatly contributes to food security, nutritional balance and income for resource poor growers (FAO, 2017). The country`s total production was 400,204 tons on an area of 24,074 ha with a value of KES. 11.8 billion in the year 2014. It ranks second to potato in value and third in area under production among vegetable crops grown in the country (HCD, 2014).

While the availability and pricing of the produce in the market is mostly dictated by weather conditions (HCDA, 2011), the demand for the crop remains high throughout the year hence ensuring ready market. In the food processing industry, tomato is used as raw material for the production of juices, sauces, purees, pastes and canned products. Besides, tomato consumption has been associated with the prevention of several diseases (Clinton, 1998) mainly due to the content of antioxidants, including carotenes, ascorbic acid; tocopherol and phenolic compounds. Being a labour intensive crop, additional jobs can be generated on farm, and in transport and processing of products with increased production of the crop (Weinberger and Lumpkin, 2005).

Despite the potential of tomato in improving the livelihoods of the rural population of Kenya, yield as low as 7 tons/ha has been reported in the country especially under rain-fed conditions against a world average of 75tons/ha (FAO, 2008; 2010). This yield gap has been attributed to a number of production constraints among them biotic (Maerere *et al*., 2006) and abiotic stresses (Mahajan and Tuteja, 2005). Insect pests are among the major biotic constraints of tomato production in the world. As high as 100% yield loss has been reported in East Africa due to insect pest attack especially when infestation is high (UMADEP, 2003). Some of the most common pests of tomato include Whitefly (*Bemisia tabaci* Gennadius), Leaf miners (*Tuta absoluta*), Thrips (*Thrips tabaci* Lindeman), Cotton Aphids (*Aphis gossypii* Glover), and

African Bollworm (*Helicoverpa armigera* Hubner). Although pesticides are available for control of most insect pests of tomato, they tend to be quite expensive and unaffordable to small scale farmers who are the majority of tomato growers. In addition, such chemicals are not friendly to humans as well as to the environment (Weinberger and Lumpkin, 2005).

Common abiotic stresses include temperature, moisture and humidity fluctuations (Tumwine *et al*., 2002) which tend to hinder crop growth and development while favouring pest development leading to low tomato yields and quality. Greenhouse tomato production has been advocated for as a way of solving some of these problems. However, its adoption in many of the developing countries, including Kenya has been extremely slow, due to high investment costs. As a result, majority of farmers still grow their tomato in the open fields, despite all the challenges (HCDA, 2006).

A number of other simple technologies have been tested in different parts of the world and proved successful in protecting crops against adverse weather conditions and insect pests. Netting technology has been used in agriculture to protect crops against environmental hazards like excessive solar radiation, wind, hail, flying insects, to improve plant microclimate through reduction in heat/chill, drought stresses, and moderation of rapid climatic stresses leading to improved crop yield and quality (Shahak *et al*., 2004). The use of net covers in crop production offers a cheaper and less energy consuming technology than greenhouses (Shahak, 2008). Most commonly used nets have been the black shade nets, anti-hail and insect proof nets typically made of either clear or white threads or a combination of the two (Shahak, 2008; Shahak *et al*., 2004).

Coloured (photo-selective) shading nets are currently being developed with the aim of improving crop production by taking advantage of their optical properties. Coloured nets modify the spectral composition of the transmitted and reflected sunlight (Shahak *et al*., 2004). While black nets have been shown to reduce light intensity reaching the underneath plants but have no effect on light quality, transparent nets scatter the light transmitted through them (Shahak, 2008). Translucent photo-selective nets tend to be unique due to their ability to manipulate the light spectrum and scatter the transmitted light quality all of which tend to have differential effects on insect pests and crop performance (Shahak *et al*, 2008; Shahak, 2008).

In general, better crop growth, yield and quality have been reported for coloured shade nets compared to conventional nets or open field production as a result of better microclimate within the covers (Milenkovic *et al*., 2008; Grinberger *et al*., 2000). Besides the direct effect on crop performance, coloured nets have also been shown to offer better insect pest control in several crops compared to conventional net colours (Shahak *et al*., 2008).

1.2 Statement of the Problem

Tomato is one of the most commonly eaten vegetables and yet its yields in smallholder cropping system in Kenya are generally far below the potential of the crop. Insect pests have caused extensive economic losses to tomato growers in the country over the years. Currently, efficient control of pests using pesticides has remained problematic due to rapid development of resistance by most pests which has reduced the efficacy of many of the existing insecticides. At the same time, most open field tomato growers are faced with abiotic pressures of high solar radiation and fluctuating temperatures and moisture conditions all of which reduce tomato yield and quality, besides exacerbating the insect pest problem. Although greenhouses are available to mitigate some of these problems, they are quite expensive for the resource-poor to afford. This has forced many of the smallholder tomato growers to continue producing their crop in open fields with low yields and poor quality being a common scenario. There is therefore need to find alternative ways of controlling insect pests of tomatoes such as the use of different colours of nets. Nets have been used to improve crop performance through protection of crops against insect pests and adverse environmental conditions with some degree of success in several parts of the world. Tomato farmers in Kenya are yet to embrace or are slowly embracing the potential benefit of this technology.

1.3 Justification of the Study

Tomato is a vegetable with high demand due to the fact that consumers appreciate its taste, nutritional value and broad use in the human diet. Tomato and tomato products constitute the major source of dietary lycopene responsible for the prevention of several degenerative diseases. Conventional production of tomato in the open field is susceptible to extremes of solar radiation, rainfall and temperatures as well as insect pests and diseases. Use of agronet covers in crop production will not only protect crops against insect pests but also environmental hazards and microclimate conditions leading to increased yields.

Agronet covers provide a physical barrier between the pest and the crop which can give a high level of protection that is reliable from season to season at all levels of pest pressure. The use of agronet covers in tomato production could therefore reduce the use of insecticides which cause both ecological and human health problems. Besides, the technology has been shown to modify temperatures and relative humidity as well as block excessive solar radiation within the vicinity of the growing crop hence conserving soil moisture and reducing on the need for watering. Using net covers in tomato production therefore stands to present a system of production which creates harmony between the environment and agriculture. An understanding of the specific effects of the different colours of agronet on pest infestation and plant growth and morphology would be critical in ensuring better use of the technology. Findings of this study will also contribute towards the existing knowledge on tomato culture.

1:4 Objectives of the Study

1:4:1 General Objective

To contribute towards increased tomato productivity and environmental safety through provision of an alternative pest control and protected cropping system that is relatively affordable to small scale growers.

1:4:2 Specific Objectives

The specific objectives of the study were to determine the effects of:

1. The colour of agronet cover on relative humidity, photosynthetically active radiation, air temperature and soil moisture of the immediate tomato crop environment.
2. The colour of agronet cover on insect pest population on tomato.
3. The colour of agronet cover on growth and yield of tomato.
4. The colour of agronet cover on postharvest quality of tomato.

1.5 Hypotheses

The hypotheses of the study were:

1. The colour of agronet cover has no effect on relative humidity, light quality, temperature and moisture of the immediate tomato crop environment.
2. The colour of agronet cover has no effect on insect pest population on tomato.
3. The agronet cover colour has no effect on growth and yield of tomato.
4. The colour of agronet cover has no effect on postharvest quality of tomato.

CHAPTER TWO
LITERATURE REVIEW

2.1 Tomato and Its Uses

Tomato is one of the most important edible and nutritious vegetable crops in the world. It belongs to the family Solanaceae which also includes other important species such as peppers, (*Capsicum spp*.), potato (*Solanum tuberosum*), aubergine (*Solanum melongena*), nightshade (*Solanum nigrum*), tomatillo (*Physalis ixocarpa*), tobacco (*Nicotiana tabacum*) and ornamentals in the genera *Petunia, Lycium, Solanum, Datura, Nicotiana* and *Nierembergia* among others (Naika *et al*., 2005).

Tomato is an annual which can grow to a height of over two meters. Shape of the fruit varies depending on the cultivar ranging from circular to oblong while fruit colour ranges from yellow to red. Tomato is classified into determinate and indeterminate types. With determinate types, vegetative growth stops with the commencement of reproductive stage. The plants are erect and bushy with restricted flowering and fruiting periods. In indeterminate types, the main stem grows indefinitely. Vegetative growth continues together with reproductive development, and such cultivars are ideal for long harvest period (Naika *et al*., 2005).

Tomato has its origin in the South American Andes region. The cultivated tomato was brought to Europe by the Spanish conquistadors in the sixteenth century and later introduced from Europe to Southern and Eastern Asia, Africa and Middle East (Naika *et al*., 2005). It is widely cultivated in tropical, subtropical and temperate climates. Kenya is among Africa`s leading producers of tomato and is ranked 6th in the continent with a total production of 397007 tons (FAO, 2012). In Kenya, tomato production is done in almost all parts of the country, but major producing areas are Mwea, Nakuru, Meru, Nyeri and Taita Taveta (Ssejjemba, 2008).

Tomato forms an integral part of human diet being widely consumed fresh or utilized in preparation of a wide range of processed products such as tomato juice, soup, paste, puree, ketchup, and sauce (Ray *et al*., 2011; Helyes *et al*., 2009). Tomato is a major contributor of antioxidants such as carotenoids with the most abundant in the ripened fruit being lycopene which accounts for approximately 80–90% of the total pigments (Helyes *et al*., 2009). Tomatoes and tomato products are the primary suppliers of lycopene to the human diet with at least 85% of our dietary lycopene derived from these foods and the remainder being obtained from other dietary sources such as apricots, pink grapefruit, watermelon, guava, and papaya (Capanoglu *et al*., 2010). Of all the carotenoid pigments, lycopene is not only the most abundant but also the most efficient free radical scavenger with a capacity found to be more than twice that of β-carotene. Lycopene in tomato also seems to be more stable to changes occurring during peeling and juicing than the other carotenoids (Capanoglu *et al*., 2010). Studies have suggested a possible role for lycopene in the protection against prostate cancer (Kucuk, 2001). Besides, tomato is also rich in minerals (iron and phosphorus), vitamins (B and C), essential amino acids, sugars and dietary fibre (Khan *et al*., 2006).

2.2 Tomato Growth and Yield

Tomato is an annual plant classified as a warm season crop. It is widely cultivated in tropical, subtropical and temperate climates. The optimum temperature for most varieties lies between 21^{o}C and 24^{o}C. Vegetative and reproductive growth of the crop is limited at lower temperatures while an extended period of growth at 12^{o}C or less can result in chilling injury (Naika *et al*., 2005).

Germination, plant growth, flowering, fruit set, photosynthesis and yield are all influenced by temperature (Voican *et al*., 1995). There is marked influence of temperature on initiation of flowers with optimum temperature for flower initiation being between 20^{o}C and 25^{o}C. Fruit set in tomato is impaired at high temperatures. Day temperatures above 28^{o}C during flowering are known to cause pollen sterility. Under low temperatures, less assimilates go to fruits causing a reduction in truss and fruit development rates early in the season (Ploeg and Heuvelink, 2005). Temperature ranging between 22^{o}C and 25^{o}C give the most favourable rate of lycopene production, which is further enhanced by sunlight (Lumpkin, 2005).

Light is the source of energy and a major regulatory factor in plant life. All the physiological processes from emergence of the seedling right up to fruit production are essentially dependent on light (Shahak *et al*., 2004). Quantity as well as quality of light plays a very important role in the functioning of the plant. Light energy that the plant harvests from the sun is the energy that the plant needs to support functions such as photosynthesis, respiration and transpiration that are essential for survival. Low light irradiance reduces pigment synthesis, resulting in uneven fruit colouring and low fruit soluble sugar content. On the other hand, high light irradiance, especially direct light on fruit can lead to sunscald injury and uneven ripening which reduces tomato fruit quality (Dorais *et al*., 2001). In tomato production, plant growth and development and the quality of fruit produced is also affected by soil moisture content. To maximize crop productivity and optimize water use, it is important to ensure adequate water supply to meet evapo-transpiration at all times (Cooper and Hurd, 1968). Excessively watered tomato plants have been reported to have 20% more fruit with cracked skin than those with sufficient water (Peet and Willits, 1995). Veit-Kohler *et al*. (1999)

found that a reduction in water supply led to an increase in sugars and decrease in titratable acids of tomato fruit which are responsible for a higher fruit quality. Buds and flowers drop off and fruits split due to water stress and long dry periods (Naika *et al*., 2005).

2.3 Insect Pests of Tomato

Tomatoes are subject to several insect pests from the time of emergence to harvesting. Severe damage may also occur since some pests are disease vectors. Some pests have less damage on the tomato plants while others can cause as high as 100% yield loss in the field (Mayfield *et al*., 2003; Pascual *et al*., 2003). Some of the most common pests of tomato include Whitefly (*Bemisia tabaci* Gennadius), Cotton Aphids (*Aphis gossypii* Glover), Thrips *(Thrips tabaci* Lindeman), Leaf miners (*Tuta absoluta*), Spider mites (*Tetranychus spp*) and African bollworm (*Helicoverpa armigera* Hubner).

Whitefly (*Bemisia tabaci*) attack tomatoes at all stages of growth by depositing eggs on the underside of leaves. Upon hatching the first instar nymph (0.3mm in length) (commonly known as “crawler”) moves about the leaf in search of a place to insert its needle-like mouthparts into the plant to suck plant phloem (Nyoike, 2007). As nymphs feed, they excrete large quantities of liquid waste in the form of honeydew. Honeydew is rich in plant carbohydrates and as whiteflies feed and excrete, this waste is distributed onto plant leaves, flowers and fruit supporting the growth of sooty mould fungus, causing the plant to turn black (Nyoike, 2007). High population of *B. tabaci* could cause transmission of viral disease Tomato Yellow Leaf Curl Virus causing total crop loss. The sucking of sap from the tomato plant by this insect results in stunted growth, yellowing of the leaves, wilting, fruit drop, and premature fruit ripening (Ofori *et al*., 2014). Whitefly reportedly causes losses up to 100% in tomato in tropical and subtropical regions (Friedman *et al*., 1998; Lapidot *et al*., 1997).

Aphids are small, soft bodied, pear-shaped insects with winged forms having two pairs of membranous wings and ranked high as invasive pests due to their ease of transport and parthenogenetic mode of reproduction (Footit *et al*., 2008). Aphids suck sap from plant parts such as stems, leaves and fruits causing damages to the leaves and fruits. They excrete honeydew, a sugar-rich substrate that promotes the growth of sooty mould on harvestable plant parts and leaves, lowering their quality (Nyoike, 2007). Infested leaves are destroyed and yellowed by the aphids feeding and sucking activities. Plant become desiccated and may eventually die. Besides causing direct damage to the host by sucking the sap from various plant parts, they also indirectly transmit common mosaic viruses which result in early plant death (Blaney *et al*., 1990) causing 70-80% of yield losses (Aslam *et al*., 2007).

Thrips feed on the lower surface of the leaf and suck up the sap that exudes from the leaves (Ssemwogerere *et al*., 2013). They also attack buds, flowers and fruits and the attacked leaves show a silvery sheen and small black spots, thrips excreta. Collapse of plant cells can result in formation of deformed flowers, leaves, stems, shoots and fruits. Under heavy infestation, buds and flowers may fall off and the fruits may be deformed leading to a reduction in quality. Heavy infestation causes premature wilting, delay in leaf development and distortion of young shoots (Varela *et al.*, 2003). Thrips are also virus carriers of tomato spotted wilt virus which can cause a 100% yield loss in a field (Mayfield *et al*., 2003).

Spider mites are less than 1 millimetre (0.04 mm) in size and vary in colour living on the undersides of leaves of plants where they spin protective silk webs to protect the colony from predators (Clotuche, 2011). Spider mites suck plant sap with their stylet-like mouth parts (Muzemu *et al*., 2011) thus interfering with nutrient transportation and may be serious pest in hot weather and during drought (Knapp, 1999). Increased infestation can lead to defoliation and the affected plants produce small fruits and can cause up to 90% yield loss (Jayasinghe and Mallik, 2013).

Leaf miner is an impending threat to tomato in Africa (Zekeya *et al*., 2017). *T. absoluta* damage is characterized by extensive wilting of whole plants and distortion of shoots with signs of dieback. The leaves show lesions of different sizes and necrotic areas (Mutamiswa *et al*., 2017). It mines into the leaf tissue, feeds extensively (Santos *et al*., 2011) and also bores into fruits leaving symptomatic tiny holes. Fruits attacked in early stages are distorted and relatively smaller in size. Most damaged mature fruits show signs of secondary infection, subsequent decomposition and loss of internal fruit contents (Mutamiswa *et al*., 2017). Economic losses due to *T. absoluta* infestation in tomato have been reported to range from 80-100% in some countries in Africa particularly Kenya, Sudan and Ethiopia (Ayalew, 2015; Tonnang *et al*., 2015).

Bollworm adult moth is fleshy, yellowish-brown with a dark speck, greyish irregular lines and a black kidney-shaped mark on the forewings. They bore into the fruit and feed on the inner parts of the fruit, releasing plenty of excreta (frass) which is noticeable on damaged fruits. Feeding by the bollworm causes tomato fruit rot as a result of secondary infections by bacterial and fungal pathogens which penetrate fruit through the feeding holes (Komarova and Kuznetsova, 1969; Sukhareva, 1999). Heavy infestation by *Helicoverpa armigera* has been reported to cause yield losses ranging from 20-60% (Lal and Lal, 1996).

2.4 Effects of Net Colours on Crop Microclimate

Nets are generally classified as either coloured-colour or neutral-colour nets. Coloured-colour nets (red, yellow, green and blue nets products) screen specific spectral bands of the solar radiation (Ultra- violet). Neutral-colour nets (pearl, white and grey) screen specific spectral bands of the solar radiation (Near Infra-red- Infra red) and or transform direct light into scattered light (Shahak, 2008). Netting is frequently used to protect agricultural crops from excessive solar radiation, improving the thermal climate and sheltering the crop from wind and hail. Net covers are either applied by themselves over net- house constructions or combined with greenhouse technologies. The most commonly used nets are made of black plastic and transmit light evenly throughout the visible part of the light spectrum thus acting as neutral density filters (Oren-Shamir *et al*., 2001). Transparent nets scatter the light transmitted through them, but do not alter its spectral composition (Shahak, 2008; Shahak *et al*., 2004).

Coloured shade netting not only influence the microclimate to which the plant is exposed to but also have the advantage of exhibiting special optical properties that allow the control of light (Oren-Shamir *et al*., 2001) offering physical protection against excessive solar radiation and environmental changes (Shahak *et al*., 2004). The spectral manipulation intends to specifically promote desired physiological responses, which are light regulated, while the scattering improves the penetration of the modified light into the inner canopy (Zoratti *et al*., 2015). Shade nets are of special importance where they reduce both light intensity and effective heat during day time. Saidi *et al*. (2013) found that the use of eco-friendly nets and floating row covers on tomato (*Lycopersicon esculentum*) growing reduced the light quantity that reached the crop. Similarly, Abdrabbo *et al*. (2013) recorded highest light intensity on potato (*Solanum tuberosum* L.) under open field treatment compared to under white and yellow net. At the same period, light intensity under blue and black net was lower than under white and yellow net. Besides decreasing light intensity, shade netting alters light quality to a varying extent which may also change other environmental conditions (Shahak *et al*., 2004). Contrary to light levels, the use of net covers has on the other hand been shown to increase temperatures of the immediate crop environment. Muleke *et al*. (2013) reported a 5.5^oC, 3.2^oC, 1.2^oC and 0.6^oC increase in temperature following the use of 0.4mm agronet maintained permanently covered, 0.4mm agronet opened thrice a week, 0.9mm agronet maintained permanently covered and 0.9mm opened thrice a week, respectively compared to the control treatment in a study conducted on cabbage (*Brassica oleraceae* var. *capitata*). Grinberger *et al*. (2000) registered a higher heat generation under an Aluminet shading net compared with pearl, red and the blue coloured net on lettuce (*Lactuca sativa*). Similarly, Arthurs *et al*. (2013) reported higher average daily maximum temperatures while using coloured nets (red, blue and pearl) compared with open field with highest air temperature recorded under red net. Tinyane *et al*. (2013) reported increased average air temperature under photo-selective nettings (red, yellow and pearl) than the black net used as control while working on tomato. Additionally, pearl net provided the most stable microclimatic conditions while yellow net was noted to have the least ability to stabilize the fluctuation of the environmental factors measured throughout the study. Following the use of two shade net treatments (black or green) on tomato (*Solanum lycopersicon*), Zakher and Abdrabbo (2014) revealed that air temperature tended to be lower under the black and green nets (2- 3°C), due to the interception of radiation which is greater than the gain of temperature caused by the use of nets due to their role in the interception of air circulation or "greenhouse effect". Stamps (1994) on the other hand reported increased temperature under netting regardless of colour which was attributed to reduced wind speeds. Throughout the evaluation period, air temperature was highest under the 0.4untreated AgroNet® and lowest under the control (open) following a study conducted by Gogo *et al*. (2017).

Other studies have also reported decreased temperatures with the use of net covers. Abul-Soud *et al*. (2014) working with three cultivars of cabbage (Chinese, red and white) reported higher temperature under open field treatment followed by red and white nets, with the lowest temperature under black net. In this study, maximum temperature tended to be lower under blue and black net in comparison with open field. Gaurav *et al*. (2016b) and Shahak *et al*. (2004) reported reduced temperature fluctuations in cordyline and apple orchard following the use of coloured net covers, respectively. Use of floating row covers and eco-friendly nets reduced the diurnal temperature range during tomato (Saidi *et al*., 2013) and cabbage (Muleke *et al*., 2014) production throughout the study period. Maklad *et al*. (2012) reported lower temperatures following the use of black and white nets on cucumber (*Cucumis sativus* L.) compared to polyethylene sheet. Ilic *et al*. (2012) reported decreased temperature while working on pepper (*Capsicum annuum* L.) under nets compared with open field. The average air temperature under different colours of shade net was between 0.9°C (pearl) and 3.0°C (black) lower in comparison with air temperature in the open field. On the other hand, Oren-Shamir *et al*. (2001) reported no significant differences in air temperatures recorded inside the plant canopies of *Pittosporum* growing under six different colours of nets (green, red, blue; grey, black and reflective). Mudau *et al*. (2017) reported decreased air temperature under photoselective nets (red, pearl and black) compared to under control or yellow net. However, it was observed by Zoratti *et al.* (2015) that under white, red, blue and black coloured net, although there was an increase in temperature during the night hours however, a progressive decrease in temperature was recorded during the warmest period of the day.

The use of net covers stabilizes temperatures of the immediate crop environment. Muleke *et al*. (2014) reported lowered diurnal temperature range within the vicinity of cabbage with the use of agronet covers compared with uncovered control. Similarly, Saidi *et al.* (2013) and Gogo *et al*. (2013) reported reduced diurnal temperature range following the use of eco-friendly nets and floating row covers on tomato. In addition, Gogo *et al*. (2017) reported decreased diurnal temperature under 0.9 treated AgroNet® followed by the 0.9 untreated then control and which were not significantly different from each other while the 0.4 untreated AgroNet® had the lowest diurnal temperature range. Iglesias and Alegre (2006) conducted an experiment on the influence of nets (crystal and black) on maximum orchard temperatures and their role in increasing minimum daily temperature. Results showed that the use of nets exerted a limited influence on orchard temperature. Contrary to these observations, Nangare *et al*. (2015) reported no effect of coloured nets on air temperature on tomato.

Shade netting also reduces sunlight or radiation levels reaching the crop. Arthurs *et al*. (2013) reported reduced photosynthetically active radiation (PAR) following the use of coloured nets (blue, red and pearl) compared with uncovered sites with some differences also observed among different net colours. Observed PAR values were most reduced under black nets and least under red nets with blue and pearl nets being intermediate. Contrary to these observations, Tinyane *et al*. (2013) reported higher PAR under black net used as a control than under red net in a study on tomato cultivars in Pretoria. On the other hand, Costa *et al*. (2010) working on *Ocimum selloi* observed higher PAR values under open field (1500 $\mu molm^{-2}s^{-1}$) compared with blue and red shade nets which had a PAR of 650$\mu molm^{-2}s^{-1}$ and 690 $\mu molm^{-2}s^{-1}$, respectively. In a study by Gardner and Fletcher (1990), black netting reduced radiation on deciduous fruit trees by 33-37% and white netting by 4-8%. Shahak *et al*. (2004) reported a 30% reduction in total PAR intensity following the use of net covers. Ilic *et al*. (2012) reported greatest decrease in radiation under black net compared with red, white and blue net. Similarly, Grinberger *et al*. (2000) recorded a lower radiation on lettuce under Aluminet shade net compared with pearl, red and blue net. A study conducted to determine light modification by colour nets (red, pearl, blue and black) reported that PAR was halved in comparison to open field under all used shade nets. The maximal level of PAR under the nets was 934 $\mu molm^{-2}$ s^{-1}

while the maximum intensity of PAR in the open field reached 2020 µmolm^{-2} s^{-1} (Ilic *et al*., 2017a). In another study on sweet pepper, Ilic *et al*. (2017b) recorded lower PAR under coloured shade-nets (red, black, pearl and blue) with black net (771.8 µmolm^{-2} s^{-1}) recording the lowest while control (1661.3 µmolm^{-2} s^{-1}) recorded the highest PAR. Similarly, Mudau *et al*. (2017) and Gaurav *et al*. (2016b) recorded highest PAR under open field while lowest was recorded under protected environment.

In an attempt to establish the effect of coloured nets on PAR reaching `Mondial Gala` apples, black nets were observed to intercept about 25% more incident radiation than the control while crystal net intercepted 12% more than open field (Iglesias and Alegre, 2006). The use of net covers reduced PAR reaching tomato (Nangare *et al*., 2015; Saidi *et al*., 2013) and cabbage (Muleke *et al*., 2014) crops. Holcman and Sentelhas (2012) evaluated the influence of shading screens of different colours (red, blue, black) with nominal shade factors of 70% on solar radiation transmissivity on bromeliads (*Aechmea fasciata*) and found that red screen promoted the highest solar radiation transmissivity of 27% while a black screen had the lowest solar radiation transmissivity of 10.4%. Legarrea *et al*. (2009) compared the photo-effects of seven different screens on pepper and observed that spidernet plus, bionet white and p-optinet transmitted less than 40% of Ultra Violet (UV) radiation whereas Anti-virus 50 mesh and T-Anti insect net allowed more than 75% of incident light to reach the crop. Bionet transparent and P-Antinet insect net fell in between transmitting 40% and 50% of UV radiation. It was found by Meena *et al*. (2014) that both light intensity and PAR was lower inside the coloured shade nets than outside. The maximum light intensity and PAR was recorded in white, followed by red, green and black in both summer and rainy season. Both the parameters recorded values lower during rainy season and higher during summer season. The light intensity recorded was reduced by 47.8-67.1% under white, 55.4-72.5% under red, 63.7-74.3% under green and 62-82.7% under black colour shade net. The PAR was reduced by 33.4-42.7% under white, 26.7-36.1% under red, 19.4-32.5% under green and 17.2-20.1% under black coloured shade net.

Relative humidity is often higher under netting than outside as a result of water vapour being transpired by the crop and reduced mixing with drier air outside the netted area (Elad *et al*., 2007) even when the temperatures under the netting are higher than outside (Stamps, 1994). Iglesias and Alegre (2006) noted that the greatest value of relative humidity was detected under polyethylene cover followed by black net cover. Muleke *et al*. (2013) reported an increase in relative humidity under nets compared to open field. Similarly, Shahak *et al*. (2004) working with agricultural crops reported a 3-10% increase in relative humidity under coloured nets.

Abdrabbo *et al*. (2013) reported an increase in relative humidity in coloured nets by 4-8% compared with open field while working on potato. Abul-Soud *et al*. (2014) also reported increased average relative humidity following the use of nets (white, yellow, blue and black) compared to open field during the two seasons of their study. In addition, Solomakhin and Blanke (2009) while working with apples reported an increase in relative humidity by 2% (cloudy) to 5% (sunny) under coloured nets (red, green, black and white nets) compared to control (without cover). Covering of tomato plants using AgroNet® also increased the relative humidity of the immediate tomato crop environment in a study by Gogo *et al.* (2017). Throughout the data collection period, the control treatment registered the lowest relative humidity with no significant differences noted amongst all the AgroNet® covered treatments. A study in Pretoria to evaluate the response of baby spinach to photo-selective nettings (black, pearl, yellow and red) on plant growth and postharvest reported significantly higher relative humidity under black net than under open field (Mudau *et al*., 2017). Contrary to these observations, Maklad *et al*. (2012) reported a decrease in relative humidity under coloured nets on cucumber while Nangare *et al*. (2015) and Arthurs *et al*. (2013) reported no effect of coloured nets on relative humidity on tomato and floricultural crops, respectively.

Nettings also reduce wind speed and wind run, which can affect temperature, relative humidity and gas concentrations resulting from reductions in air mixing (Stamps, 1994). These changes can affect transpiration, photosynthesis, respiration and other processes. Shahak *et al*. (2004) reported a slower wind velocity under nets compared to open field. Similarly, reports have pointed out that with the installation of netting, wind speed within an apple orchard is reduced by 40-50% (Tanny and Cohen, 2003). Arthurs *et al.* (2013) also reported differences in wind speed under shade nets with red, blue and pearl providing greater wind resistance compared with black nets. In another study on sweet pepper, Ilic *et al*. (2017b) recorded lower wind speed under coloured shade-nets (red, black, pearl and blue) while control recorded the highest wind speed.

Use of nets has also been shown to improve soil moisture of the immediate crop environment. In trials on cabbage (Muleke *et al*., 2014) and tomato (Saidi *et al*., 2013) nets maintained higher soil moisture content measured as volumetric water content compared to open field production. Gogo *et al*. (2017) also reported significantly lower soil moisture under the in the control treatment with no significant differences recorded for all the AgroNet® covered treatments except at 61 and 89 DAT when soil moisture tended to be significantly higher under the 0.4 untreated net compared with the other net covered treatments in another study.

2.5 Effects of Net Covers on Pest Infestation

Netting is a reliable method of controlling insect pests as it places a physical barrier between the pest and the crop. Coloured netting is an emerging approach to protected cultivation which introduces additional benefits on top of the various protective functions. Some of the coloured shade nets (yellow and blue) contain pigments known to attract whiteflies and thrips. Therefore, crops grown under yellow or blue nets could potentially be at a higher or lower risk for pest infestation depending on the photo-selective filtration of sunlight of the cover used (Antignus and Ben-Yakir, 2004).

Different insect pests have been shown to respond differently to different shades of net covers. Ben-Yakir *et al*. (2008) reported higher whitefly populations on cotton (*Gossypium hirsutum*) leaves under yellow nets compared with black, blue and red netting. Contrary to these observations, a study conducted in Besor region Israel on tomato using yellow, black, red and pearl nets reported lower aphid and whitefly infestation under tunnels covered by yellow or pearl nets compared with black or red nets (Ben-Yakir *et al.*, 2012). Contrary to these observations, Maklad *et al*. (2012) reported an increase in aphid population in cucumber following the use of black and white shade nets.

In an attempt to establish pest preference for coloured nets (yellow, blue, black and red), it was observed that yellow and blue shade nets (ChromatiNet) were preferred by thrips compared with black and red nets while whiteflies preferred yellow shade nets compared with black, blue and red nets. In addition, in a study using cucumber, tomato and chive, whitefly penetration and establishment under the nets decreased following the use of yellow or blue nets (Ben-Yakir, 2006).

Plastic films are being used as a photo-selective barrier to control insect vectors in different horticultural crops. A two-year experiment carried out in Northeastern Spain to evaluate the impact of UV-blocking film on the population density of insect pests on head lettuce showed that UV-blocking film was effective in reducing the abundance and in delaying the colonization of lettuce by aphids and thrips. No effective control of the greenhouse whitefly was achieved (Diaz *et al.,* 2006). Carmier *et al.* (2015) investigated the use of exclusion net in the control of spotted wing Drosophila in blue berry fields. Results showed that no spotted wing *Drosophila suzukii* were recorded under exclusion nets compared to open field.

Ben-Yakir *et al.* (2012) investigated the effects of red, yellow and pearl coloured shade nets on infestation by aphids and whitefly on bell pepper and tomato. Results showed that shade nets permitted free passage of pests with the infestation levels of aphids and whitefly under yellow or pearl nets being consistently 3 times lower compared with those of tunnels covered with black or red net. Legarrea *et al.* (2009) evaluated pest infestation on sweet pepper in Gilat, Israel using net covers and found that Bionet white and P-Optinet cover which absorbed and reflected the highest amount of UV radiation, respectively offered the best protection against the main pests (thrips, whiteflies and broad mites) of pepper compared to open field.

Use of coloured net covers reduces the flight activity of insects. Limiting the dispersal of pests such as aphids and whiteflies is important because of their major role as vectors of plant viruses. Legarrea *et al*. (2012) examined the dispersal ability of three vector species, *Bemisia tabaci*, *Macrosiphum euphorbiae* and *Myzus persicae* in cages covered with coloured nets. Results showed that the ability of whitefly to reach the target plant was reduced by coloured nets while that of aphids was increased. Similarly, Daniel and Baker (2013) reported netting to reduce flight activity and fruit infestation of European cherry fruit fly by 77% and 91%, respectively.

New types of UV-blocking materials such as polyethylene films and nets have been developed in recent years as a promising tool to control insect vectors of horticultural crops. Fajinmi and Fajinmi (2010) reported that maintaining okra (*Abelmoschus esculentus* Moench.) plots under netting for more than 28 days after emergence reduced the number of *Podagrica uniforma* (Jac.) and *Podagrica sjostedti* (Jac.) considerably when compared with that of the un-netted plots or plots netted up to 21 days after seedling emergence. Gogo *et al*. (2014) reported significant reduction of the number of leaf miners, cotton bollworms, onion thrips, mites, silver leaf whitefly and aphids on tomato following the use of nets compared with uncovered control treatment. Similarly, Mutisya *et al*. (2016) reported that the use of agronet cover was associated with less infestation of tomato plants by Bemisia tabaci. Throughout the data collection period, B. tabaci infestation on agronet covered treatments was significantly lower than in uncovered treatments in both seasons. Kelderer *et al*. (2009) reported that single row netting structures deployed before flowering of pome granate (*Punica granatum*) fruits resulted in a highly significant reduction of codling moth fruit damage of almost 100% compared with the open field.

2.6 Effects of Net Colours on Crop Growth and Yield

Coloured net technology can be applied to enhance commercially desired plant responses thus substituting for the use of growth regulators or pruning. Following the use of different colours of nets (red, green, black and white) on *Dracaena fragrans*, Gaurav *et al*. (2016a) recorded tallest plants under red net and shortest plants under control. A study in Pretoria to evaluate the response of baby spinach to photo-selective nettings (black, pearl, yellow and red) on plant growth and postharvest reported significantly higher leaf petiole length under photoselective nets except for black net than those grown in an open field (Mudau *et al*., 2017). Bandara *et al*. (2014) investigated the effect of different colours of shade nets on growth and development of selected horticultural crop species grown using five coloured shade nets; Aluminet, white, silver, red and black. Results showed a significant difference in plant height, leaf size, chlorophyll content and dry weight gains under white colour shade net on *Lycopersicon esculentum*. Additionally, there was also a significant increase in plant height, dry weight and colour development in leaves of *Corydyline fruticosa* var. `purple compacta` and *Chlorophytum tuberosum* under red colour shade net followed by Aluminet. Abdrabbo *et al*. (2013) reported highest potato height under black net followed by blue net with open field giving the shortest plant height during their study. Similarly, Moniruzzaman *et al*. (2009) reported more vigorous plant growth under shade nets than for open field (unshaded conditions). Costa *et al*. (2010) also reported taller plants of *Ocimum selloi* grown under shade than those grown under direct full sunlight with no difference in height of plants grown under red and blue shading. Shade nets did not, however, affect the diameter of stems.

Working with cast iron plant (*Aspidistra elatior*), Stamps (2008) observed that leaf variegation and the percentage of all green leaves of the plant was not affected by the use of black, blue, grey or red net covers. Ngelenzi *et al*. (2016) investigated the effect of different coloured agronet covers (white, grey; yellow, tricolor and blue) on pod growth of French bean (*Phaseolus vulgaris* L.). Results showed that plant height and internode length was highest under yellow net cover compared to control treatment. Branching was highest under net covers compared to control while highest collar diameter was recorded under white, grey and tricolor compared to control. Following the use of two shade net treatments (black or green) on tomato (Solanum lycopersicon), Zakher and Abdrabbo (2014) recorded tomato plants characterized by more vigorous vegetative growth expressed as plant height, number of branches and leaves per plants, fresh and dry weight compared with those plants grown without protection treatments. Contrary to these observations, Oliveira *et al*. (2015) reported an increase in plant height on

Melissa officinalis L. under blue net compared with open field.). On tomato, Nangare *et al*. (2015) recorded highest plant height under green shade net compared open field. African nightshade under blue net were significantly taller compared to those in open field. Unlike African nightshade, spider plant grown under the white net cover had tallest plants in all sampling dates. On the other hand, the shortest plants were obtained from blue net throughout the study. On African nightshade, yellow net cover improved primary branching while white net cover recorded increased branching on spider plant (Ochieng *et al*., 2017).

Ilic *et al*. (2017a) tested the effect of light modification by color net (red, pearl, blue and black) on quality of lettuce in summer production. Total chlorophyll content, as well as the contents of both chlorophyll a and b were significantly higher in shaded leaves of lettuce than in control plants. Leaves of lettuce plants, cultivated under blue (450.7 μg/g FW) and black (447.5 μg/g FW) shade nets had the highest total chlorophyll content in comparison to plants cultivated under other color shade nets, and the differences were statistically significant. Additionally, following the use of two shade net treatments (black or green) on tomato (*Solanum lycopersicon*), Zakher and Abdrabbo (2014) recorded tomato plants with high chlorophyll content compared with those plants grown without protection treatments. Similarly, Mudau *et al*. (2017) and Soares *et al*. (2017) recorded higher leaf chlorophyll content under photoselective nettings compared to under open field. When the chlorophyll profile of *Spinacia oleracea* grown under different coloured *viz.*, white, red, green and black shade nets was studied, it was found that the plants under red recorded 54 to 67 per cent, green 52 to 62 per cent, white 19 to 35 per cent and black 12 to 31 per cent more content than the control. Similar results were obtained during the rainy season (Meena *et al.*, 2014).

On several cultivars of lisianthus (*Eustoma grandiflorum*), sunflower (*Helianthus annuus*) and *Trachelium spp.* plants, Shahak *et al*. (2008) observed that the length of flowering stems was longer and thicker under red and yellow nets while shorter under blue, compared with the black (reference) net. Moreover, red net induced shorter time to flowering in some species. Plants grown under yellow net were also exceptional in their heavier flowering stems. Under the grey net, sunflower yielded the highest number of flowering stems per plant compared with any other net. Similarly, flowering of Hermosa peaches (*Prunus persica*) was increased following the use of coloured nets (white, 12% shading; blue, pearl, red and yellow, 30% shading) compared with the no net control after two years under netting (Shahak *et al*., 2004). Leite *et al*. (2008) also reported earlier flowering in orchid (*Phalaenopsis spp.*) following the use of black and blue net covers. Contrary to these observations, Basile *et al*.

(2008) reported reduced number of flowers and inflorescence per shoot in kiwifruit (*Actinidia chinensis*) under white, red, blue and grey net covers compared with no net treatments. Takeda *et al*. (2010) also reported delayed flowering in `Sultana` seedless grapes (*Vitis vinifera*) following the use of red or blue shade nets and enhanced flowering in no shade control plants. Colour shade nets have widely been used to improve productivity by moderating climatic extremes.

A three-year study in Serbia conducted to evaluate the influence of different colours of shade nets (pearl, red, blue and black) on yield of bell pepper (*Capsicum annum* L.) reported significantly higher yield under red and yellow shade nets compared with black nets (Ilic *et al*., 2012). Similarly, Fallik *et al*. (2009) reported higher export quality pepper fruit yield under red and yellow shade nets with pepper grown under net covers resulting in a 113% to 131% increase in the total fruit yield compared to open field depending on the year. In another study on tomato using pearl, red, blue and black coloured nets, Milenkovic *et al*. (2008) found that shading increased the marketable yields of tomato by about 35% compared to non-shaded conditions. Red and pearl shade nets significantly increased the total yield which was associated with both higher fruit numbers per plant and larger fruits. The total fruit yields under the coloured shade nets were higher by 11.9-22.8%. Abdrabbo *et al*. (2013) reported increased tuber yield per plant in potato under white net compared to other nets during a two season's trial. Yellow net came in second followed by open treatment with the lowest yield obtained under black and blue covers. Similarly, Oliveiria *et al*. (2015) recorded reduced oil yield under blue net cover while working on *Melissa officinalis* L. Ledone (2014) on the other hand reported higher yields of sweet pepper under ChromatiNet red and lowest under green net cover. In addition, yellow and red nets recorded higher number of fruits of extra quality compared to under other treatments.

The use of net covers in crop production may change the amount and quality of the light supplied to the plants, subsequently affecting yield and quality of crops. Mugnozza *et al*. (2011) reported that peach plants grown under red, pearl, grey, and yellow colour nets resulted in higher yield than the no net control plants. Similarly, Mutisya *et al*. (2016) recorded higher yields (fruit number and marketable weight) under agronet cover compared to control. Ilic *et al*. (2010) found that growing tomato under red and pearl shade net resulted in a significant increase in total yield which was associated with both higher productivity (no. of fruits produced per plant) and larger fruits. Abul-Soud *et al.* (2014) recorded highest vegetative characteristics for three cultivars of cabbage (Chinese, red and white) under white net in terms of number of leaves, total leaf area and fresh and dry weight of yield. On mango (*Mangifera indica* L.), white net produced the highest yield followed by yellow net while open field control produced lowest yield (Abul-Soud *et al*., 2014). Similarly, Ngelenzi *et al*. (2016) recorded highest pods per plant under white net cover compared to control.

Mashego (2001) reported higher tomato fruit number of about 47 per plant under 12% white shade and 40% black shade compared with 30% black netting which produced about 35 fruits per plant. A higher yield of tomato was produced under 18% white shade net compared to full exposure to sunlight. Similarly, Bosco *et al*. (2018) investigated the effects of hail net coverage on apple tree yield in Brazil. Results showed that the hail net recorded highest number of fruits per plant, fruit weight and yield compared to open field. Grinberger *et al*. (2000) reported higher yields in lettuce under pearl and red nets compared with blue net. On yield, Ilic *et al*. (2017a) recorded highest head weight of lettuce under pearl (331g) and red (319g) in comparison with unshaded plants which recorded lower fresh weight of 252g. In another study by Ilic *et al*. (2017b) on sweet pepper, highest number of fruits and total yield was recorded under pearl and lowest under other treatments (black, blue, red and control).

A study involving use of nets on table grapes has been reported from Israel (Shahak *et al*., 2008). Berry and cluster weights of cultivar Superior were increased under yellow, black, red and white nets but reduced under grey net compared with the no net control. In other trials using cultivar Red Globe, the authors reported increased berry size under the 30% yellow shade net compared with five other coloured nets and increased berry weight under black, red and white netting compared with no net. Coloured netting was also shown to affect the rate of fruit maturation with pearl and white colours increasing the rate of maturation and black and red nets delaying maturation. Preliminary results of studies on pear (*Pyrus communis*) indicated that coloured shade nets influenced pear fruit size and russeting with pearl netting increasing fruit yield and red netting reducing fruit russeting (Shahak *et al*., 2008). Ochieng *et al.* (2017) recorded significantly higher leaf fresh yield of African nightshade (*Solanum scabrum* Mill.) under yellow net cover.

On bell pepper (*Capsicum annuum*), Shahak (2008) observed that production was increased by 16% to 32% under pearl and red net covers compared with black netting. Similarly, Elad *et al*. (2007) reported increased yields of two sweet pepper cultivars when grown under black, blue, blue-silver, silver and white shade nets as compared with the no net control. Contrary to these observations, Basile *et al*. (2008) reported reduced yields in kiwifruit (*Actinidia chinensis*) following the use of blue, grey; red and white coloured net covers.

Ambrozy *et al*. (2015) conducted a study to determine yield in sweet pepper under net shading (yellow, red, green, white and ChromatiNet red) revealed that yellow and red net significantly recorded higher yield compared with the control. On marketable yield, all shading nets had significantly positive effect against sunscald except for the white shading net at the first harvest. No sunscald fruits were recorded under ChromatiNet red or green nets. In contrast, higher amount of sunscald fruits was recorded under no net control. Similarly, Ngelenzi *et al*. (2016) and Nangare *et al*. (2015) recorded higher marketable yield under shade net compared to open field.

A study conducted to determine yield in turnip (*Brassica rapa*) roots and shoots grown under different photo-selective nettings (blue, red and yellow) revealed that netting did not significantly affect shoot yield and had an inconsistent effect on root yield (Justen *et al*., 2012). However, Casierra-Posada *et al*. (2012) reported significantly higher values of root to shoot ratio of straw berry (*Fragaria spp.*) under green cover (86.77% higher) compared with control plants with no cover. Additionally, green cover induced a 91.34% reduction in the value of harvestable dry matter as compared to control plants grown without cover. Bastias *et al*. (2012) reported higher total dry matter production (fruit + leaf + annual shoot) of apples under blue net which was on average 30% higher than red, grey and white nets.

Saidi *et al*. (2013) tested the effect of agronet covers on yield of tomato. Fruit number and marketable fruits were significantly enhanced under agronet covers compared to control. On cabbage, Muleke *et al*. (2014) observed that total head weight was significantly increased under agronet covers compared to the control. In addition, Meena and Vashisth (2014) found that spinach (Spinacia oleracea L.) plants recorded higher total dry biomass when grown under shade nets (white, black, red and green) compared to control plants. The harvested biomass of the summer crop was 20-22, 29-33, 48-59 and 63- 67% higher in white, black, red and green shade nets. However, in rainy season, the biomass was lower in black and white as compared to control. The increase in biomass was 20-48% in red and 28-57% in green shade net. Ribeiro *et al*. (2018) investigated the effect of coloured shade nets on growth and essential oil of *Pogostemon cablin*. Results showed that coloured shade nets recorded higher leaf, stem and total dry weight compared to plants grown under full sunlight.

2.7 Effects of Net Colours on Postharvest Quality of Horticultural Crops

The crop micro-environment created following the use of net covers can influence quality of horticultural produce including red pigmentation, soluble solids concentration, fruit size and mass as well as maturity development. Gardner and Fletcher (1990) showed that when black nylon netting was installed over a `Jonathan` apple orchard, fruit colour was reduced by 10-16%. The effect of netting on fruit colour development, however, seems to be cultivar and netting type dependent. Widmer (2001) observed that black netting had no significant effect on fruit colour for `Jonagored` cultivar of apple but resulted in reduction in fruit colour of `Jonagold` cultivar. Stampar *et al*. (2001) found that fruits of `Elstar` cultivar of apples produced the best colour under white netting but had the worst colour development in the uncovered control while colouration of `Jonagold` fruits was negatively affected under black netting and positively affected under white netting. Guerrero *et al*. (2002) also found that colour development on `Redchief Delicious` apples was better on fruit trees covered by white netting than those of trees under black netting. Shahak *et al*. (2004) reported enhanced red colouration of fruits of `Topred` apple cultivar following the use of different colours of nets (blue, red, yellow, grey, pearl and white) compared to control. In another study, `Royal Gala` and `Fuji` cultivars of apples showed a reduction in red colour with the installation of shade netting (Leite *et al*., 2002).

With the installation of shade netting, the total soluble solids (TSS) and titratable acidity (TA) content may be affected due to alterations in carbon dioxide assimilation and water availability. Iglesias and Alegre (2006) also reported decreased TSS following the use of black net although values were similar for the crystal net and control but nets had no effect on TA. Dussi *et al*. (2005) reported greater TSS under control treatment and a lower TSS content following the use of nets. Sen *et al*. (2012) also reported higher TSS content (20-27%) of grapes under unshaded control (100% light) treatments during the first year of study compared with those harvested from vines that were shaded (35%, 55% and 75%). In the second year of the study, TSS content of unshaded and 35% shaded grapes were higher (8-14%) than those grown under 55% and 75% shade. Similarly, Hepaksoy and Dayioglu (2016) reported higher TSS under control (13.10%) compared to black net cover (11.37%). Contrary to these observations, Gogo (2013) reported lowest sugars on tomato grown under the control compared with those grown under net treatments. Carmier *et al*. (2015) and Nangare *et al*. (2015) reported no significant difference in TSS and acidity by shade net structures on blueberry and tomato, respectively. Similarly, Meena *et al*. (2016) recorded no significant difference on TSS following the use of net covers on pome granate (*Punica granatum*).

Widmer (1997) found that `Jonagold` and `Jonagored` apple fruits tended to be more acidic when grown under netting than in the open. Stampar *et al*. (2001) found TA to be significantly higher for fruits produced under white netting for `Elstar` cultivar but no difference between netted and uncovered fruits for `Jonagold` cultivar. In tomato, Ilic and Milenkovic (2012) reported lower TSS content in fruits produced under protected environment compared to those grown in the open field. In this study, fruits produced in the open field had higher fruit sugar: acid ratio than those produced in the protected environment. Tinyane *et al*. (2013) reported higher TSS and TA under black net used as control compared to photo selective nets (red, yellow and pearl). To the contrary, Gogo (2013) and Saidi *et al*. (2013) reported lower TA in tomato grown under nets compared with the no net control. Moreover, fruits harvested from the control treatments had lower TSS: TA while those grown under nets had higher TSS: TA. A study in southern Serbia investigating the use of coloured nets on production of tomato cultivar Vedeta, reported that tomato fruits produced under net covers were less acidic registering lower titratable acidity values of 0.34% citric acid compared to fruits produced in open field (0.37% citric acid) (Caliman *et al*., 2010). Field grown fruits were also found to have higher TSS content and lower lycopene content than those in protected environment. Similarly, Hepaksoy and Dayioglu (2016) and Meena *et al*. (2016) reported higher TA under open field fruits compared to those produced under protected environment. Dussi *et al*. (2005) found that fruits produced in the field had higher TSS: TA ratio and more reducing sugar and TSS than those produced under protected conditions.

As observed in various studies, netting can affect fruit size which should be put into consideration when installing nets. In a `Jonathan` apple orchard covered with shade netting, the fruit size (mean diameter) was slightly reduced (Gardner and Fletcher, 1990). Tinyane *et al*. (2013) also reported smaller fruits at harvest from tomato plants grown under black shade nets compared with those grown under (red, yellow and pearl nets). Contrary to these observations, Shahak *et al*. (2004) found that fruit size of apples was significantly larger under all nets (blue, red, yellow, grey, pearl, white and red/white), with diameters about 5mm greater than the control at about 7 weeks prior to the expected harvest. Bastias *et al*. (2012) also reported larger apple fruits under grey net compared with white net. On the other hand, Iglesias and Alegre (2006) reported no significant effect on fruit size distribution of apple following the use of nets.

Fruit firmness and starch conversion rates are used as indicators of fruit maturity. Widmer (1997) found that `Jonathan` apples grown under netting were firmer than uncovered apples. Garner and Fletcher (1990) also found that apples harvested from netted areas tended to be slightly firmer than those from non-netted trees. Similarly, Muleke *et al*. (2014) and Saidi *et al*. (2013) respectively reported the use of net covers on cabbage and tomato to result in firmer heads and fruits compared to no net controls. Tinyane *et al*. (2013) also reported firmer tomato fruits grown under net with black net having less firm fruits compared to red, yellow and pearl nets. Ilic and Milenkovic (2012) recorded a greater maturity index (sugar acid ratio) of tomato from open field (14.68) in comparison with tomato from colour shade nets (red, black, white and blue). Similarly, Sen *et al*. (2012) obtained higher maturity in unshaded grapes compared with fruits harvested from vines that were shaded.

Iglesias and Alegre (2006) reported higher lycopene content under red shade netting compared with field grown tomato while increased β- carotene was recorded for fruits grown under pearl net. Similarly, Tinyane *et al*. (2013) reported significantly higher lycopene content in tomato grown under black nets whereas tomato grown under pearl nets had lower lycopene with those under red net showing higher lycopene content than those grown under the pearl net. Additionally, β- carotene and phenolic compounds were significantly higher under the black net than from other nets. Ilic *et al*. (2012) reported highest concentration of lycopene in tomato grown in plastic houses integrated with red colour nets (64.9μgg^{-1} fresh weight), while those grown in fields covered with pearl nets had the lowest levels of lycopene (46.7μgg^{-1}fresh weight) and a significantly higher β- carotene of 2.25μgg^{-1} and 2.17μgg^{-1} in control and under pearl net, respectively than fruits grown under blue nets (1.50μgg^{-1}). Tomato fruits grown under integrated plastic house with red net (2.01μgg^{-1}) had significantly more β- carotene than those grown under plastic house covered with black (1.33μgg^{-1}) or pearl (1.25μgg^{-1}) net. Ilic et al. (2017a) investigated the effects of colour nets on quality of lettuce. Results showed that pearl net (291.8 µg/g FW) recorded highest contents of carotenoids while lowest was recorded under red (104.3 µg/g FW) or control of plants (91.6 µg/g FW). Highest β- carotene content was on the other hand recorded under black (54.2 µg/g FW) or pearl (50.6 µg/g FW) shade nets than plants grown under red (36.4 µg/g FW) or control plants (44.0 µg/g FW).

The effect of the colour of net covers on postharvest attributes of horticultural crops has also been demonstrated on sweet pepper. Kong *et al*. (2013) found that at postharvest, pepper grown under pearl netting had significantly reduced water loss, decay incidence and titratable acidity and increased fruit firmness, elasticity, ascorbic acid level and antioxidant activity compared to that grown under black netting. Furthermore, fruits grown under pearl netting effectively maintained postharvest fruit quality than fruits under the traditional black netting. Alkalia-Tuvia *et al*. (2014) also reported significantly lower percentage decay incidence in sweet pepper grown under pearl net compared with pepper fruit grown under commercial black net. Netting did not, however, present significant differences on fruit weight loss, firmness and

TSS content after 16 days of storage and three additional days at 20^{0}C. Selahle *et al*. (2014), on the other hand reported higher weight loss of three tomato cultivars under black shade net whereas photo-selective nets (pearl, red and yellow) had less weight loss. Madona *et al*. (2015) recorded significantly lower weight loss after postharvest storage under photo-selective nets (pearl, red and yellow) compared to black net cover.

CHAPTER THREE

MATERIALS AND METHODS

The study entailed two parts: (i) an evaluation of the effect of the colour of agronet cover on the field performance of tomato and (ii) a laboratory part to establish the effect of the colour of agronet cover during production on the postharvest attributes of the fruits.

3.1 Site Description

The study was conducted in two seasons at the Horticulture Research and Demonstration Field of Egerton University during the period of November 2013 to February 2014 and May to September 2014. While part one of the studies was conducted in the open field, part two was conducted in the laboratory in the same field. The site is situated within Nakuru county of Kenya at approximately 175 km North-West of Nairobi. The farm lies at a latitude of 0^{o}23`S longitude $35^{o}$35`E and an altitude of 2238 m. The area receives a total annual rainfall ~1000 mm while average maximum and minimum temperatures range from 19^{o}C to 22^{o}C and 5^{o}C to 8^{o}C, respectively. The soils are well drained dark reddish clays classified as *Mollic andosols* (Jaetzold and Schmidt, 1983).

3.2 Tomato Field Production Experiment

3.2.1 Planting Material

Plant material used in this part of the study was tomato seeds cv. `Rio Grande`. This determinate tomato variety was chosen because it has good level of disease tolerance and is high yielding. It is however, sensitive to variations in environmental conditions (HCDA, 2006). Seeds used were purchased from Kenya Seed Company - Eldoret.

3.2.2 Experimental Design and Treatments

A randomized complete block design (RCBD) with five replications was used. The experiment consisted of six treatments which included growing tomato under; blue, yellow, grey, white and multi-coloured (predominantly white in colour with blue and yellow stripes) net covers maintained permanently covered except during routine management practices and no net cover which served as control. The experiment therefore consisted of a total of 30 experimental units each measuring 3m by 5m arranged in five blocks each comprising of six experimental units. Of these, five experimental units in each block were under net protection and the remaining one unprotected. Each block measured 32.5m by 3m separated by 0.5m path from the adjacent block. In every experimental unit, seven posts 1.2m long were used to support the nets. Three posts were mounted on each side of the experimental unit at a 2.5m interval along the 5m length of the plot and one at the middle of the plot. The posts were grounded approximately 20cm into the soil leaving 1m of the length above the ground on which the nets were laid. The agronet used were of 0.4mm pore diameter sourced from A to Z Textile Mills Ltd., Arusha Tanzania. The experimental field layout was as shown in Figure 1.

3.2.3 Crop Establishment and Maintenance

Tomato seedlings were started in a nursery until they attained the stage of four true leaves. Hardening off of seedlings was done a week before transplanting by reducing watering frequency to only once at the beginning of the week. Prior to transplanting, the experimental field was manually prepared using a hand hoe and rake to pulverize the soil and produce a fine tilth before demarcation of the experimental units. Planting holes were made at approximately the same depth the seedlings were in the nursery using a hand hoe. Diammonium phosphate (DAP) was incorporated in every hole at a rate of 10gm/hole which translates to 240kgha^{-1} as per recommendation for tomato by HCDA (2006). Tomato seedlings were watered thoroughly in the nursery bed four hours before uprooting in order to minimize root damage. Most vigorous and disease free tomato seedlings were then selected in the nursery and transplanted late in the evening in order to reduce transplanting shock at a spacing of 50cm along the 5m length of each plot. Four rows were planted in every experimental unit spaced 75cm apart giving a total of 40 seedlings per plot. Gapping was done one week after transplanting and thereafter, the crop was kept weed free through hand weeding and irrigated whenever needed to avoid water stress. Calcium Ammonium Nitrate (CAN) was applied in two splits as a top dress at the rate of 300kgha^{-1} when the plants were three weeks old (at the first trifoliate leaf stage) and the second split three weeks later. Flower pruning was done whenever seen in plants in every plot up to the 8th week after transplanting to give the plants ample time to put up good vegetative growth. Disease control was also uniformly done in all plots on need basis.

3.2.4 Data Collection

Data collection commenced four weeks after transplanting (WAT) until termination of the study. Data on pest count, plant growth and yield were collected from 12 tagged plants in the inner rows of each experimental unit. The variables measured were:

3.2.4.1 Microclimate Variables

WatchDog 2000 series Mini Station data loggers model 2475 (Spectrum Technologies, Inc.) were used to collect microclimate data. The Data loggers were mounted on wooden posts 0.5m high at the center of each plot using screws. The Data loggers were set to collect data hourly which were averaged daily. Microclimate data collected included air temperature (^{o}C), PAR light (µmolm^{-2}s^{-1}) and relative humidity (%).

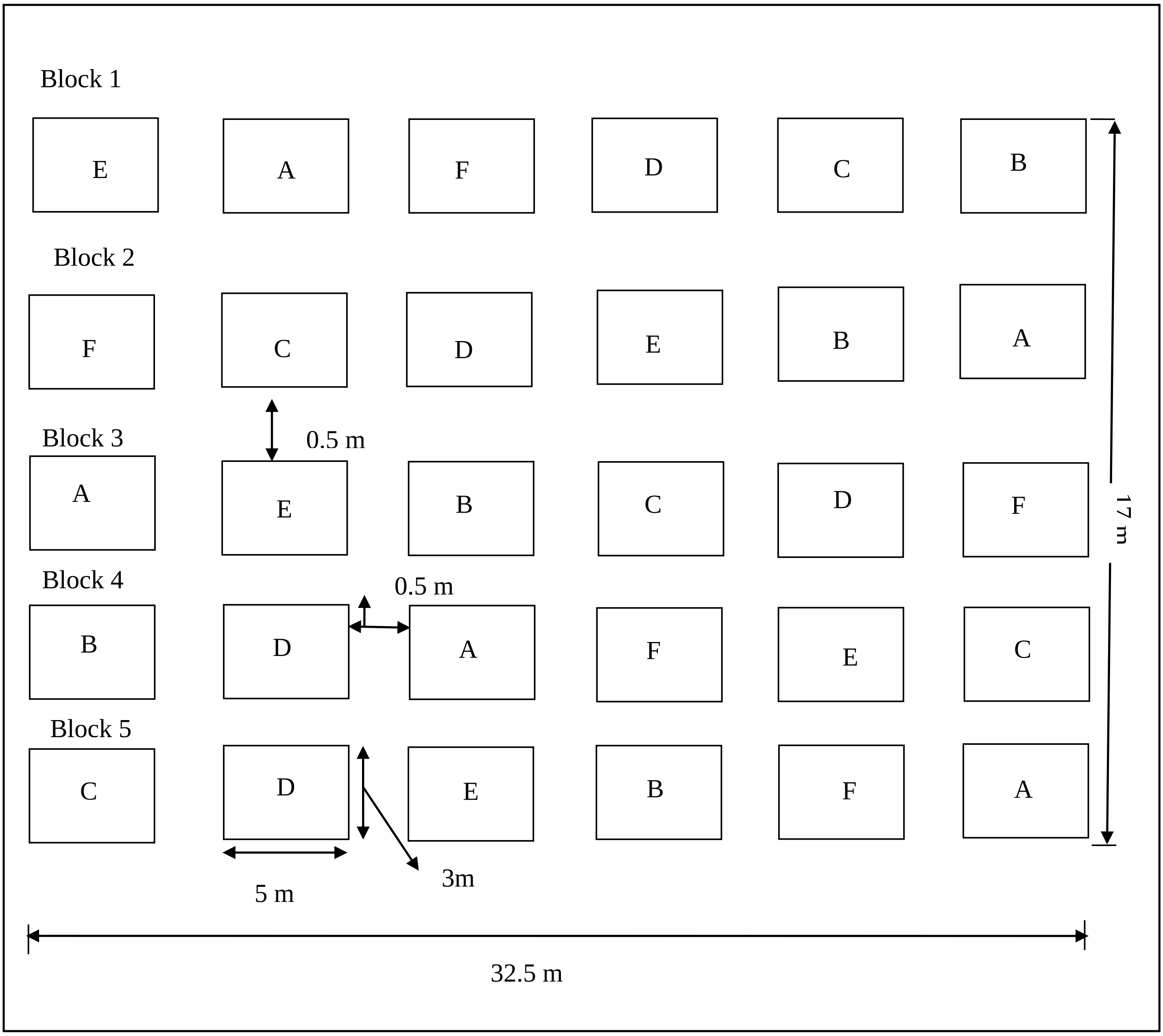

Figure 1: Experimental layout for the field experiment

Key: A-non-protected as control, B- white net, C-grey net, D- yellow net, E- blue net and F- multi-coloured (predominantly white in colour with blue and yellow stripes) net.

Data on soil moisture was also collected using an external moisture sensor (WaterScout^{TM}SM 100) buried into the soil at a depth of ~5 cm with 1.8 m cable connected to the port of the WatchDog plant growth station. Soil moisture was recorded as percentage volumetric water content (%VWC).

3.2.4.2 Pest Infestation Variables

Pest monitoring commenced four weeks after transplanting and continued thereafter until the crop matured. Pest infestation data collected included counts of adult silverleaf whitefly (*Bemisia tabaci*), spider mites (*Tetranychus urticae*), onion thrips (*Frankliniella intonsa*) and nymphs of aphid (*Aphis gossypii*). Hand lenses were used to magnify the pests for ease of counting.

(a) Silverleaf Whitefly

Adult silverleaf whitefly populations were counted early in the morning hours when these insect pests are inactive by carefully inverting the leaves of sample plants and physically counting the numbers of whitefly on each leaf. Data obtained were later used to compute the average number of whitefly per plant. In addition, yellow sticky traps from Koppert Biological Systems (K) Ltd., Nairobi were also mounted at the middle of each plot to trap flying whiteflies and later those stuck on the traps were counted. Data obtained were later used to compute average number of whitefly per plot.

(b) Aphids

Population of aphids was determined by carefully inverting the same leaves of sample plants used for determination of population of whitefly and physically counting the number of aphid nymphs on each leaf. Data obtained were later used to compute the average number of aphids per plant.

(c) Mites

Population of mites was also counted on the underside of the leaves of selected plants and numbers recorded. Data obtained were later used to compute the average number of mites per plant.

(d) Thrips

Thrips population was counted on the underside of the leaves of selected plants and numbers recorded. In addition, a white sheet of paper was placed beneath the flowers of selected plants and thrips were dislodged onto the sheet of paper by shaking the plants and thereafter counting was done. At the end of sampling, population of thrips obtained from the leaves and flowers were summed up and later used to compute the average number of thrips per plant.

3.2.4.3 Plant Physiological and Growth Variables

(a) Leaf Stomatal Conductance

Stomatal conductance was determined on three recently fully expanded leaves on each plant using a steady state leaf porometer (SC-1; Decagon Devices, Pullman, WA, USA) beginning four weeks after transplanting and thereafter continued at two weeks interval until the crop matured. Stomatal conductance readings were taken directly from the leaf porometer and recorded in $mmolm^{-2}sec^{-1}$.

(b) Plant Height

Tomato plant height in centimeters (cm) was obtained by measuring the height of the tagged plants in each experimental unit from the ground level to the main apex using a meter ruler and data obtained used to compute the average plant height.

(c) Number of Branches

Number of branches on each of the tagged tomato plants were counted and recorded. Data obtained were later used to compute the average number of branches per plant.

(d) Internode Numbers

The number of internodes on each tagged plant was counted and recorded. It was then used to compute the average number of internodes per plant.

(e) Internode Length

The length of each internode on each tagged plant was measured using a meter tape and data obtained used to compute the average internode length of plants in centimeters (cm).

(f) Collar Diameter

Collar diameter for each tagged plant was measured 5cm from the ground using a digital vernier caliper (Model 599-577-1/ USA) and data obtained used to compute the average collar diameter of plants in millimeters (mm).

3.2.4.4 Yield Variables

(a) Number of Fruit per Plant

Harvesting was done once every week from when the first fruits were at breaker stage over a period of 4 weeks in each of the two seasons. On each plant, two fruits were left to ripen on the plant before harvesting for lycopene determination and thereafter, the numbers and weight of the fruits were determined and added to that of the fruits harvested at the breaker stage. The number of fruits from the 12 tagged tomato plants for each experimental unit was separately counted after each harvest. The data obtained was summed up at the end of each season and divided by 12 to give the mean number of fruits per plant.

(b) Marketable and Unmarketable Fruit Numbers

At each harvest, fruits were categorized as marketable or unmarketable. Fruits with cracks, damaged by insects, diseases, birds, very small in size (below 30mm diameter) and those with sunburn were considered as unmarketable (Lemma, 2002). Those which were free from visible damage were considered as marketable and were separated from unmarketable fruits and the numbers for each category established and recorded. The data obtained was summed up at the end of each season and divided by 12 to give the average number of marketable and unmarketable fruits per plant.

(c) Yield

At every harvest, the weight of fruits harvested from each experimental unit was determined in grams (gms) using a weighing balance (XJ-4K801; Shangai Precision and Scientific Instrument CO., Shangai, China) and data recorded. At the end of each season, fruit weight obtained from each treatment during the individual harvests were summed up and expressed as total fruit weight in kilograms per hectare ($kgha^{-1}$).

(d)Marketable and Unmarketable Weight

At every harvest, marketable and unmarketable fruits were weighed using a weighing balance (XJ-4K801; Shangai Precision and Scientific Instrument CO., Shangai, China). At the end of each season, marketable and unmarketable fruit weights obtained from each treatment during the individual harvests were summed up and expressed as marketable or unmarketable fruit weight in kilograms per hectare ($kgha^{-1}$). Relative % increase in marketable weight for the different treatments was also determined by getting the difference between marketable weight under a specific cover and marketable weight of the control then dividing the difference by the marketable weight of the control. Relative % decrease in unmarketable weight was on the other hand obtained by getting the difference between unmarketable weight under control and unmarketable weight under specific cover then dividing by the unmarketable weight of the control based on the formula given by Gogo *et al*. (2014).

3.2.5 Data Analysis

Data collected were subjected to Analysis of Variance (ANOVA) and means for significant treatments separated using Tukey's Honestly Significant Difference (THSD) test at $P \leq 0.05$. Data for pest population was transformed. The statistical model fitted for experiment was:

$Y_{ijk} = \mu + S_i + \beta_j + T_k + TS_{ik} + \varepsilon_{ijkl}$

i = (season) (1, 2); j = (block) (1, 2, 3, 4, 5) k= (treatment) (1, 2, 3, 4, 5, 6)

Where; Y_{ijk} – Tomato response

μ – Overall mean

S_i– The Effect of i^{th} season

β_j- The Effect of the j^{th} block

T_k– The Effect of the k^{th} treatment

TS_{ik} – The interactive effect of the i^{th} season and k^{th} treatment

ε_{ijkl}– Random error component

3.3 Tomato Postharvest Experiment

3.3.1 Plant Material

Tomato fruits of uniform size were then selected from the marketable yields of each treatment and were later wiped with a moist cloth to remove dust and any other dirt that may have been on the fruit surface in readiness for use as the experimental material for the laboratory experiment.

3.3.2 Experimental Design and Treatments

A completely randomized design (CRD) with four replications was used in this experiment.

3.3.3 Data Collection

Destructive sampling was done on three fruits per treatment per replicate during each data collection day to determine firmness, total soluble solids and titratable acidity beginning at harvest (day 0) and thereafter at 4- day interval until termination of the experiment at 16 days after harvesting when fruits were unusable.

Shelf life, days to ripening, weight loss and decay were also studied during the entire storage period until termination of the study. Lycopene content was determined on red ripe tomato fruits harvested directly from the field. The procedures used to obtain data for the various variables are presented below:

(a) Fruit Firmness

Fruit firmness was determined using a hand-held penetrometer (Model 62/DR, UK). Before using the penetrometer, the tomato skin was removed from opposite sides of the equatorial section of each fruit. A cylindrical plunger with 8 mm diameter probe was attached to the crosshead, driven vertically into the tomato fruit. The display value was noted as described by (Marsic *et al*., 2011) and results reported in kilogram force (KgF).

(b) Total Soluble Solids (TSS)

Total soluble solids content of fruits was analyzed for the same fruits used for determination of fruit firmness, by squeezing out juice onto a hand-held refractometer (0-30 ^{0}Brix) (RHW Refractometer Optoelectronic Technology Company Ltd. UK) as per the procedure described by (Majidi *et al*., 2011) and results reported as ^{0}Brix.

(c) Titratable Acidity

This was also determined from the same fruits used to determine fruit firmness and TSS using the titration method described by Majidi *et al*. (2011). Titratable acidity was determined by titrating the juice extract of tomato with 0.1N sodium hydroxide to an end point of neutral pH with phenolphthalein (95% volume ethanol) as colorimetric indicator. Percentage titratable acidity (TA) was calculated using the formula:

$$TA\ (\%) = (T \times A) \times 100 / V$$

Where

A= Acid factor of 0.1 M NaOH which is equivalent to 0.0064g citric acid

V= Volume (ml) of Sample

T= Titre (ml) of 0.1 M NaOH. TA was determined on the basis of citric acid.

(d) Sugar: Acid Ratio

The values obtained for TSS and TA were used to compute sugar acid ratio of fruit using the formula described by Rangana (1986) where;

$$\text{Sugar: Acid Ratio} = \frac{^{o}\text{Brix value}}{\%\ \text{Citric Acid}}$$

(e) **Lycopene Content**

Lycopene was extracted from three marketable red ripe tomato fruits per treatment per replicate according to the procedure reported by Nagata and Yamashita (1992). Tomato sample was crushed using a mortar and pestle. Thereafter, one gram of sample was used for lycopene content extraction using 10ml acetone-hexane (4:6) and subsequently centrifuged using a centrifuge (KUBOTA; 6800) at 3000 ×g for 5 minutes at 4^{o}C. The optical density of the supernatants was measured spectrophotometrically (UV-200-RS; MRC) at 505nm using acetone- hexane (4:6) as a blank. Lycopene was then quantified using the equation proposed by Fish *et al*. (2002) as follows:

$$\textbf{Lycopene (mg/kg)} = \frac{A_{505nm} \times 31.2}{\text{g tissue}}$$

Where

A_{505nm} = Absorbance at 505 nanometers

g= weight of sample in grams

(f) Weight Loss

An additional batch of twenty fruits at breaker stage was taken from the harvest of each treatment to make four replications of five fruits each and stored for determination of weight loss. Weight of the tomato fruits of each replication of a given treatment was measured using a weighing balance (XJ-4K801; Shangai Precision and Scientific Instrument CO., Shangai, China) before storage and thereafter at a four-day interval until 50% of weight had been lost. Weight loss was expressed as a percentage of the initial weight using the formula:

$$\textbf{\% Fruit weight loss} = \frac{\text{Initial weight} - \text{Final weight}}{\text{Initial weight}} \times 100$$

(g) Days to Ripening

The number of days taken by the fruits to ripen from the breaker stage (a noticeable break in colour with <10% of other than green colour) to red ripe stage (100% red) was also monitored using the same fruits used to determine fruit weight loss as defined by The California Tomato Board (1975). Based on the results obtained, time required for fruits to get to the red ripe from the breaker stage was computed in days.

(h) Decay Percentage

Decay of stored tomato fruits of the different treatments was determined using the same fruits used to determine fruit weight loss and days to ripening based on visual appearance. Decay was expressed as a percentage of the number of decayed fruits out of the total initial fruit number as described by Alkalia-Tuvia *et al*. (2014).

(i) Shelf Life of Fruits

The shelf life of tomato fruit was determined by counting the number of days from harvest to when they were unacceptable for marketing which was marked by decrease in 50% of fruit firmness as defined by Moneruzzaman *et al*. (2009).

3.3.4 Data Analysis

Data collected were subjected to ANOVA and means for significant treatments separated using Tukey`s Honestly Significant Difference (THSD) test at $P \leq 0.05$. The general model used for the statistical analysis was:

$Y_{ij} = \mu + T_j + \varepsilon_{jk}$

j = (treatment) (1, 2, 3, 4, 5, 6)

Where; Y_{ij} – the observation of i^{th} time at j^{th} treatment

μ – Overall mean

T_j – The effect of the j^{th} treatment

ε_{jk} – Random error term

CHAPTER FOUR

RESULTS

This chapter presents the results obtained for both the field and laboratory experiments. The results have been presented in the order of effects of different colours of agronet cover on; i) microclimate variables, ii) population of major tomato pests, iii) physiology and growth, iv) fruit yields and v) postharvest quality of tomato.

4.1 Effects of Different Colours of Agronet Cover on Tomato Plant Microclimate

Microclimate variables measured in this study included i) temperature, ii) photosynthetically active radiation, iii) soil moisture and iv) relative humidity.

i)Temperature

The use of the different colours of agronet cover increased temperature of the immediate crop environment (Figure 2). In both seasons, white agronet cover recorded the highest temperatures in most sampling dates during the study period while the lowest temperature was recorded under the control treatment. In season one, mean temperature was 21.3^oC under white cover and 18.8^oC under yellow, 18.2^oC under grey, 17.7^oC under multi-coloured, and 17.0^oC under blue; against 16.7^oC under the control treatment. In the second season, a similar trend was observed with white, yellow, grey, multi-coloured and blue cover recording mean temperatures of 20.8, 18.7, 18.2, 18.2, and 17.2^oC, respectively compared with 16.0^0C for the control.

ii) Photosynthetically Active Radiation

Photosynthetically active radiation (PAR) reaching the tomato crop was reduced following the use of different colours of agronet cover (Figure 3). In both seasons, tomato plants under the control treatment received higher PAR levels in all weeks of data collection compared to agronet covered tomato. The mean PAR received by plants under the control treatment was 1076.4µmolm^{-2} s^{-1} in season one with the lowest PAR of 501.9µmolm^{-2} s^{-1} recorded under blue agronet. Among the other treatments, PAR values were 731.9µmolm^{-2} s^{-1}under white cover, 701.4µmolm^{-2} s^{-1} under multi-coloured cover, 690.2µmolm^{-2} s^{-1} under grey cover and 538.3µmolm^{-2} s^{-1} under yellow cover. In the second season, a similar trend was observed with the control having the highest PAR of 893.6µmolm^{-2} s^{-1} against 639.4µmolm^{-2} s^{-1}, 547.9µmolm^{-2} s^{-1}, 496.1µmolm^{-2} s^{-1}, 368.3µmolm^{-2} s^{-1} and 330.3µmolm^{-2} s^{-1} for white, multi-coloured, grey, yellow and blue cover, respectively.

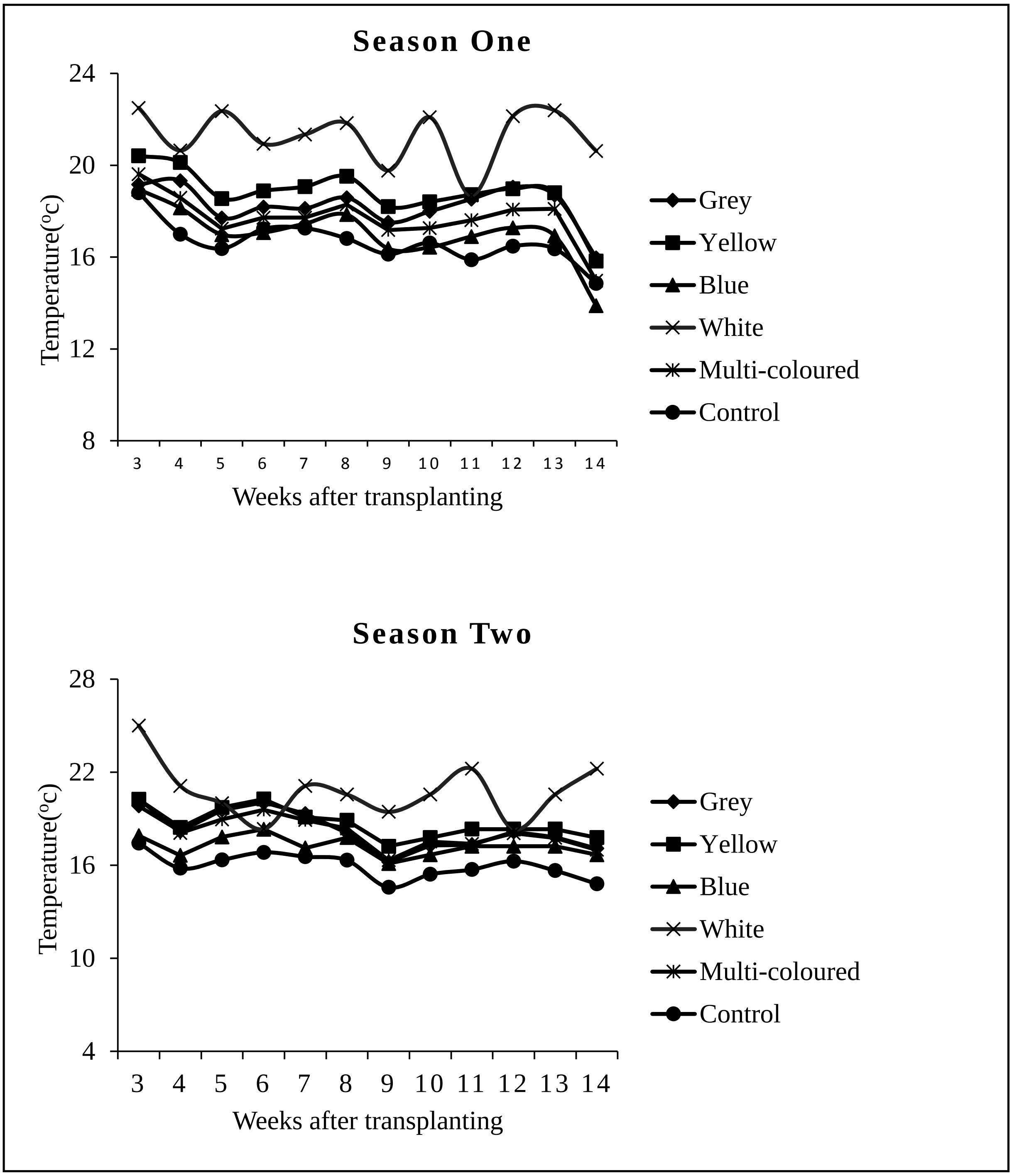

Figure 2: Effects of different colours of agronet cover on air temperature (°c) in season one (Nov 2013- Feb 2014) and season two (May- Sep 2014)

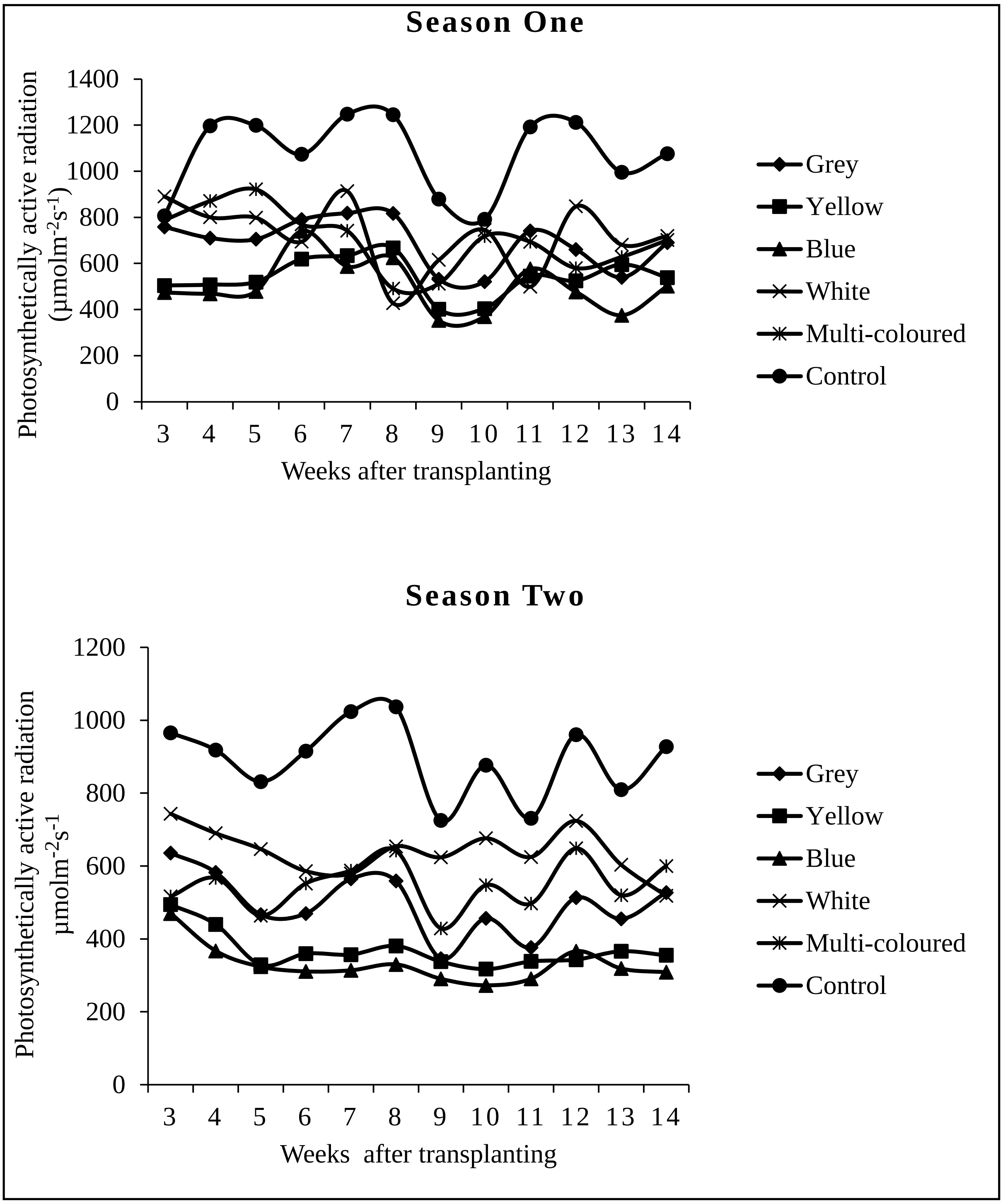

Figure 3: Effects of different colours of agronet cover on photosynthetically active radiation in season one (Nov- Feb 2014) and season two (May- Sep 2014)

iii) Soil Moisture

Use of different colours of agronet cover resulted in high soil moisture content in most weeks of data collection in both seasons (Figure 4). Averaged within the season, soil moisture content was lowest under the control treatment (14.9%) and highest under blue cover (29.4%). Among the other treatments, the highest soil moisture content was obtained under yellow (24.7%) followed by grey (23.3%) then white (20.5%) with moisture content being lowest under multi-coloured cover (19.6%). In the second season, the highest mean soil moisture content was also recorded under blue cover (31.5%) and lowest under control (14.7%). Among other treatments, moisture content was 28.9% under the multi-coloured cover, 28.8% under the yellow cover, 25.8% under the white cover and lowest was under grey cover at 22.8%.

iv) Relative Humidity

The use of the different colours of agronet cover increased percentage relative humidity within the immediate environment of the tomato crop (Figure 5). In most data collection dates, relative humidity was higher under agronet covered treatments compared to the control treatment. Averaged across each season, lowest mean relative humidity was recorded under the control treatment at 62.1% and 67.7% in season one and two, respectively while the highest relative humidity was under the multi-coloured cover at 73.8% and 78.7% in season one and two, respectively. Among the other treatments, mean relative humidity recorded was 71.2% under grey cover followed by 71.0% under blue cover, then 68.4% under yellow cover and 65.1% under white cover in season one. In season two, mean relative humidity was 76.6% under grey cover followed by 73.9% under blue cover, then 71.2% under yellow cover and 69.6% under white cover.

4.2 Effects of Different Colours of Agronet Cover on the Population of Tomato Pests

Major tomato pests recorded during the two seasons of the study were: silverleaf whitefly, aphids, thrips and mites. Other pests recorded in small numbers were cotton bollworm and leaf miner. In this section only results of the pests recorded in large numbers have been presented.

4.2.1 Effects of Different Colours of Agronet Cover on the Population of Silverleaf Whitefly on Tomato Plants

During all sampling dates, the number of silverleaf whitefly per plant was significantly influenced by the colour of agronet cover as presented in Table 1. At all data collection days, the population of silverleaf whitefly was lowest under the yellow net followed by the grey, then

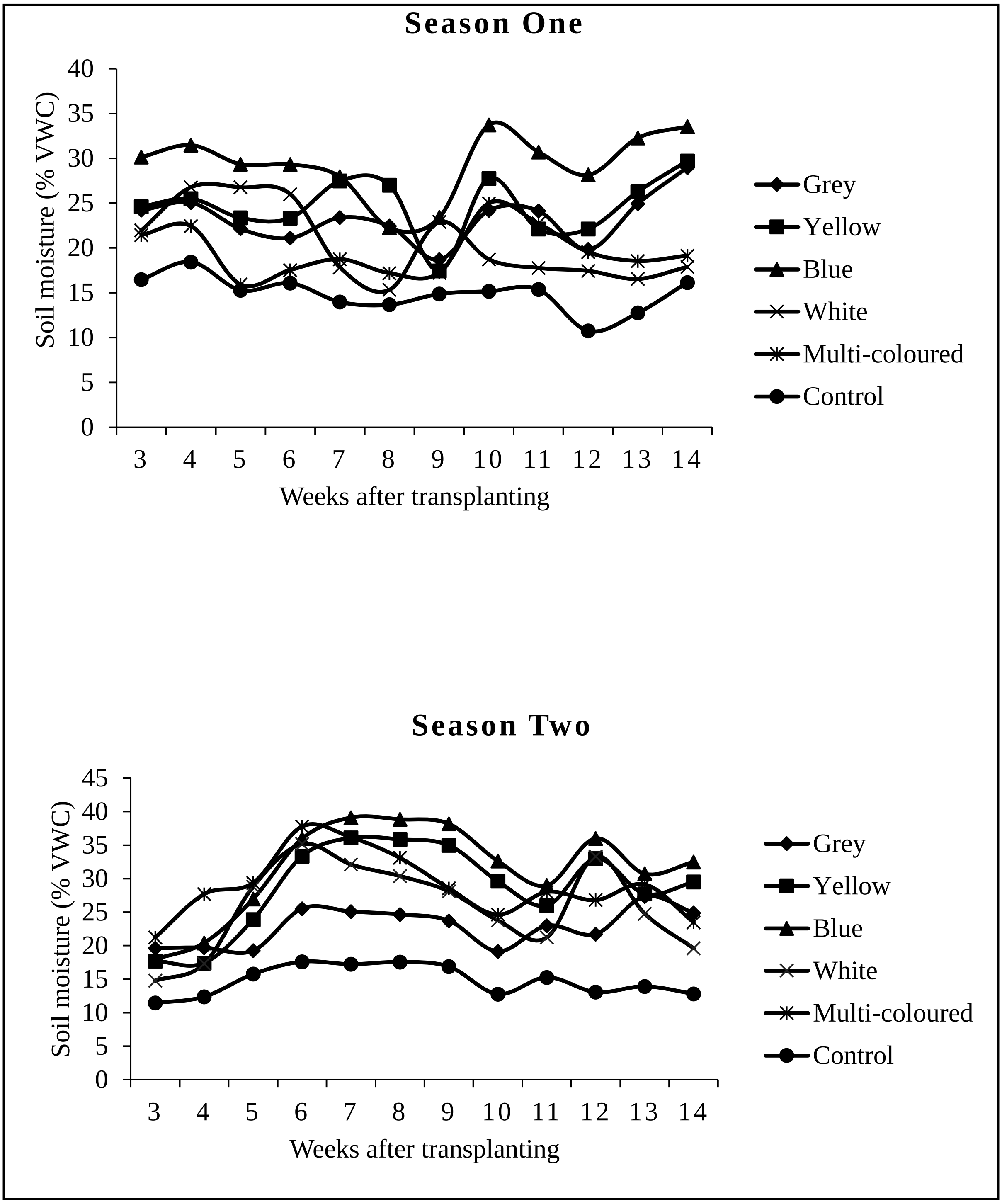

Figure 4: Effects of different colours of agronet cover on soil moisture (% volumetric water content) in season one (Nov 2013- Feb 2014) and season two (May- Sep 2014)

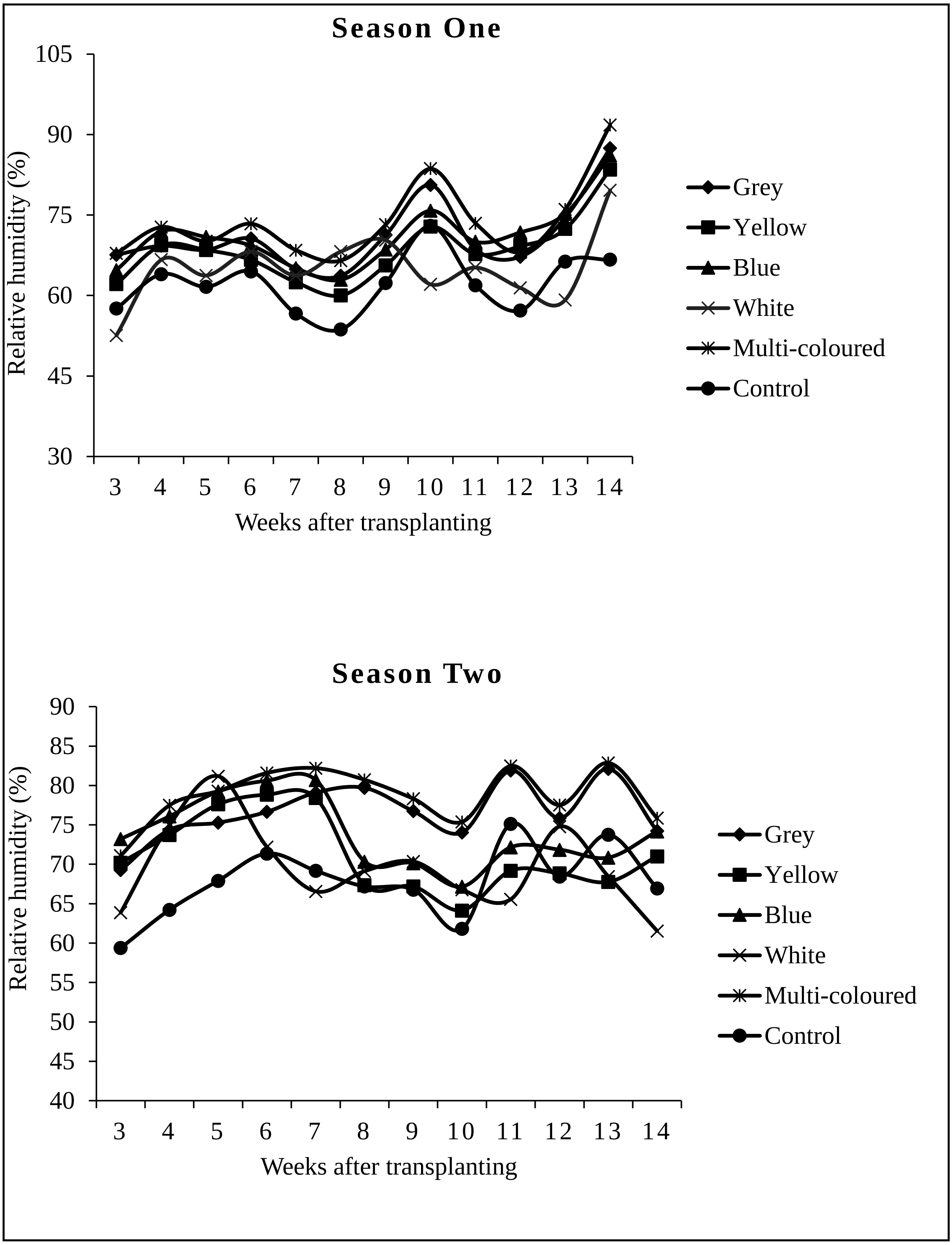

Figure 5: Effects of different colours of agronet cover on relative humidity (%) in season one (Nov 2013- Feb 2014) and season two (May- Sep 2014)

multi-coloured then white while the highest population was mostly obtained under the control treatment with no net cover. Among the net covered treatments, silverleaf whitefly population was highest under the blue net in all sampling dates with the population recorded under this cover being even higher than that of the control at 56 DAT. Generally, a lower population of whitefly was experienced in season two than in season one with season effect being significant at 56 and 70 DAT. The interaction between season and treatment was not significant in all sampling dates except at 70 DAT. Although season × net colour interaction was significant at this sampling date, a similar trend could be established with plants under open field recording the highest number of silverleaf whitefly per plant and those under yellow net cover recording the lowest number of silverleaf whitefly per plant regardless of the season.

Silverleaf whitefly data collected from the sticky traps mounted at the center of each plot showed a trend similar to that of the populations obtained on individual plants. The colour of agronet cover significantly influenced the number of silverleaf whitefly observed on the yellow sticky traps in all sampling dates as presented in Table 2. The highest number of silverleaf whitefly on the yellow sticky traps was recorded under the control treatment and lowest under yellow net in all sampling dates. Among the other treatments, number of silverleaf whitefly on the yellow sticky traps were in descending order from blue, white, multi-coloured and grey net in all sampling dates although the difference was not statistically significant. The effect of season on silverleaf whitefly population that stuck on the yellow traps was significant at 70 and 84 DAT, with higher populations recorded in season one than in season two. The interaction between season and treatment was not significant in all sampling dates except at 28 and 84 DAT. Although the interaction between season and treatment was significant at these sampling dates, a similar trend could be established with open field and yellow net cover having the highest and the lowest number of silverleaf whitefly on yellow sticky traps, respectively regardless of the season with the interaction being in terms of magnitude of the difference between the means of the different treatments.

4.2.2 Effects of Different Colours of Agronet Cover on the Population of Aphids on Tomato Plants

The use of different colours of agronet cover also significantly influenced the number of aphids that infested tomato plants in all sampling dates except at 84 DAT as presented in Table 3. Aphid numbers were highest under the control treatment in all sampling dates, and lowest under yellow and white net covers in most sampling dates with intermediate aphid numbers recorded under the grey, blue and multi-coloured covers in most sampling dates.

Table 1: Effects of different colours of agronet cover on the population of silverleaf whitefly on tomato plants in season one (Nov 2013-Feb 2014) and season two (May-Sep 2014)

	Days After Transplanting (DAT)											
	28			56			70			84		
Treatment	Season 1	Season 2	**Treatment Mean**	Season 1	Season 2	**Treatment Mean**	Season 1	Season 2	**Treatment Mean**	Season 1	Season 2	**Treatment Mean**
	Number of silverleaf whitefly (no/plant)											
Grey	1.54*	1.43	**1.49b****	1.44	1.34	**1.39bc**	1.28	1.48	**1.38cd**	1.57	1.20	**1.38b**
Yellow	1.43	0.98	**1.21b**	1.30	1.08	**1.19c**	0.79	1.08	**0.94d**	1.07	0.81	**0.94c**
Blue	2.19	1.82	**2.00a**	2.35	1.69	**2.02a**	2.38	1.44	**1.91ab**	2.46	2.56	**2.50a**
White	1.55	1.70	**1.62ab**	1.97	1.62	**1.80ab**	1.92	1.28	**1.60bc**	1.28	1.54	**1.41b**
Multi-coloured	1.67	1.74	**1.70ab**	1.84	1.81	**1.83ab**	1.16	1.36	**1.26cd**	1.38	1.42	**1.40b**
Control	2.28	1.85	**2.07a**	2.32	2.04	**2.18a**	2.48	1.70	**2.09a**	2.79	2.73	**2.76a**
Season Means	**1.78**	**1.59**		**1.87A*****	**1.60B**		**1.67A**	**1.39B**		**1.76**	**1.71**	

**Means within a sampling date followed by the same letters are not significantly different according to Tukey's honest significant difference (THSD) test at $P \leq 0.05$.

***Season means within a sampling date followed by the same letter or no letter are not significantly different according to Tukey's honest significant difference (THSD) test at $P \leq 0.05$.

Table 2: Effects of different colours of agronet cover on the population of silverleaf whitefly on yellow sticky traps in season one (Nov 2013-Feb 2014) and season two (May-Sep 2014)

	Days After Transplanting (DAT)											
	28			56			70			84		
Treatment	Season 1	Season 2	**Treatment Mean**	Season 1	Season 2	**Treatment Mean**	Season 1	Season 2	**Treatment Mean**	Season 1	Season 2	**Treatment Mean**
	Number of Silverleaf Whitefly on traps (no/plot)											
Grey	1.75c	2.15c*	**1.95b****	1.84	2.26	**2.05bc**	1.99	2.47	**2.23bc**	2.28c	1.14b	**1.71bc**
Yellow	1.62c	1.35c	**1.49c**	1.79	1.68	**1.73c**	1.92	1.94	**1.93c**	2.09c	0.82b	**1.45c**
Blue	2.10bc	2.45c	**2.27b**	2.19	2.60	**2.39b**	2.26	2.77	**2.52b**	2.66c	1.43b	**2.05b**
White	1.97c	2.33c	**2.15b**	2.09	2.42	**2.25b**	2.19	2.61	**2.40b**	2.40c	1.36b	**1.88b**
Multi-coloured	1.84c	2.28c	**2.06b**	1.94	2.36	**2.15b**	2.15	2.56	**2.35b**	2.45c	1.48b	**1.97b**
Control	3.03ab	2.91a	**2.97a**	3.11	2.99	**3.05a**	3.16	3.12	**3.14a**	3.22bc	1.96a	**2.59a**
Season Means	**2.05B**	**2.25A*****		**2.16B**	**2.38A**		**2.28B**	**2.58A**		**2.52A**	**1.36B**	

*Interaction of season and treatment means within a sampling date followed by the same letters or no letters are not different according to Tukey's honest significant difference (THSD) test at P≤ 0.05.

**Means within a sampling date followed by the same letters are not significantly different according to Tukey's honest significant difference (THSD) test at P≤ 0.05.

***Season means within a sampling date followed by the same letter are not significantly different according to Tukey's honest significant difference (THSD) test at P≤ 0.05.

Aphid populations were generally lower in season one than in season two with season effect being significant during all sampling dates. The interaction between season and treatment was not significant in all sampling dates.

4.2.3 Effects of Different Colours of Agronet Cover on the Population of Thrips on Tomato Plants

In all sampling dates, the number of thrips per plant was significantly influenced by the colours of agronet cover except at 70 DAT as presented in Table 4. Thrips population was highest under the open field (control) treatment and lowest under blue net cover in all sampling dates. Among the other treatments, the numbers of onion thrips per plant recorded was lower under the yellow net cover than under multi-coloured, grey and white covers with no statistical differences noted in the mean number of thrips recorded for these treatments in all sampling dates. Generally, coloured-colour nets (blue and yellow) reduced the number of onion thrips per plant compared to neutral-colour nets (white, multi-coloured and grey). Season two generally recorded more thrips than season one with season effect being significant in all sampling dates except at 84 DAT. Season x Treatment interaction was on the other hand not significant at all sampling dates.

4.2.4 Effects of Different Colours of Agronet Cover on the Population of Mites on Tomato Plants

The number of mites per tomato plant was significantly influenced by the colour of agronet cover in all sampling dates except at 28 DAT as presented in Table 5. Throughout the study period, mite population per plant was highest under the control treatment or the blue net cover. At 84 DAT, mite population recorded under control treatment was not significantly different from those obtained under yellow and multi-coloured net cover. The lowest mite population was observed under the grey net throughout the study period except at 56 DAT when the lowest population of mites per plant was observed under the white net cover. Among the net treatments, mite numbers tended to be lower under the white net followed by multi-coloured net but slightly higher under the yellow net and highest under the blue cover in most sampling dates. Season effect was also significant with lower mite populations recorded in season one than two. The interaction between season and treatment was however not significant at all sampling dates.

Table 3: Effects of different colours of agronet cover on the population of aphids on tomato plants in season one (Nov 2013-Feb 2014) and season two (May-Sep 2014)

	Days After Transplanting (DAT)											
	28			56			70			84		
Treatment	Season 1	Season 2	**Treatment Mean**	Season 1	Season 2	**Treatment Mean**	Season 1	Season 2	**Treatment Mean**	Season 1	Season 2	**Treatment Mean**
	Number of Aphids (no/plant)											
Grey	0.53*	0.74	**0.64ab****	0.95	1.54	**1.24b**	0.71	1.59	**1.15b**	0.78	1.84	**1.31b**
Yellow	0.34	0.47	**0.40c**	0.87	1.45	**1.16b**	0.83	1.70	**1.26b**	0.70	1.74	**1.22b**
Blue	0.49	0.74	**0.62ab**	1.00	1.57	**1.28ab**	0.88	1.82	**1.35b**	0.80	1.79	**1.29b**
White	0.37	0.51	**0.44c**	0.85	1.36	**1.11b**	0.71	1.63	**1.17b**	0.69	1.73	**1.21b**
Multi-coloured	0.40	0.64	**0.52bc**	0.91	1.53	**1.22b**	0.81	1.83	**1.32b**	0.70	1.85	**1.27b**
Control	0.60	0.83	**0.71a**	1.27	1.65	**1.46a**	1.30	1.92	**1.61a**	1.53	1.86	**1.70a**
Season Means	**0.45B**	**0.65A*****		**0.97B**	**1.52A**		**0.87B**	**1.75A**		**0.86B**	**1.80A**	

*Interaction of season and treatment is not significant according to Tukey's honest significant difference (THSD) test at P≤ 0.05.

**Means within a sampling date followed by the same letters are not significantly different according to Tukey's honest significant difference (THSD) at P≤ 0.05.

***Season means within a sampling date followed by the same letter are not significantly different according to Tukey's honest significant difference (THSD) at P≤ 0.05.

Table 4: Effects of different colours of agronet cover on the population of thrips on tomato plants in season one (Nov 2013-Feb 2014) and season two (May-Sep 2014)

	Days After Transplanting (DAT)											
	28			56			70			84		
Treatment	Season 1	Season 2	**Treatment Mean**	Season 1	Season 2	**Treatment Mean**	Season 1	Season 2	**Treatment Mean**	Season 1	Season 2	**Treatment Mean**
	Number of Thrips (no/plant)											
Grey	0.53*	0.77	**0.65ab****	1.07	0.93	**1.00ab**	0.83	1.10	**0.97**	0.73	0.51	**0.62b**
Yellow	0.24	0.70	**0.47b**	0.87	1.05	**0.96ab**	0.70	0.87	**0.79**	0.93	0.34	**0.63b**
Blue	0.24	0.58	**0.41b**	0.78	0.56	**0.67b**	0.70	0.71	**0.71**	0.52	0.51	**0.51b**
White	0.60	0.81	**0.70ab**	0.98	1.11	**1.05a**	0.78	1.09	**0.94**	0.90	0.56	**0.73b**
Multi-coloured	0.48	0.81	**0.65ab**	1.08	1.25	**1.17a**	0.86	1.01	**0.93**	0.99	0.79	**0.89ab**
Control	0.97	0.96	**0.97a**	0.91	1.34	**1.12a**	1.07	0.90	**0.98**	1.29	1.35	**1.32a**
Season Means	**0.51B**	**0.77A*****		**0.95**	**1.04**		**0.82B**	**0.95A**		**0.89A**	**0.68B**	

*Interaction of season and treatment is not significant according to Tukey`s honest significant difference (THSD) test at P≤ 0.05.

**Means within a sampling date followed by the same letters or no letters are not significantly different according to Tukey`s honest significant difference (THSD) test at P≤ 0.05.

***Season means within a sampling date followed by the same letter are not significantly different according to Tukey`s honest significant difference test at P≤ 0.05.

Table 5: Effects of different colours of agronet cover on the population of mites on tomato plants in season one (Nov 2013-Feb 2014) and season two (May-Sep 2014)

	Days After Transplanting (DAT)											
	28			56			70			84		
Treatment	Season 1	Season 2	**Treatment Mean**	Season 1	Season 2	**Treatment Mean**	Season 1	Season 2	**Treatment Mean**	Season 1	Season 2	**Treatment Mean**
						Number of Mites (no/plant)						
Grey	0.22*	1.48	**0.85**	0.66	1.17	**0.91bc****	0.31	1.02	**0.67c**	0.47	1.84	**1.15b**
Yellow	0.42	1.47	**0.94**	0.46	1.18	**0.82bc**	0.43	1.09	**0.76bc**	0.60	1.94	**1.27ab**
Blue	0.67	1.75	**1.21**	0.66	1.47	**1.07ab**	0.49	1.59	**1.04b**	0.75	2.28	**1.52ab**
White	0.39	1.47	**0.93**	0.44	0.94	**0.69c**	0.49	1.16	**0.82bc**	0.54	1.82	**1.19b**
Multi-coloured	0.47	1.52	**1.00**	0.42	0.99	**0.70c**	0.40	0.35	**0.87bc**	0.54	2.08	**1.31ab**
Control	0.69	1.75	**1.22**	1.01	1.56	**1.28a**	1.15	1.68	**1.41a**	1.15	2.08	**1.62a**
Season Means	**0.47B**	**1.57A*****		**0.61B**	**1.22A**		**0.54B**	**1.31A**		**0.68B**	**2.01A**	

*Interaction of season and treatment is not significant according to Tukey's honest significant difference (THSD) test at P≤ 0.05.

**Means within a sampling date followed by the same letters or no letters are not significantly different according to Tukey's honest significant difference (THSD) at P≤ 0.05.

***Season means within a sampling date followed by the same letter are not significantly different according to Tukey's honest significant difference (THSD) test at P≤ 0.05.

4.3 Effects of Different Colours of Agronet Cover on Tomato Plant physiology and Growth

The plant physiological attribute measured in this study was stomatal conductance while plant height, stem collar diameter, number of internodes, internode length and number of branches were studied as a measure of tomato plant growth.

4.3.1 Effects of Different Colours of Agronet Cover on Tomato Leaf Stomatal Conductance

In all sampling dates, tomato leaf stomatal conductance was not significantly influenced by the colour of agronet cover as presented in Table 6. Although not significantly different, leaf stomatal conductance of plants grown under the different colours of agronet covers tended to be slightly higher than that of plants grown in the open field at all sampling dates. Generally, a lower leaf stomatal conductance was recorded in season two than in season one with season effect being significant at all sampling dates except during the first sampling date. The interaction between season and treatment was also not significant at all sampling dates.

4.3.2 Effects of Different Colours of Agronet Cover on Tomato Plant Height

Tomato plant height was significantly influenced by the colour of agronet cover in all sampling dates except during the first sampling date at 28 DAT as presented in Table 7. In all sampling dates, the shortest plants were obtained under the control treatment. The tallest plants at 42 and 56 DAT were obtained under the blue net. Among the other treatments, plants tended to be shortest under multi-coloured followed by those under white net then under grey net then under the yellow net cover during these sampling dates. At 70 DAT, the tallest plants were recorded under the white net while among the other treatments; plants were shortest under multi-coloured followed by those under yellow net then those under blue net and tallest under the grey net cover. At 84 DAT, the tallest plants were obtained under the yellow net. Among the other treatments, plants were also shortest under multi-coloured net followed by white then grey and tallest under the blue net cover. Season effect was also significant with plants of season one being taller than those of season two early during the season up to 56 DAT and those of season two being taller than those of season one later in the season from 70 DAT. The interaction between season and treatment was however not significant in all sampling dates except at 84 DAT when the tallest plants were obtained under the yellow net cover surpassing those under blue and white net in height.

Table 6: Effects of different colours of agronet cover on tomato leaf stomatal conductance in season one (Nov 2013- Feb 2014) and season two (May- Sep 2014)

	Days After Transplanting (DAT)											
	28			42			70			84		
Treatment	Season 1	Season 2	**Treatment Mean**	Season 1	Season 2	**Treatment Mean**	Season 1	Season 2	**Treatment Mean**	Season 1	Season 2	**Treatment Mean**
					Stomatal conductance							
Grey	63.60*	57.87	**60.74****	61.39	50.28	**55.84**	60.68	35.13	**47.91**	63.26	30.42	**46.84**
Yellow	60.07	52.62	**56.34**	61.88	49.65	**55.77**	53.49	29.10	**41.29**	63.23	32.92	**48.07**
Blue	44.31	46.19	**45.25**	59.60	48.22	**53.91**	58.06	39.92	**48.99**	54.16	36.02	**45.09**
White	57.18	62.67	**59.93**	58.73	48.12	**53.42**	48.28	35.25	**41.76**	49.91	36.08	**43.00**
Multi-coloured	54.65	54.89	**54.77**	60.13	45.95	**53.04**	54.62	32.66	**43.64**	54.05	28.52	**41.29**
Control	45.78	38.67	**42.22**	55.09	37.97	**46.53**	41.85	28.65	**35.25**	42.00	39.97	**40.99**
Season Means	**54.27**	**52.15**		**59.47a*******	**46.70b**		**52.83a**	**33.45b**		**54.43a**	**33.99b**	

*Interaction of season and treatment is not significant according to Tukey's honest significant difference (THSD) test at P≤ 0.05.

**Means within a sampling date having no letters are not significantly different according to Tukey's honest significant difference (THSD) at P≤ 0.05.

*** Season means within a sampling date followed by the same letter are not significantly different according to Tukey's honest significant difference (THSD) test at P≤ 0.05.

Table 7: Effects of different colours of agronet cover on tomato plant height (cm) in season one (Nov 2013- Feb 2014) and season two (May- Sep 2014)

Treatment	Days After Transplanting (DAT) 28			42			56			70			84		
	Season 1	Season 2	Treatment Mean	Season 1	Season 2	Treatment Mean	Season 1	Season 2	Treatment Mean	Season 1	Season 2	Treatment Mean	Season 1	Season 2	Treatment Mean
							Plant Height (cm)								
Grey	26.12*	24.18	25.15	38.58	27.84	33.21ab**	42.24	41.67	41.96a	43.81	54.29	49.05a	44.55c*	64.93a	54.74a
Yellow	27.43	22.46	24.94	40.69	26.27	33.48ab	44.82	40.55	42.68a	45.74	51.51	48.62a	46.93c	66.02a	56.48a
Blue	26.01	23.62	24.81	39.74	28.29	34.02a	45.20	41.16	43.18a	47.37	50.69	49.03a	48.18bc	61.69 a	54.94a
White	26.98	21.80	24.39	39.59	25.73	32.66ab	42.63	40.84	41.73a	44.17	54.87	49.52a	45.16 c	61.40a	53.28a
Multi-coloured	25.37	19.96	22.67	38.04	23.06	30.51ab	42.59	37.47	40.03ab	43.71	50.31	47.01a	45.43c	58.76ab	52.10a
Control	24.67	19.09	21.88	34.54	22.67	28.60b	36.78	32.35	34.56b	37.33	39.69	38.51b	38.99 c	45.56c	42.12b
Season Means	26.10A***	21.85B		38.53A	25.64B		42.38A	39.01B		43.69B	50.23A		44.87B	59.68A	

*Means followed by the same letter are not significantly different according to Tukey's honest significant difference (THSD) test at P≤ 0.05.

**Means within a sampling date followed by the same letters or no letters are not significantly different according to Tukey's honest significant difference (THSD) test at P≤ 0.05.

***Season means within a sampling date followed by the same letter are not significantly different according to Tukey's honest significant difference (THSD) test at P≤ 0.05.

4.3.3 Effects of Different Colours of Agronet Cover on Tomato Collar Diameter

The collar diameter of tomato plants was significantly influenced by the colour of agronet cover as presented in Table 8. In all sampling dates, collar diameter was largest under the white net cover. Collar diameter was on the other hand smallest under the control treatment early in the season at 42 and 56 DAT and under the blue net cover late in the season at 70 and 84 DAT. Among the other treatments, plants tended to be thicker under the multi-coloured cover followed by the grey cover and thinner under the yellow cover in most sampling dates. Season effect on collar diameter was also significant during all sampling dates except at 84 DAT with plants of season one being thicker than those of season two in most sampling dates. The interaction between season and net colour was however not significant in all sampling dates.

4.3.4 Effects of Different Colours of Agronet Cover on the Number of Branches

Branching of tomato plants was significantly influenced by the colour of agronet cover in all sampling dates except during the first sampling date at 42 DAT as presented in Table 9. Plants grown under the white net cover registered the highest number of branches while the lowest number of branches was observed under the blue net cover in all sampling dates. Among the other treatments, more branches were obtained for plants grown under the multi-coloured cover followed by those under the grey cover. While control plants registered slightly more branches than those grown under yellow cover at 42 and 70 DAT, plants under the same cover had more branches than control plants at 56 and 84 DAT although the difference was not significant. Season effect on the number of branches per plant was also significant during all sampling dates with the highest branching recorded in plants of season one compared to those of season two. No significant interaction between season and net colour was recorded in all sampling dates.

4.3.5 Effects of Different Colours of Agronet Cover on the Number of Internodes of Tomato Plants

The colour of agronet cover did not significantly influence the number of internodes in all sampling dates as presented in Table 10. Although the influence of net colour was not significant, a trend could be established marked by lower internode numbers under the control compared to agronet covered treatments, with the highest number of internodes recorded under white or multi-coloured cover in most sampling dates. Season effect on the number of internodes was however significant during all sampling dates with season two plants producing

Table 8: Effects of different colours of agronet cover on tomato collar diameter (mm) in season one (Nov 2013- Feb 2014) and season two (May-Sep 2014)

	Days After Transplanting (DAT)											
	42			56			70			84		
Treatment	Season 1	Season 2	**Treatment Mean**	Season 1	Season 2	**Treatment Mean**	Season 1	Season 2	**Treatment Mean**	Season 1	Season 2	**Treatment Mean**
						Collar Diameter (mm)						
Grey	5.39*	5.22	**5.31ab****	6.18	5.68	**5.93ab**	7.68	9.17	**8.42ab**	9.93	10.61	**10.27ab**
Yellow	5.30	4.29	**4.80ab**	6.40	4.69	**5.55b**	7.20	8.71	**7.96b**	10.43	10.26	**10.34ab**
Blue	5.04	4.67	**4.85ab**	6.07	5.02	**5.54b**	7.44	7.71	**7.58b**	10.18	9.23	**9.71b**
White	6.29	5.41	**5.85a**	7.57	6.19	**6.88a**	8.61	10.17	**9.39a**	11.06	11.71	**11.38a**
Multi-coloured	5.07	4.38	**4.73b**	6.02	4.93	**5.48b**	7.64	9.26	**8.45ab**	11.27	10.58	**10.93ab**
Control	4.71	4.08	**4.40b**	5.29	4.53	**4.91b**	6.84	8.45	**7.65b**	10.28	9.80	**10.04ab**
Season Means	**5.30A*****	**4.68B**		**6.26A**	**5.17B**		**7.57B**	**8.91A**		**10.53**	**10.36**	

*Interaction of season and treatment is not significant according to Tukey's honest significant difference (THSD) test at P≤ 0.05.

**Means within a sampling date followed by the same letter are not significantly different according to Tukey`s honest significant difference (THSD) test at P≤ 0.05.

***Season means within a sampling date followed by the same letter are not significantly different according to Tukey's honest significant difference (THSD) test at P≤ 0.05.

Table 9: Effects of different colours of agronet cover on number of branches in season one (Nov 2013- Feb 2014) and season two (May- Sep 2014)

	Days After Transplanting (DAT)											
	42			56			70			84		
Treatment	Season 1	Season 2	**Treatment Mean**	Season 1	Season 2	**Treatment Mean**	Season 1	Season 2	**Treatment Mean**	Season 1	Season 2	**Treatment Mean**
						Number of Branches						
Grey	4.40*	4.60	**4.50**	7.40	7.00	**7.20ab****	10.60	10.80	**10.70ab**	11.60	14.20	**12.90a**
Yellow	5.00	3.80	**4.40**	7.80	5.60	**6.70bc**	11.00	8.20	**9.60b**	11.60	13.40	**12.50a**
Blue	3.40	3.80	**3.60**	6.00	4.80	**5.40c**	7.80	6.60	**7.20c**	9.00	9.20	**9.10b**
White	5.40	5.00	**5.20**	9.40	7.60	**8.50a**	13.20	11.60	**12.40a**	14.60	15.00	**14.80a**
Multi-coloured	5.20	4.00	**4.60**	8.40	6.60	**7.50ab**	11.20	10.00	**10.60ab**	11.80	14.20	**13.00a**
Control	5.80	3.60	**4.70**	7.20	5.80	**6.50bc**	10.60	9.20	**9.90b**	11.00	13.20	**12.10a**
Season Means	**4.87A*****	**4.13B**		**7.70A**	**6.23B**		**10.73A**	**9.40B**		**11.60A**	**13.20B**	

*Interaction of season and treatment is not significant according to Tukey's honest significant difference (THSD) test at P≤ 0.05.

**Means within a sampling date followed by the same letter or no letters are not significantly different according to Tukey's honest significant difference (THSD) test at P≤ 0.05.

***Season means within a sampling date followed by the same letter are not significantly different according to Tukey's honest significant difference (THSD) test at P≤ 0.05.

Table 10: Effects of different colours of agronet cover on number of internodes on tomato plants in season one (Nov 2013- Feb 2014) and season two (May- Sep 2014)

	Days After Transplanting (DAT)											
	42			56			70			84		
Treatment	Season 1	Season 2	**Treatment Mean**	Season 1	Season 2	**Treatment Mean**	Season 1	Season 2	**Treatment Mean**	Season 1	Season 2	**Treatment Mean**
						Number of Internodes						
Grey	4.40*	8.00	**6.20****	5.60	10.00	**7.80**	7.20	11.40	**9.30**	8.00	11.40	**9.70**
Yellow	4.40	7.40	**5.90**	5.60	9.80	**7.70**	7.20	11.20	**9.20**	7.80	11.60	**9.70**
Blue	4.80	7.40	**6.10**	5.40	9.80	**7.60**	8.80	10.80	**9.80**	9.40	11.00	**10.20**
White	4.60	7.60	**6.10**	6.20	10.40	**8.30**	7.40	11.20	**9.30**	7.40	11.80	**9.60**
Multi-coloured	4.80	7.20	**6.00**	5.20	10.00	**7.60**	7.80	11.80	**9.80**	8.60	11.80	**10.20**
Control	4.20	6.60	**5.40**	5.00	9.20	**7.10**	6.60	11.40	**9.00**	6.40	11.80	**9.10**
Season Means	**4.53B**	**7.37A*****		**5.50B**	**9.87A**		**7.27B**	**11.30A**		**8.20B**	**11.57A**	

*Interaction of season and treatment is not significant according to Tukey's honest significant difference (THSD) test at P≤ 0.05.

**Means within a sampling date followed by the same letters or no letters are not significantly different according to Tukey's honest significant difference (THSD) test at P≤ 0.05.

***Season means within a sampling date followed by the same letter are not significantly different according to Tukey's honest significant difference (THSD) test at P≤ 0.05.

more internode numbers compared to those of season one. The interaction between season and treatment was however not significant at all sampling dates.

4.3.6 Effects of Different Colours of Agronet Cover on Internode Length of Tomato Plants

The internode length of tomato plants was significantly influenced by the colour of agronet cover in all sampling dates as presented in Table 11. In all sampling dates, plants grown under the blue net cover exhibited the longest internode lengths while the shortest internode length was obtained under the control treatment. Among the other treatments, plants grown under yellow and grey net covers tended to have longer internodes than those grown under white and multi-coloured net covers. Season effect on plant internode length was also significant during all sampling dates with plants in season two having longer internode lengths compared to those of season one. The interaction between season and treatment was significant in all sampling dates except at 42 DAT but with plants under blue net cover still recording the highest internode length while those under control and neutral-colour (white, multi-coloured and grey) nets recording shorter internode lengths regardless of the season.

4.4 Effects of Different Colours of Agronet Cover on Tomato Fruit Yields

Yield variables measured in the study were number of fruits per plant, marketable and unmarketable fruit numbers per plant, total fruit yield, and marketable and unmarketable fruit yield.

4.4.1 Effects of Different Colours of Agronet Cover on Tomato Fruit Numbers

(a) Total Number of Fruits per Plant

The total number of fruits per plant was significantly influenced by the colour of agronet cover as presented in Table 12. The highest number of fruits per plant was obtained under white net while the blue net cover yielded the lowest number of fruits per plant with control treatment yielding an intermediate number of fruits per plant but giving more fruits per plant than grey, yellow and the blue net. Among the other covered treatments, more fruits per plant were recorded under the multi-coloured cover followed by grey cover with the least number obtained under the yellow cover. In general, more fruits per plant were realized under the neutral-colour nets (white and multi-coloured) compared to the control while the grey net and the coloured-colour nets (yellow and blue) yielded less fruit numbers than the control. Season effect was also significant with higher fruit numbers per plant obtained in season one than in season two. The interaction of season and treatment was on the other hand not significant.

Table 11: Effects of different colours of agronet cover on tomato internode length (cm) in season one (Nov 2013- Feb 2014) and season two (May- Sep 2014)

	Days After Transplanting (DAT)											
	42			56			70			84		
Treatment	Season 1	Season 2	**Treatment Mean**	Season 1	Season 2	**Treatment Mean**	Season 1	Season 2	**Treatment Mean**	Season 1	Season 2	**Treatment Mean**
	Internode Length (cm)											
Grey	3.51	3.69	**3.60ab****	3.62c	5.07a*	**4.35ab**	4.06bc	5.25a	**4.75a**	4.26c	5.55a	**4.91a**
Yellow	3.16	3.83	**3.49ab**	3.81bc	5.07a	**4.44a**	4.06bc	5.20a	**4.63a**	4.45bc	5.45a	**4.95a**
Blue	3.72	3.92	**3.82a**	3.82bc	5.14a	**4.48a**	4.25bc	5.25a	**4.75a**	4.59bc	5.56a	**5.07a**
White	3.06	3.50	**3.28b**	3.84bc	5.04a	**4.44a**	4.10bc	5.18a	**4.64a**	4.23c	5.51a	**4.87a**
Multi-coloured	3.45	3.41	**3.43ab**	3.92bc	4.69ab	**4.30ab**	3.99c	4.86ab	**4.42a**	4.30c	5.08ab	**4.69ab**
Control	3.08	3.39	**3.24b**	3.83bc	3.82bc	**3.82b**	3.79c	3.93c	**3.86b**	4.18c	4.40bc	**4.29b**
Season Means	**3.33B*****	**3.62A**		**3.81B**	**4.81A**		**4.04B**	**4.94A**		**4.33B**	**5.26A**	

*Means within a sampling date followed by the same letters or no letters are not significantly different according to Tukey`s honest significant difference (THSD) test at P≤ 0.05.

**Means within a sampling date followed by the same letters are not significantly different according to Tukey`s honest significant difference (THSD) test at P≤ 0.05.

***Season means within a sampling date followed by the same letter are not significantly different according to Tukey's honest significant difference (THSD) test at P≤ 0.05

Table 12: Effects of different colours of agronet cover on number of fruits per plant of tomato in season one (Nov. 2013 to Feb. 2014) and season two (May to Sep. 2014)

Treatment	Number of Fruits (no./plant)		
	Season 1	Season 2	Treatment Means
Grey	42.80*	41.20	**42.00bc****
Yellow	37.60	32.00	**34.80cd**
Blue	33.60	24.40	**29.00d**
White	53.20	52.80	**53.00a**
Multi-coloured	51.40	44.00	**47.70ab**
Control	45.00	43.60	**44.30abc**
Season Means	**43.93A*****	**39.67B**	

*Interaction of season and treatment is not significant according to Tukey's honest significant difference (THSD) test at P≤ 0.05.

**Means followed by the same letters are not significantly different according to Tukey's honest significant difference (THSD) test at P≤ 0.05.

***Season means followed by the same letter are not significantly different according to Tukey's honest significant difference (THSD) test at P≤ 0.05.

b) Marketable Number of Fruits per Plant

The number of marketable fruits per plant was significantly influenced by the use of different colours of agronet cover as presented in Table 13. The highest number of marketable fruits per plant was obtained under the white net while the lowest number of marketable fruits per plant was recorded under the blue net cover. Among the other treatments, the number of marketable fruits obtained was in descending order from multi-coloured, grey, yellow and control treatment. In general, the use of neutral-colour nets (white, multi-coloured and grey) resulted in more marketable fruits per plant compared to the control while marketable fruit numbers were on the other hand lower following the use of coloured-colour nets (yellow and blue) with the number of marketable fruits obtained under the blue net being even lower than that obtained for the control treatment. The highest percentage increase in marketable number of fruits per individual plants of 94.7% was recorded under the white net while a percentage decrease of -5.29% was recorded under the blue net cover. Among the other treatments, percentage increase in marketable number of fruits was 62.4% under the multi-coloured net followed by 40.7% under grey net, and lowest (21.7%) under yellow net. Season effect was also significant with higher marketable fruit numbers per plant obtained in season one than in season two. The interactive effect of season and treatment on marketable fruit numbers was on the other hand not significant.

(c) Unmarketable Number of Fruits per Plant

The number of unmarketable fruits per plant was significantly influenced by the use of the different colours of agronet cover as presented in Table 14. The lowest number of unmarketable fruits per plant was realized under the blue net cover while the highest number was obtained under open field. Among the other treatments, the number of unmarketable fruits obtained were in ascending order from yellow, to grey, to white and highest under the multi-coloured cover. Generally, neutral-colour nets (white, multi-coloured and grey) recorded higher number of unmarketable fruit per plant compared to coloured-colour (yellow and blue) nets. The highest percentage decrease in unmarketable number of fruit per plant of 56.3% was recorded under the blue net while lowest percentage decrease of 33.1% was obtained under the multi-coloured net. Among the other treatments, percentage decrease in unmarketable number of fruit per plant was 53.5% under the yellow net followed by 39.4% under grey net, and lowest (36.3%) under the white net. Generally, coloured-colour nets recorded a higher percentage decrease in unmarketable number of fruits per plant compared to neutral-colour nets. Season effect on unmarketable number of fruits was also significant with higher unmarketable fruit

Table 13: Effects of different colours of agronet cover on the number of marketable fruits per plant of tomato in season one (Nov. 2013 to Feb. 2014) and season two (May to Sep. 2014)

	Marketable Fruits (no./plant)			
Treatment	Season 1	Season 2	Treatment Means	% Relative Increase
Grey	30.40*	22.80	**26.60bc****	**40.74**
Yellow	26.80	19.20	**23.00bc**	**21.69**
Blue	24.20	11.60	**17.90c**	**-5.29**
White	40.80	32.80	**36.80a**	**94.71**
Multi-coloured	34.60	22.80	**28.70ab**	**62.43**
Control	21.00	16.80	**18.90c**	
Season Means	**29.63A*****	**21.00B**		

*Interaction of season and treatment is not significant according to Tukey's honest significant difference (THSD) test at P≤ 0.05.

*Means followed by the same letters are not significantly different according to Tukey's honest significant difference (THSD) test at P≤ 0.05.

***Season means followed by the same letter are not significantly different according to Tukey's honest significant difference (THSD) test at P≤ 0.05.

Table 14: Effects of different colours of agronet cover on the number of unmarketable fruits per plant of tomato in season one (Nov. 2013 to Feb. 2014) and season two (May to Sep. 2014)

Treatment	Unmarketable Fruits (no./plant)			
	Season 1	Season 2	Treatment Means	% Relative Decrease
Grey	12.40*	18.40	**15.40bc****	**39.37**
Yellow	10.80	12.80	**11.80c**	**53.54**
Blue	9.40	12.80	**11.10c**	**56.30**
White	12.40	20.00	**16.20bc**	**36.22**
Multi-coloured	16.80	21.20	**19.00b**	**33.07**
Control	24.00	26.80	**25.40a**	
Season Means	**14.30B*****	**18.00A**		

*Interaction of season and treatment is not significant according to Tukey's honest significant difference (THSD) test at $P \leq 0.05$.

**Means followed by the same letters are not significantly different according to Tukey`s honest significant difference (THSD) test at $P \leq 0.05$.

*** Season means followed by the same letter are not significantly different according to Tukey's honest significant difference (THSD) test at $P \leq 0.05$.

numbers per plant obtained in season one than in season two. The interactive effect of season and treatment was however not significant.

4.4.2 Effects of Different Colours of Agronet Cover on Tomato Fruit Yield

(a) Total Fruit Weight

Total fruit weight was significantly influenced by the colour of agronet cover as presented in Table 15. The highest total fruit weight was obtained under white net cover while the lowest fruit weight was obtained under the blue net cover. Among the other treatments, higher total fruit yield was obtained under the multi-coloured net, followed by the grey net, then yellow net and lowest under the control treatment with no net cover. In general, neutral-colour nets recorded higher total fruit weight compared to coloured-colour nets. Season effect was also significant with a higher fruit weight obtained in season one than in season two. The interaction between season and treatment was however not significant.

(b) Marketable Fruit Weight

Marketable fruit weight followed a trend almost similar to that of total fruit weight with the highest and lowest marketable fruit weight obtained in plants grown under the white net and control treatments, respectively. Among the other treatments, marketable fruit weight was highest under the multi-coloured net, followed by the grey net then the yellow net with the lowest marketable fruit weight recorded under the blue net (Table 16). The highest percentage increase in marketable fruit weight of 103.0% was recorded under the white net while the lowest percentage increase of 24.9% was obtained under the blue net cover. Among the other treatments, percentage increase in marketable fruit weight was 72.3% under the multi-coloured net followed by 41.4% under grey net, and lowest (32.7%) under yellow net. In general, neutral-colour nets recorded higher percentage increase in marketable fruit weight compared to coloured-colour nets. Season effect was also significant with a higher total marketable fruit weight obtained in season one than in season two. The interaction between season and treatment was however not significant.

c) Unmarketable Fruit Weight

Unmarketable fruit weight on the other hand recorded a trend almost opposite to that of marketable fruit weight, with the highest unmarketable fruit weight recorded under the control treatment. Among the other treatments, unmarketable fruit weight obtained was highest under the grey net followed by the white net then under the multi-coloured net followed by the yellow net cover and lowest under the blue net cover. Generally, the use of coloured-colour nets resulted in a greater reduction in unmarketable fruit weight compared to the use of neutral-

Table 15: Effects of different colours of agronet cover on the total fruit weight of tomato in season one (Nov. 2013 to Feb. 2014) and season two (May to Sep. 2014)

	Total fruit weight ($KgHa^{-1}$)		
Treatment	Season 1	Season 2	**Treatment Mean**
Grey	25299.79*	13750.53	**19525.16abc****
Yellow	22489.31	11119.93	**16804.62bc**
Blue	20149.57	8952.53	**14551.05b**
White	31693.93	18183.81	**24938.87a**
Multi-coloured	29424.99	13478.87	**21451.93ab**
Control	22909.27	9085.76	**15997.52bc**
Season Means	**25327.81A*****	**12428.57B**	

*Interaction of season and treatment is not significant according to Tukey's honest significantly difference (THSD) test at P≤ 0.05.

**Means followed by the same letters are not significantly different according to Tukey`s honest significant difference (THSD) test at P≤ 0.05.

***Season means followed by the same letter are not significantly different according to Tukey's honest significantly difference (THSD) test at P≤ 0.05.

Table 16: Effects of different colours of agronet cover on the marketable fruit weight of tomato in season one (Nov. 2013 to Feb. 2014) and season two (May to Sep. 2014)

	Marketable fruit weight (KgHa^{-1})			
Treatment	Season 1	Season 2	**Treatment Mean**	**%Relative Increase**
Grey	16954.19*	7874.49	**12414.34bc****	**41.36**
Yellow	15515.19	7786.16	**11650.68bc**	**32.67**
Blue	14916.99	7015.68	**10966.34bc**	**24.88**
White	24585.86	11075.50	**17830.68a**	**103.04**
Multi-coloured	21511.80	8750.94	**15131.37ab**	**72.30**
Control	13859.16	3704.52	**8781.84c**	
Season Means	**17890.53A*****	**7701.22B**	`	

*Interaction of season and treatment is not significant according to Tukey's honest significantly difference (THSD) test at P≤ 0.05.

**Means followed by the same letters are not significantly different according to Tukey`s honest significant difference (THSD) test at P≤ 0.05.

***Season means followed by the same letter are not significantly different according to Tukey's honest significantly difference (THSD) test at P≤ 0.05.

Table 17: Effects of different colours of agronet cover on the unmarketable weight of tomato in season one (Nov. 2013 to Feb. 2014) and season two (May to Sep. 2014)

Treatment	Unmarketable fruit weight ($KgHa^{-1}$) Season 1	Season 2	**Treatment Mean**	**% Relative Decrease**
Grey	8345.59*	5876.04	**7110.82a****	**1.45**
Yellow	6974.12	3333.77	**5153.95ab**	**28.57**
Blue	5232.58	1936.87	**3584.73b**	**50.32**
White	7108.06	7108.31	**7108.19a**	**1.49**
Multi-coloured	7913.19	4727.93	**6320.56ab**	**12.41**
Control	9050.11	5381.24	**7215.68a**	
Season Means	**4727.36B**	**7437.28A*****		

*Interaction of season and treatment is not significant according to Tukey's honest significantly difference (THSD) test at P≤ 0.05.

**Means followed by the same letters are not significantly different according to Tukey`s honest significant difference (THSD) test at P≤ 0.05.

***Season means followed by the same letter are not significantly different according to Tukey's honest significantly difference (THSD) test at P≤ 0.05.

colour nets. The highest percentage decrease in unmarketable fruit weight of 50.3% was recorded under the blue net while the lowest percentage decrease of 1.5% was obtained under the grey net. Among the other treatments, percentage decrease in unmarketable fruit weight was 28.6% under the yellow net followed by 12.4% under the multi-coloured net, with the lowest percentage decrease of 1.5% under the white net. Generally, coloured-colour nets recorded a higher percentage decrease in unmarketable fruit weight compared to neutral-colour nets. Season effect was also significant with a higher unmarketable fruit weight recorded in season two than in season one. The interaction between season and treatment was however not significant.

4.5 Effects of Different Colours of Agronet Cover on Postharvest Quality of Tomato

Postharvest variables measured in the study were fruit firmness, total soluble solids (TSS), titratable acidity (TA), sugar acid ratio, weight loss, lycopene content, decay, days to ripening and shelf life.

a) Fruit Firmness

Tomato fruit firmness was significantly influenced by the use of the different coloured agronet covers during production in all sampling dates of trial one except at 4 days after harvest (4-DAH) while no significant difference was recorded in all sampling dates of trial two except at harvest (0-DAH) (Figure 6). During most data collection days in trial one, the highest fruit firmness was recorded in fruits produced under the white net cover followed by those produced under either grey or multi-coloured net then yellow or blue net cover while the lowest fruit firmness was mostly obtained for fruits produced under the control treatment. Although the influence of colour of agronet cover used during production was not significant in most sampling dates in trial two, a trend similar to that observed in trial one could be established with the highest fruit firmness being observed for fruits produced under white net cover and the lowest firmness observed in fruits from the control treatment. Among the other treatments, firmness was higher for fruits produced under grey cover followed by those produced under multi-coloured net and lowest for fruits produced under yellow or blue net cover. The general observation was that fruits harvested from trial two were firmer than those of trial one. Fruits produced under neutral-colour nets (white, grey and multi-coloured) also tended to be more firm compared to those produced under coloured-colour nets (yellow and blue). As expected, tomato fruit firmness decreased with storage period.

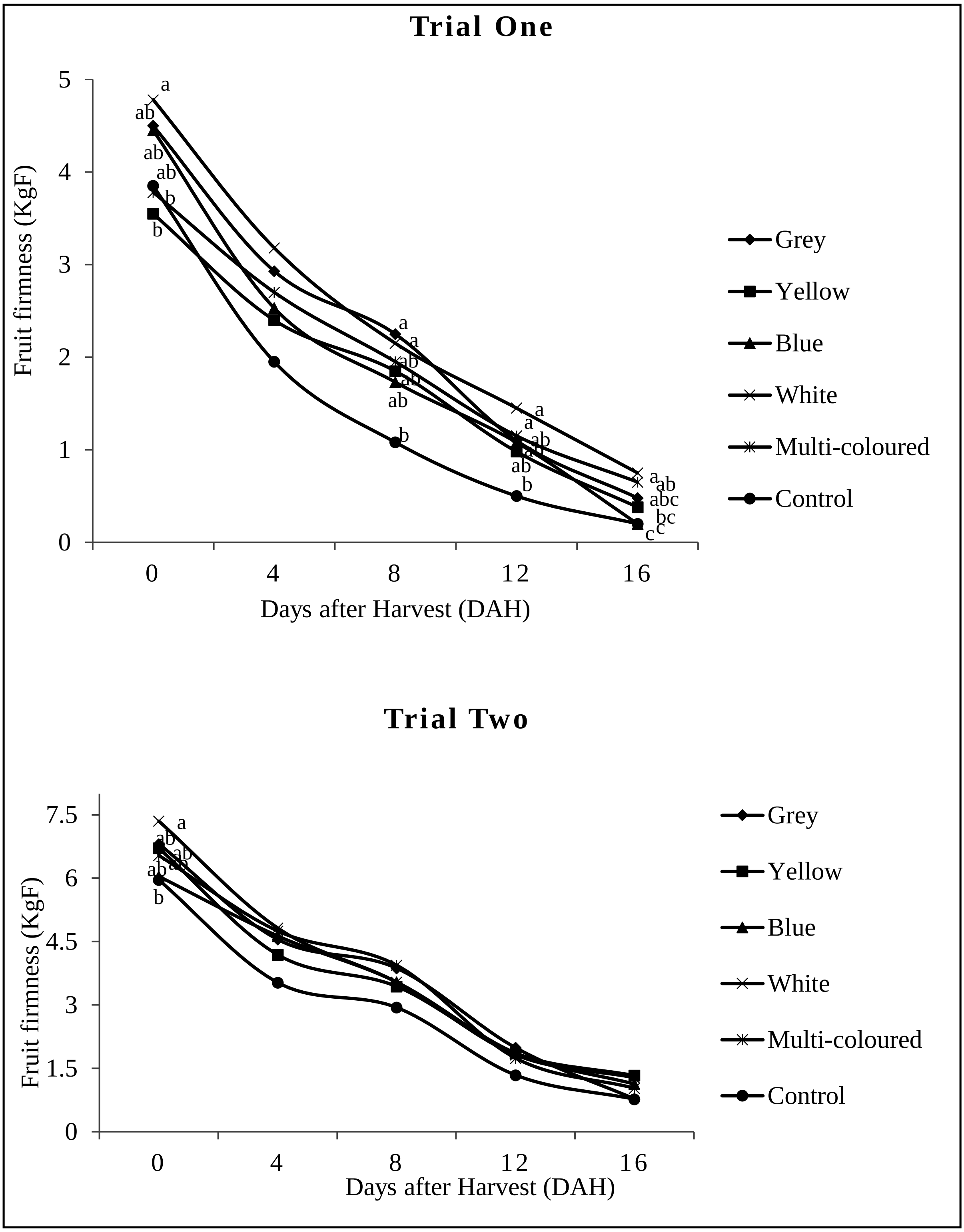

Figure 6: Effects of different colours of agronet cover on tomato fruit firmness (KgF) in trial one (Feb 2014) and trial two (Sep 2014).

For a given trial, data points having the same letter within a sampling date are not significantly different according to Tukey`s honest significant difference (THSD) test at P≤ 0.05.

b) Total Soluble Solids

During all sampling dates, there were significant differences in total soluble solids (TSS) of tomato grown under the different colours of agronet cover during production in trial one except at 0-DAH and 8-DAH but the effect was significant only at 16-DAH in trial two (Figure 7). During most sampling dates of trial one, the highest TSS was obtained in fruits produced under the grey net cover while the lowest TSS was obtained in fruits produced under the control treatment. Among the other treatments, TSS of tomato was higher for fruits produced under multi-coloured net cover followed by white then yellow and lowest in fruits produced under blue net. Although the influence of colour of agronet cover used during production was not significant in most sampling dates in trial two, an almost similar trend could be established with highest TSS obtained in fruits produced under the grey net and lowest under control treatment. Among the other treatments, TSS was highest under multi-coloured net followed by blue, then yellow and lowest under white net cover. The general trend observed showed that fruits of trial two had more TSS compared to those of trial one and TSS in fruits generally increased under storage.

c) Titratable Acidity

Titratable acidity (TA) of tomato calculated as % citric acid was significantly influenced by use of different colours of agronet cover during production in all sampling dates except at 0-DAH in both trials as shown in Figure 8. During all data collection days during trial one, titratable acidity of tomato was highest for tomato produced under the control treatment and lowest for fruits produced under multi-coloured net cover. Among the other treatments, TA was higher for tomato fruit produced under the blue net followed by those produced under grey then white cover and lowest for fruits produced under yellow net cover. In trial two, almost a similar trend was established with titratable acidity being highest under the control treatment in all sampling dates but lowest in fruits produced under the white net cover. Among the other treatments, TA was higher for fruits produced under the blue net followed by multi-coloured net then grey and lowest under yellow net cover. Generally, higher TA was recorded in fruits of trial one than in fruits of trial two. As expected, tomato TA decreased with storage time.

d) Sugar: Acid Ratio

Tomato fruit sugar: acid ratio was significantly influenced by the different colours of agronet cover used during production in all sampling dates of trial one except at 0-DAH and 8-DAH and at 0-DAH in trial two as presented in Figure 9. Sugar: acid ratio of tomato was highest in fruits grown under the multi-coloured net cover and lowest in fruits produced under control

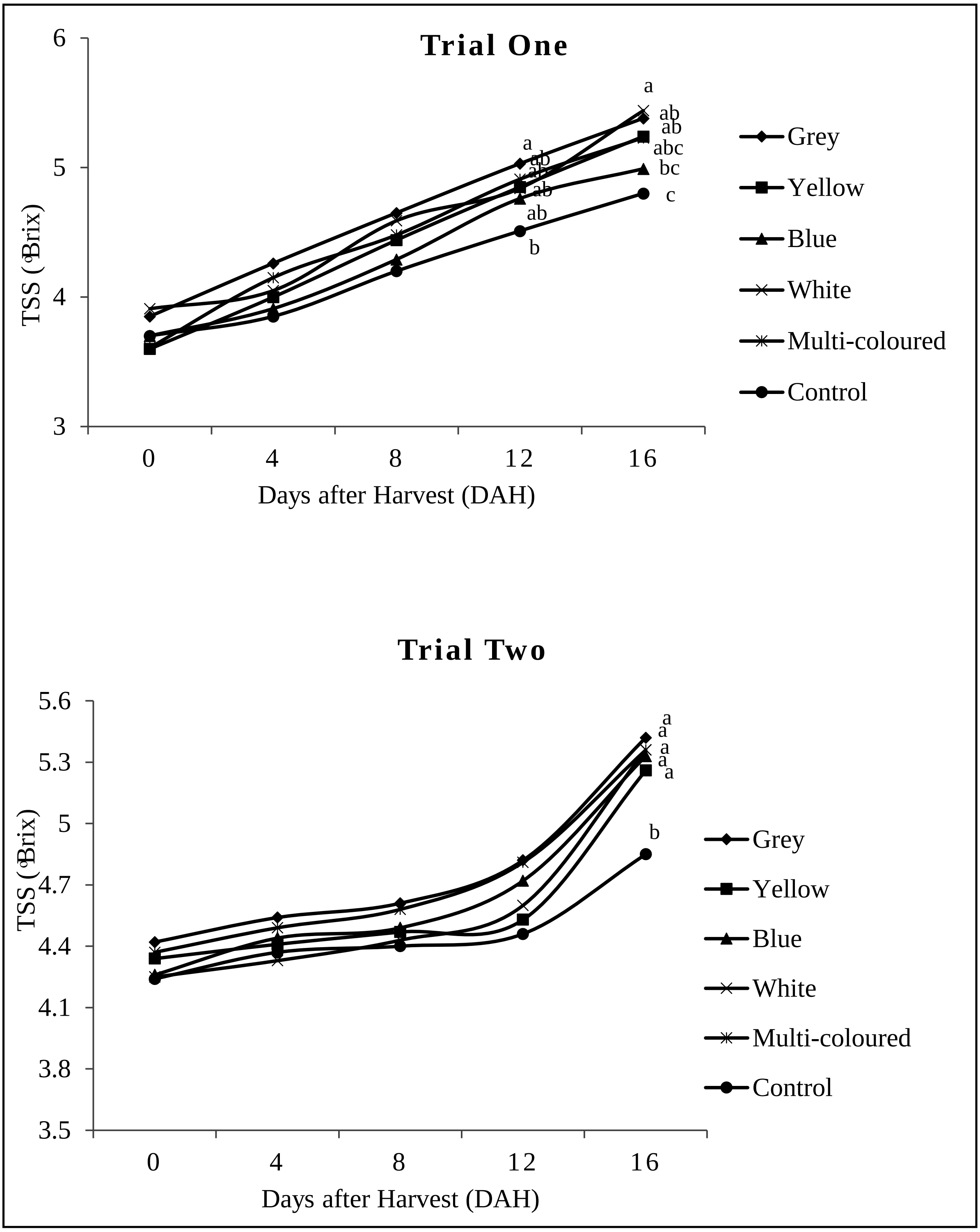

Figure 7: Effects of different colours of agronet cover on tomato total soluble solids (ºBrix) in trial one (Feb 2014) and trial two (Sep 2014).

For a given trial, data points having the same letter within a sampling date are not significantly different according to Tukey`s honest significant difference (THSD) test at P≤ 0.05.

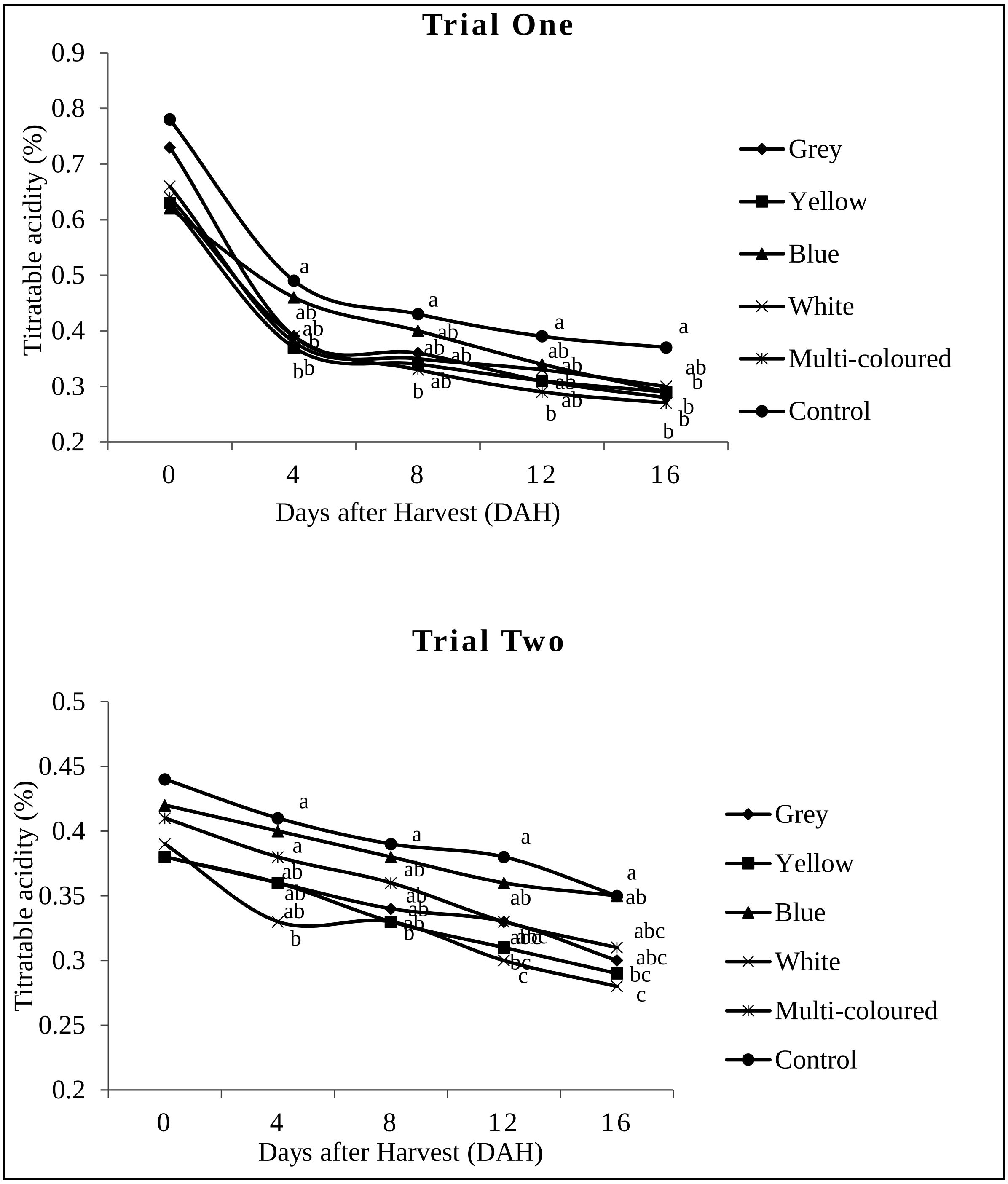

Figure 8: Effects of different colours of agronet cover on tomato titratable acidity (% citric acid) in trial one (Feb 2014) and trial two (Sep 2014).

For a given trial, data points having the same letter within a sampling date are not significantly different according to Tukey`s honest significant difference (THSD) test at P≤ 0.05.

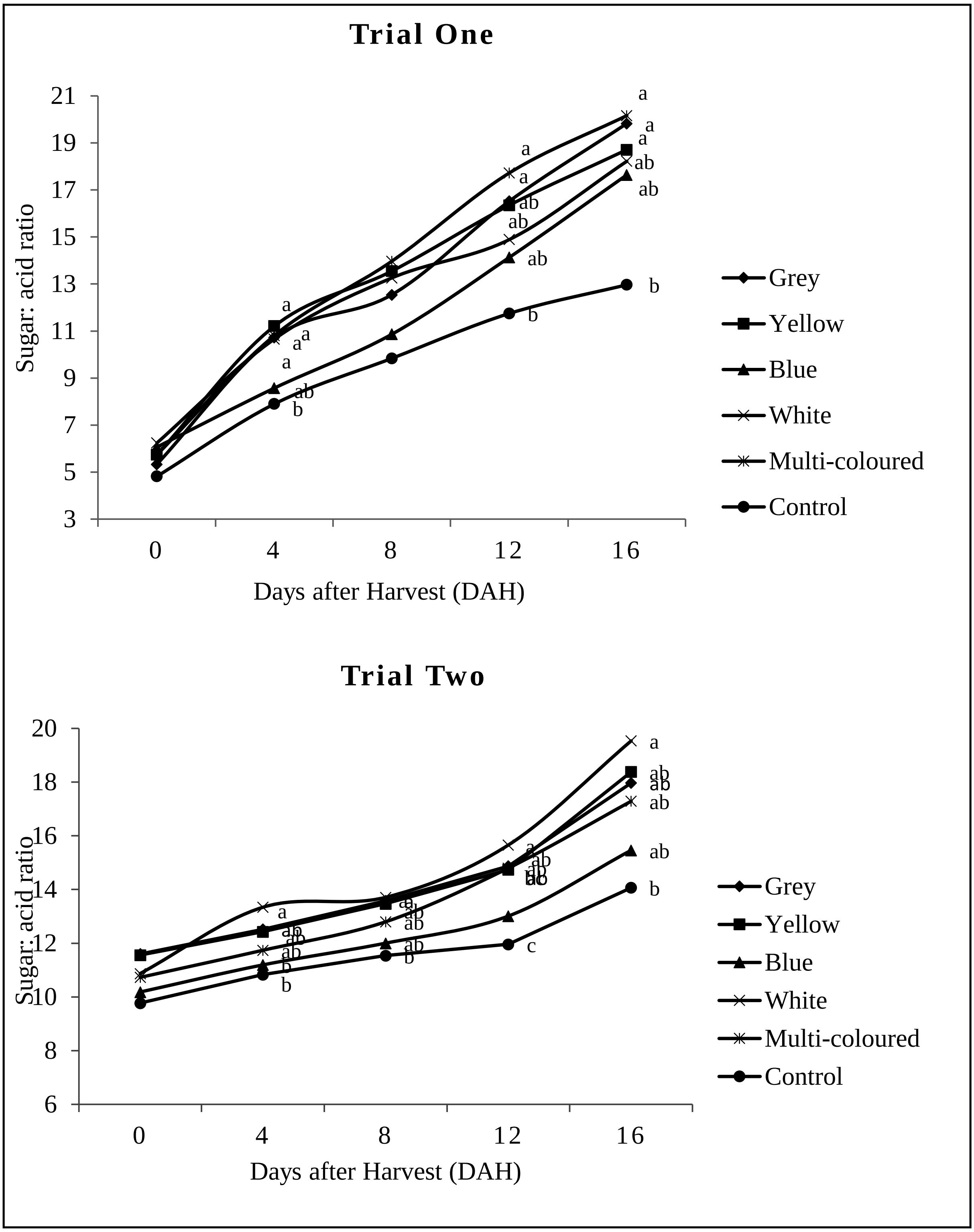

Figure 9: Effects of different colours of agronet cover on tomato sugar acid ratio in trial one (Feb 2014) and trial two (Sep 2014).

For a given trial, data points having the same letter within a sampling date are not significantly different according to Tukey`s honest significant difference (THSD) test at P≤ 0.05.

treatment in most sampling dates of trial one. Among the other treatments, sugar: acid ratio of tomato was higher in fruits produced under the yellow net cover followed by those produced under grey then white covers and lowest for fruits produced under the blue net cover. Although sugar: acid ratio of fruits was not significantly different in most sampling dates of the second trial, almost a similar trend to that of trial one could be established with the lowest sugar: acid ratio being recorded in fruits produced under the control treatment. The highest sugar: acid ratio during this trial was recorded in fruits produced under white cover in most sampling dates. Among the other treatments, sugar: acid ratio was higher in fruits produced under either yellow or grey net covers followed by those grown under multi-coloured net covers and lowest in fruits produced under either yellow or grey net covers followed by those grown under multi-coloured net covers and lowest in fruits grown under the blue net cover. The general trend observed showed that sugar: acid ratio increased with increase in time of storage.

e) Weight loss

Fruit weight loss of tomato expressed as a percentage was significantly influenced by use of the different colours of agronet cover during production in all sampling dates of trial one except during the second sampling at 4-DAH while no significant difference in fruit weight loss was recorded in trial two (Figure 10). Tomato fruit weight loss was highest in fruits produced under the control treatment in all data collection days in trial one, and lowest in fruits produced under the multi-coloured net cover in most sampling dates. Among the other treatments, fruit weight loss was higher in fruits produced under the blue net cover followed by those produced under grey net, then yellow net and lowest in fruits produced under the white net cover in most sampling dates. Although the influence of colour of agronet cover used during production was not significant in trial two, a trend almost similar to that observed in trial one could be established with the highest fruit weight loss being observed for fruits produced under control treatment and the lowest weight loss observed in fruits from the multi-coloured net cover. Among the other treatments, weight loss of tomato fruit was higher for fruits produced under yellow cover followed by those produced under white net and lowest in fruits produced under blue or grey net cover. In general, use of different colours of agronet cover during production reduced fruit weight loss during tomato storage compared to the control treatment.

f) Lycopene Content

The effect of colour of agronet cover used during production on fruit lycopene content (mg/kg) was significant at third harvest in both trials (Figure 11). During the third harvest in trial one, lycopene content was highest for tomato produced under the blue net cover and lowest

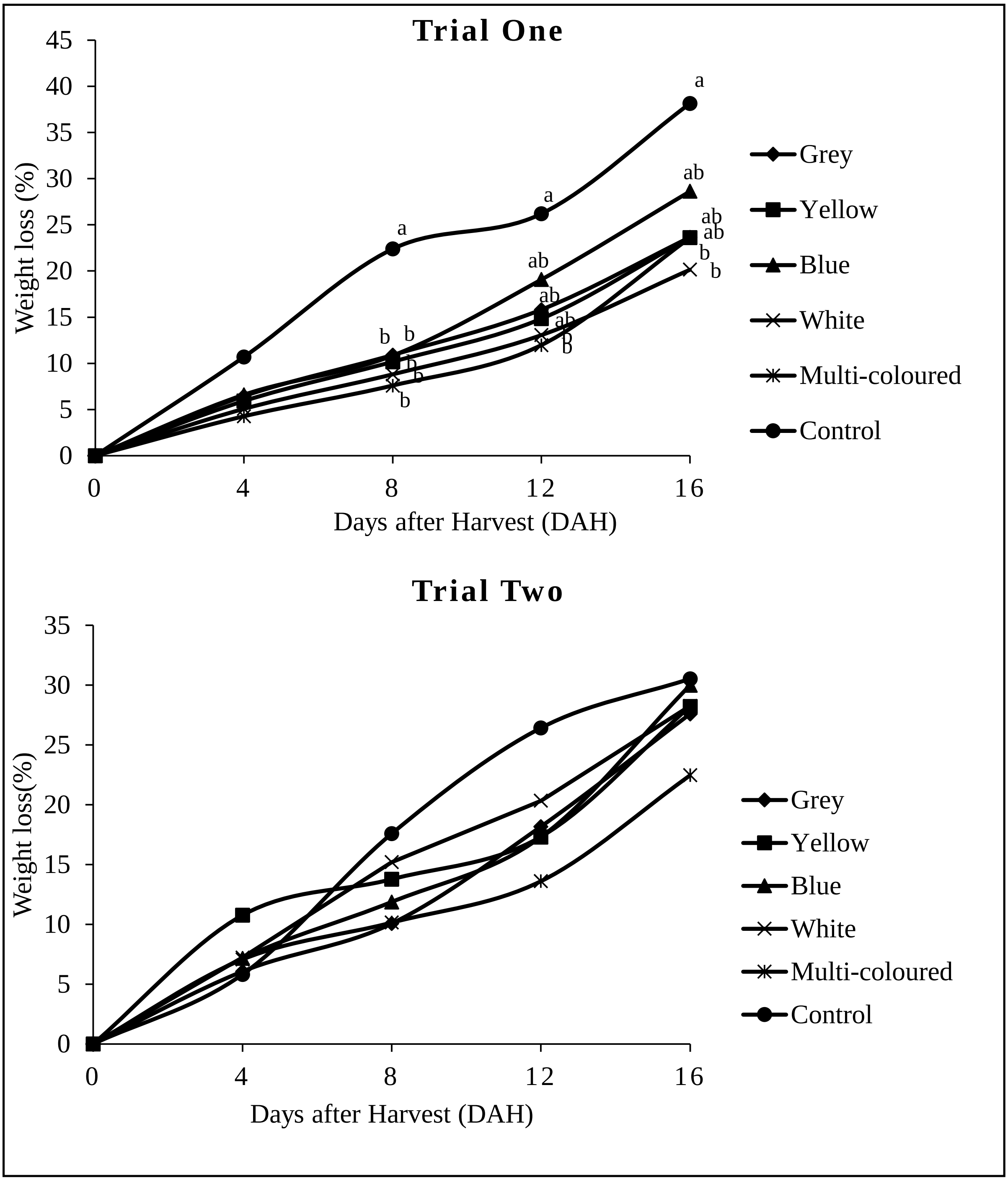

Figure 10: Effects of different colours of agronet cover on tomato weight loss (%) in trial one (Feb 2014) and trial two (Sep 2014).

For a given trial, data points having the same letter within a sampling date are not significantly different according to Tukey`s honest significant difference (THSD) test at P≤ 0.05.

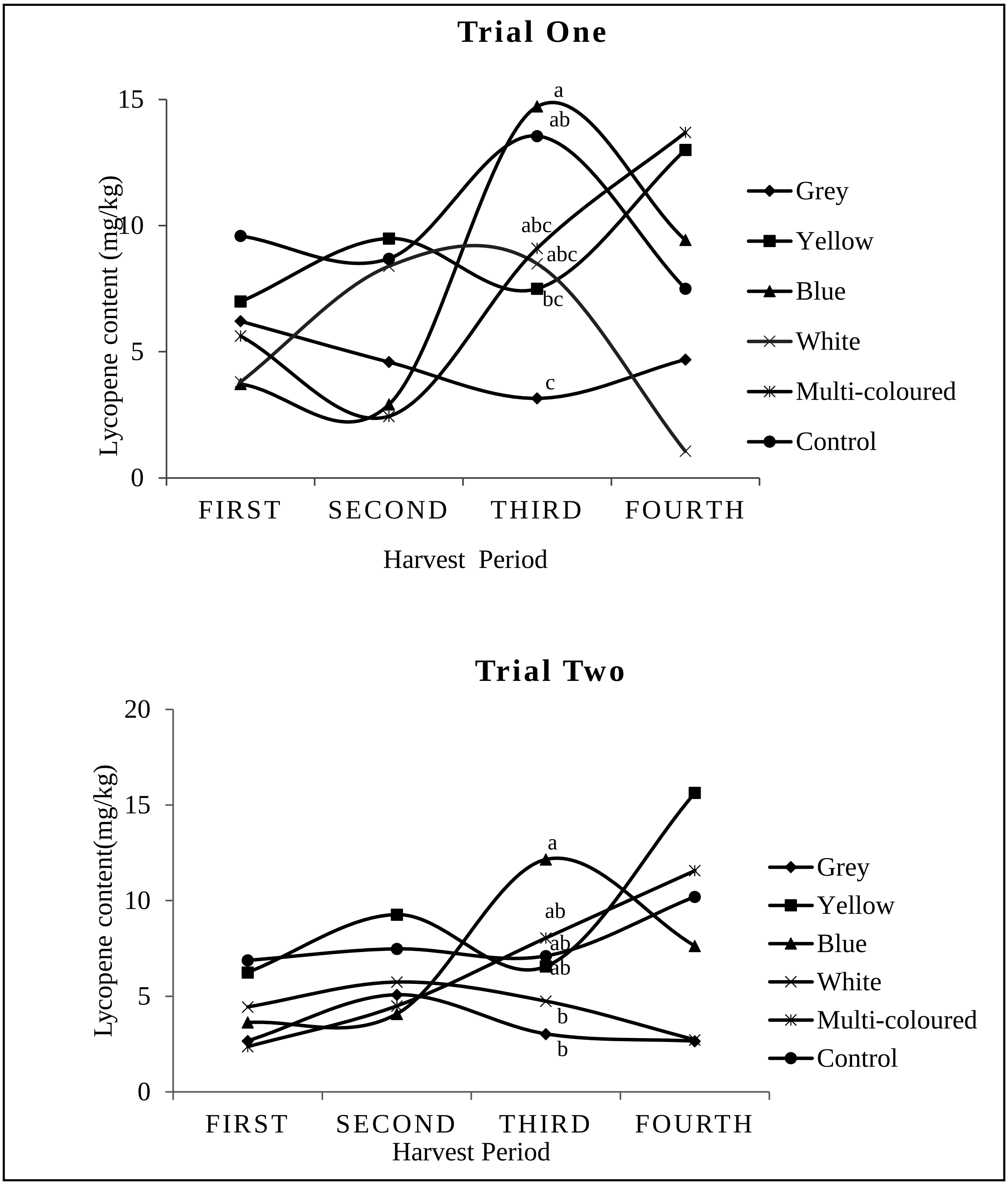

Figure 11: Effects of different colours of agronet cover on lycopene content of tomato (µg/100g) in trial one (Feb 2014) and trial two (Sep 2014).

For a given trial, data points having the same letter within a sampling date are not significantly different according to Tukey`s honest significant difference (THSD) test at P≤ 0.05.

for fruits produced under grey net cover. Among the other treatments, lycopene content was highest for tomato fruit produced under the control treatment followed by those produced under multi-coloured cover then white cover and lowest for fruits produced under yellow net cover. In the second trial at third harvest, almost a similar trend was established with fruits produced under blue net cover also recording the highest lycopene content while lowest was recorded under grey net cover. Among the other treatments, highest lycopene content was obtained from tomato fruit under the multi-coloured net, followed by those produced under the control treatment, then yellow net while the lowest lycopene content was recorded in fruits grown under white net cover.

g) Decay

The percentage decay during tomato storage was significantly influenced by use of different colours of agronet cover during production of the crop in trial one while no significant difference was recorded in trial two as presented in Table 18. In trial one, percentage decay was highest in fruits obtained from control treatment. Although not significantly different, percentage decay was on the other hand lowest under the agronet covers regardless of colour. Among the net covered treatments, percentage decay recorded was in descending order from blue, white, yellow, multi-coloured and grey cover treatments. Although the influence of colour of agronet cover used during production was not significant in trial two, a trend could be established marked by lower percentage decay in tomato produced under agronet covers compared to the control treatment. Percentage decay was generally lower in trial one than in trial two. Regardless of the colour, the use of agronet covers during production generally reduced percentage decay on tomato.

h) Days to ripening

In both trials, number of days taken by tomato to attain red ripe stage from breaker stage was not significantly influenced by the colour of agronet cover used during production as presented in Table 19. Although the influence of net colour on number of days taken by tomato to attain red ripe stage was not significantly different, a trend could be established marked by least number of days to ripening on tomato fruits produced under the multi-coloured net cover compared to other treatments with the longest number of days to ripening observed with tomato produced under blue net cover in both trials.

i) Shelf life

The shelf life of tomato fruit expressed as % loss of firmness was significantly influenced by the use of agronet cover used during production in all sampling dates of trial one

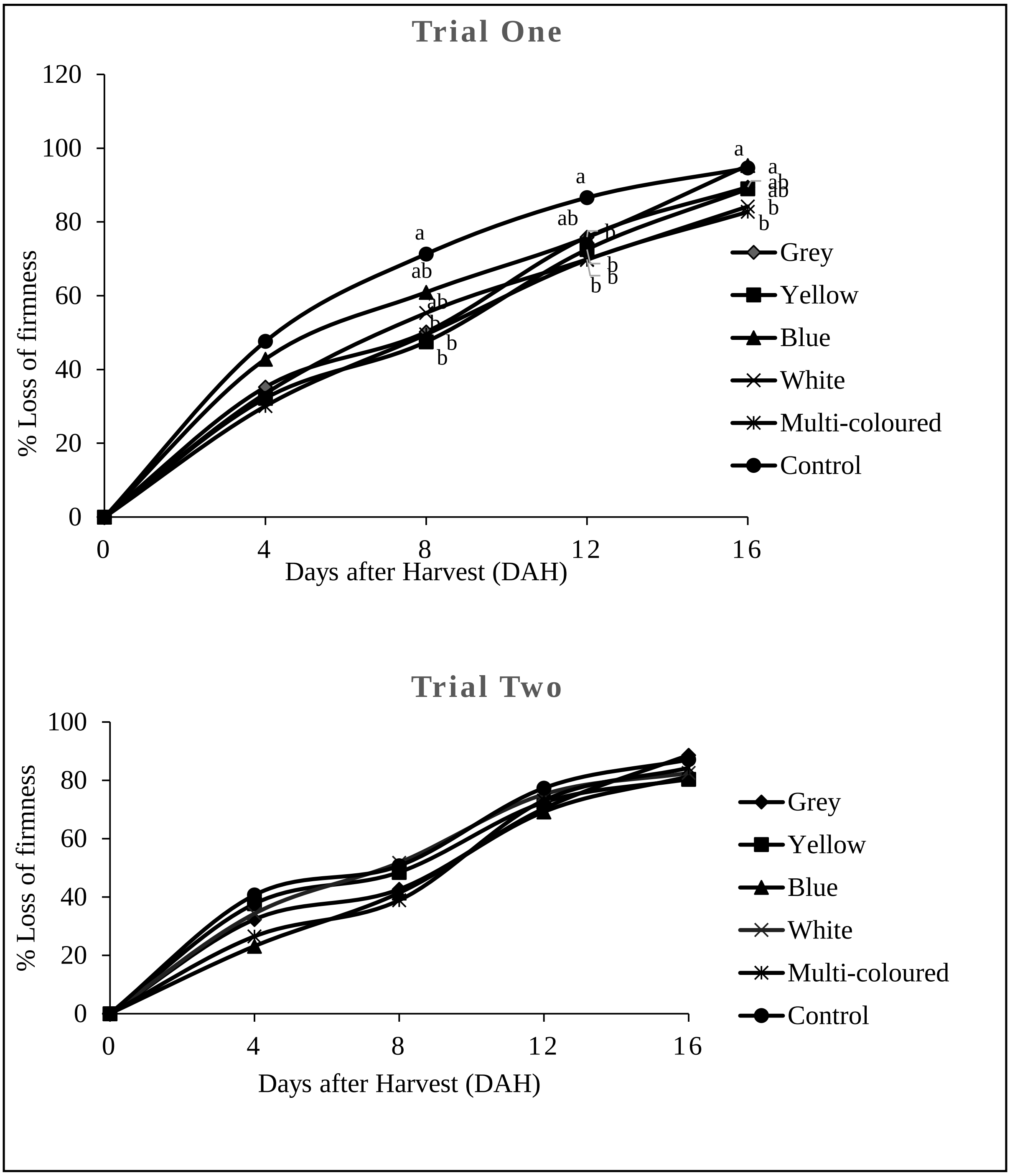

Figure 12: Effects of different colours of agronet cover on tomato shelf life (expressed as % loss of firmness) in trial one (Feb 2014) and trial two (Sep 2014).

For a given trial, data points having the same letter within a sampling date are not significantly different according to Tukey`s honest significant difference (THSD) test at $P \leq 0.05$.

Table 18: Effects of different colours of agronet cover used during production on tomato decay in trial one (Feb 2014) and trial two (Sep 2014)

	Decay (%)	
Treatment	Trial 1	Trial 2
Grey	4.29b*	20.00
Yellow	5.00b	25.00
Blue	10.00b	20.00
White	6.19b	30.00
Multi-coloured	5.00b	15.00
Control	40.00a	35.00

*Means followed by the same or no letters within a column are not significantly different according to Tukey`s honest significant difference (THSD) at P≤ 0.05.

Table 19: Effects of different colours of agronet cover used during production on number of days to ripening on tomato in trial one (Feb 2014) and trial two (Sep 2014)

	Number of days to ripening	
Treatment	Trial 1	Trial 2
Grey	10.08*	7.70
Yellow	8.35	7.98
Blue	11.18	9.30
White	9.85	8.35
Multi-coloured	6.00	6.60
Control	9.65	8.85

*Means followed by the same or no letters within a column are not significantly different according to Tukey`s honest significant difference (THSD) at $P \leq 0.05$.

except at 4-DAH while no significant difference was recorded in all sampling dates of trial two (Figure 12). In trial one, fruits grown under multi-coloured agronet cover recorded longest number of days to lose 50% firmness while the shortest number of days on the shelf was recorded for fruits produced under the control treatment. Among the other treatments, more number of days on the shelf was recorded for fruits produced under the yellow net cover followed by those grown under white, then under grey cover with shelf life being shortest for fruits grown under the blue net cover. Although the influence of colour of agronet cover used during production was not significant in trial two, fruits produced under the different colours of agronet cover tended to have slightly higher number of days on the shelf than fruits produced under the control treatment. Generally, fruits obtained from agronet covers took more number of days on the shelf to lose 50% firmness regardless of colour of agronet cover used during production.

CHAPTER FIVE

DISCUSSION

5.1 Effects of Different Colours of Agronet Cover on Tomato Microclimate

Using different colours of agronet cover in the current study effectively modified the microclimate around the growing tomato plants. Regardless of the colour of agronet cover, air temperature remained higher under the agronet cover treatments compared with the control treatment. The existence of net covers has been shown to alter the plants micro-environment by increasing air temperature outside of a cover due to warm air rising that is captured underneath the net (Solomakhin and Blanke, 2010) leading to higher temperatures inside the cover (Gordon, 2006) during the day and into the night (Motsenbocker and Arancibia, 2002). Netting also offers a partial barrier (Guiselin and Sentelhas, 2004) that reduce the mixing of outside air with inside air thus reduce heat loss to the surrounding atmosphere, which leads to temperature build up (Tanny *et al*., 2003). Furthermore, row covers create warm air around the plants, and can even warm the soil within the row (Ibarra- Jimenez *et al*., 2004).

In the current study, the higher temperatures recorded for agronet covered tomato plants compared with control could therefore be attributed to differences in the levels of restriction in air movement around the growing tomato crop amongst the different treatments leading to a differential effect in air temperature. Generally, air temperature tended to be higher under neutral-colour net covers (white, multi-coloured and grey) compared to blue and yellow coloured net covers which may be attributed to difference in light transmission recorded under these net covers. Higher air temperatures observed under neutral-colour nets compared to coloured-colour nets in the current study is also attributed to the ability of neutral-colour nets to maintain slightly higher air temperatures under the net covers during the night hours which could be as a result of the reflective nature of these net covers; a property that allows them to absorb heat very slowly but also lose it very slowly, resulting in higher average air temperature. Similar to observations of the current study, Tinyane *et al*. (2013) reported increased air temperature over the crop under pearl net (neutral-colour) compared to open-field temperature.

Soil moisture content measured as percentage volumetric water content was also higher under the different colours of agronet cover compared with no net control (open field). Use of shade netting, regardless of colour reduces solar radiation levels reaching the crops underneath resulting to a decrease in evaporation, thus maintaining higher soil moisture content (Elad *et al*., 2007). Air movement is also restricted under net (Nair and Ngouajio, 2010) which results in reduced wind damage to the crop allowing air beneath the nets to remain humid (Ilic *et al*., 2012). The existence of a net cover may in the current study have reduced soil evaporation rate under netted areas due to restricted air movement, resulting in higher soil water retention. Iglesias and Alegre (2006) also demonstrated that reduction of transpiration under net covers led to increased moisture retention in the soil due to minimized water uptake by plants. Findings of the current study corroborated with those of earlier studies on spinach (Meena *et al*., 2014), cabbage (Muleke *et al*., 2014) and tomato under net covers (Saidi *et al*., 2013). Higher relative humidity and lower air temperature recorded under coloured-colour net covers in the current study may have contributed to reduced evaporation rate leading to higher soil moisture under these nets compared to neutral-colour net covers.

In the current study, relative humidity was higher under the agronet covers than in the uncovered plots. According to Elad *et al*. (2007), relative humidity is often higher under nets than outside, as a result of water vapour being transpired by the crop and reduced mixing of drier air outside with that of the netted area, even when the temperatures under netting are higher than outside. Reduction in radiation resulting from netting also contributes to increased relative humidity (Stamps, 1994). Besides reducing radiation, nettings also reduce wind speed and wind run which in turn decreases evaporation due to reduced air mixing which result in an increase in relative humidity (Elad *et al*., 2007). These arguments lend support to the observations made in the current study where a higher relative humidity was observed under agronet covered plots than in the uncovered plots. Higher relative humidity under coloured-colour net covers in the current study could be attributed to higher soil moisture, and lower air temperature and light intensities recorded under these net covers leading to increased relative humidity compared to neutral-colour net covers. The higher values of relative humidity recorded under the blue and yellow net cover could have been as a result of these net covers imposing a higher shading factor and greater resistance to air movement than other net covers. Similar to observations of the current study, Abdrabbo *et al*. (2013) reported an increase in relative humidity in coloured nets compared with open field.

Contrary to temperature, moisture levels and relative humidity, photosynthetically active radiation that reached the tomato crop were lowered by the use of the different coloured agronet covers. Netting is frequently used to offer physical protection against excessive solar radiation (Shahak *et al*., 2004) and exhibits special optical properties that allow control of light that reaches the plants (Oren-Shamir *et al*., 2001). Covers have also been shown to block light from entering into the canopy of plants (Arthurs *et al*., 2013; Antignus *et al*., 1998). The reduction in PAR under covers in the current study could therefore be attributed to the light blocking properties of the materials. Neutral-colour nets scatter more light resulting into availability of more diffused radiation therefore light reaches a larger volume of the plant, in a more homogenous way (Nissim-Levi *et al*., 2008) while coloured-colour nets essentially act as opaque material giving less reflection of all light spectra (Shahak, 2008). This could explain the higher PAR recorded under the neutral-colour net covers may be attributed to the transparent nature of the net covers as transparent nets have been shown to scatter light transmitted through them but do not alter its spectral composition (Shahak, 2008; Shahak *et al*., 2004). The obtained results are in agreement with those of Stamps (2009) who reported that nettings, regardless of color, reduce radiation reaching crops underneath.

5.2 Effects of Different Colours of Agronet Cover on the Population of Major Tomato Pest

Using different coloured agronet covers significantly influenced the population of insect pests on tomato plants. Covering tomato plants with different colours of agronet covers reduced populations of silverleaf whitefly, aphids, thrips and mites compared with the control treatment. Net covers serve as an effective physical barrier excluding a wide range of lepidopteran pests from growing plants (Licciardi *et al*., 2008; Martin *et al*., 2006; Bextine and Wayandande, 2001). The use of such covers in the current study may therefore have protected tomato plants from infestations by excluding major pests. In addition, nets have properties to filter the UV radiation (280-400nm) interfering with the vision of insect pests to see the host plants and to discern the plants from their background by blocking the view (Shahak *et al*., 2004). The elimination of the UV portion of the light spectrum interferes with UV vision of insects and as a consequence, their behaviour related with movement, host location ability and their population parameters (Diaz and Fereres, 2007) is interfered with hence lowering their population under agronet covers. It has also been reported that lower light intensities may also contribute to reduced flight activity of whitefly (Doukas and Payne 2007). These arguments lend support to the observations made in the current study where a reduced number of whitefly was observed under agronet covered plots than in uncovered plots. Previous studies by Gogo *et al.* (2014) and Berlinger *et al.* (2002) have also demonstrated that insect exclusion screens can be used effectively as physical barriers against pests of tomatoes.

Some of the coloured shade nets (yellow and blue) are known to attract whiteflies and thrips. Therefore, crops grown under these nets could potentially be at a higher or lower risk of pest infestation depending on the photoselective filtration of sunlight of the cover used (Antignus and Ben-Yakir, 2004). Flying aphids and whiteflies are repelled by a high intensity of reflected light (Simmons *et al*., 2010). This could possibly explain the reduction of whitefly and aphids under yellow net cover compared to other agronet covers used in the current study. Due to the optical property and light reflection of the yellow net cover, whiteflies and aphids land and stay arrested on it for an extended period of time without penetrating through the net (Ben-Yakir *et al*., 2012; Shahak *et al*., 2008 and Bukovinszky *et al*., 2005). Therefore, yellow net cover used in the current study may have also protected tomato plants from infestation by whitefly, aphids and thrips due to the colour and reflectivity of the nets that reduced the rates of pest infestation. Licciardi *et al*. (2008) and Martin *et al*. (2006) observed a delay in the infestation of cabbage by aphids under netting.

Thrips prefer landing on blue net cover and stay arrested on it for an extended period of time without penetrating through the net (Bukovinszky *et al*., 2005) and this net is known to attract thrips. Therefore, crops grown under blue net cover could potentially be at a lower risk of pest infestation (Antignus and Ben-Yakir, 2004). In the current study, blue net cover recorded lower number of thrips compared to other agronet covers. Blue net could have attracted higher number of thrips that remained on top of the net without penetrating through the net hence the lower number. This could also be attributed to the lack of correlation between the number of pests landing on their preferred coloured net and the number penetrating through this net cover. The lower number of thrips recorded under the blue net cover in the current study could have been also as a result of higher relative humidity and lower average air temperatures recorded under this net cover compared to the other net covers. Relatively high temperatures and dry conditions have been associated with increase in thrips population, while high relative humidity and rainfall reduce thrips population and vice versa (Hamdy and Salem, 1994).

5.3 Effects of Different Colours of Agronet Cover on Physiological and Growth Variables of Tomato

Use of different colours of agronet cover resulted to improved growth of tomato compared to open field production. Plants under net covers had higher stomatal conductance, more branches and internodes, longer internodes length, thicker and longer stems compared to those grown in the open field. Air and soil temperature, relative humidity, solar radiation, soil moisture and crop water use or evapotranspiration at a given site are the meteorological elements governing growth and development (Rajasekar *et al*., 2013; Refaie *et al*., 2012)). Favourable weather conditions (increase in relative humidity, temperature, light irradiance and lower wind speed) under nets improves vegetative growth in comparison with open field conditions in spite of lower amount of PAR (Iglesias and Alegre, 2006). Following the use of nets, plant water stress is reduced, photosynthesis and availability of carbohydrates is increased and therefore increase in plant vigour (Iglesias and Alegre, 2006; Jifon and Syvertsen, 2003). Rajasekar *et al*. (2013) also demonstrated that favourable microclimatic conditions under net covers enhances photosynthesis and respiration. Net covers used in the current study modified microclimate marked by higher air temperature, relative humidity and soil moisture which could have favoured better physiological development of tomato through reduction in plant water stress, an increase in photosynthesis and increased availability of carbohydrates leading to better plant vigour. Besides, higher stomatal conductance enhances photosynthetic activities (Adams *et al*., 2001) resulting to more photosynthates being transported to the growing points leading to enhanced growth. Previous studies by Gogo *et al*. (2014) have also demonstrated that net covers improve crop performance as a result of modified and stabilized crop microclimate under the covers marked by lower diurnal temperature ranges and higher volumetric water as well as reduced wind speed (Arthurs *et al*., 2013).

In the current study, plant growth variables were influenced differently by the different coloured net covers. Growing plants under the white net cover enhanced collar diameter and branching, resulting in stout and compact plants. Growing plants under the blue net cover, on the other hand stimulated number of internodes and internode elongation resulting in taller but slender tomato plants with reduced collar diameter and branching. Longer and thin plants observed under the blue net elicit elongation of stems at the expense of their thickness which can be attributed to reduction of R/FR ratio (Kasperbauer, 1994).

Plants grown under low light levels have been found to be more apical dominant than those grown in high light environment (Casierra-Posada *et al*., 2012) due to the stimulation of the synthesis of Gibberellin (GA) which accelerates elongation of node, internode and cells expand more to receive light for photosynthesis resulting in taller plants (Nooprom *et al*., 2013). This could explain the taller plants obtained under net covers in the current study compared to control plants. Lower light intensity inside nets also induce shoot and stem elongation as a shade avoidance mechanism causing plants to grow taller in order to increase their light interception and to facilitate the photosynthetic processes (Kasperbauer, 1987). Increased tomato plant height observed under agronet covers in the current study could also be attributed to the increased internode length favoured by the lower amount of PAR received by plants under the agronet covers leading to taller plants. These results are in agreement with Costa *et al*. (2010) and Abdrabbo *et al*. (2013) who reported taller plants under shade nets compared to open field. Potter *et al*. (1999) reported increased gibberellin contents with decreasing light intensity from 500 to 25µmolm^{-2} s^{-1} in stems of *Brassica napus* seedlings. Increased tomato plant height observed under coloured-colour net covers in the current study could be attributed to the possibly increased GA concentration favoured by the lower amount of PAR compared to under neutral-colour net covers. Shade material is also transparent to FR radiation (700-800nm wavelength) and partially filter the visible radiation (400-700nm wavelength) including red light (600-700nm wavelength) which leads to the reduction of R: FR ratio, thereby increasing the plant height (Khattak *et al*., 2007). Far-red light promotes conversion of inactive gibberellins (GA) to active forms (Rajapakse *et al*., 1999) which are potent promoters of stem elongation (Cummings *et al*., 2008) and regulate internode length in response to altered light condition (Maki *et al*., 2002).

Coloured nets selectively filter solar radiation to promote specific wavelengths of light (Arthurs *et al*., 2013) and increase light scattering which influences plant branching and crop compactness (Abul-Soud *et al*., 2014). Depending on type of colour, photoselective nets absorb differentially the ultra-violet light, blue, green, yellow, red, far red and infra-red spectral regions and increases the ratio of scattered, diffused light, regulating physiological plant responses (Shahak *et al*., 2008). The scattering property of nets allows plants to receive more overall light exposure and also better penetration in the plant canopy allowing increased photosynthetic efficiency, which leads to accelerated plant growth and increased number of secondary branches (Shahak *et al*., 2004). Increased number of tomato branches observed under neutral-colour net covers in the current study could also be attributed to reduced apical dominance brought about by decreased internode length. According to Nissim-Levi *et al*. (2008), increased scattered light recorded under pearl net (neutral-colour net) led to plants with a larger number of branches. The increase in number of branches under neutral-colour net covers could be attributed to increased scattered light recorded under these net covers in the current study compared to under the coloured-colour net covers. The results from the study also correspond to the findings of Parvej *et al*. (2010) and Rajasekar *et al*. (2013) who reported maximum number of branches on individual plants grown under shade compared to open field.

The concomitant increase in plant height and internode length clearly explains the contribution of internode length to plant height. Increase in plant height in coloured-colour net covers compared to under neutral-colour net covers in the current study could be attributed to higher internodal length recorded under these net covers compared to under neutral-colour net covers. The increase in plant height under coloured-colour net covers compared to neutral-colour net covers in the current study could possibly be explained by reduction of both PAR and air temperature compared to under neutral-colour net covers. This could have resulted in a reduction in plant water stress, an increase in photosynthesis and increased availability of carbohydrates which are factors that are conducive for increase in plant vigour (Iglesias and Alegre, 2006).

Collar diameter was also adversely affected by use of agronet covers that recorded reduced PAR levels. Higher collar diameter was recorded under neutral-colour net covers compared to under coloured-colour net covers. Corre (1983) reported that stem length increase occurs at the expense of stem girth. This could possibly explain the higher collar diameter under neutral-colour net cover which recorded lower plant height and internode length. Moreover, the decreased collar diameter recorded under coloured-colour net covers could be attributed to increased plant height and internode length recorded under these net covers in the current study compared to under neutral-colour net covers.

5.4 Effects of Different Colours of Agronet Cover on Tomato Fruit Yield

From the study, use of neutral-colour net covers resulted to higher total fruit number and fruit yield while the lowest was obtained under coloured-colour net covers. Neutral-colour nets scatter more light resulting into availability of more diffused radiation causing higher absorption of PAR resulting to more light use efficiency (LUE) and photosynthetic rate, whereas coloured-colour nets essentially act as opaque material giving less reflection of all light spectra thereby reducing absorption of PAR, light use efficiency, photosynthetic rate and dry matter accumulation (Shahak, 2008). Spectral modification of composition of light by nets in the current study could have promoted fruit set and fruitlet survival due to higher content of scattered or diffuse light which could have led to the higher yields obtained under neutral-colour nets compared to under coloured-colour nets. Besides, the increase in yields under neutral-colour net covers could also be attributed to the higher number of branches registered under these net covers in the current study compared to under the coloured-colour net covers. According to Nissim-Levi *et al*. (2008), increased scattered light recorded under pearl net (neutral-colour net) led to plants with a larger number of branches. Plants under neutral-colour net covers tended to be taller with thicker collar diameters and more branches depicting better biomass accumulation and providing a greater bearing surface and more stored food reserves for translocation to developing fruits compared to coloured-colour plants.

Lower penetration capacity of blue and red range radiation under coloured net covers reduces photosynthetic activity (Ombodi *et al*., 2015) possibly explaining the lower yields recorded for coloured-colour net covers in the current study. Lower productivity under coloured-colour net covers is also attributable to the redirection of photo-assimilates for leaf area production in order to increase the solar radiation gathering leaving less energy for the formation of fruit as explained by Atkinson *et al*. (2006). Several studies have also reported increased total fruit yield under neutral-colour net covers and decreased yields obtained under coloured-colour net covers (Abul-Soud *et al*., 2014; Abdrabbo *et al*., 2013 and Santana *et al*., 2012). Low yields under coloured-colour nets could also be associated with higher late blight disease caused by *Phytophthora infestans* incidences which, was the most common disease of tomato observed in the current study. The disease incidence tended to be highest under the blue net covers which recorded higher soil moisture content in the current study that may have created cool humid and dampy conditions exposing the tomato crop to late blight disease that reduced yields in these covers.

At harvest, the mean number of marketable fruits was significantly higher for tomato harvested from the different coloured agronet cover treatments compared with the non-protected tomato. Growing tomato under agronet covers therefore produced fruits of higher quality. Net covering serve as an effective physical barrier excluding a wide range of pests from growing plants (Licciardi *et al*., 2008; Martin *et al*., 2006; Bextine and Wayandande, 2001). As a result, covers used in the current study reduced the number of pests injuring fruits leading to lower unmarketable yields. Net covers protect crops against direct solar radiation thus avoiding damage to the fruit epidermis and promote better solar radiation distribution within the plant canopy, improving the size, ripeness, colour and taste of fruits (Stamps, 2009). Besides, the modified microclimate (increased air temperature and soil moisture) under covered treatments may also have contributed to the improved crop performance and reduced physiological disorders favouring the production of more fruit that met the market standards. El-Aidy and Sidaros (1996) and Nair and Ngouajio (2010) similarly reported higher marketable yields of tomato and cucumber, respectively under nets compared with control. The increase in marketable yield in neutral-colour net covers compared to coloured-colour net covers could be due to production of more fruit number and higher total fruit weight under these covers in the current study.

5.5 Effects of Different Colours of Agronet Cover on Postharvest Quality of Tomato

Fruits obtained from agronet covers were more firm, had more total soluble solids, less titratable acidity and more sugar acid: ratio. Temperature and water are among the preharvest factors that play an important role in the quality development of fruits (Weerakkody *et al*., 1999). Grown under covers, tomato plant quality tends to be enhanced (Waterer *et al*., 2003). Wax development, cell wall composition, cell number or cell turgor properties is enhanced by modified internal temperature and high soil moisture under covers leading to firm fruits under covered treatments compared to control (Saidi *et al*., 2013). Higher air temperature recorded under neutral-colour net covers compared to coloured-colour net covers in the current study may have encouraged higher absorption and uptake of calcium required for cell wall formation by tomato plants. This could probably explain the higher firmness of fruits obtained from neutral-colour net covers compared to coloured-colour net covers. The degree of shading provided by the nets increases fruit firmness due to ripening- retarding effect of shading (Sen *et al*., 2016; Callejon-Ferre *et al*., 2009).

According to Khanal *et al*. (2013), fruit firmness decreases with storage period due to water loss and further ripening of the fruit. Results of the current study support this argument. During ripening and storage, fruit pulp gradually becomes softer as a result of enzymatic digestion of the cell wall (Grierson and Kader, 1986) and; solubilization and depolymerization of pectins resulting in increased water soluble protein cell wall loosening and, disintegration of the fruit cell wall (Lurie *et al*., 1986). Ripening-related softening of fruit tissues is generally associated with a decrease in strength of cell-cell adhesion. As a result, tissue fracture increasingly occurs by cell separation as ripening progresses (Harker *et al*., 1997; Pitt and Chen 1983; Pitt, 1982). Loss of firmness in tomato leads to decrease in protopectin, cellulose and thickness of cell walls due to the action of enzymes (cellulase, pectinesterase and polygalacturonase) on cell wall, middle lamella and plasmatic membrane (Garcia and Barrett, 2002) which are thought to act by disrupting hydrogen bonds between wall proteins (Mc-Queen-Mason and Cosgrove 1994), possibly at the interface between cellulose microfibrils and matrix polysaccharides. Loss of firmness of tomato fruits in the current study could therefore be attributed to such activities during fruit ripening.

High nutrient levels are required for formation of high soluble sugars in the fruit (Nerson, 1992). Modified internal temperature under covers enhances soil environment around the roots which may have encouraged nutrient absorption and uptake (Hasanein *et al*., 2011), favouring formation of higher TSS and sugar to acid ratio under covered treatments. Carbon import into the fruit is dependent on fruit temperature (Gautier *et al*., 2005). Exposing the fruits to higher temperatures especially during fruit cell division and ripening increases TSS in tomato, predominantly due to changes in carbohydrate biosynthetic enzyme activity (Walker and Ho, 1977) and increased transpiration (Gautier *et al*., 2009). This argument could possibly offer explanation for the higher TSS recorded for tomato grown under neutral-colour net covers that recorded higher air temperature in the current study that may have favoured higher sugar importation from leaves to the fruits compared to coloured-colour net covers. Higher stomatal conductance recorded under agronet covers compared to control could have also enhanced photosynthesis resulting in more starch storage on fruits under covered treatments. Photo oxidation conditions occur under high illumination as reported by Hasanein *et al*. (2011). The increase in TSS composition under net treatments may also be due to the lower illumination that occurred under net covers that reduced photo oxidation resulting to higher TSS.

Nets having bright colours reflect almost all the incident PAR (visible light) over the whole spectrum band of the PAR. On the other hand, a net with a dark colour reflects the incident PAR over the spectrum band of the net colour only (i.e. narrow band) and absorbs the incident PAR over the remaining spectrum of the complementary colours (Al-Helal and Abdel-Ghany, 2010). Neutral-colour nets therefore scatter more light resulting into availability of more diffused radiation causing higher absorption of PAR resulting to more light use efficiency (LUE), higher photosynthetic rate, and dry matter accumulation (Shahak, 2008), hence more starch storage compared to under coloured-colour nets. This could possibly offer explanation for the increased TSS in fruits produced under grey, multi-coloured or white net cover compared with blue or yellow net covers. As fruits ripen, starch levels decrease and soluble solids increase as a result of greater degradation of polysaccharides and accumulation of sugars (Molinari *et al*., 1999). Breakdown of stored carbohydrates during respiration into simple sugars or the hydrolysis of cell wall polysaccharides leads to increase in TSS during storage (Moneruzzaman *et al*., 2009). This could possibly explain the observed increase in total soluble solids during storage in the current study.

Higher temperatures favour the degradation of acids (Volschenk *et al*., 2006). In the current study, temperatures remained higher in the nets compared to the control throughout the study period. The differences in temperature between the net covered and control treatment could possibly account for the differences in TA. Neutral-colour net covers recorded higher air temperature compared to coloured-colour net covers that could have favoured the degradation of acids resulting into reduced TA of tomato produced under these net covers in the current study. According to Sen *et al*. (2012), titratable acidity decreases with the passage of time after harvest, due to fruit senescence as the storage period is extended. Decrease in organic acids during storage has also been associated with them being used as substrate in respiration (Yumbya *et al*., 2014). These arguments offer possibly explanation for the decrease in titratable acidity of tomato with storage time observed in the current study. Similarly, Dorais *et al*. (2001) recorded a decrease in titratable acidity of tomato during storage.

Use of different colours of agronet cover used during production increased the sugar: acid ratio of tomato. The use of blue net cover resulted in the lowest sugar: acid ratio during postharvest due to higher TA recorded under this net in the current study compared to other agronet covers. Higher temperatures during production slow down the production of organic acids (Aldrich *et al*., 2010). Higher sugar acid ratio recorded under neutral-colour net covers could be attributed to the higher air temperature recorded under these nets during production which may have slowed down the production of organic acids.

Use of blue agronet cover during production increased the lycopene contents of tomato. During fruit ripening, increasing PAR and more precisely blue light, increases the fruit content of lycopene (Gautier *et al*., 2005). Higher intensity of blue light has been shown to result in overexpression of cryptochrome CRY2 genes and increase the accumulation of lycopene levels in ripe tomato fruits (Giliberto *et al*., 2005). Blue net cover is designed to absorb ultra-violet, red and far red while enriching the blue regions (Rajapakse and Shahak, 2007) which is most effective in enhancing the biosynthesis and accumulation of lycopene in tomato fruits during ripening (Alba *et al*., 2000; Salunkhe *et al*., 1974). Higher contents of lycopene recorded under the blue net cover compared to other agronet covers in the current study could be attributed to higher blue light provided by the net that accelerated the biosynthesis of lycopene. Lycopene biosynthesis is highest when the temperature ranges between 12-32^oC with an optimal temperature of 22-26^oC (Helyes *et al*., 2007). The lycopene biosynthesis is inhibited when the temperature of fruits is below 12^oC and decreases significantly if the temperature exceeds 30^oC (Brandt *et al*., 2006). Temperature recorded under the current study was in the range of 16.7-21.3^oC and 16.0-20.8^oC in season one and two, respectively. The temperature recorded did not exceed 30^oC that could cause reduction of lycopene content in the current study. The PAR values under study fluctuated in the optimal range and did not also reach the critical amount of approximately 2900 $\mu molm^{-2}s^{-1}$ which would inhibit lycopene accumulation.

Different colours of agronet cover used during production reduced percentage decay during postharvest storage compared to when tomato was produced under open field. Lower decay incidence under net has been attributed to the scattered light spectrum and the high ratio between the Red/Far red and blue/UV which led to light fragment alteration under net that reduces the innoculum level of *Alternaria spp* (Kong *et al*., 2013). Reduction in decay development on produce grown under net after harvest has also been attributed to the inhibited fungal sporulation and delayed fruit ripening (Goren *et al*., 2011). Similarly, Amarante *et al*. (2002) recorded reduced percentage decay of apples under net compared to open field.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusion

The conclusions of the study were made based on the findings of every objective by either rejecting or accepting the stated null hypotheses. Based on the results, the null hypotheses of all objectives were rejected and the study concludes that:

a) The colour of agronet cover influences microclimate of the immediate crop environment with highest temperature, soil moisture and relative humidity being recorded under white net, blue and multi-coloured net cover, respectively.

b) The colour of agronet cover influences populations of silverleaf whitefly and aphids, thrips and mites infesting the crop. Growing tomato crop under yellow net cover reduces population of silverleaf whitefly and aphids while blue net cover reduces thrips population. Regardless of the colour, growing tomato crop under net cover reduces population of mites.

c) The colour of agronet cover affects growth and yield of tomato with white cover promoting highest growth and yields.

d) The colour of agronet cover used during production affects postharvest quality of tomato with neutral-colour nets (white, grey and multi-coloured) enhancing fruit firmness, TSS, sugar acid ratio and shelf life while reducing TA and decay. Use of blue net cover during production enhances fruit lycopene content.

6.2 Recommendations

a. Smallholder farmers should consider using white, blue or multi-coloured net cover as part of tomato protection strategy against environmental hazards and microclimate improvement in an effort to reduce the need for watering.

b. Smallholder tomato farmers should consider using yellow agronet cover in the control of whitefly and aphids. Moreover, blue, multi-coloured or white agronet cover should be used in the control of thrips and mites. These can be used as part of integrated pest management strategy in an effort to protect tomato from pest incidence thus reducing applications of insecticides which increases the cost of production and environmental pollution.

c. White agronet cover is recommended in the production of tomato for enhanced growth and maximum yields.

d. Neutral-colour net covers (white, grey and multi-coloured) used in production are recommended for maintenance of overall fruit quality during postharvest storage.

6.3 Suggestions for further study

The study suggests the following for further studies**;**

a. Studies should be conducted on the effects of using agronet covers on plant hydric status and water needs. These are considerations of potential interest due to the effects of nets on microclimate modification.
b. Studies need to be undertaken on the effect of coloured agronet covers on the management of tomato diseases and beneficial insects (pollinators and natural enemies).
c. Studies should be undertaken on tomato to establish the effects of different colours of agronet cover on other nutritional properties of tomato.
d. Additional studies on the subject using different cultivars of tomato, mesh sizes of the net covers and in different agroecological zones to further validate the results is also recommended.

REFERENCES

Abdrabbo, M.A.A., Farag, A.A., and Abul-Soud, M. (2013). The Intercropping Effect of Potato under Net House as Adaptation Procedure of Climate Change Impacts. *Researcher,* 5(6):48-60.

Abul-Soud, M.A., Emam, M.S.A., and Abdrabbo, M.A.A. (2014). Intercropping of some Brassica Crops with Mango Trees under Different Net House Color. *Research Journal of Agriculture and Biological Sciences,* 10(1):70-79.

Adams, S. R., Cockshull, K.E., and Cave, C.R.J. (2001). Effect of Temperature on the Growth and Development of Tomato Fruits. *Annals of Botany,* 88:869-877.

Akhter, N., Rahman, M.M., Mirza, H., and Nahar, K. (2009). Plant Characters and Seed Yield of Garden Pea under Different Light Intensity. *American-Eurasian Journal of Agronomy,* 2(3):152-155.

Alba, R.M.M., Cordonnier-Pratt, L.H., and Pratt, L.H. (2000). Fruit-Localized Phytochromes Regulate Lycopene Accumulation Independently of Ethylene Production in Tomato. *Plant Physiology,* 23:363-370.

Aldrich, H.T., Salandaran, K., Kendall, P., Bunning, M., Stonaker, F., Kulen, K., and Stushnoff, C. (2010). Cultivar Choice Provides Options for Local Production of Organic and Conventionally Produced Tomatoes with Higher Quality and Antioxidant Content. *Journal of Science, Food and Agriculture,* 90: 2548-2555.

Al-Helal, I.M., and Abdel-Ghany, A.M. (2010). Responses of Plastic Shading Nets to Global and Diffuse PAR Transfer: Optical Properties and Evaluation. *Wageningen Journal of Life Sciences,* 57: 125-132.

Alkalia-Tuvia, S., Goren, A., Perzelan, Y., Weinberg, T., and Fallik, E. (2014). The Influence of Colored Shade Nets on Pepper Quality after Harvest- A Possible Mode of Action. *Agriculture and Forestry,* 6(2):7-18.

Amarante, C., Banks, N.H., and Max, S. (2002). Effect of Preharvest Bagging on Fruit Quality and Postharvest Physiology of Pears (*Pyrus communis*) New Zealand. *Crop and Horticultural Sci*ence, 30:99-107.

Amarante, C.V.T., Steffens, C.A., and Argenta, L.C. (2011). Yield and Fruit Quality of `Gala` and `Fuji` Apple Trees Protected by White Anti-Hail Net. *Scientia Horticulturae,* 129:79-85.

Ambrozy, Z.S., Daood, H., Nagy, Z.S., Darazsiledo, H., and Helyes, L. (2015). Effect of Net Shading Technology and Harvest Times on Yield and Fruit Quality of Sweet Pepper. *Applied Ecology and Environmental Research,* 14 (1): 99-109.

Andhale, R.P., Sinare, B.T., and Tumbare, A.D. (2014). Effect of Shade Net Intensities and Colours on Micrometeorological Parameters, Growth and Yield of Capsicum. *Indian Journal of Science, Research and Technology,* 2(4):11-15.

Antignus, Y., and Ben-Yakir, D. (2004). *Ultraviolet Absorbing Barriers, an Efficient Integrated Pest Management Tool to Protect Greenhouses from Insects and Virus Diseases.* In: A.R Horowitz and I. Ishaaya (Eds). Insect Pest Management- Field and Protected Crops. Springer Publishers, Berlin, 319-335.

Antignus, Y., Lapidot, M. Hadar, D., Messika, M., and Cohen, C. (1998). Ultraviolet Absorbing Screens Serve as Optical Barriers to Protect Crops from Virus and Insect Pests. *Journal of Economic Entomology,* 9:1140-1405.

Arthurs, S.P., Stamps, R.H., and Giglia, F.F. (2013). Environmental Modification inside Photo-selective Shade houses. *HortScience,* 48(8): 975-979.

Aslam, M., Razaq, M., Ahmad, F., and Mirza, Y.H. (2007). Population Abundance of Aphids (*Brevicoryne brassicae* L.) and *Lipaphis erysimi* (Kalt.) on Indian Mustard (*Brassica juncea* L.). *African Crop Science Proceedings,* 8:935-938.

Atkinson, C.J., Dodds, P.A.A., Ford, Y.Y., Miere, J.L.E., Taylor, J.M., Blake, P.S. and Paul, N. (2006). Effects of Cultivar, Fruit Number and Reflected PAR on *Fragaria*× *annanassa* Productivity and Fruit Ellagic Acid and Ascorbic Acid Concentrations. *Annals of Botany,* 97(3):429-441.

Ayalew, G. (2015). Efficacy of Selected Insecticides against the South American Tomato Moth, *Tuta absoluta* Meyrick (Lepidoptera; Gelechiidae) on Tomato in the Central Rift Valley of Ethiopia. *African Entomology,* 23:410-417.

Bandara, R.M.U.C., Perera, T.M.R.S., Balasuriya, B.L.H.N., Dabarera, R. and Beneragama, C.K. (2014). Effects of Different Colour Shade Nets on Growth and Development of Selected Horticultural Crop Species. *Plant Science and Forestry,* (18), Abstract No; 904.

Basile, B.R., Romano, M., Giaccone, E., Barlotti, V., Colonna, C, Cirillo, Y., Shahak, Y., and Forlani, M. (2008). Use of Photoselective Nets for Hail Protection of Kiwifruit Vines in Southern Italy. *Acta Horticulturae,* 770:185-192.

Bastias, R.M., Manfrini, L., and Grappadelli, L.C. (2012). Exploring the Potential use of Photo-selective Nets for Fruit Growth Regulation in Apple. *Chilean Journal of Agricultural Research,* 72(2):224-231.

Ben-Yakir, D., and Antignus, Y., Offir, Y., and Shahak, Y. (2012). Colored Shading Nets Impede Invasion and Decrease the Incidences of Insect Transmitted Viral Diseases in Vegetable Crops. *Entomologia Experimentalis et Applicata,* 144(3):249-257.

Ben-Yakir, D., Hadar, M.D., Offir, Y., Chen, M., and Tregerman, M. (2008). Protecting Crops from Pests using OptiNet® Screens and ChromatiNet® Shading Nets. *Acta Horticulturae,* 770:205-212.

Berlinger, M. J., Taylor, R. A. J., Lebiush-Mordechi, S., Shalhevet, S., and Spharim, I. (2002). Efficiency of Insect Exclusion Screens for Preventing Whitefly Transmission of Tomato Yellow Leaf Curl Virus of Tomatoes in Israel. *Bulletin of Entomological Research,* 92:367-373.

Bextine, B., and Wayandande, A. (2001). Effect of Insect Exclusion on the Incidence of Yellow Vine Disease and of the Associated Bacterium in Squash. *Plant Disease,* 85:875-878.

Blaney, W.M., Simmonds, M.S.J., Ley, S.V., Anderson, J.C., and Toogood, P.L. (1990). Antifeedant Effects of Azadirachtin and Structurally Related Compounds on Lepidopterous Larvae. *Entomologia Experimentalis et Applicata,* 55:149-160.

Bosco, L.C., Bergamaschi, H., Cardoso, L.S., de Paula, V.A., Marodin, G.A.B., and Brauner, P.C. (2018). Microclimate Alterations Caused by Agricultural Hail Net Coverage and Effects on Apple Tree Yield in Subtropical Climate of Southern Brazil. *Bragantia Campinas*, 77(1):181-192.

Brandt, S., Pek, Z. and Barna, E. (2006). Lycopene Content and Colour of Ripening Tomatoes as Affected by Environmental Conditions. *Journal of the Science of Food and Agriculture,* 86:568-572.

Briassoulis, D., Mistriotis, A. and Eleftherakis, D. (2007). Mechanical Behaviour and Properties of Agricultural Nets. Part 1: Testing Methods for Agricultural Nets. *Polymer Testing,* 26:882-832.

Bukovinszky, T., Potting, R.P.J., Clough, Y., van Lenteren, J.C., and Vet, L.E.M. (2005). The Role of Pre- and Post- Alighting Detection Mechanisms in the Responses to Patch Size by Specialist Herbivores. *Oikos,* 26:882-832.

Caliman, F.R.B., da Silva, D.J.H., Stringheta, P.C., Fontes, P.C.R., Moreira, G.R., and Mantovani, E.C. (2010). Quality of Tomatoes Grown under a Protected Environment and Field Conditions. *IDESIA (Chile),* 28(2):75-82.

Callejon-Ferre, A.J., Manzano-Agugliaro, F., Diaz-Perez, M., Carreno-Ortega, A., and Perez-Alonso, J. (2009). Effect of Shading with Aluminised Screens on Fruit Production and Quality in Tomato (*Solanum lycopersicum* L.) under Greenhouse Conditions. *Spanish Journal of Agricultural Research,* 7(1): 41-49.

Capanoglu, E., Beekwilder, J., Boyacioglu, D., de Vos, R.C.H., and Hall, R.D. (2010). The Effect of Industrial Food Processing on Potentially Health-Beneficial Tomato Antioxidants. *Critical Reviews in Food Science and Nutrition,* 50:919-930.

Casierra-Posada, F., and Ludders, P. (2001). Influence of summer pruning and nitrogen nutrition on mineral content in apple trees under hail protection net. *Erwerbsob,* 43:106–113.

Casierra-Posada, F., Pena-Olmes, J.E., and Ulrichs, C. (2012). Basic Growth Analysis in Strawberry Plants (*Fragaria sp.*) Exposed to Different Radiation Environments. *Agronomia Colombiana,* 30 (1): 25-33.

Clinton, S.K. (1998). Lycopene: Chemistry, Biology and Implications for Human Health and Disease. *Nutrition Reviews,* 56:35-51.

Clotuche, G., Mailleux, A.C., Fernandez, A.A., Deneubourg, J.L, Detrain, C. and Hance, T. (2011). The Formation of Collective Silk Balls in the Spider Mite Tetranychus urticae Koch. *Plos ONE,* 6(4):1-9.

Cooper, A.J., and Hurd, R.G. (1968). The Influence of Cultural Factors on Development of the First Inflorescence of Greenhouse Tomatoes. *HortScience,* 43:243-248.

Cormier, D., Veilleux, J., and Firlej, A. (2015). Exclusion Net to Control Spotted Wing *Drosophila* in Blueberry Fields. *Integrated protection of fruit crops Subgroup "Soft Fruits" IOBC-WPRS Bulletin,* 109:181-184.

Costa, L.C.B., Pinto, J.E.B.P., Castrol, E.M., Alves, E., Bertolucci, S.K.V. and Rosal, L.F. (2010). Effects of Coloured Shade Netting on the Vegetative Development and Leaf Structure of *Ocimum selloi*. *Bragantia, Campinas,* 69(2):349-359.

Crouch, I. (2003). 1-Methylcyclopropene Smartfresh^{TM}) as an Alternative to Modified Atmosphere and Controlled Atmosphere Storage of Apples and Pears. *Acta Horticulturae,* 600:433-436.

Daniel, C, and Baker, B. (2013). Dispersal of *Rhagoletis cerasi* in Commercial Cherry Orchards: Efficacy of Soil Covering Nets for Cherry Fruit Fly Control. *Insects,* 4:168 176.

Davies, J.N and Hobson, G.E. (1981). The Constituents of Tomato Fruit- the Influence of Environment Nutrition and Genotype. *Critical Reviews in Food Science and Nutrition,* 15:205-280.

Diaz, B.M., and Fereres, A. (2007). Ultraviolet-Blocking Material as a Physical Barrier to Control Insect Pests and Plant Pathogens in Protected Crops. *Pest Technology,* 1(2):85-95.

Diaz, B.M., Biurrun, R., Moreno, A., Nebreda, M., and Fereres, A. (2006). Impact of Ultraviolet Blocking Plastic Films on Insect Vectors of Virus Disease Infesting Crisp Lettuce. *HortScience,* 41(3):711-716.

Dorais, M., Papadopoulas, A.P., and Gosselin, A. (2001). Greenhouse Tomato Fruit Quality. *Journal of the American Society and Horticultural Science*, 26:239-319.

Doukas, D., and Payne, D. (2007). The Use of Ultraviolet- Blocking Films in Insect Pest Management in the UK; Effects on Naturally Occurring Arthropod Pest and Natural Enemy Populations in a Protected Cucumber Crop. *Annals of Applied Biology,* 151:221-231.

Dussi, M.C., Giardina, G., Sosa D., Junyent, R.G., Zecca, A. and Reeb, P. (2005). Shade Nets Effect on Canopy Light Distribution and Quality of Fruit and Spur Leaf on Apple Cv. Fuji. *Spanish Journal of Agricultural Research*, 3(2):253-260.

Elad, Y., Messika, Y., Brand, M., David, D.R., and Sztejnberg, A. (2007). Effect of Colored Shade Nets on Pepper Powdery Mildew (*Leveillula taurica*). *Phytoparasitica,* 35:285-299.

El-Aidy, F., and Sidaros, S.A. (1996). The Effect of Protected Tomato Seedling on Growth and Yield of Late Summer Tomato in Egypt. *Cahiers Options Mediterraneens* 31:385-389.

Fajinmi, A.A., and Fajinmi, O.B. (2010). Incidence of Okra Mosaic Virus at Different Growth Stages of Okra Plants (*Abelmoschus esculentus* Moench.) under Tropical Condition. *Journal of General and Molecular Virology* 2(1):28-31.

Fallik, E., Alkalia-Tuvia, S., Parselan, Y., Aharon, Z., Elmann, A., Offir, Y., Matan, E., Yehezkel, H., Ratner, K., Zur, N., and Shahak, Y. (2009). Can Colored Shade Nets Maintain Sweet Pepper Quality During Storage and Marketing? *Acta Horticulturae,* 830:37-44.

FAOSTAT. (2017). *Food and agricultural commodities production*. Retrieved June 17, 2017, from http://faostat.fao.org

Fish, W.W., Perkins-Veazie, P., and Collins, J.K. (2002). A Quantitative Assay for Lycopene that Utilizes Reduced Volumes of Organic Solvents. *Journal of Food Composition and Analysis,* 15:309-317.

Fontes, P.C.R., and Araujo, C. (2006). Use of a Chlorophyll Meter and Plant Visual Aspect for Nitrogen Management in Tomato Fertigation. *Journal of Applied Horticulture,* 8 (1):8-11.

Foottit, R.G., Maw, H.E.L., Von Dohlen, C.D. and Hebert, P.D.N. (2008). Species Identification of Aphids (Insecta: Hemiptera: Aphididae) through DNA Barcodes. *Molecular Ecology Resources,* 8:1189–1201.

Friedmann, M., Lapidot, M., Cohen, S., Pilowsky, M. (1998). Novel Source of Resistance to Tomato Yellow Leaf Curl Virus Exhibiting a Symptomless Reaction to Viral Infection. *Journal of American Society of Horticulture and Science,* 123:1004-1007.

Garcia, E., and Barret, D.M. (2002). *Preservative Treatments for Fresh-cut Fruits and Vegetables.* In: Lamikanra, O. (Ed.), Fresh-cut Fruits and Vegetables, Science Technology, and Market. CRC Press, Boca Raton, FL. 267-303.

Gardner, R.A.W., and Fletcher, C.A. (1990). Hail Protection Systems for Deciduous Fruit Trees. *Deciduous Fruit Grower,* 40:206-212.

Gaurav, A.K., Raju, D.V.S., Janakiram, T., Singh, B., Jain, R., and Krishnan, S.G. (2016b). Effect of Different Coloured Shade Nets on Production and Quality of Cordyline. *Indian Journal of Agricultural Sciences,* 86 (7): 865–869.

Gaurav, A.K., Raju, D.V.S., Janakiram, T., Singh, B., Jain, R., and Krishnan, S.G. (2016a). Effect of Coloured Shade Net on Production of *Dracaena fragrans*. *Indian Journal of Horticulture,* 73 (1):94-98.

Gautier, H., Massot, C., Stevens, R., Serino, S., and Genard, M. (2009). Regulation of Tomato Fruit Ascorbate Content is more Highly Dependent on Fruit Irradiance than Leaf Irradiance. *Annals of Botany,* 103:495-504.

Gautier, H., Rocci, A., Buret, M., Grasselly, D., Dumas, Y., and Causse, M. (2005). Effect of Photoselective Filters on the Physical and Chemical Traits of Vine-ripened Tomato Fruits. *Canadian Journal of Plant science,* 85: 439-446.

Gogo, E.O. (2013). Influence of Ecofriendly Nets and Floating Row Covers on Microclimate Modification, Pest Infestation, Growth and Yield of Tomato (*Lycopersicon esculentum* Mill.). Master's Thesis, Egerton University.

Gogo, E.O., Saidi, M., Itulya, F.M., Martin, T., and Ngouajio, M. (2014). Eco-Friendly Nets and Floating Row Covers Reduce Pest Infestation and Improve Tomato (*Solanum lycopersicon* L.) Yields for Smallholder Farmers in Kenya. *Agronomy,* 4:1-12.

Gogo, E.O., Saidi, M., Opiyo, A.M., Martin, T., and Ngouajio, M. (2017). Effects of Alpha-cypermethrin Impregnated Agricultural Net Covers on the Crop Environment, Insect Pest Population and Yield of Tomato (*Lycopersicon esculentum* Mill.). *African Journal of Horticultural Science,* 11:59-71.

Gordon, G.G. (2006). The Effects of Color Plastic Mulches and Row Covers on the Growth and Production of Okra and Summer Squash. Master`s Thesis, Auburn University, Alabama.

Goren, A., Alkalia-tuvia, S., Perzelan, Y., Aharon, Z., and Fallik, E. (2011). Photoselective Shade Nets Reduce Postharvest Decay Development in Pepper Fruits. *Advances Horticultural Science*, 25:26-31.

Grierson, D., and Kader, A.A. (1986). *Fruit Ripening and Quality.* In The Tomato Crop, a Scientific Basis for Improvement. (Atherton, J.G., Rudich, J., Eds.). Chapman & Hall, New York, USA. 241-281.

Grinberger, A., Shomron, M. and Ganelevin, R. (2000). Shading Nets Testing. 1-4.

Guerrero, V.M., Orozco, J.A., Romo, A., Gardea, A.A., Molina, F.J., Sastre, B., and Martinez, J.J. (2002). The Effect of Hail Nets and Ethephon on Colour Development of `Red chief Delicious` Apple Fruit in the Highlands of Chihuahua, Mexico. *Journal of American Pomological Society,* 56(3):132-135.

Guiselin, C. and Sentelhas, P.C. (2004). Use of Shading Screens in Greenhouse I: Effect on Temperature and Relative Humidity. *Revista Brasileira de Agrometeorologia,* 12:9-17.

Gunter, S., Stimm, B., Cobrera, M., Diaz, M.L., Lojan, M., Ordonez, E., Richter, M., and Weber, M. (2008). Tree Phenology in Montane Forests of Southern Ecuador can be explained by Precipitation, Radiation and Photoperiodic Control. *Journal of Tropical Ecology,* 24:247-258.

Hamdy, M. K. and Salem, M. (1994). The effect of plantation dates of onion, temperature and relative humidity on the population density of the onion thrips, in Egypt. *Annals of Agricultural Science,* 39(1): 417-424.

Haque, M.M., Hasanuzzaman, M., and Rahman, M.L. (2009). Effect of Light Intensity on the Morpho-Physiology and Yield of Bottle Gourd *(Lagenaria vulgaris). Academic Journal of Plant Sciences*, 2(3):158-161.

Harker, F.R., Redgwell, R.J., Hallet, K., Murray, S.H., and Carter, G. (1997). Texture of Fresh Fruits. *Horticultural Reviews of American Society of Horticultural Science,* 20: 121-124.

Hasanein, N.M., El- Mola, M.M.H.G., and Aly, M.A.M. (2011). Influence of Different Colors of Shade on Growth and Yield of Strawberries and Different Colors of Mulch under Low Tunnels Conditions. *Research Jour5nal of Agriculture and Biological Sciences,* 7(6):483-490.

HCD, (2014). *Horticulture Validated Report 2014, USAID-KHCP Horticulture Performance 2012-2014.*

HCDA, (2006). *Fruits and Vegetables. Agricultural Information Resource Centre, Nairobi, Kenya.* 150.

Helyes, L., Lugasi, A., and Pek, Z. (2007). Effect of Natural Light on Surface Temperature and Lycopene Content of Vine Ripened Tomato Fruit. *Canadian Journal of Plant Science,* 87:927-929.

Helyes, L., Lugasi, A., Pogonyi, Á., and Pék, Z. (2009). Effect of Variety and Grafting on Lycopene Content of Tomato (*Lycopersicon lycopersicum* L. Karsten) Fruit. *Acta Aliment Hungary,* 38(1):27-34.

Hepaksoy, S., and Dayioglu, A. (2016). Fruit Quality and Sunburn of Apple CV. Early Red One under Shading Nets. *Journal of Agricultural Faculty of Uludag University*, 30:642-646.

Hobson, G.E. (1987). Low- Temperature Injury and the Storage of Ripening Tomatoes. *Journal of Horticultural Science,* 62:55-62.

Holcman, E., and Sentelhas, P.C. (2012). Microclimate under Different Shading Screens in Greenhouses Cultivated with Bromeliads. *Ravista Brasileira de Engenharia Agricola Ambiental,* 16 (8):858-863.

Huang, S., Ashley, D.A., and Boerma, H.R. (1993). Light Intensity, Row Spacing and Photoperiod Effects on Expression of Brachytic Stem in Soybean. *Crop Science,* 33:29-37.

Ibarra-Jimenez, L., Quezada-Martin, M.R., and de la Ros-Ibarra, M. (2004). The Effect of Plastic Mulch and Row Covers on the Growth and Physiology of Cucumber. *Australian Journal of Experimental Agriculture,* 44:91-94.

Iglesias, I., and Alegre, S. (2006). The Effect of Anti-hail nets on Fruit Protection, Radiation, Temperature, Quality and Profitability of 'Mondial Gala' Apples. *Journal of Applied Horticulture,* 8(2):91-100.

Ilic, Z., Milenkovic, L., Durovka, M., and Kapoutas, N. (2012). The effect of color shade nets on the greenhouse climate and pepper yield. Proceedings 46th Croatian and 6th International Symposium on Agriculture. Opatija.Croatia, 529-532.

Ilic, Z.S., and Milenkovic, L. (2012). The Influence of Photo-selective Shade Nets on Quality of Tomatoes Grown under Plastic Tunnels and Field Conditions, in Proceedings of an International Conference on Bioscience: Biotechnology and Biodiversity, Step in the Future. Novi Sad, Serbia, 25–34.

Ilic, Z.S., Milenkovic, L., Cvetkovic, D., Kevresan, Z., Fallik, E., and Mastilovic, J. (2017). Light Modification by Color Nets Improve Quality of Lettuce from Summer Production. *Scientia Horticulturae*, 226:389-397.

Jaetzold, R., and Schmidt, H. (1983). *Farm Management Handbook of Kenya.* Volume II Natural Conditions and Farm Management Information-PART B. (Central Kenya (Rift Valley and Central Provinces). Ministry of Agriculture Kenya.

Jayasinghe, G. G., and Mallik B. (2013). Growth Stage Based Economic Injury Levels for Two Spotted Spider Mite, *Tetranychus urticae* Koch (Acari, Tetranychidae) on Tomato, *Lycopersicon esculentum* Mill. *Tropical Agricultural Research*, 22(1): 54-65.

Jifon, J.L., and Syvertsen, J.P. (2003). Moderate Shade can Increase Net Gas Exchange and Reduce Photoinhibition in Citrus Leaves. *Tree Physiology,* 23:119-127.

Justen, V.L., Fritz, V.A. and Cohen, J.D. (2012). Seasonal Variation in Glucosinolate Accumulation in Turnips Grown under Photo-selective Nettings. *Horticulture, Environment and Biotechnology,* 53(2):108-115.

Kasperbauer, M.J., (1987). Far-Red Light Reflection from Green Leaves and Effects on Phytochrome-Mediated Assimilate Partitioning under Field Conditions. *Plant Physiol*ogy, 85:50-354.

Kelderer, M., Casera, C, Lardscheider, E., and Rainer, A. (2009). Controlling Codling Moth with Different Netting Structures and their Influence on Crop Yield and Quality. *Reviewed papers*, 183-190.

Kerckhoffs, L.H.J., Schreuder, M.E.L., Tulnen, A.V., Koornneef, M., and Kendrick, R.E. (1997). Phytochrome Control of Anthocyanin Biosynthesis in Tomato Seedlings: Analysis using Photomorphogenic Mutants. *Photochemistry and Photobiology,* 65(2):374-381.

Khanal, B., Suthaparan, A., Huckstadt, A.B., Wold, A.B., Mortensen, L., and Gislerod, H.R. (2013). The Effect of High Day and Low Night Temperature on Pollen Production, Pollen Germination and Postharvest Quality of Tomatoes. *American Journal of Plant Sciences,* 4:19-25.

Khattak, A.M., Salam, A., and Nawab, K. (2007). Response of Exotic Tomato Lines to different Light Intensities. *Sarhad Journal of Agriculture*, 23(4):927-932.

Knapp, M. (1999). Biology, Pest Status and Control of Mites in Tomatoes in Eastern and Southern Africa, ICIPE, Nairobi, Kenya.

Komarova, O.S., and Kuznetsova, M.S. (1969). Cotton Bollworm. In: Polyakov I.Ya., Chumakov A.E., eds. Distribution of Pests and Diseases of Agricultural Cultures in the USSR in 1966. Proceedings of VIZR. Leningrad: VIZR. V. 34: 74-80. (In Russian).

Kong, Y., Avraham, L., Perzelan, Y., Alkalia-Tuvia, S., Ratner, K., Shahak, Y., and Fallik, E. (2013). Pearl Netting Affects Postharvest Fruits Quality in ''Vergasa' Sweet Pepper via Light Environment Manipulation. *Scientia Horticulturae*, 150:290-298.

Kucuk, O., Sarkar, F.H., Sakr, W., Djuric, Z., Pollak, M.N., Khachik, F., Li, Y., Banerjee, M., Grignon, D., Bertram, J.S., Crissman, J.D., Pontes, E.J., and Wood, J.D.P. (2001). Phase II Randomized Clinical Trial of Lycopene Supplementation before Radical Prostatectomy. *Cancer Epidemiology, Biomarkers and Prevention*, 10:861–868.

Lal, O.P., and Lal, S.K. (1996). Failure of Control Measures against *Heliothis armigera* Infesting Tomato in Heavy Pesticidal Application areas in Delhi and Satelite towns in Western UP and Haryana. *Journal of Entomological Research,* 20(4): 355-364.

Lapidot, M., Friedmann, M., Lachman, O., and Yehezkel, A. (1997). Comparison of Resistance Level to Tomato Yellow Leaf Curl Virus among Commercial Cultivars and Breeding Lines. *Plant Disease*, 81:1425–1428.

Legarrea, S., Karnieli, A., Fereres, A., and Weintraub, P.G. (2009). Comparison of UV Absorbing Nets in Pepper Crops: Spectral Properties, Effects on Plants and Pest Control. *Photochemistry and Photobiology,* 86:324-330.

Legarrea, S., Weintraub, P.G., Plaza, M., Vinuela, E., and Fereres, A. (2012). Dispersal of Aphids, Whiteflies and their Natural Enemies under Photoselective Nets. *International Organization for Biological Control*, 57(4):523-532.

Leibee, G. L. (1984). Influence of Temperature on Development and Fecundity of L. trifolii (Burgess) (Diptera: Agromyzidae) on Celery. *Journal of Environmental Entomology*, 13: 497-501.

Leite, C.A., Ito, R.M., Lee, G.T.S., Gaelevin, R., and Fagnani, M.A. (2008). Light Spectrum Management using Colored Nets to Control the Growth and Blooming of *Phalaenopsis. Acta Horticulturae,* 770:177-184.

Leite, G.B., Petri, J.L., and M. Mondaro (2002). Effect of Hailstorm Net Shield on Some Characteristics of Apples. *Revista Brasileira de Fruticultura,* 24(3):714-716.

Lemma, D. (2002). Research Experience and Production Prospects. Ethiopian Agricultural Research Organization (EARO), Addis Ababa, Ethiopia. 20-28.

Licciardi, S., Assogba-Komlan, F., Sidick, I., Chandre, F., Hougard, J.M., and Martin, T. (2008). A Temporary Tunnel Screen as an Eco-Friendly Method for Small-Scale Farmers to Protect Cabbage Crops in Benin. *International Journal of Tropical Insect Science*, 27:152-158.

Lobos, G.A., Ratemales, J.B. and Del Pozo, A. (2009). Physiological Response of *Vaccinium corymbosum* 'Elliott' to Shading Nets in Michigan. *Acta Horticulturae,* 810:465-470.

Lumpkin, H.A. (2005). *Comparison of Lycopene and other Phytochemicals in Tomatoes Grown under Conventional and Organic Management Systems.* Technical Bulletin No. 34, AVRDC 05-623. Taiwan, 48.

Maerere, A.P, Mwanjombe, K.K and Sibuga, K.P. (2006). Baseline Survey Report of Tomato Production in Mvomero District, Morogoro Region, Tanzania. Regional IPM Program for East Africa Kenya, Tanzania and Uganda. 21.

Mahajan, S. and Tuteja, N. (2005). Cold, Salinity and Drought Stresses. An Overview. *Biochemistry Biophysics,* 444:139-158.

Mahdi, M.A., Al-Ani, A., Eamus, D., and Tan, K.Y.D. (2012). A New Image Processing Based Technique to Determine Chlorophyll in Plants. *American Eurasian Journal of Agriculture and Environmental Science,* 12(10):1323-1328.

Majidi, H., Minaei, S., Almasi, M. and Mostofi, Y. (2011). Total Soluble Solids, Titratable Acidity and ripening index of Tomato in Various Storage Conditions. *Australian Journal of Basic and Applied Sciences,* 5(12):1723-1726.

Maki, S. L., Rajapakse, S., Ballard, R. E. and Rajapakse, N. C. (2002). Role of gibberellins in chrysanthemum growth under far red light-deficient greenhouse environments. *Journal of the American Society for Horticultural Science,* 127: 639-643.

Maklad, A.M.H., Abolmaaty S.M., Hassanein M.K. and EL-Ghafor, N.Y.A. (2012). Impact of Type of Greenhouse Cover Sheets on certain Major Cucumber Pest under Protected Cultivation. *New York Science Journal,* 5(7):19-24.

Marsic, N.K., Gasperlin, L., Abram, V., Budic, M., and Vidrih, R. (2011). Quality Parameters and Total Phenolic Content in Tomato Fruits Regarding Cultivar and Microclimatic Conditions. *Turkish Journal of Agriculture,* 35: 185-194.

Martin, T., Assogba-Komlan, F., Houndete, T., Hougard, J.M., and Chandre, F. (2006). Efficacy of Mosquito Netting for Sustainable Small Holder's Cabbage Production in Africa. *Journal of Economic Entomology,* 99:450-454.

Mashego, D.C. (2001). The Production of Vegetable Crops under Protection for Small Scale Farming Situations, University of Pretoria. Master`s Thesis, University of Pretoria.

Mayfield, J. L., Hudgins J. L., and Smith J. L. (2003). Integrated Management of Thrips and Tomato Spotted Wilt Virus in Field Grown Fresh Market Tomatoes. *Proc. Fla. State Horticultural Society*, 116: 161-164.

McQueen-Mason, S., and Cosgrove, D.J. (1994). Disruption of Hydrogen-bonding between Plant-cell Wall Polymers by Proteins that Induce Extension. *Proc. Natl. Academic Science,* U.S.A 91:6574-6578.

Meena, R.K., and Vashisth, A. (2014). Effect of Microenvironment under Different Colour Shade Nets on Biophysical Parameters and Radiation Use Efficiency in Spinach (*Spinacia oleracea* L.). *Journal of Agricultural Physics,* 14 (2): 181-188.

Meena, R.K., Vashisth, A., Singh, R., Singh, B., and Manjaih, K.M. (2014). Study on Change in Microenvironment under Different Colour Shade Nets and its Impact on Yield of Spinach (*Spinacia oleracea* L.). *Journal of Agrometeorology,* 16(1):104-111.

Meena, V.S., Kashyap, P., Nangare, D.D., and Singh, J. (2016). Effect of Coloured Shade Nets on Yield and Quality of Pomegranate (*Punica granatum*) cv. Mridula in Semi-arid Region of Punjab. *Indian Journal of Agricultural Sciences,* 86 (4): 500–505.

Milenkovic, L., Ilic, Z.S., Sunic, L., Trajkovic, R., Kapoulas, N, and Durovka, M. (2008). Reducing of Tomato Physiological Disorders by Photoselective Shade Nets. Proceedings 47th Croatian and 7th International Symposium on Agriculture. Opatija.Croatia 419-423.

Molinari, A.F., Castro, L.R., Antoniali, L.R., Pornchaloempong, P., Fox, A.J., and Sargent, S.A. (1999). The Potential for Bell Pepper Harvest Prior to Full Color Development. *Proc. Fla. State Horticultural science*, 112:143-146.

Moneruzzaman, K.M., Hossain, A.B.M.S., Sani, W., Saifuddin, M., and Alenazi, M. (2009). Effect of Harvesting and Storage Conditions on the Post-Harvest Quality of Tomato (*Lycopersicon esculentum* Mill) cv. Roma VF. *Australian Journal of Crop Science,* 3(2):113-121.

Moniruzzaman, M., Islam, M.S., Hossain, M.M., Hossain, T. and Miah, M.G. (2009). Effects of Shade and Nitrogen Levels on Quality Bangladhonia Production. *Bangladesh Journal of Agriculture Research*, 34(2):205-213.

Motsenbocker, C.E., and Arancibia, R.A. (2002). In-row Spacing Influences Triploid Watermelon Yield and Crop Value. *Hort-Technology*, 34(2):437-440.

Mudau, A.R., Soundy, P., and Mudau, F.N. (2017). Response of Baby Spinach (*Spinacia oleracea* L.) to Photoselective Nettings on Growth and Postharvest Quality. *HortScience*, 52(5): 719-724.

Mugnozza, G.S., Vox, G., and Schettini, E. (2011). Radiometric Properties of Coloured Nets for Peach Tree Protected Cultivation. *Belgirate*, 22-24.

Muleke, E.M., Saidi, M., Itulya, F.M., Martin, T., and Ngouajio, M. (2013). The Assessment of the Use of Eco-friendly Nets to Ensure Sustainable Cabbage Seedling Production in Africa. *Agronomy,* 3:1-12.

Muleke, E.M., Saidi, M., Itulya, F.M., Martin, T., and Ngouajio, M. (2014). Enhancing Cabbage (*Brassica oleraceae var. capitata*) Yields and Quality through Microclimate Modification and Physiological Improvement using Agronet Covers. *Sustainable Agriculture Research*, 3(2):24-34.

Mutamiswa, R., Machekano, H., and Nyamukondiwa, C. (2017). First Report of Tomato Leafminer, Tuta absoluta (Meyrick) (Lepidoptera: Gelechiidae), in Botswana. *Agriculture and Food Security,* 6(49):1-10.

Mutisya, S., Saidi, M., Arnold Opiyo, A., Mathieu Ngouajio, M., and Martin, T. (2016). Synergistic Effects of Agronet Covers and Companion Cropping on Reducing

Whitefly Infestation and Improving Yield of Open Field-Grown Tomatoes. *Agronomy*, 6(42):1-14.

Muzemu, S., Mvumi, B.M., Nyirenda, S.P.M., Sileshi, G.W., Sola, P., Kamanula, J.F., Belmain, S.R., and Stevenson, P.C. (2011). Pesticidal Effects of Indigenous Plants Extracts against Rape Aphids and Tomato Red Spider Mites. *African Crop Science Conference Proceedings*, 10: 169 – 171.

Nagata, M., and Yamashita, I. (1992). Simple Method for Simultaneous Determination of Chlorophyll and Carotenoids in Tomato Fruit. *Journal of Japan Society of Food Science and Technology,* 39:925-928.

Naika, S., de Jeude, J.V.L., de Goffau, M., Hilmi, M., and Dam, B.V. (2005). *Cultivation of Tomato, Production, Processing and Marketing*. Agromisa Foundation and CTA, Wageningen. 6-9.

Nair, A., and Ngouajio, M. (2010). Integrating Row Covers and Soil Amendments for Organic Cucumber Production; Implications on Crop Growth, Yield and Microclimate. *HortScienc*e, 45: 566-574.

Nangare, D.D., Singh, J., Meena, V.S., Bhushan, B., and Bhatnagar, P.R. (2015). Effect of Green Shade Nets on Yield and Quality of Tomato (*Lycopersicon esculentum* Mill) in Semi-arid Region of Punjab. *Asian Journal of Advances in Basic and Applied Science,* 1(1): 1-8

Nerson, H. (1992). Effects of Soil Type, Mineral Nutrition and Salinity on Greenhouse Grown Muskmelons in Winter. *Journal of Plant Nutrition,* 15: 2381-2403.

Ngelenzi1, M.J., Mwanarusi, S., and Ogweno, J.O. (2017). Improving French Bean (*Phaseolus vulgaris* L.) Pod Yield and Quality Through the Use of Different Coloured Agronet Covers. *Sustainable Agriculture Research*, 6(1): 62-72.

Nissim-Levi, A., Lilach, F., David, H., Rinat, O., Izhak, F., Sima, K., and Oren-Shamir, M. (2008). Light Scattering Shade Net Increases Branching and Flowering in Ornamental Pot Plants. *The Journal of Horticultural Science and Biotechnology,* 83(1):9-14.

Nooprom, K., Santipracha, Q., and Te-Chato, S. (2013). Effect of Shading and Variety on the Growth and Yield of Broccoli during the Dry Season in Southern Thailand. *International Journal of Plant, Animal and Environmental Sciences,* 3(2):111-115.

Nyoike, T. W. (2007). Evaluation of Living and Synthetic Mulches with and without Imidacloprid for Suppression of Whiteflies and Aphids, and Insect Transmitted Viral Diseases in Zucchini squash. Masters' Thesis, University of Florida; Gaineville.

Ochieng, O.H., Opiyo, A.M., and Saidi, M. (2017). Different Agronet Covers Influence Physiological Traits, Growth and Yield of African Nightshade (*Solanum scabrum* Mill.) and Spiderplant (*Cleome gynandra* L.). *Journal of Plant and Soil Science,* 15(6): 1-12.

Ofori, E.S.K., Yeboah, S., Nunoo, J., Quartey, E.K., Torgby-Tetteh, W., and Gasu, E.K., and Ewusie, E.A. (2014). Preliminary Studies of Insect Diversity and Abundance on Twelve Accessions of Tomato, *Solanum lycopersicon* L. Grown in a Coastal Savannah Agro Ecological Zone. *Journal of Agricultural Science,* 6(8): 72-82.

Oliveira, G.C., Vieira, W.L., Bertolli, S.C., and Pacheco, A.C. (2015). Photosynthetic Behavior, Growth and Essential Oil Production of *Melissa officinalis* L. Cultivated under Colored Shade Nets. *Chilean Journal of Agricultural Research,* 76(1): 123-128.

Ombodi, A., Pek, Z., Szuvandzsiev, P., Taskovics, T.Z., Kohazi-Kis, A., Kovacs, A., Darazsi, H.L., and Helyes, L. (2015). Effects of External Coloured Shade Nets on Sweet Peppers Cultivated in Walk-in Plastic Tunnels. *Notulae Botanicae Horti Agrobotanici,* 43(2):398-403.

Oren-Shamir, M., Gussakovsky, E.E., Shpiegel, E., Nissim-Levi, A., Ratner, K., Ovadia, R., Giller, Y.E. and Shahak, Y. (2001). Coloured Shade Nets can improve the Yield and Quality of Green Decorative Branches of *Pittosporum variegatum*. *The Journal of Horticultural Science and Biotechnology,* 76(3):353-361.

Parvej, M.R., Khan, M.A.H., and Awal, M.A. (2010). Phenological Development and Production Potentials of Tomato under Polyhouse Climate. *The Journal of Agricultural Sciences*, 5(1): 19-31.

Pascual, S., Nombela, G., Avile's, M., and Muniz, M. (2003). Induced Resistance in Tomato to Whitefly *Bemisia tabaci* by Bion®. IOBC wprs Bulletin, 26(10): 61-64.

Peet, M.M., and Willits, D.H. (1995). Role of Excess Water in Tomato Fruit Cracking. *HortScience,* 30:65-68.

Pitt, R.E. (1982). Models for the Rheology and Statistical Strength of Uniformity Stressed Vegetative Tissue. *American Society of Agriculture and Engineering,* 25:1776-1784.

Pitt, R.E., and Chen, H.L. (1983). Time-dependent Aspects of the Strength and Rheology of Vegetative Tissue. *American Society of Agriculture and Engineering,* 26:1275-1280.

Ploeg, A.V., and Heuvelink, E. (2005). Influence of Sub-optimal Temperature on Tomato Growth and Yield. *Horticultural Sciences and Biotechnology,* 80(6):652-65.

Potter, T.I., Rood, S.B., and Zanewich, K.P. (1999). Light Intensity, Gibberellin Content and the Resolution of Shoot Growth in Brassica. *Planta*, 207:505-511.

Prohens, J., Miro, R., Rodroguez-Burruezo, A., Chiva, S., Verdu, G., and Nuez, F. (2004). Temperature, Electrolyte Leakage, Ascorbic Acid Content and Sunscald in Two Cultivars of Pepino, *Solanum muricatum*. *The Journal of Horticultural Science and Biotechnology,* 79(3):375-379.

Rajapakse, N. C. and Shahak, Y. (2007). Light Quality Manipulation by Horticulture Industry. In: G. Whitelam and K. Halliday (eds.), *Light and Plant Development,* Blackwell Publishing, UK. 290-312.

Rajapakse, N. C., Young, R. E., McMahon, M. J. and Oi, R. (1999). Plant Height Control by Photoselective Filter: Current Status and Future Prospects. *HortTechnolgy,* 9: 618-624.

Rajasekar, M., Arumugam, T., and Kumar, S.R. (2013). Influence of Weather and Growing Environment on Vegetable Growth and Yield. *Journal of Horticulture and Forestry,* 5(10):160-167.

Ranganna, S. (1986*). Handbook of Analysis and Quality Control for Fruit and Vegetable Products.* Tata McGraw Hill Publishing Co. Ltd., New Delhi.

Ranganna, S. (1997). *Manual of Analysis of Fruit and Vegetable Products.* Tata McGraw Hill Publishing Co. Ltd., New Delhi.

Ray, R.C., El Sheikha, A.F., Panda, S.H., and Montet, D. (2011). Anti-oxidant Properties and Other Functional Attributes of Tomato: An Overview. *International Journal of Food and Fermentation Technology,* 1(2):139-148.

Refaie, K.M., Esmail, A.A., and Medany, M.A. (2012). The Response of Banana Production and Fruit Quality to Shading Nets. *Journal of Applied Sciences Research,* 8(12): 5758-5764.

Ribeiro, A.S., Ribeiro, M.S., Bertolucci, S.K.V., Bittencourt, W.J.M., Carvalho, A.A.D., Tostes, W.N., Alves, E., and Pinto, J.E.B.P. (2018). Colored Shade Nets Induced Changes in Growth, Anatomy and Essential Oil of *Pogostemon cablin. Annals of the Brazilian Academy of Sciences,* 1-13.

Saidi, M., Gogo, E.O., Itulya, F., Martin, F., and Ngouajio, M. (2013). Microclimate Modification using Eco-friendly Nets and Floating Row Covers Improves Tomato (*Lycopersicon esculentum*) Yield and Quality for Smallholder Farmers in East Africa. *Agricultural Sciences,* 4(11):577-584.

Salunkhe, D.K., Jadhav, S.J., and Yu, M.H. (1974). Quality and Nutritional Composition of Tomato Fruit as Influenced by Certain Biochemical and Physiological Changes. *Quality Plant,* 1(2): 85-113.

Santana, J.Q., Balbino, M.A., Tavaros, T.R., Bezerra, R.S., Farias, J.G., and Ferreira, R.C. (2012). Effect of Photoselective Screens in the Development and Productivity of Red and Yellow Sweet Pepper. *Acta Horticulturae,* 956: 493-500.

Selahle, M.K., Sivakumar, D., and Soundy, P. (2014). Effect of Photo-selective Nettings on Post-harvest Quality and Bioactive Compounds in Selected Tomato Cultivars. *Journal of Science, Food and Agriculture,* 94:2187-2195.

Sen, F., Altun, A., Kesgin, M., and Inan, M.S. (2012). Effect of Different Shading Practices used at Pre-harvest Stage on Quality and Storage Life of Sultan Seedless Grapes. *Agricultural Science and Technology,* 2: 1234-1240.

Sen, F., Oksar, R.E., and Kesgin, M. (2016). Effects of Shading and Covering on `Sultana Seedless` Grape Quality and Storability. *Journal of Agricultural Science and Technology*, 18:245-254.

Shahak, Y. (2008). Photoselective Netting for Improved Performance of Horticultural Crops. A Review of Ornamental and Vegetable Studies Carried Out in Israel. *Acta Horticulturae*, 770:161-168.

Shahak, Y. and Gussakovsky, E.E. (2004). ColorNets: Crop Protection and Light Quality Manipulation in One Technology. *Acta Horticulturae*, 659:143-151.

Shahak, Y., Gal E., Offir Y. and Ben-Yakir, D. (2008). Photoselective Shade Netting Integrated with Greenhouse Technologies for Improved Performance of Vegetable and Ornamental Crops. *Acta Horticulturae,* 797:75-80.

Shahak, Y., Gussakovsky, E.E., Cohen, Y., Lurie, S., Stern, R., Kfir, S., Naor, A., Atzmon, I., Doron, I., and Greenblat-Avron, Y. (2004). Colournets: A New Approach for Light Manipulation in Fruit Trees. *Acta Horticulturae,* 636:609-616.

Shahak, Y., Ratner K., Giller Y.E., Zur, N., Or, E., Gussakovsky, E.E., Stern, R., Sarig, P., Raban, E., Harcavi, E., Doron, I., and Greenblat-Avron, Y. (2008). Improving Solar Energy Utilization, Productivity and Fruit Quality in Orchards and Vineyards by Netting. *Acta Horticulturae,* 772:65-72.

Simmons, A. M., Kousik, C. S. and Levi, A. (2010). Combining Reflective Mulch and Host Plant Resistance for Sweet Potato Whitefly (Hemiptera: *Aleyrodidae*) Management in Watermelon. *Crop Protection,* 29: 898-902.

Soares, J.D.R., Dias, G.M.G., Silva, R.A.L., Pasqual1, M., Labory, C.R.G., Asmar, S.A., Ramos, J.D. (2017). Photosynthetic Pigments Content and Chloroplast Characteristics of Tamarind Leaves in Response to Different Colored Shading Nets. *Australian Journal of Crop Science*, 11(3):29-299.

Solomakhin, A. and Blanke, M.M. (2010). Can Coloured Hailnets Improve Taste (Sugar, Sugar Acid Ratio), Consumer Appeal (Colouration) and Nutritional Value (Anthocyanin, Vitamin C) of Apple Fruits? *Food Science Technol*ogy, 43:1277-1284.

Solomakhin, A., and Blanke, M. (2009). The Microclimate under Coloured Hailnets Affect Leaf and Fruit Temperature, Leaf Anatomy, Vegetative and Reproductive Growth as well as Fruit Colouration in Apple. *Annals of Applied Biology,* 156:121-136.

Ssejjemba, K.F. (2008). Value Chain Analysis: Fresh Tomatoes in Uganda and Kenya 1-7.

Ssemwogerere, C., Ochwo-Ssemakula, N., Kathrynn, M., Kovach, J., Kyamanywa, S., and Karungi, J. (2013). Species Composition and Occurrence of Thrips on Tomato and Pepper as Influenced by Farmers' Management Practices in Uganda. *Journal of Plant Protection Research*, 53: 158-164.

Stampar, F., Veberic, R., Zadravec, P., Hudira, M., Usenik, V., Solar, A., and Osterc, G. (2002). Yield and Fruit Quality of Apples cv. `Jonagold` under Hail Protection Nets. *Gartenbauwissenschaft*, 67(5):205-210.

Stamps, R.H. (1994). Evapotranspiration and Nitrogen Leaching during Leatherleaf Fern Production in Shadehouses, SJRWMD Spec. Publ. SJ94-SP10. St. Johns River Water Management District, Palatka, FL.

Stamps, R.H. (2008). Differential Effects of Coloured Shade Nets on Three Cut Foliage Crops. *Acta Horticulturae*, 770:169-176.

Stamps, R.H. (2009). Use of colored shade netting in horticulture. *HortScience*, 44(2):239-241.

Sukhareva, I. L. (1999). Noctuidae. In: Kuznetsov V.I., ed. Insects and Mites -Agricultural Pests. V. 3, part 2. Lepidoptera. St. Petersburg: Nauka, 332-378.

Takeda, F., Glenn, D.M., Callahan, A., Slovin, J., and Stutte G.W. (2010). Delaying Flowering in Short Day Strawberry Transplants with Photo-selective Nets. *International Journal of Fruit Science*, 10:134-142.

Tanny, J., and Cohen, S. (2003). The Effect of a Small Shade Net on the Properties of Wind and Selected Boundary Layer Parameters above and within a Citrus Orchard. *Biosystems Engineering*, 84(1):57-67.

Tanny, J., Cohen, S. and Teitel, M. (2003). Screenhouse Microclimate and Ventilation: An Experimental Study. *Biosystems Engineering,* 84:331-341.

Tinyane, P.P., Sivakumar, D., and Soundy, P. (2013). Influence of Photo-selective Netting on Fruit Quality Parameters and Bioactive Compounds in Selected Tomato Cultivars. *Scientia Horticulturae,* 161:340-349.

Toker, C., Erler, F., Ceylan, F.O. and Canci, H. (2010). Severity of Leaf Miner (*Liriomyza cicerina*) (Rondani, 1875) (Diptera: Agromyzidae) Damage in Relation to Leaf Type in Chickpea. *Turkish Entomology Derg,* 34(2):211-225.

Tonnang, H.E., Mohamed, S.F., Khamis, F., and Ekesi, S. (2015). Identification and Risk Assessment for Worldwide Invasion and Spread of T*uta absoluta* with a Focus on Sub-Saharan Africa: Implications for Phytosanitary Measures and Management. *PLoS ONE,* 10(8):1-19.

Tumwine, J., Frinkling, H.D. and Jedger, M.J. (2002). Integrated Cultural Control Methods for Tomato Late Blight (*Phytophthora infestans*) in Uganda. *Annals of Applied Biology,* 14:225-236.

Ubelhor, A., Gruber, S., Schlayer, M., and Claupein, W. (2014). Influence of Row Covers on Soil Loss and Plant Growth in White Cabbage Cultivation. *Plant Soil Environment,* 60(9):407-412.

Uluguru Mountains Agriculture Development Project (UMADEP) (2003). Baseline Survey Report for Mlali Division Tanzania. 65.

Unemoto, L.K., de Faria, R.T., de Assis, A.M., and Destro, D. (2010). The Vegetative Development of *Sinningia leucotricha* Hoehne (Moore) under Different Levels of Shading. *International Journal of Brazilian Archives of Biology and Technology,* 53(1):47-53.

Varela, A.M.; Seif, A. and Lohr, B. (2003). *A guide to Integrated Pest Management (IPM) in Tomato production in Eastern and Southern Africa*. ICIPE Science press, Nairobi. 128.

Veit-Kohler, U., Krumbein, A., and Kosegarten, H. (1999). Effect of Different Water Supply on Plant Growth and Fruit Quality of *Lycopersicon esculentum*. *Journal of Plant Nutrition and Soil Science,* 162:583-588.

Velioglu, Y.S., Mazza, G., Gao, L., and Oomah, B.D. (1998). Antioxidant Activity and Total Phenolics in Selected Fruits, Vegetables and Grain Products. *Journal of Agricultural Food Chemistry,* 46:4113-4117.

Voican, V., Lacatus, V., and Tanasescu, M. (1995). Growth and Development of Tomato plants Related to Climatic Conditions from some Areas of Romania. *Acta Horticulturae,* 412:355-365.

Volschenk, H., van Vuuren, H.J.J., and Viljoen-Bloom, M. (2006). Malic Acid in Wine: Origin, Function and Metabolism during Vinification. *South Africa Journal of Enology Viticulture,* 27(2):123-136.

Walker, A.J., and Ho, L.C. (1977). Carbon Translocation in Tomato- Effects of Fruit Temperature on Carbon Metabolism and Rate of Translocation. *Annals of Botany,* 41:825-832.

Waterer, D., Bantle, J., and Sander, T. (2003). *Evaluation of Row covers Treatments for Warm Season Crops.* Saskatchewan Agriculture and Food. University of Saskatchewan, Saskatchewan, Canada. 410.

Weerakkody, W.A.P., Peiris, B.C.N., and Karunananda, P.H. (1999). Fruit Formation, Marketable Yield and Fruit Quality of Tomato Varieties Grown under Protected Culture in Two Agro-ecological Zones during the Rainy Season. *Journal of Natl. Sci. Foundation Sri Lanka,* 27:177–186.

Weinberger, K., and Lumpkin, T.A. (2005) *Horticulture for Poverty Alleviation- the unfunded revolution.* Shanhua, Taiwan. 220.

Widmer, A. (1997). Light Conditions, Assimilation and Fruit Quality under Hailnets. *Obst und Weinbau,* 133(8):197-199.

Widmer, A. (2001). Light and Fruit Quality under Hail Protection Nets. *Acta Horticulturae,* 557:421-427.

Yumbya, P., Ambuko, J., Shibairo, S., and Owino, W.O. (2014). Effect of Modified Atmosphere Packaging (MAP) on the Shelf Life and Postharvest Quality of Purple Passion Fruit (*Passiflora edulis* Sims). *Journal of Post-Harvest Technology,* 2(1): 25-36.

Zakher, A.G., and Abdrabbo, M. A. A. (2014). Reduce the Harmful Effect of High Temperature to Improve the Productivity of Tomato under Conditions of Newly Reclaimed Land. *Egyptian Journal of Horticulture,* 41(2): 85 -97.

Zekeya, N., Chacha, M., Ndakidemi, P.A., Chris Materu, C., Chidege, M., and Mbega, E.R. (2017). Tomato Leafminer (*Tuta absoluta* Meyrick 1917): A Threat to Tomato Production in Africa. *Journal of Agriculture and Ecology Research International,* 10(1): 1-10.

Zoran, S., Ilic, Milenkovic, L., Sunic, L., Baraci, S., Mastilovic J., Kevresan, Z., Fallik, E. (2017). Effect of Shading by Coloured Nets on Yield and Fruit Quality of Sweet Pepper. *Zemdirbyste-Agriculture,* 104(1): 53-62.

Zoratti, L., Jaakola, L., Haggman, H., and Giongo, L. (2015). Modification of Sunlight Radiation through Coloured Photo-Selective Nets Affects Anthocyanin Profile *Vaccinium Spp*. Berries. *PLoS ONE,* 10(8):1-17.

APPENDIX

Appendix I: Mean square table for factors affecting insect pest infestation of tomato

a). Whiteflies

Source of variation	df	Mean Square values							
		WF1	WF 2	WF 3	WF 4	WFT 1	WFT 2	WFT 3	WFT 4
Treatment	5	1.04***	1.41***	1.82***	5.23***	2.35***	1.94***	1.62***	1.45***
Season	1	0.55ns	1.11**	1.16**	0.04ns	0.56*	0.75**	1.36***	19.92***
Treatment*season	5	0.17ns	0.12ns	0.79***	0.13ns	0.23ns	0.18ns	0.15ns	0.04ns
Mean		94.13	100.33	89.67	184.07	302.48	372.17	489.82	300.67
C.V (%)		22.38	20.77	21.62	18.02	14.98	12.78	11.02	13.83

WF1- Whitefly at 28 DAT, WF2- Whitefly at 56 DAT, WF3- Whitefly at 70 DAT and WFT 4-Whitefly at 84 DAT

WFT1- Whitefly on yellow traps at 28 DAT, WFT2- Whitefly on yellow traps at 56 DAT WFT3-, Whitefly on yellow traps at 70 DAT WFT4- Whitefly on yellow traps at 84 DAT

*- significant at 0.05, **- significant at 0.01, ***- significant at 0.001 and ns- not significant

b). Aphids and Mites

Source of variation	df	Mean Square values							
		A1	A2	A3	A4	M1	M2	M3	M4
Treatment	5	0.15 ***	0.15***	0.28***	0.33***	0.24 ns	0.53***	0.72***	0.34**
Season	1	0.61***	4.40***	11.42***	13.17***	18.17***	5.60***	8.87***	26.56***
Treatment*season	5	0.01ns	0.02ns	0.04ns	0.22**	0.02ns	0.04ns	0.11ns	0.12ns
Mean		2.95	21.75	34.95	40.63	47.57	14.40	17.83	68.33
C.V (%)		23.46	11.55	13.83	16.77	40.56	29.77	28.65	20.90

A1- Aphids at 28 DAT, A2- Aphids at 56 DAT, A3- Aphids at 70 DAT and A4-Aphids at 84 DAT

M1- Mites at 28 DAT, M2- Mites at 56 DAT, M3- Mites at 70 DAT and M4- Mites at 84 DAT

*- significant at 0.05, **- significant at 0.01, ***- significant at 0.001 and ns- not significant

c). Thrips

Source of variation	df	Mean square values			
		T1	T2	T3	A4
Treatment	5	0.38**	0.31**	0.13*	0.85***
Season	1	1.03**	0.12^{ns}	0.23**	0.72*
Treatment*season	5	0.06^{ns}	0.14^{ns}	0.08^{ns}	0.14^{ns}
Mean		4.95	11.30	8.05	8.55
C.V (%)		46.23	27.25	25.20	44.85

T1- Thrips at 28 DAT, T2- Thrips at 56 DAT, T3- Thrips at 70 DAT and T4-Thrips at 84 DAT

*- significant at 0.05, **- significant at 0.01, ***- significant at 0.001 and ns- not significant

Appendix II: Mean square table for factors affecting growth of tomato

a). Plant height and diameter

		Mean Square values								
Source of variation	df	H1	H2	H3	H4	H5	D1	D2	D3	D4
Treatment	5	18.54^{ns}	43.52^{*}	101.72^{***}	178.83^{***}	269.88^{***}	2.63^{**}	4.34^{***}	4.55^{**}	3.72^{*}
Season	1	270.31^{***}	2490.76^{***}	170.52^{***}	641.68^{***}	3287.26^{***}	5.85^{**}	17.55^{***}	27.07^{***}	0.39^{ns}
Treatment*season	5	6.67^{ns}	7.70^{ns}	7.89^{ns}	30.60^{ns}	64.11^{*}	0.24^{ns}	0.47^{ns}	0.69^{ns}	1.19^{ns}
Mean		23.97	32.09	40.60	46.96	52.27	4.99	5.72	8.24	10.44
C.V (%)		14.40	12.33	11.72	10.86	9.52	16.81	13.46	11.67	11.76

H1- Height at 28 DAT, H2- Height at 42 DAT, H3- Height at 56 DAT, H4- Height at 70DAT and H5- Height at 84 DAT

D1- Diameter at 28 DAT, D2- Diameter at 56 DAT, D3- Diameter at 70 DAT and D4- Diameter at 84 DAT

*- significant at 0.05, **- significant at 0.01, ***- significant at 0.001 and ns- not significant

b). Number of branches and leaf stomatal conductance

Source of variation	df	Mean Square values							
		B1	B2	B3	B4	LSC1	LSC2	LSC3	LSC4
Treatment	5	2.72^{ns}	10.87^{***}	29.19^{***}	178.83^{***}	596.21^{ns}	116.93^{ns}	249.49^{ns}	86.01^{ns}
Season	1	8.07^{*}	32.27^{***}	26.67^{**}	641.68^{***}	67.18ns	2466.22^{**}	5633.77^{***}	6270.99^{***}
Treatment*season	5	2.43^{ns}	0.99^{ns}	2.31^{ns}	30.60^{ns}	72.92^{ns}	15.29^{ns}	74.99^{ns}	332.28^{ns}
Mean		4.50	6.97	1.54	12.40	53.21	53.08	43.14	44.21
C.V (%)		29.08	14.80	15.26	17.12	38.87	29.32	30.97	35.90

B1- Number of Branches at 28 DAT, B2- Number of Branches at 42 DAT, B3- Number of Branches at 56 DAT and B4- Number of Branches at 70DAT

LSC1- Leaf Stomatal Conductance at 28 DAT, LSC2- Leaf Stomatal Conductance at 56 DAT, LSC3- Leaf Stomatal Conductance at 70 DAT and LSC4- Leaf Stomatal Conductance at 84 DAT

*- significant at 0.05, **- significant at 0.01, ***- significant at 0.001 and ns- not significant

c). Number of internodes and internode length

Source of variation	df	Mean Square values							
		IN1	IN2	IN3	IN4	IL 1	IL 2	IL 3	IL 4
Treatment	5	0.83^{ns}	1.50^{ns}	1.08^{ns}	1.71^{ns}	0.46^{**}	0.60^{*}	1.08^{***}	0.77^{***}
Season	1	120.42***	286.02***	216.60***	198.02***	1.29^{**}	15.00^{***}	12.20^{***}	12.76^{***}
Treatment*season	5	0.54^{ns}	0.14^{ns}	2.24^{ns}	4.06^{ns}	20.14^{ns}	0.75^{**}	0.38^{*}	0.39^{*}
Mean		5.95	7.68	9.40	9.75	3.48	4.31	4.49	0.37
C.V (%)		12.58	14.65	11.49	13.29	10.38	10.03	7.81	7.64

IN1- Internode Number at 28 DAT, IN2- Internode Number at 56 DAT, IN3- Internode Number at 70 DAT and IN4- Internode Number at 84DAT

IL1- Internode Length at 28 DAT, IL2- Internode Length at 56 DAT, IL3- Internode Length at 70 DAT and IL4- Internode Length at 84 DAT

*- significant at 0.05, **- significant at 0.01, ***- significant at 0.001 and ns- not significant

Appendix III: Mean square table for factors affecting yield of tomato

Source of variation	df	Mean Square values					
		No. of fruits	No. of unmarketable fruit	No. of marketable fruits	Total weight	Marketable fruit weight	Unmarketable fruit weight
Treatment	5	758.76***	276.02***	493.02***	150193244***	103441019***	21102633.40***
Season	1	273.07*	286.02***	1118.02***	2495854499***	1557332918***	110154589***
Treatment*season	5	33.11ns	11.06ns	23.98ns	8785682ns	15081361ns	4878593.9ns
Mean		41.80	16.48	25.32	18878.8	12795.87	6082.32
C.V (%)		17.36	25.74	26.74	23.35	26.13	35.65

*- significant at 0.05, **- significant at 0.01, ***- significant at 0.001 and ns- not significant

Appendix IV: Mean square table for factors affecting post-harvest quality of tomato

a). Firmness

		Mean Square values									
		Trial One					**Trial Two**				
Source of variation	df	F1	F2	F3	F4	F5	F1	F2	F3	F4	F5
Treatment	5	0.96^{**}	0.73^{ns}	0.70^{*}	0.38^{**}	0.21^{***}	0.72^{*}	0.25^{ns}	0.17^{ns}	0.13^{ns}	0.29^{ns}
Mean		4.15	2.61	1.83	1.04	0.44	6.69	4.64	3.69	1.92	1.18
C.V (%)		10.02	20.01	22.79	26.77	36.35	7.02	17.04	15.04	16.18	33.33

F1- Firmness at 0-DAH, F2- Firmness at 4-DAH, TSS3- Firmness at 8-DAH, F4- Firmness at 12-DAH and F5- Firmness at 16-DAH

*- significant at 0.05, **- significant at 0.01, ***- significant at 0.001 and ns- not significant

b).Total Soluble Solids (TSS)

		Mean Square values									
		Trial One					**Trial Two**				
Source of variation	df	TSS1	TSS2	TSS3	TSS4	TSS5	TSS1	TSS2	TSS3	TSS4	TSS5
Treatment	5	0.07^{ns}	0.06^{ns}	0.09^{ns}	0.13^{ns}	0.24**	0.04^{ns}	0.02^{ns}	0.02^{ns}	0.09**	0.17***
Mean		3.75	4.07	4.44	4.80	5.18	4.31	4.43	4.53	4.69	5.26
C.V (%)		5.76	5.16	7.79	5.23	3.66	2.91	2.03	2.52	2.65	2.84

TSS1- TSS at 0-DAH, TSS2- TSS at 4-DAH, TSS3- TSS at 8-DAH, TSS4- TSS at 12-DAH and TSS5- TSS at 16-DAH

*- significant at 0.05, **- significant at 0.01, ***- significant at 0.001 and ns- not significant

c). Titratable Acidity (TA)

		Mean Square values									
		Trial One					**Trial Two**				
Source of variation	df	TA1	TA2	TA3	TA4	TA5	TA1	TA2	TA3	TA4	TA5
Treatment	5	0.006^{ns}	0.004^{ns}	0.003^{ns}	0.002^{ns}	0.001^{ns}	0.003^{ns}	0.003*	0.003*	0.004**	0.003**
Mean		0.66	0.40	0.36	0.31	0.29	0.40	0.37	0.35	0.33	0.31
C.V (%)		14.91	10.86	9.79	10.82	12.82	9.04	7.66	7.42	7.25	8.16

TA1- Titratable Acidity at 0-DAH, TA2- Titratable Acidity at 4-DAH, TA3- Titratable Acidity at 8-DAH, TA4- Titratable Acidity at 12-DAH and TA5- Titratable Acidity at 16-DAH

*- significant at 0.05, **- significant at 0.01, ***- significant at 0.001 and ns- not significant

d). Sugar: acid ratio

		Mean Square values									
		Trial One					**Trial Two**				
Source of variation	df	SA1	SA2	SA3	SA4	SA5	SA1	SA2	SA3	SA4	SA5
Treatment	5	0.39	4.38*	5.36ns	10.00ns	8.55ns	1.93ns	2.75*	2.49ns	4.80**	16.74**
Mean		5.81	10.25	12.72	15.61	18.35	10.81	11.96	12.94	14.25	17.14
C.V (%)		15.50	11.71	15.82	12.55	13.82	9.49	7.19	7.83	6.07	10.17

SA1- Sugar: Acid Ratio at 0-DAH, SA2- Sugar: Acid Ratio at 4-DAH, SA3- Sugar: Acid Ratio at 8-DAH, SA4- Sugar: Acid Ratio at 12-DAH and SA5- Sugar: Acid Ratio at 16-DAH

*- significant at 0.05, **- significant at 0.01, ***- significant at 0.001 and ns- not significant

Effect of Coloured Agro-net Covers on Insect Pest Control and Yield of Tomato (*Solanum lycopersicum* L.)

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Abstract

Tomato (*Solanum lycopersicon* Mill) is one of the most important vegetable crops consumed throughout the world; and is rich in important vitamins, minerals and antioxidants. Production of the crop in open fields is however constrained by several biotic and abiotic stresses that lead to low tomato yields and quality. This study aimed at determining the effects of coloured agro-net covers on microclimate, pest infestation and yield of tomato cultivar ''Rio Grande''. The study consisted of two trials conducted using a randomized complete block design (RCBD) with five replications and six treatments. Tomato plants were grown under blue, yellow, grey, white or multi-coloured net covers with a no net cover as the control. Data were collected on microclimate (temperature, soil moisture, relative humidity and photosynthetically active radiation), pest counts and crop yield variables. Net covering modified the tomato crop microclimate with highest temperatures and soil moisture and, relative humidity levels recorded under white (21.03^{o}C), blue (30.03%) and multi-coloured net covers (76.26%), respectively compared to the no net control treatment (16.32^{o}C, 14.82% and 64.90%). Photosynthetically active radiation (PAR) was lowest under the blue agro-net cover (416.09µmolm^{-2} s^{-1}) and highest under control treatment (985.00µmolm^{-2} s^{-1}). Tomato plants grown under coloured-colour nets (yellow and blue) had lower population of silverleaf whitefly, thrips and aphids while mite population was lower under neutral-colour net covers (white, grey and multi-coloured). The neutral-colour net covers (24938.87, 19525.16 and 21541.93kg/ha) resulted in higher yields compared to coloured-colour net covers (16804.62 and 14551.05kg/ha). Results of the study indicate that use of agro-net covers especially the neutral-colour net cover can improve microclimate, protect tomato against insect pests and can be considered a viable strategy for tomato production by smallholder growers.

Key words: *Solanum lycopersicum*; protected production; microclimate modification; agro-net cover