INFLUENCE OF ECO-FRIENDLY NETS AND FLOATING ROW COVERS ON MICROCLIMATE MODIFICATION, PEST INFESTATION, GROWTH AND YIELD OF TOMATO (*Lycopersicon esculentum* Mill.)

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DECLARATION AND RECOMMENDATION

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DEDICATION

To all my family members and friends who have encouraged me to aim for the sky in life. I thank you very much and may God bless you all.

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I humbly express my obeisance to the bountiful Lord Almighty, besides whom none is worthy for being worshiped, who bestowed me the health and courage to complete the assignment. I fortified myself to undertake the Masters of Science in Horticulture under the guidance of Dr. M. Saidi and Prof. F.M Itulya of Egerton University and Prof. M. Ngouajio of Michigan State University. I felt blessed being provided with such academic advisors. May I express my sincere and deep sense of gratitude for their personal affection, unified approach, towering personality, constant embodiment and generosity bestowed on me without which this work would have been an uphill task for me. May I also acknowledge Egerton University and the Department of Crops, Horticulture and Soils for their support during my study especially in the research work. It is beyond my means and capacity to put in words the generous support of the American people through the United States Agency for International Development (USAID) under Horticulture Collaborative Research and Support Program (HortCRSP) in the Award No. EPP-A-00-09-00004 for their financial support. I wish to acknowledge the project partners, KARI and ICIPE in Kenya; CIRAD in France, A to Z textiles in Tanzania and University of Abomey, INRAB, and APPRETEC in Benin for all the support they accorded in planning and implementation of the project. It gives me immense and fathomless pleasure to place on record my heartfelt gratitude to my parents and all my family members whose affection, concern, patience, dedication, sacrifice and blessing have always been my source of inspiration thus enabling me to complete the work successfully. Am deeply obliged to all those who helped directly or indirectly towards timely completion of this thesis work. Last but not least, I thank my critics whose imprecates gave me energy to correct any imperfections.

ABSTRACT

Tomato (*Lycopersicon esculentum* Mill.) is one of the important vegetables in human diets worldwide, especially for supplying vitamins, minerals and fiber. Successful production of the crop in many parts is, however, constrained by environmental variations as well as pest and diseases that severely affect its performance especially under open field production. In trying to address these constraints, a study was conducted in the Horticulture Research and Teaching Field, Egerton University, Kenya. The main objective was to determine the influence of agronets herein called eco-friendly nets (EFNs) and floating row covers (FRCs) on microclimate modification, pest infestation, growth and yield of tomato.

The research consisted of two parts: i) Transplant production and ii) Field production, each conducted over a span of two growing seasons. A Randomized Complete Block design with five replications was used in both the experiments. In transplant production, tomato seedlings were raised in the open or under permanent fine mesh net (0.4-mm pore diameter). In the field experiment, tomato was grown either in the open unsprayed or sprayed with chemicals (alphacypermethrine); under FRC maintained permanently covered or opened thrice a week from 9 am to 3 pm or under fine mesh (0.4-mm pore diameter) or large mesh EFN (0.9-mm pore diameter) maintained permanently covered or opened thrice a week from 9 am to 3 pm.

Covering plants with EFN or FRC modified the microclimate with higher temperature (26.8°C) and relative humidity (58.2%) recorded in both seasons. Starting seedlings under netting advanced seedling emergence by 2 to 3 days and resulted in higher emergence percentage (96.2%), thicker collar diameter, more leaves, and faster growth leading to early maturity of seedlings in readiness for transplanting in both seasons. Netting improved root development by increasing root quantity and length. In both seasons, leaf stomatal conductance and chlorophyll content were higher in seedlings under netting compared with the control. Insect pest and diseases were also reduced under net covering. The use of the net in transplant production resulted in 27.2% and 24.8% reduction in seed cost in season 1and 2, respectively. In the field tomato production, covering plants modified microclimate with higher temperatures, lower diurnal temperature range, lower relative humidity, and higher soil moisture under FRC used permanently compared with other treatments in both seasons. Tomato under FRC used permanently also resulted in significantly higher transplant take, thicker stems, more leaves, faster growth, better physiological development and early maturity. Yields and quality were generally improved under FRC and EFN treatments, with tomato under FRC used permanently giving more flower trusses and fruits per plant, marketable fruits, marketable weight, and marketable unit fruit weight compared with control treatments in both seasons. Fruits from covered treatments also had better quality attributes marked by firmer fruits, higher total sugar, less titratable acidity and higher sugar acid ratio compared with fruits under control treatments. Covering also helped in pest and disease control with less pest and disease incidences recorded in permanently covered treatments, compared with treatments where nets were opened 3 times a week as well as chemical sprayed treatments. Covers with smaller pore diameter and used permanently performed better than covers with larger pore diameter opened thrice a week. Results of this study indicate that ENFs and FRCs can be customized not only for their effective microclimate modification, improvement on growth, yield and quality of tomato, but also for pest and disease management in the nursery or field alone or as a component of integrated pest and disease management.

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LIST OF ABREVIATIONS AND ACRONYMS

ANOVA-	Analysis of Variance
CCIs-	Chlorophyll Concentration Index Units
DAP-	Days after Planting
DAT-	Days after Transplanting
EFNs-	Eco-friendly Nets
FAO-	Food and Agricultural Organization for United Nations
FRCs-	Floating Row Covers
GDD-	Growing Degree Day
HCDA-	Horticultural Crops Development Authority
HortCRSP-	Horticulture Collaborative Research Support Program
ICIPE-	International Centre of Insect Physiology and Ecology
IITA-	International Institute of Tropical Agriculture
MOARD-	Ministry of Agriculture and Rural Development
PAR-	Photosynthetic Active Radiation
RCBD-	Randomized Complete Block Design
SAS-	Statistical Analysis System
TA-	Titratable Acidity
TSS-	Total Sugar Solids
USAID-	United States Agency for International Developments
VPD-	Vapour Pressure Deficit
VWC-	Volumetric Water Content
WAT-	Weeks after Transplanting

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Tomato (*Lycopesicon esculentum* Mill.) belongs to the family Solanaceae (Britannica, 1990). It is believed to have originated in the coastal strip of western South America, from the equator to about 30° latitude south (Lanny, 2001; Naika et al., 2005). Being first domesticated in Mexico, the cultivated tomato was brought to Africa in the 16th century (Naika et al., 2005) and later to East Africa by colonial settlers in early 1900 (Wamache, 2005).

The crop is a half hardy, annual sub-tropical fruit vegetable, classified as a warm-season crop. It requires warm temperatures for good vegetative and reproductive growth. Optimum temperature for growth, yield and fruit quality of tomato is 20 to 24°C. At temperatures below 10°C or above 30°C, flowers are often shed, with a consequent poor fruit set. The quality of the fruits produced under such conditions may also be detrimentally affected. Although, the crop requires light for the process of photosynthesis, tomato may still produce better yields under reduced light conditions (Heinze and Borthwick, 1952; Al-Helal and Abdel-Ghany, 2010). The crop can also withstand a wide range of relative humidity conditions, as long as the changes are not drastic or frequent. While high relative humidity during the day has been shown to improve fruit set, it may also encourage disease development (Naika et al., 2005).

Tomato is a popular and versatile food crop that is grown and consumed all over the world and the second most important vegetable crop to potato (*Solanum tuberosum*) (Naika et al., 2005). The popularity of tomato among consumers has made it an important source of vitamins especially vitamins A and C in diets of many people. Apart from these vitamins, tomatoes have also been reported to be rich in lycopene, an antioxidant which purportedly fights free radicals that can interfere with normal cell growth and activity; thus reducing cancer, heart diseases and premature aging. Besides, tomatoes also contain good amounts of minerals and fiber (Nkondjock et al., 2005). The current world production is at about 300 million tons of fresh fruit produced on 3.7 million hectares of land (FAO, 2012). According to Food and Agricultural Organization statistical database, tomato production has been reported for 144 countries. Currently, China is the leading producer with 33,811,732 tons, with Kenya ranked 33rd

producing only 559,680 tons annually. In Africa, Kenya is ranked 6th after Egypt, Nigeria, Morocco, Tunisia, and Algeria (FAO, 2012).

Tomato production is one of the most promising areas for horticultural expansion and development in Kenya (MOARD, 2003; HCDA, 2006). It is an important vegetable crop for both small-scale and medium-scale growers with a potential for increasing income and creating employment opportunities. This may improve living standards in rural areas where poverty is prevalent (MOARD, 2003; Ortiz and Hartmann, 2003). The crop is grown for both fresh domestic and export market, with increasing demand for processing. In Kenya, tomato is produced in 18,692 ha of land (HCDA, 2011). According to HCDA (2011), tomato is the second most locally consumed vegetable after kales (*Brassica oleracea* var. acephala) and cabbages (*Brassica oleracea* var. capitata) combined (Brassicas). However, the yields are extremely low, 8 to 12 t/ha in the open fields (Mungai et al., 2000; Lanny, 2001) against the recommended (30 to 40 t/ha) (FAO, 2012). This has been attributed to both biotic stresses mainly insect pests and diseases as well as abiotic stresses, especially too much or limited rainfall and extreme temperature (Gielen et al., 1996; Abate et al., 2000; Tumwine et al., 2002; HCDA, 2006).

Late blight caused by *Phytophthora infestans*, is the most common disease of tomato and can cause yield loss of up to 100% if not controlled, especially during cool humid conditions (Tumwine et al., 2002). This being mostly the typical scenario during rainy season in the Kenyan highlands, especially under open field tomato production, farmers get discouraged from growing the crop during these periods due to the high prevalence of the disease. Insect pests like silverleaf whiteflies (*Bemisia tabaci*), aphids (*Macrosipham euphorbiae*) and thrips (*Frankliniella* sp.) that cause direct damage through sucking of plant sap and indirect damage through the transmission of viral diseases, also tend to be a common scenario, especially in open field production. Fungicides and pesticides are available for control, but they are quite expensive and small-scale farmers who account for the most tomato growers may not afford them. In addition, such chemicals are not friendly to humans as well as to the environment as a whole (Weinberger and Lumpkin, 2005). Greenhouse tomato production is being promoted to solve some of these problems. However, its adoption has been extremely slow, especially in the developing countries such as Kenya mainly due to the high costs involved in buying materials and erecting such

structures, rendering the technology not affordable to many farmers. As a result, majority of farmers still grow their tomatoes in the open fields, despite all the challenges (HCDA, 2006).

Use of eco-friendly nets (EFNs) in protected cultivation was tested in Africa (Martin et al., 2006; Licciardi et al., 2007) and proved to be effective against certain pests on cabbage. Moreover, such nets have also been used to protect crops from excessive solar radiation or other environmental hazards in the developed countries (Majumdar, 2010). As a result of microclimate improvement and pest exclusion, nets have been reported to increase yields and enhance quality of crops. Furthermore, use of nets in crop production has also been shown to reduce the use of pesticides, thus offering environmentally friendly means of controlling insect pests, and is relatively affordable to farmers (Martin et al., 2006; Licciardi et al., 2007; Majumdar, 2010).

The use of floating row covers (FRCs) as an effective pest management tool has also been increasing as a result of their ability to serve as a barrier against various insect pests, including aphids, cucumber beetles (*Acalymma* and *Diabrotica* sp.), whiteflies, and their related pathogens (Bextine and Wayadande, 2001; Berlinger et al., 2002; Boisclair and Bernard, 2006). In addition to insect exclusion, another noted effect of row covers on plants is the modification of environmental factors such as light, humidity, air movement and temperature within the vicinity of the growing crop (Wells and Loy, 1985). All these factors have been shown to have a direct impact on plant growth and development and hence, yield and quality. Row covers have been reported to significantly alter air temperature, thereby affecting plant growth through changes in leaf characteristics, biomass accumulation, and relative growth rate (Soltani et al., 1995). Row covers are also environmentally friendly since they reduce application of pesticides on crops by effectively managing pest through exclusion. Waterer (1995) demonstrated that use of row covers was both feasible from management perspective and desirable as a means for reducing cost and crop waste due to pest damage without sacrificing crop yields.

1.2 Statement of the Problem

Tomato production especially in the open field is greatly affected by unfavourable weather and heavy infestations from pest and diseases that severely reduce yield and quality. High relative humidity, unfavourable temperature during rainy season favours the development

of pest and diseases leading to more damage on tomato. During off season tomato production, water scarcity, high solar radiation and temperature cause flower or fruit abortion, poor pollination and encourage growth and development of certain pests, such as, aphids (*Aphis* sp.), silverleaf whiteflies, mites (*Tetranychus* sp.), onion thrips (*Thrips tabaci*), leafminers (*Lyriomyza* sp.) and cotton bollworms (*Helicoverpa armigera*) that even cause more damage to the crop. Use of greenhouses can mitigate such problems, but they are quite expensive, and most resource-poor farmers may not afford the materials and the installation cost involved. As a result, many farmers continue to grow tomato in open fields with low yields and quality as a common scenario during rainy seasons, and scarcity and high cost of produce in off seasons. Eco-friendly nets (EFNs) and FRCs technologies have successfully been used in other parts of the world to overcome some of these problems. The potentials of these technologies on microclimate modifications, their impact on pest infestation and crop production have, however, not been fully studied and exploited in Kenya.

1.3 Justification of the Study

Horticultural Crops Development Authority (HCDA, 2006) emphasized the need to increase the production of tomato in Kenya, especially during the rainy or off season when the demand for the crop is high and the production is low (8 to 12 t/ha). Tomato is highly susceptible to pest and diseases and this is more serious during bad weather. Eco-friendly nets (EFNs) and FRCs have not only been tested and found to be effective against pest and disease control in other countries, but also regulate microclimate for better growth, yield and quality of crops. These technologies have been used to modify temperatures, relative humidity as well as blocking excessive solar radiation within the vicinity of the growing crop thus reducing the need for frequent watering through effective soil moisture conservation. They also physically exclude pests as well as discourage the development of some pests and diseases by creating unfavourable conditions around the growing crop, while making conditions favourable for the growth and development of plants. The use of EFNs or FRCs reduces the need for application of pesticides and other chemicals, thus improving the environmental quality. Understanding microclimate changes, pest infestation and their impact on plant growth and morphology as a result of use of

these technologies is critical for making good use of the technologies. These technologies will provide farmers with an alternative protected cropping system that is affordable with improved microclimate control, reduced pest incidences for better yields and marketable quality tomatoes. In turn, these lead to increased production of tomatoes thus improving the health and living standards of people while maintaining a healthier environment. In addition, the results of this study will add to the existing knowledge in tomato production.

1.4 Objectives of the Study

1.4.1 General Objective

The main objective of this study was to contribute towards increased tomato yields and quality by providing alternative means of protected cropping through use of eco-friendly nets (EFNs) and floating row covers (FRCs) that are environmentally friendly, inexpensive and relatively affordable to farmers.

1.4.2 Specific Objectives

The specific objectives of this study were to:

a) Determine the effects of EFNs on tomato transplant growth and quality.
b) Determine the effects of EFNs and FRCs on microclimate modification, pest population and damage, growth and yield of tomato.
c) Determine the effects of cover pore diameter on microclimate modification, pest population and damage, growth and yield of tomato.
d) Determine the effects of cover opening on microclimate modification, pest population and damage, growth and yield of tomato.
e) Establish the relationship between microclimate conditions, growth and yield of tomato.

1.5 Research Hypotheses

The following research hypotheses were tested:

1. Eco-friendly nets (EFNs) improve tomato transplant growth and quality.
2. Eco-friendly nets (EFNs) and FRCs affect microclimate; reduce pest population and damage, improve growth and yield of tomato.

3. Cover pore diameter affects microclimate, pest population and damage, growth and yield of tomato.
4. Cover opening affects microclimate, pest population and damage, growth and yield of tomato.
5. Relationships exist between microclimate conditions, growth and yield of tomato.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 A Brief Overview of Tomato under Protected Culture

There is a growing interest among tomato growers in systems that ensure continuous production due to an increasing demand for the produce among consumers and processors. One way to achieve this is through protected cultivation. Protected culture is predominantly used in temperate regions where seasonal agro-climatic changes restrict all year round cultivation of perishable horticultural crops under open-field conditions. In addition, such systems protect plants from pest problems and adverse environmental conditions, enabling the production of high yields and quality produce (Aoki, 1995). According to El-Aidy and Sidaros (1996), higher tomato yield may be achieved from protected tomato seedlings than non-protected seedlings. Their results indicated that use of protected tomato seedlings improved plant height, number of leaves, branches, and flower buds per plant. Total yield was higher by about 58 to 92% than of non- protected seedlings. On the other hand, low yield of protected tomato were reported by Jourbert and Poissonier (1991) during summer in France as a result of high heat accumulation based on which, they recommended periodic opening of the structure during day time in such situations.

Insect pests and diseases are serious problems in the cultivation of tomato. In a study done in Israel, Berlinger et al. (2002) reported effective management of TYLCV (tomato yellow leaf curl virus) through physical exclusion of silverleaf whiteflies in tomato grown under exclusion screen. In another study, TYLCV infection ratio was decreased from 35% in non-protected seedlings to 20% in protected ones (El-Aidy and Sidaros, 1997). Significantly higher transplant success (84%), dry weight and height of tomato plants grown in row covers than those in the control (uncovered) were reported due to modified internal temperatures (Weerakkody, 1998). Due to these advantages, Iqbal (1987) recommended its applicability in the tropical environments especially for cultivating high value crops such as tomato during rainy seasons.

2.2 Influence of Nets on Microclimate Modification, Pests and Performance of Crops

Netting is frequently used to protect agricultural crops from unfavourable environmental conditions and pests. It is either applied by itself over net-house constructions, or combined with greenhouse technologies. Black nets are commonly used for shading, while clear and transparent nets are used against unfavourable environmental conditions, or pest protection. In many parts of the world, nets or screens are commonly used in crop production for reducing excessive solar radiation and to keep away insects (Majumdar, 2010). Net-houses or its variants have been used in some European, South American, South East Asian and African countries for producing eggplant (*Solanum melongena*) (Kaur et al., 2004) and cabbage (Martin et al., 2006; Licciardi et al., 2007). In Benin, mobile net-houses made of mosquito nets were effective as physical barrier against diamondback moth (*Plutella xylostella*), cutworms (*Agrotis* sp.) and loopers (*Trichoplusia ni*) (Martin et al., 2006).

Protecting vegetables with a screen in rural areas of tropical countries may reduce or even eliminate often indiscriminate insecticide applications by small-scale farmers (Licciardi et al., 2007). The advantages of such approach are protection of human health by reducing insecticide sprays, reducing environmental pollution from insecticide residues and increasing effectiveness of crop protection. Tunnel screens are well adapted for farmers cultivating intensively on small plots. In a study conducted to test the ability of screened tunnels to protect cabbage, Licciardi et al. (2007) reported that tunnel screens impregnated with deltamethrin were particularly well adapted for protecting young plants in nurseries against infestations by aphid (*Lipaphis erysimi*). In addition, the number of diamondback moth and borer (*Hellula undalis*) on cabbage protected with the tunnel screen was significantly lower than in plots conventionally treated with insecticides. However, a tunnel screen was not efficient against the armyworm (*Spodoptera littoralis*) which laid eggs on the screen. After planting out, the use of a temporary screen from 1700 to 0900 h gave better control against pests than the use of a permanent screen (Martin et al., 2006; Licciardi et al., 2007). In a study done on cauliflower (*Brassica oleracea* var. botrytis), Kashyap and Dhiman (2010) noted that covering the nursery with nylon net reduced the incidences of alternaria blight (*Alternaria brassicicola*) and black rot (*Xanthomonas campestris*) by 20 and 15%, respectively.

Research in Israel suggested that coloured net-houses (ColorNets) may reduce temperature fluctuations and promote better physiological growth of plants (Shahak et al., 2004). In studies with several crops grown under various coloured shade nets of the same shading factor (50 to 80% shade), it was reported that black net had higher yields than the other coloured nets. Compared with the black net, red and yellow nets stimulated overall vegetative growth, while blue caused dwarfing. Grey, on the other hand, enhanced branching, yielding "bushy" plants with short branches, smaller leaves and less variegation. In cut flower crops, the ColorNets also differentially affected the flowering time and quality (Oren-Shamir et al., 2001; Shahak et al., 2002).

A field experiment was carried out to study the microclimate and air exchange rate of an insect exclusion fine mesh net for pepper (*Cupsicum annuum*) cultivation in Israel. Diurnal courses of plant transpiration, internal temperature and humidity at three heights were measured across the nethouse. Humidity and temperature profiles showed that within the nethouse, temperature increased and absolute humidity decreased with increasing height. Ventilation rates were compared with a theoretical calculation for an open pepper field. Covering the field with a nethouse reduced ventilation rates by 51–71% (Tanny et al., 2003). Use of netting in crop production may also reduce photosynthetic active radiation (PAR), especially during the cloudy conditions. However, in summer seasons, the photosynthetic active radiation (PAR; 400–700 nm) that is transmitted through net-covered structures usually fulfills crop growth requirements because outside incident PAR is high (Al-Helal and Abdel-Ghany, 2010).

Mesh size of the nets is very critical in crop production. Antignus et al., (1998) reported that, size of the openings on the nets has an effect on insect penetration and microclimate modification. A study in Benin has already proven and recommended the use of appropriate mesh size of insect proof nets for different insect pest exclusion. However, knowledge on the effect of mesh sizes on the climate inside the net is still limited (Martin et al., 2006). Harmanto et al. (2006) reported that net opening has an influence on the air exchange rates and also affects the light quantity transmission (Klose and Tantau, 2004). Mutwiwa et al. (2007) showed that large ventilation openings increased air exchange rate and hence, lower air temperature, but

allowed in more pests. More studies involving nets and different crops including tomato which are affected by weather and pests may thus be beneficial.

2.3 Influence of Floating Row Covers on Microclimate Modification, Pests and Performance of Crops

Many warm season crops such as tomato may benefit from the cover provided by row covers. Waterer et al. (2001) reported that crops grown under row covers were robust and healthy making them ideally suited for a confined environment. Recently, photo-selective row filters have been developed that are able to alter the ratio of red to far red in incoming sunlight for photo-morphogenesis control. In a study conducted on both photo-selective row cover and standard perforated clear polythene on melon (*Cucumis melo*) and pepper, there was a significant increase on vine length and fruit yield on both crops grown under the covers (Waterer et al., 2001).

Under normal field conditions, carbon dioxide gas (CO_2) levels are typically between 350 and 400 ppm. Once the CO_2 levels fall below 200 ppm, photosynthesis and growth slow down while higher than normal CO_2 levels (350 and 400 ppm) can accelerate plant growth. Deficit CO_2 commonly occur within the confines of row covers by restricting air movement in the vicinity of the crop just like in greenhouses. In a study of CO_2 levels in the low tunnels using perforated and non-perforated row covers, the photosynthetic activity of the crops under perforated row covers were not affected especially for those which were periodically opened during the day. Crops grown under non-perforated polythene tunnels suffered from CO_2 deficiency and heat stress associated with the absence of adequate ventilation. However, perforated clear polythene resulted in the greatest enhancement of air temperatures and CO_2 in the vicinity of the crop (Waterer et al., 2002). Non-perforated polythene tunnels can therefore be beneficial in the cooler environments, but temperatures under clear poly covers may become excessive on warm sunny days, thus necessitating opening (Gerber et al., 1989).

Currently, the concept of zip tunnels has been introduced in an effort to combine the best of both perforated and non-perforated row covering. Such tunnels are constructed of clear non-perforated polyethylene to produce maximum warming, but the tops of the tunnels are always open to allow for some ventilation. A drawstring system allows the size of this opening to be

varied, depending on the prevailing conditions and the needs of the crop. In a study conducted using clear non-perforated row covers, perforated row covers (Reemay) and zip row covers on melon and pepper, total yields of both crops from the different covers were not significantly different. However, in the 'Reemay' treatments, over 25% of pepper turned red prior to frost compared with only 7 to 12% of the other treatments. The more porous woven 'Reemay' covers were reported to produce more stable and moderate growing conditions that eventually led to higher yields and quality pepper. In the case of melon, the poly covers allowed twice as many of the fruits to reach maturity prior to frost than in the zip tunnels. Thus, zip tunnels which theoretically were the best, were found to be costly and difficult to manage with no appreciable advantages over the standard types of row covers (Waterer et al., 2003).

In Canada, a study was done on modified transplant production techniques to increase yield and improve earliness of Brussels sprouts (*Brassica oleracea* var. gemmifera) (Gaye and Maurer, 1991). Their results indicated that, use of row covers increased soil temperatures and advanced seedling development and transplanting dates compared with uncovered treatments. In addition, more marketable yield was recorded under row covers compared with uncovered treatments. In the same country, Rekika et al. (2008) reported improved germination and reduction in carrot weevil (*Listronotus oregonensis*) infestations in carrot (*Daucas carota*) by use of floating row covers compared with uncovered treatments.

In Michigan State University, Nair and Ngouajio (2010) noted increase in the growing degree-day (GDD) accumulations, air and soil temperature by 50% under row covers when compared with uncovered treatment and the impact of row covers on the growth of cucumber (*Cucumis sativus*) was significant. Use of row covers increased vine length, flower count, leaf area, leaf count, plant biomass, and total marketable yield. It was also noted that row covers may also reduce the amount of sunlight reaching the plants with the reduction being dependent on the row cover material. Moreno et al. (2002) reported reduced instantaneous solar radiation by 13% while using standard row covers and lower cumulative solar radiation by 17 and 16% under perforated polythene and polypropylene FRCs, respectively. Nair and Ngouajio (2010) reported strong correlation between growing degree hours with leaf number and leaf dry weight.

Although it is desirable to maintain a higher air temperature near the plant canopy, it can also lead to crop injury (Soltani et al., 1995). Higher temperatures under row covers have been correlated with yield loss when temperatures exceed 40 °C (Peterson and Taber, 1991). Furthermore, increased temperatures have been reported to induce heat stress thus affecting pollination and fruit set (Gerber et al., 1989; Gaye et al., 1992).

Soil temperature is also important in crop production. Nair and Ngouajio (2010) noted increased soil temperatures under row covers compared with uncovered treatment. Increased soil temperature has been shown to be beneficial to crops as it enhances root growth and accelerates nutrient uptake, plant growth and overall development (Gordon, 2006). Relative humidity is also critical for both crop and pest and disease development. Very high relative humidity (greater than 90%) is undesirable for production since it encourages disease development. Relative humidity tends to be higher under row covers as a result of reduced evapotranspiration and condensation of water within the row covers under field conditions (Lamont, 1996; Moreno et al., 2002). However, it is also possible that the high temperature under the row covers may reduce relative humidity by increasing vapor pressure deficit (VPD) as demonstrated by Nair and Ngouajio (2010).

Limited studies have been done regarding the role of FRC in pest exclusion in Africa. In the USA, Bextine and Wayandande (2001) reported reduced incidences of aphids, cucumber beetles and whiteflies, which in turn reduced the applications of pesticides associated with the pests under FRC compared with uncovered treatment. In Canada, Thériault et al. (2009) also noted reduced incidences of cabbage worm (*Pieris rapae*) on broccoli (*Brassica oleracea* var. italica) under FRC. In the same country, FRC completely excluded cabbage maggots (*Delia radicum*) and significantly reduced flea beetle (*Phyllotreta* sp.) damage by 60% compared with control plots (Rekika et al., 2008). In Spain FRC also significantly reduced the incidences of cucumber mosaic virus, tomato spotted wilt virus and tomato yellow leaf curl virus associated with such vectors as aphids, thrips and whiteflies, respectively on pepper (Avilla et al., 1997). Delayed removal of row cover treatments significantly suppressed bacterial wilt (*Erwinia tracheiphila*) and enhanced muskmelon (*Cucumis melo*) yield compared with the control (uncovered) in USA (Rojas et al., 2011).

CHAPTER THREE

3.0 METERIALS AND METHODS

The study comprised of 2 parts: i) Tomato transplant production and ii) Tomato field production.

3.1 Experimental Site

Both the nursery and field studies were conducted at the Horticulture Research and Teaching Field, Egerton University, Njoro, Kenya. The field lies at latitude of 0°23'S and longitude 35°35'E in the Lower Highland III Agro Ecological Zone (LH3) at an altitude of ~2238 m above sea level. Average maximum and minimum temperatures range from 19 to 22°C and 5 to 8°C, respectively, with a total annual rainfall of 1200 to 1400 mm. Soils are predominantly andosols with a pH of 6.0 to 6.5 (Kassilly, 2002).

3.2 Tomato Transplant Production

The nursery experiment was conducted in a span of two seasons (Mar. to Apr. 2011 and Sept. to Oct. 2011).

3.2.1 Planting Material

'Rio Grande' tomato seeds (Kenya Seed Co., Kitale, Kenya) were used in the experiment. This is a determinate tomato variety and was chosen because of its great tolerance to diseases and a high yielding potential that makes it preferred by many farmers (HCDA, 2006).

3.2.2 Experimental Material, Design and Treatments

The experimental design used was a Randomized Complete Block design with two treatments and five replications (Fig. 1). Treatments consisted of tomato seeds raised either under fine mesh net (0.4-mm pore diameter) (AgroNet; A to Z Textile Mills, Arusha, Tanzania) or in the open (control). Immediately after sowing, metal arches (U-shape) 0.5-m high and 1-m wide were placed over the plots and secured in the soil. These arches were then used to support the net over the nursery. Once placed, the nets were pegged at each corner to minimize wind interference.

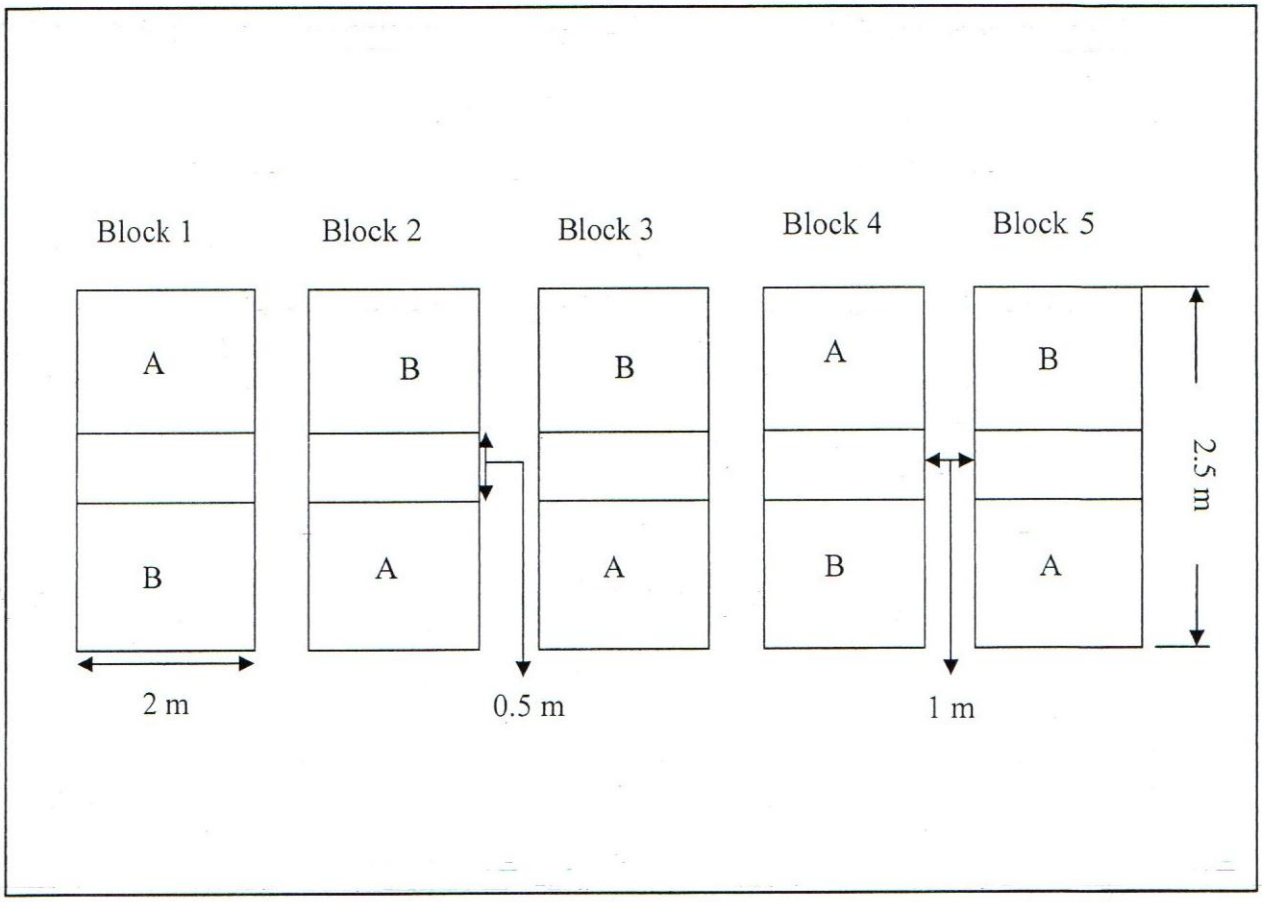


Fig. 1. Experimental layout for the nursery experiment. A- Unprotected nursery bed (control) and B- Nursery bed with fine mesh net (0.4-mm pore diameter) used permanently.

3.2.3 Land Preparation and Maintenance Practices

Experimental plots were manually prepared to about 20-cm depth with final preparation using a fine tooth rake. Beds of 1 x 2 m were prepared and raised to 15-cm high. Thirteen drills, 1-m long and 15-cm apart, were prepared per bed. Tomato seeds were sown at a spacing of 1 cm within the drills. For the control experiments, mulching with dry grass was done, but the mulch was removed after first seedling emergence, as a standard practice used by local farmers. Thereafter, watering was done manually to field capacity whenever necessary ensuring that an equal amount was applied to each plot. Weeding and all other management practices were applied uniformly in all plots.

3.2.4 Data Collection

(i) Microclimate

A thermo-Hygrometer (HM9; Shangai Precision and Scientific Instrument Co., Shangai, China) was mounted at the center of each bed to monitor relative humidity and air temperature. Data were collected and recorded on daily basis in the morning (8.00 AM), at noon, and in the evening (4.00 PM) and averaged to get the daily average relative humidity and temperature.

(ii) Leaf Stomatal Conductance and Chlorophyll Content

Leaf stomatal conductance ($mmol \cdot m^{-2} \cdot s^{-1}$) and chlorophyll content in chlorophyll content index units (CCIs) were determined on the two lower true leaves of 20 randomly selected tomato seedlings from the central rows of each plot, starting 21 days after planting (DAP) through the fifth week on a weekly basis. A steady state leaf porometer (SC-1; Decagon Devices, Pullman, WA) and chlorophyll content meter (CCM-200 plus; Opti-Sciences, Tyngsboro, MA) were used, respectively.

(iii) Seedling Emergence

The number of days from planting to first seedling emergence was recorded for every treatment. Thereafter, seedling numbers were counted on a 2-days interval for 1 week, and the progressive emergence percentages were computed for each treatment.

(iv) Seedling Growth

Twenty central tomato seedlings were randomly selected and tagged for data collection on the first day of seedling growth data collection. From these plants, seedling height was measured using a ruler (GTS-R-078; Shangai Precision and Scientific Instrument Co., Shangai, China), collar diameter using vernier calipers (BS-H074; Shangai Precision and Scientific Instrument Co., Shangai, China), and number of leaves were determined on a weekly interval. During seedling harvesting, 10 seedlings were randomly selected, carefully uprooted, the roots washed with clean water and the length of the main root measured using a ruler and number of lateral roots counted.

(v) Insect Pest Population and Disease Incidences

The species and number of insect pests were counted on a weekly basis from 20 central tomato seedlings selected at random in each plot at each data collection date beginning 1 week after emergence. From the same seedlings, those that showed disease symptoms were also counted and recorded to determine percent disease incidence.

vi) Seed Requirement and Cost per Unit Area

From the percentage emergence, seed requirement and cost of seed per hectare were estimated for the different treatments.

3.2.5 Data Analysis

The Proc univariate procedure of SAS (version 9.1; SAS Institute, Cary, NC) was used to check for normality of the data before analysis. Data for pest population and disease incidences were transformed using square root and arcsine transformation, respectively. Data were then subjected to Analysis of Variance (ANOVA) at $P \leq 0.05$ using GLM. Means for significantly different treatment were separated using Tukey's honestly significant difference (THSD) test at $P \leq 0.05$. The fitted statistical model was:

$Y_{ijk} = \mu + \beta_i + \alpha_j + s_k + \alpha s_{jk} + e_{ijk},,$ where; Y_{ijk} is the tomato seedling response, μ is the overall mean, β_i is the i^{th} blocking effect, α_j is the j^{th} net covering effect, s_k is the k^{th} season effect, αs_{kj} is

the interaction effect between the j^{th} net covering and k^{th} season and ε_{ijk} is the random error term which are normally and independently distributed about zero means with a common variance σ^2.

3.3 Tomato Field Production Experiment

The field production experiment was conducted in a span of two seasons (May. to Oct. 2011 and Oct. 2011 to Mar. 2012).

3.3.1 Planting Material

'Rio Grande' tomato transplants were used in the experiment. Seedlings used in the field experiment were taken from the protected nursery. This was done because the seedlings in the protected nursery were found to be more superior than those from the unprotected ones.

3.3.2 Experimental Design and Treatment Application

The experimental design was a Randomized Complete Block design with five replications (Fig. 2). Transplants were established under the following treatments: i) open unsprayed (as the control), ii) open sprayed with chemicals (alphacypermethrine and lambda cyhalothrine), iii) FRC used permanently, iv) EFN with fine mesh (0.4-mm pore diameter) used permanently, v) EFN with large mesh (0.9-mm pore diameter) used permanently, vi) FRC opened three times a week from 9:00 am to 3:00 pm, vii) EFN with fine mesh (0.4-mm pore diameter) opened three times a week from 9:00 am to 3:00 pm, and viii) EFN with large mesh (0.9-mm pore diameter) opened three times a week from 9:00 am to 3:00 pm. Row covers and nets were manufactured by Agribon; Mooreville, NC and AgroNet; A to Z Textile Mills, Arusha, Tanzania, respectively.

There were a total of 40 plots in the field experiment each measuring 1 x 8 m of which 10 were covered with 0.4-mm mesh size and another 10 covered with 0.9-mm mesh size. 10 plots were also covered with FRC and the remaining 10 plots were left in the open out of which 5 were unsprayed and the other 5 were sprayed with chemicals. FRC and EFN used measured 3 m wide and 11 m long (Fig. 3). Each block measured 71 x 1 m separated by a 1-m buffer from the adjacent block. In every plot, three, posts 1.2 m long were placed 4 m apart along the 8 m bed to

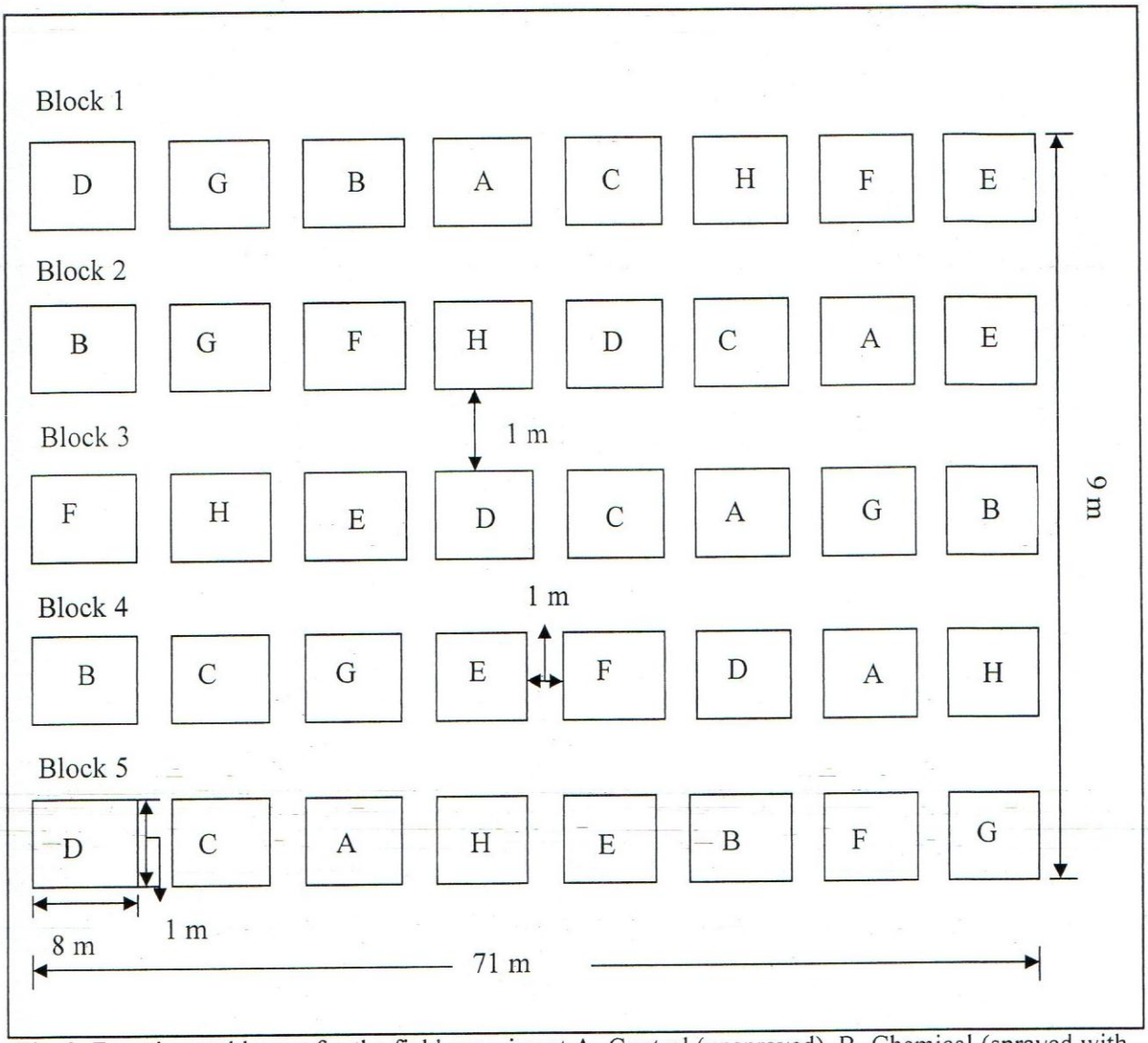


Fig. 2. Experimental layout for the field experiment A- Control (unsprayed), B- Chemical (sprayed with alphacypermethrine), C- FRC used permanently, D- EFN with fine mesh (0.4-mm pore diameter) used permanently, E- EFN with large mesh (0.9-mm pore diameter) used permanently, F- FRC opened 3 times a week from 9:00 am to 3:00 pm, G- EFN with fine mesh (0.4-mm pore diameter) opened 3 times a week from 9:00 am to 3:00 PM, and H- EFN with large mesh (0.9-mm pore diameter) opened 3 times a week from 9:00 am to 3:00 pm.



Fig. 3. Structure of floating row covers and eco-friendly nets covering the tomato crop in the field A- Floating row cover B- Control C- 0.9-mm net D- 0.4-mm net.

act as the net and the crop support system. These were grounded to 20 cm depth, and then binding wire 9 m long was pinned 30 cm apart from the ground to the top of the posts. Additionally, for the protected treatments, ordinary mild steel (R6) were cut at 1 m length and placed on top of each post, fastened by U-nail and bent to provide a tunnel shape for dressing the nets and row covers.

3.3.3 Land Preparation, Crop Establishment and Maintenance

The field was ploughed to ~20 cm depth and later harrowed to give a fine tilth. Transplanting holes were manually dug using a jembe and diammonium phosphate (DAP 18%N, 46%P_2O_5) applied at 200 Kg/ha (HCDA, 2006) and thoroughly mixed with the soil prior to transplanting. Tomato seedlings were transplanted in one row 8-m long at 50 cm spacing (Naika et al., 2005) within the row giving 16 tomato plants per treatment. Before covering was done, a pesticide (alphacypermethrine) was sprayed on all treatments to ensure any pests that might have attacked the seedlings during transplanting process were managed. Thereafter, standard good agricultural practices including fertilizer application, watering, weeding and training were done uniformly on all treatments as deemed necessary.

3.3.4 Data Collection

a. Microclimate

WatchDog Plant Growth Station data loggers (2475; Spectrum Technologies, Plainfield, IL) were used to collect climatic data. Each Data logger was screwed 0.5 m high on a wooden post at the center of each treatment. Data were recorded and averaged weekly. On weekly basis, the data were downloaded into the computer and printed to ensure safety. Data collected included; air temperature (°C), diurnal temperature range (°C), relative humidity (%), volumetric water content (%) using an external sensor (WaterScout^{TM} SM 100), photosynthetic active radiation ($mmol \cdot s^{-1} \cdot m^{-2}$), and light quantity ($mol \cdot d^{-1}$).

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b. Physiological Characteristics of Plants

Stomatal Conductance: Leaf stomatal conductance ($mmol \cdot m^{-2} \cdot s^{-1}$) was measured on 14 middle tomato plants from each treatment using a steady state leaf porometer (SC-1, Decagon Devices, Pullman, WA) on a 2 weeks interval beginning 21 days after transplanting (DAT). Since tomato plants are hypostomatous, stomatal conductance was measured only on the abaxial leaf surface on 3 leaves on the lower, middle and the upper parts of the plant.

Chlorophyll Content: On the same leaves from which stomatal conductance was measured, chlorophyll content was also measured using a chlorophyll content meter (CCM-200 plus; Opti-Sciences, Tyngsboro, MA) in chlorophyll concentration index units (CCIs), as an estimate of chlorophyll content on leaves.

c. Growth Parameters

Transplant take: Three days after transplanting, the number of transplants that successfully took off was counted and their percentage computed.

Plant Height: Tomato plant height was measured from the ground level to the tip of the plant using a ruler (GTS-R-078; Shangai Precision and Scientific Instrument Co., Shangai, China), on the 14 middle plants. This was done weekly starting 30 DAT.

Leaf Numbers: From the same plants, on which plant height was measured, fully expanded leaves were also counted and their numbers recorded.

Collar Diameter: Collar diameter of the 14 tagged plants was also determined using vernier calipers (BS-H074; Shangai Precision and Scientific Instrument Co., Shangai, China).

Maturity: Days to first maturity of tomato fruits in the 14 middle plants were determined and recorded. Those fruits that had a turning blossom end (pink stage) were considered mature.

d. Yield and Yield Components

Number of Flowers: The number of flower trusses in each of the 14 middle plants were counted and recorded on weekly basis for two months.

Fruit Numbers per Plant: Once every two weeks, fruits on the 14 middle plants were counted and recorded. Each time the fruits were counted, the number of fruits from the previous week was subtracted from the current number to determine the fruit number for that count.

Marketable and Non-marketable fruits: Physiologically mature fruits (at pink stage) were harvested from the 14 middle plants in each treatment. Harvesting was piece meal on weekly basis. At each harvest, fruits were sorted into marketable and non-marketable (no./ha) separately and their numbers determined and recorded.

Fruit Weight: Mature marketable fruits (at pink stage) were harvested from the 14 middle tomato plants from each treatment then weighed using a spring balance (ATZ; Shangai Precision and Scientific Instrument Co., Shangai, China) at each harvest. This was later summed up to give the total marketable weight (t/ha).

Marketable Unit Fruit Weight: Ten fruits were randomly selected from each treatment and weighed using a digital weighing scale (XJ-4K801; Shangai Precision and Scientific Instrument Co., Shangai, China). The results were used to compute weight per fruit (g/fruit).

e. Quality Parameters

Firmness: Harvested tomato fruits from the individual treatments at red ripe stage were used to determine fruit firmness (KgF) using a hand held penetrometer (FT327; Shangai Precision and Scientific Instrument Co., Shangai, China).

Total Soluble Solids (TSS): Total soluble solids were determined using a hand held refractometer (RHB; Shangai Precision and Scientific Instrument Co., Shangai, China) as per the procedure described by Tigchelaar (1986).

Titratable Acidity (TA): This was determined for the same fruits used to determine total soluble solids using the coloured indicator method as described by Turhan and Seniz (2009).

TSS to TA Ratio: This was computed using the formula;

$$\textbf{Percentage acid} = \frac{\text{Titre x acid factor x 100}}{\text{10 ml of tomato juice}}$$

NB: The predominant acid in tomato is citric acid with an acid factor of 0.064 (Anonymous, 1968).

Sugar to acid ratio was then obtained using the formula;

Sugar:acid ratio = °Brix value/ Percentage acid (Gormley and Maher, 1990)

f. Pest Infestation Parameters

The species and number of pest on each of the 14 middle plants in each plot were counted once every week and the pest population recorded. Disease incidences were also scored (%) weekly on the 14 middle tomato plants with the aid of a modified Horsfall-Barratt (Berger, 1980) rating scale. The number of weeds was also counted from an area of $1m^2$ at the center of each a plot prior to weeding and the weed population per square meter recorded.

3.3.5 Data Analysis

The Proc univariate procedure of SAS (version 9.1; SAS Institute, Cary, NC) was used to check for normality of the data before analysis. The pest population and late blight incidences data were transformed using square root and arcsine transformation, respectively before analysis was done. The data collected were then subjected to analysis of variance (ANOVA) at $P \leq 0.05$ and means for significant treatments at the F test separated using Tukey's honestly significant difference (THSD) test at $P \leq 0.05$.

The experiment was analyzed as a two factor experiment using the following statistical model:

$\boldsymbol{Y_{ijk} = \mu + \beta_i + \alpha_j + s_k + \alpha s_{jk} + e_{ijk}}$, where; Y_{ijk} is the tomato response, μ is the overall mean, β_i is the i^{th} blocking effect, α_j is the j^{th} treatment effect, s_k is the k^{th} season effect, αs_{kj} is the interaction effect between the j^{th} treatment and k^{th} season and ε_{ijk} is the random error term which are normally and independently distributed about zero means with a common variance σ^2.

This model, however, could not capture the main effects of cover pore diameter, cover opening, and their interaction. A modified model was therefore used to analyze the balanced factorial part of the experiment to check on the main effects of cover pore diameter and cover opening and any possible significant interactions between the two factors. An initial analysis using season as a factor in the model showed no significant differences in season, season x cover

pore diameter, season x cover opening and season x cover pore diameter x cover opening for most of the parameters. Based on this, the data for the two seasons were analyzed separately. The modified model fitted was:

$Y_{ijk} = \mu + \beta_i + \alpha_j + \pi_k + \alpha\pi_{jk} + e_{ijk}$, where; Y_{ijk} is the tomato response, μ is the overall mean, β_i is the i^{th} blocking effect, α_j is the j^{th} cover pore diameter effect, π_k is the k^{th} cover opening effect, $\alpha\pi_{jk}$ is the interaction effect due to the j^{th} cover pore diameter and the k^{th} cover opening, and ε_{ijk} is the random error term which are normally and independently distributed about zero means with a common variance σ^2.

The following regression model was also used to determine the relationships between yield, quality and microclimate variables: $Y_i = \beta_0 + \beta_1\chi_i + \varepsilon_i$ where; Y_i is the tomato response, β_0 is the intercept, β_1 is the slope, χ_i is the microclimate and ε_i is the random error term which are normally and independently distributed about zero means with a common variance σ^2. The results obtained are presented and discussed in the subsequent chapters.

CHAPTER FOUR

4.0 RESULTS

The results are presented in two parts. The first part covers the results of the transplant production experiment and the second part covers the results of tomato field production experiment.

4.1 Transplant Production Experiment

In this section, the results are presented under the following sections; i) microclimate modification, ii) seedling physiology, iii) seedling emergence, iv) seedling growth, v) pest population and disease incidences, and vi) seedling requirement and cost per unit area.

4.1.1 Microclimate Modification using Eco-friendly Nets during Tomato Transplant Production

Net covering influenced the microclimate of tomato seedlings. Mean daily temperature and relative humidity were higher under netting treatment compared with the control throughout the study in both seasons (Fig. 4). The average daily temperature was 26.8 °C under the nets and 23.3 °C in the control treatments in season 1 reflecting a 15% increase in temperature under the nets. In season 2, a similar trend was observed with mean day temperatures of 26.7 and 23.3 °C under the net and the control, respectively, showing a 14.6% increase in temperature under the net covering. Net covering also resulted in a higher relative humidity averaging 57.6% compared with 52.3% for the control in season 1. In season 2, a similar trend was evident with relative humidity under netting recording a mean of 58.8% compared with 53.1% under the control.

4.1.2 Effect of Eco-friendly Nets on Seedling Emergence

Seedling emergence was enhanced by net covering (Table 1). During season 1, the first seedling emerged 5 DAP under the net compared with 8 DAP under the control; showing a 60% reduction in time to seedling emergence. In the second season, the first seedling under netting emerged 6 DAP compared with 8 DAP under the control, depicting a 33.3% reduction in time to seedling emergence (Fig. 5).

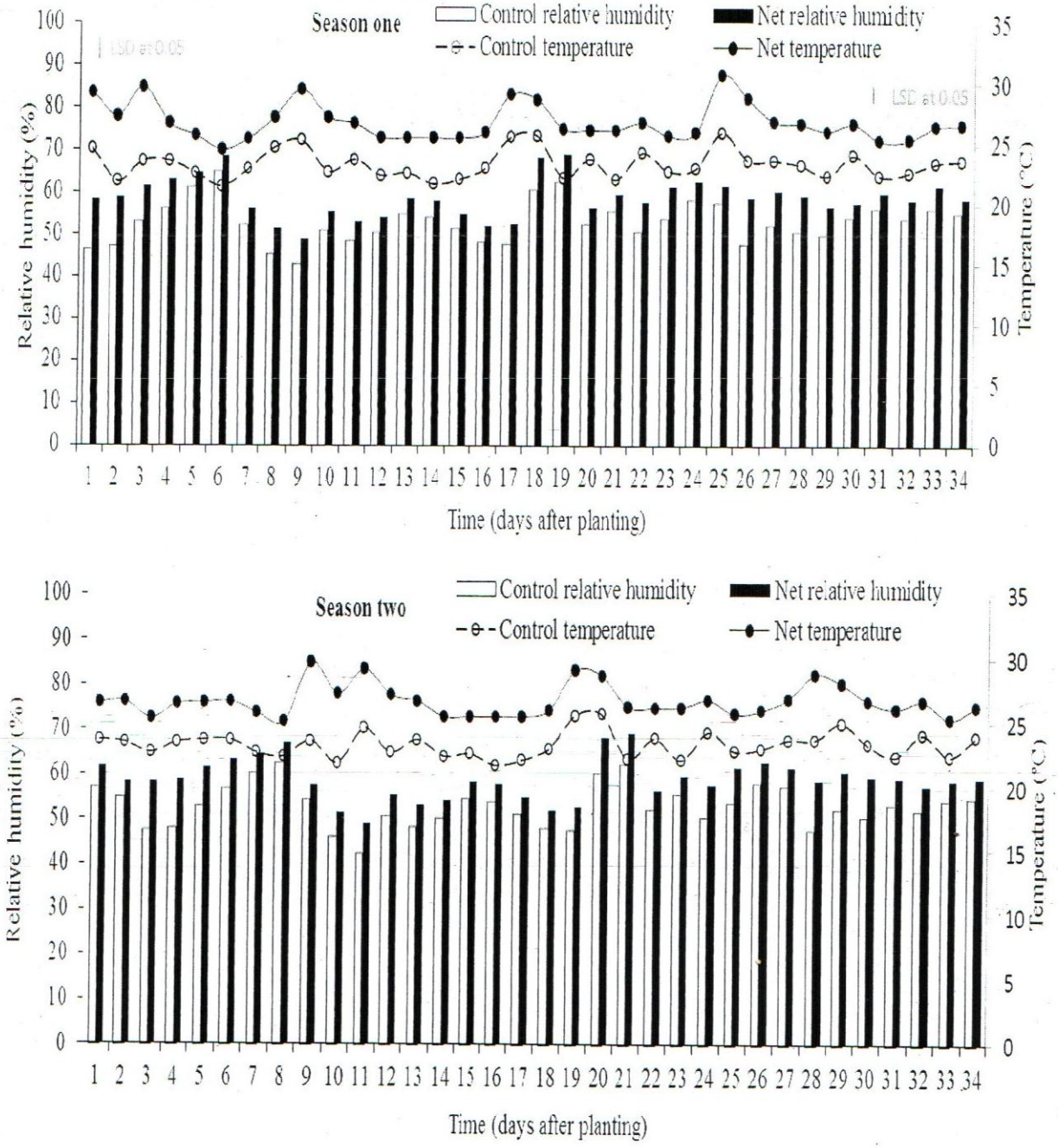


Fig. 4. Effect of eco-friendly net on daily air temperature and relative humidity during tomato transplant production in season 1 (Mar. to Apr. 2011) and Season 2 (Sept. to Oct. 2011).

Table 1. Emergence of tomato seedlings as influenced by eco-friendly net covering during season 1 (Mar. to Apr. 2011) and season 2 (Sept. to Oct. 2011).

Treatment*	Season	Time to first emergence (days)	Emergence (%)** Days after planting		
			7	9	11
Control	1	8 a***	3.3 b	54.5 b	57.1 b
Net	1	5 b	58.7 a	89.1 a	96.0 a
Control	2	8 a	11.0 b	56.5 b	62.1 b
Net	2	6 b	65.1 a	87.8 a	96.3 a

*Control treatment was mulched with dry grass as a standard practice used by farmers in the region. Net treatment was covered with a fine mesh net of 0.4-mm pore diameter.

**Data for seedling emergence was transformed using arcsine transformation before ANOVA and mean separation but means presented are the original means.

***Means followed by the same letter within a parameter and column are not significantly different according to Tukey's Honestly Significant Difference (THSD) at $P \leq 0.05$.

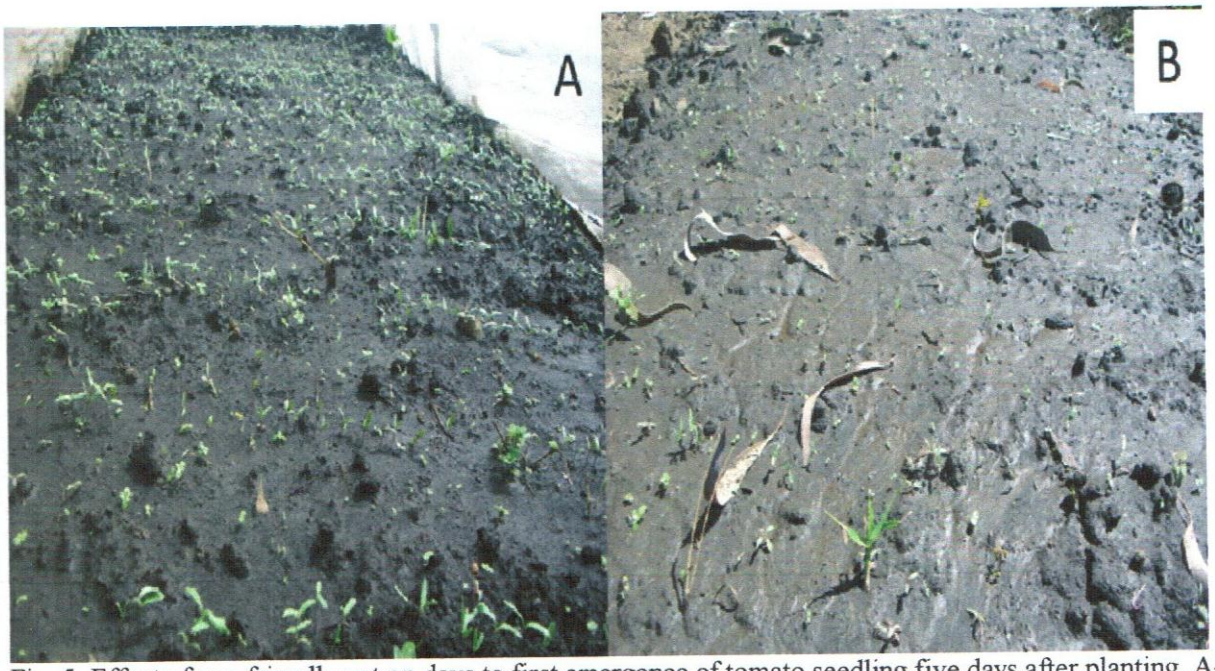


Fig. 5. Effect of eco-friendly net on days to first emergence of tomato seedling five days after planting. A- Covered permanently with fine mesh net (0.4-mm pore diameter) and B- Uncovered (Control).

Seeds sown under netting had a higher emergence percentage compared with the control throughout the evaluations. By day 7, 58.7% of sown seeds had emerged in the nets compared with only 3.3% for the control in season 1. A similar trend was observed in the second season with 65.1 and 11.0% seedling emergence by day 7 in the net and control treatments, respectively. By 11 DAP, the net treatment had 96.0% sown seeds having emerged compared with 57.1% in the control treatment during season 1. In season 2, the nets had 96.3% emergence compared with 62.1% for the control during the same time frame.

4.1.3 Effect of Eco-friendly Nets on Tomato Seedling Leaf Stomatal Conductance and Chlorophyll Content

Use of EFN significantly enhanced tomato leaf stomatal conductance and chlorophyll content (Table 2). Leaf stomatal conductance increased significantly as seedling age increased both under control and nets in both seasons. The highest leaf stomatal conductance was obtained with netting at 35 DAP (352.4 $mmol \cdot m^{-2} \cdot s^{-1}$) compared with 268.2 $mmol \cdot m^{-2} \cdot s^{-1}$ in the control treatment on the same day. Similar trend was also observed in season 2 with 352.0 $mmol \cdot m^{-2} \cdot s^{-1}$ recorded for the net treatment compared to 267.5 $mmol \cdot m^{-2} \cdot s^{-1}$ under the control at 35 DAP.

Leaf chlorophyll concentration also tended to increase with seedlings age under both treatments. During the final day (35 DAP), seedlings under the net recorded 34.2 CCI against 23.4 CCI for the control treatment in season 1. A similar trend was observed in season 2 with 33.7 CCI and 23.2 CCI recorded for seedlings under netting and control, respectively at 35 DAP.

4.1.4 Effect of Eco-friendly Nets on Seedling Growth

Seedling growth was enhanced under netting (Fig. 6). Seedling height showed a steady increase during all evaluation dates for both treatments in the two seasons. Seedlings under the net were significantly taller compared with the control seedlings recording mean heights of 12.0 and 4.7 cm, respectively, during the last data collection day (31 DAP) in season 1. In season 2, seedlings under the nets were 11.9 cm tall compared with 4.7 cm under the control at 31 DAP.

Table 2. Physiological characteristics of tomato seedlings as influenced by eco-friendly net covering during season 1 (Mar. to Apr. 2011) and Season 2 (Sept. to Oct. 2011).

		Stomatal conductance ($mmol \cdot m^{-2} \cdot s^{-1}$)			Chlorophyll content (CCI)**		
		Days after planting					
Treatment*	Season	21	28	35	21	28	35
Control	1	178.2 b***	222.6 b	268.2 b	11.0 b	17.0 b	23.4 b
Net	1	275.4 a	322.5 a	352.4 a	18.4 a	27.0 a	34.2 a
Control	2	178.4 b	222.3 b	267.5 b	10.9 b	17.0 b	23.2 b
Net	2	275.0 a	321.8 a	352.0 a	18.4 a	26.9 a	33.7 a

*Control treatment was mulched with dry grass as a standard practice used by farmers in the region. Net treatment was covered with a fine mesh net of 0.4-mm pore diameter.

**Chlorophyll content index is an estimate of chlorophyll content and higher values denote higher chlorophyll content in the leaves.

***Means followed by the same letter within a parameter and column are not significantly different according to Tukey's Honestly Significant Difference (THSD) at $P \leq 0.05$.

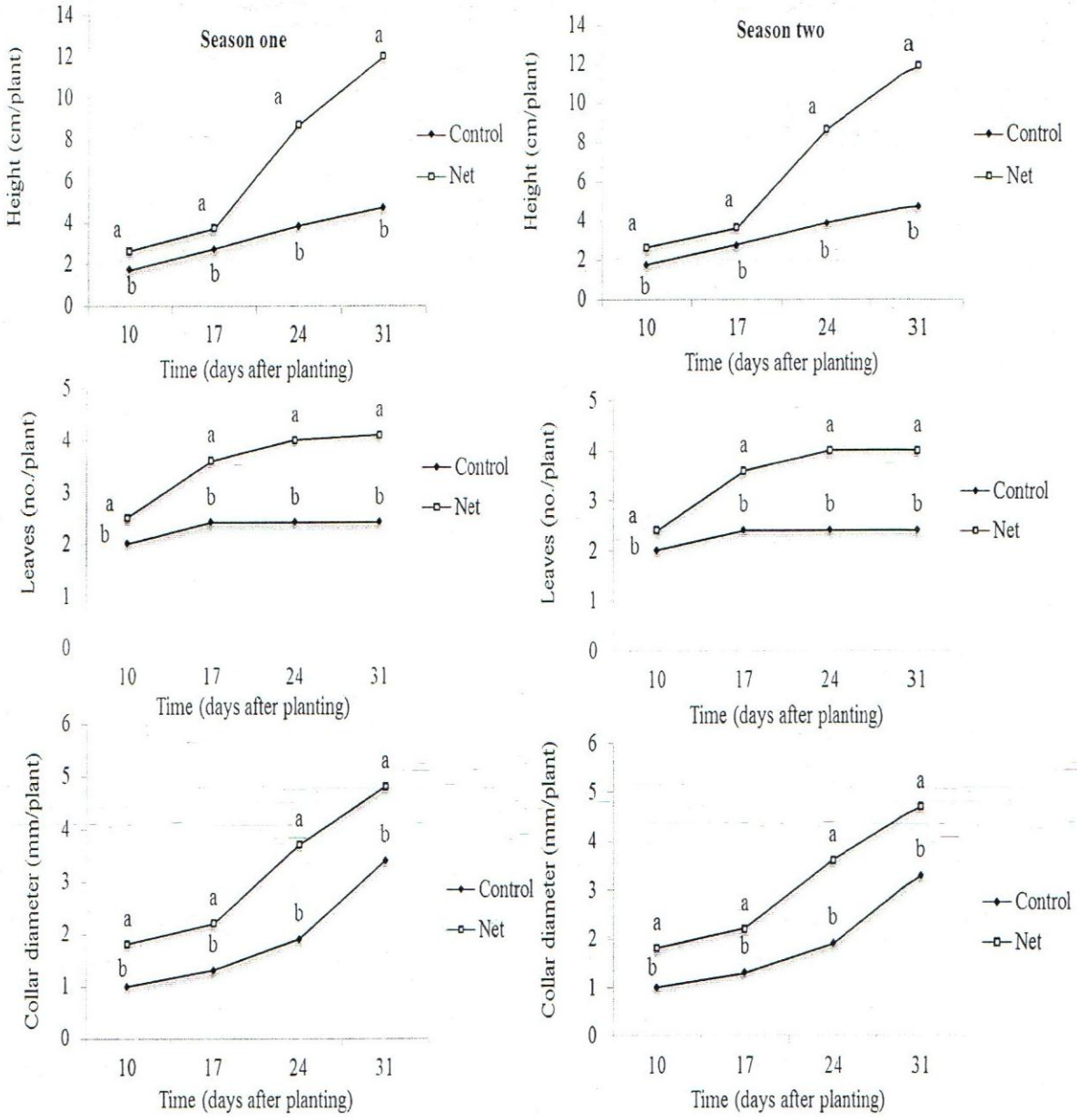


Fig. 6. Effect of eco-friendly net on seedling height, number of leaves, and collar diameter in season 1 (Mar. to Apr. 2011) and season 2 (Sept. to Oct. 2011). For a specific parameter and season, data points with the same date and letter are not significantly different according to Tukey's Honestly Significant Difference (THSD) at $P \leq 0.05$.

The number of leaves per seedling differed significantly between treatments in both seasons. Seedlings under netting had more leaves compared with those in the control at all data collection days. After 10 DAP, the number of leaves in the control remained relatively constant with 2.4 leaves per seedling in both seasons. Seedlings under the nets, however, continued to produce more leaves throughout the study, compared with the control in both seasons.

Control seedlings were thinner as depicted by the smaller stem diameters compared with those raised under netting in both seasons. There was a progressive increase in stem thickness from 10 to 31 DAP under both netting and the control in both seasons. At 31 DAP, stems of netted seedlings were 4.8 mm thick at the collar region, whereas control seedlings were 3.4 mm thick in both seasons.

Netting improved seedling root development in both seasons. Longer roots (8.8 cm) were obtained under the nets compared with a mean root length of 7.9 cm for the control in the first season (Table 3). A similar trend was also observed in season 2, where seedlings under the nets recorded 8.8 cm root length compared with 8.0 cm root length under the control. More lateral roots were also observed under the nets, compared with the control. Mean lateral root number per seedling was 26.3 and 17.0 for the seedlings under the nets and the control, respectively in the first season. Similarly, in the second season seedlings under the net treatment recorded a mean of 25.8 lateral roots against 16.9 for the control seedlings.

4.1.5 Effect of Eco-friendly Nets on Insect Pest Population and Disease Incidences

Use of EFN helped manage various pest and diseases (Table 4). The number of leafminers (*Lyriomyza* sp.), cotton bollworms (*Helicoverpa armigera*), onion thrips (*Thrips tabaci*), mites (*Tetranychus* sp.), silverleaf whiteflies (*Bemisia tabaci*), and aphids (*Aphis* sp.) per plant were significantly lower under the net covering with means of 0.1, 0.1, 0.1, 0.1, 0.1, and 0.2, respectively over the study period compared with 0.4, 0.4, 2.9, 2.4, 1.8, and 3.6, respectively under the control in season 1. In season 2, the net treatment recorded means of 0.1, 0.1, 0.2, 0.2, 0.1, and 0.2 per plant for leafminers, cotton bollworms, onion thrips, mites, silverleaf whiteflies, and aphids, respectively over the study period compared with 0.4, 0.3, 2.5, 2.1, 1.7, and 3.5, respectively under the control treatment. The major disease observed during the study was late

Table 3. Effects of eco-friendly net covering on root development of tomato seedlings in season 1 (Mar. to Apr. 2011) and season 2 (Sept. to Oct. 2011).

Treatment*	Season	Root length (cm/plant)	Roots (no./plant)
Control	1	7.9 b**	17.0 b
Net	1	8.8 a	26.3 a
Control	2	8.0 b	16.9 b
Net	2	8.8 a	25.8 a

*Control treatment was mulched with dry grass as a standard practice used by farmers in the region. Net treatment was covered with a fine mesh net of 0.4-mm pore diameter.

**Means followed by the same letter within a parameter and column are not significantly different according to Tukey's Honestly Significant Difference (THSD) at $P \leq 0.05$.

Table 4. Effect of eco-friendly net on pest population and disease attack on tomato seedling in season 1 (Mar. to Apr. 2011) and season 2 (Sept. to Oct. 2011).

Treatment*	Season	Leafminers** (no./plant)	Cotton bollworms (no./plant)	Onion thrips (no./plant)	Mites (no./plant)	Silverleaf whiteflies (no./plant)	Aphids (no./plant)	Late blight (%)
Control	1	0.4 a***	0.4 a	2.9 a	2.4 a	1.8 a	3.6 a	47.5 a
Net	1	0.1 b	0.1 b	0.1 b	0.1 b	0.1 b	0.2 b	5.0 b
Control	2	0.4 a	0.3 a	2.5 a	2.1 a	1.7 a	3.5 a	41.5 a
Net	2	0.1 b	0.1 b	0.2 b	0.2 b	0.1 b	0.2 b	3.5 b

*Control treatment was mulched with dry grass as a standard practice used by farmers in the region. Net treatment was covered with a fine mesh net of 0.4-mm pore diameter.

**Data for pest population and late blight incidences were transformed using square root and arcsine transformation, respectively before ANOVA and mean separation but means presented are the original means.

***Means followed by the same letter within a parameter and column are not significantly different according to Tukey's Honestly Significant Difference (THSD) at $P \leq 0.05$.

blight (*Phytophthora infestans*). The number of seedlings showing disease symptoms was significantly lower under netting treatments with a mean of 5.0% compared with 47.5% under the control during the first season. A similar trend was observed in season 2 with the nets and the control having 3.5% and 41.5% of seedlings showing disease symptoms, respectively.

4.1.6 Effect of Eco-friendly Nets on Cost per Unit Area Seed Requirement and

Based on seedling emergence percentage, a potential for reducing seed requirement per unit area when a net covering is used in nursery seedling production was noted when compared with seedlings production in the open (Table 5). During season 1, the nets had a final emergence of 96% while the control had only 57.1% emergence. Using the recommended spacing for 'Rio Grande' of 1 x 0.5 m, a grower would need to buy 28,580 seeds to be able to end up with enough seedlings (20,000 seedlings) to plant a hectare of tomato. On the other hand, a grower starting his seedlings under the net will only need to buy 20,800 seeds to end up with enough seedlings (20,000 seedlings) to cover a similar area, depicting a 27.2% reduction in seed requirement when transplants are started under the nets, compared with the control. In the second season, a similar trend was observed with the nets having 96.3% emergence compared with 62.1% emergence under the control depicting 24.8% reduction in cost of seeds per unit area when seedlings are started under net cover compared with open nursery.

4.2 Field Production Experiment

Results for the tomato field production experiment have been presented in two parts; the first part examines the effects of FRC and EFN on microclimate modification, tomato performance, and pest and disease incidences while the second part covers the effects of cover pore diameter and opening on microclimate modification, pest and disease incidences, and tomato performance.

4.2.1 Effects of Floating Row Covers and Eco-friendly Nets on Microclimate Modification, Tomato Performance, Pest Population and Disease Incidences

This part covers the results on; i) microclimate modification during field tomato production ii) tomato physiology iii) tomato plant growth vi) pest population and disease incidences and as influenced by the individual treatments of the study.

Table 5. Effect of eco-friendly net covering on tomato seedling emergence, seed requirement, and percentage increase in seed cost in season 1 (Mar. to Apr. 2011) and season 2 (Sept. to Oct. 2011).

Treatment*	Season	Emergence (%)	Seeds (no./ha)**	Cost decrease (%)***
Control	1	57.1	28,580	
Net	1	96.0	20,800	27.2
Control	2	62.1	27,580	
Net	2	96.3	20,740	24.8

*Control treatment was mulched with dry grass as a standard practice used by farmers in the region. Net treatment was covered with a fine mesh net of 0.4-mm pore diameter.

**Based on 100% emergence of tomato seedlings, which would have required 20000 seeds/ha according to the spacing of 'Rio Grande' (1 x 0.5 m).

***Cost reduction was calculated using the formula; (seed requirement under the control – seed requirement under the net)/seed requirement under the control) x 100.

4.2.1.1 Effects of Floating Row Covers and Eco-friendly Nets on Microclimate Modification during Tomato Field Production

Aspects of microclimate studied included; i) temperature ii) relative humidity iii) soil moisture iv) photosynthetic active radiation v) light quantity and vi) diurnal temperature range.

(i) Temperature

Covering plants with FRC or EFN influenced temperature within the vicinity of tomato plants. In both seasons FRC used permanently recorded the highest temperatures throughout the study (Fig. 7). In season 1, mean temperature for this treatment was 23.2°C. Among the other treatments, mean temperatures were 22.3, 22.7, 21.1, 20.7, and 20.4°C, under FRC opened thrice a week, 0.4-mm net covered permanently, 0.4-mm net opened thrice a week, 0.9-mm net covered permanently, and 0.9-mm net opened thrice a week, respectively compared with 18.2°C for the control. In the second season, a similar trend was observed with the FRC used permanently, FRC opened thrice a week, 0.4-mm net covered permanently, 0.4-mm net opened thrice a week, 0.9-mm net covered permanently, and 0.9-mm net opened thrice a week recording mean temperatures of 23.7, 23.4, 23.1, 22.3, 21.9, and 21.5°C, respectively compared with 20.7°C for the control. Generally temperatures were higher in season 2 (22.4°C) than in season 1 (21.2°C).

(ii) Relative Humidity

Covering the crop with EFN or FRC also had effects on relative humidity within the vicinity of the crop. In both seasons, relative humidity was highest and lowest under the control and FRC used permanently, respectively throughout the weeks of study (Fig. 8). Mean relative humidity values were 69.2, 68.3, 68.2, 67.6, 67.4, 66.0, and 65.9%, for the control, 0.9-mm net opened thrice a week, FRC opened thrice a week, 0.4-mm net opened thrice a week, 0.9-mm net covered permanently, 0.4-mm net covered permanently, and the FRC used permanently, respectively in the first season.

A similar trend was observed in the second season with the FRC used permanently recording the lowest relative humidity of 64.8% and the control, 0.9-mm net opened thrice a week, 0.4-mm net opened thrice a week, 0.9-mm net covered permanently, FRC opened thrice a week, and 0.4-mm net covered permanently, recording 67.8, 66.8, 66.5, 65.9, 65.4, and 65.1%,

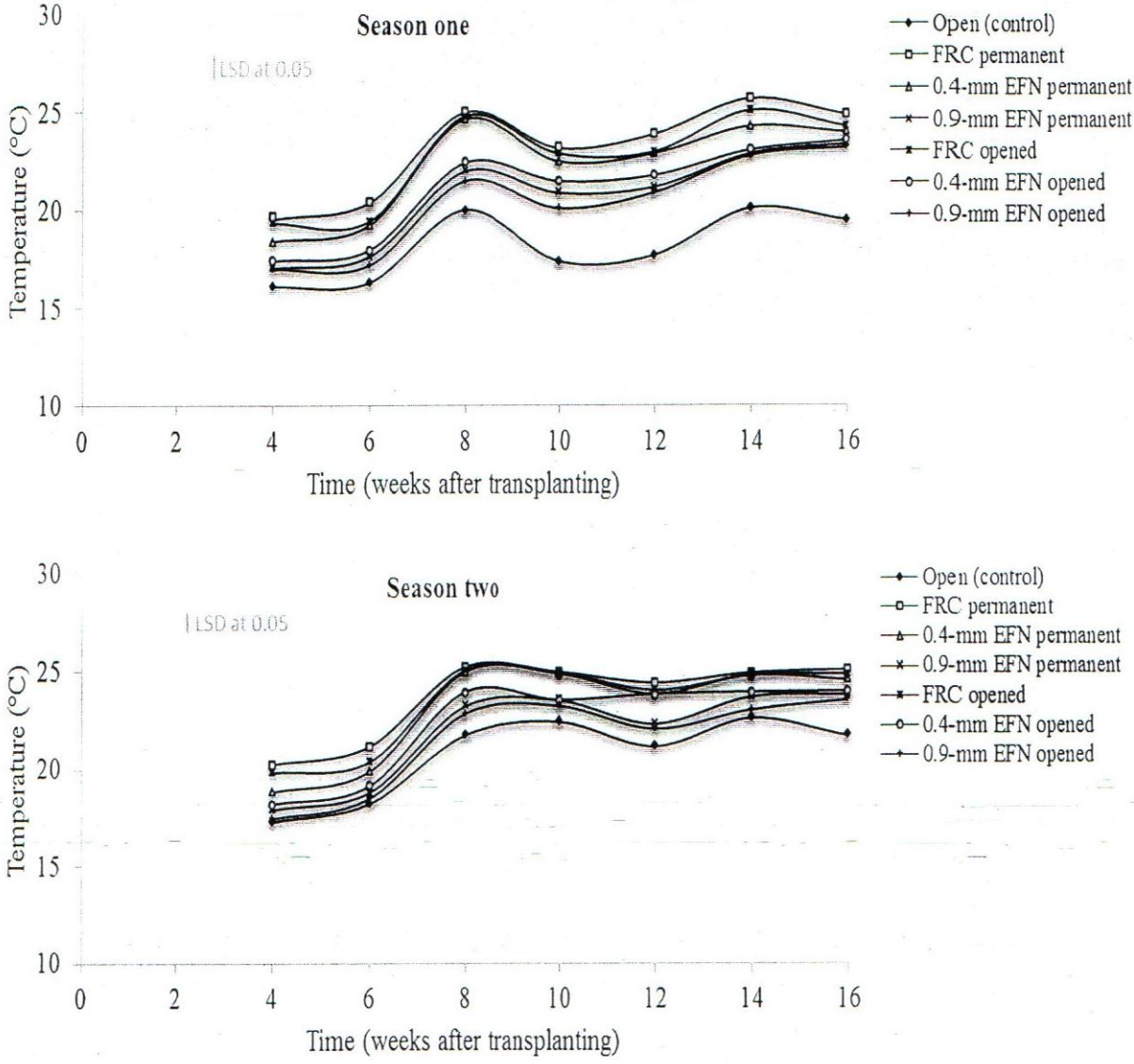


Fig. 7. Effects of floating row covers and eco-friendly nets on weekly temperature during tomato production in season 1 (May to Oct. 2011) and season 2 (Oct. 2011 to Mar. 2012). Control treatment was left uncovered; permanent is where the FRC or EFN were covered throughout except during crop maintenance periods, and opened is where the FRC or EFN were opened thrice a week from 9.00 am to 3.00 pm.

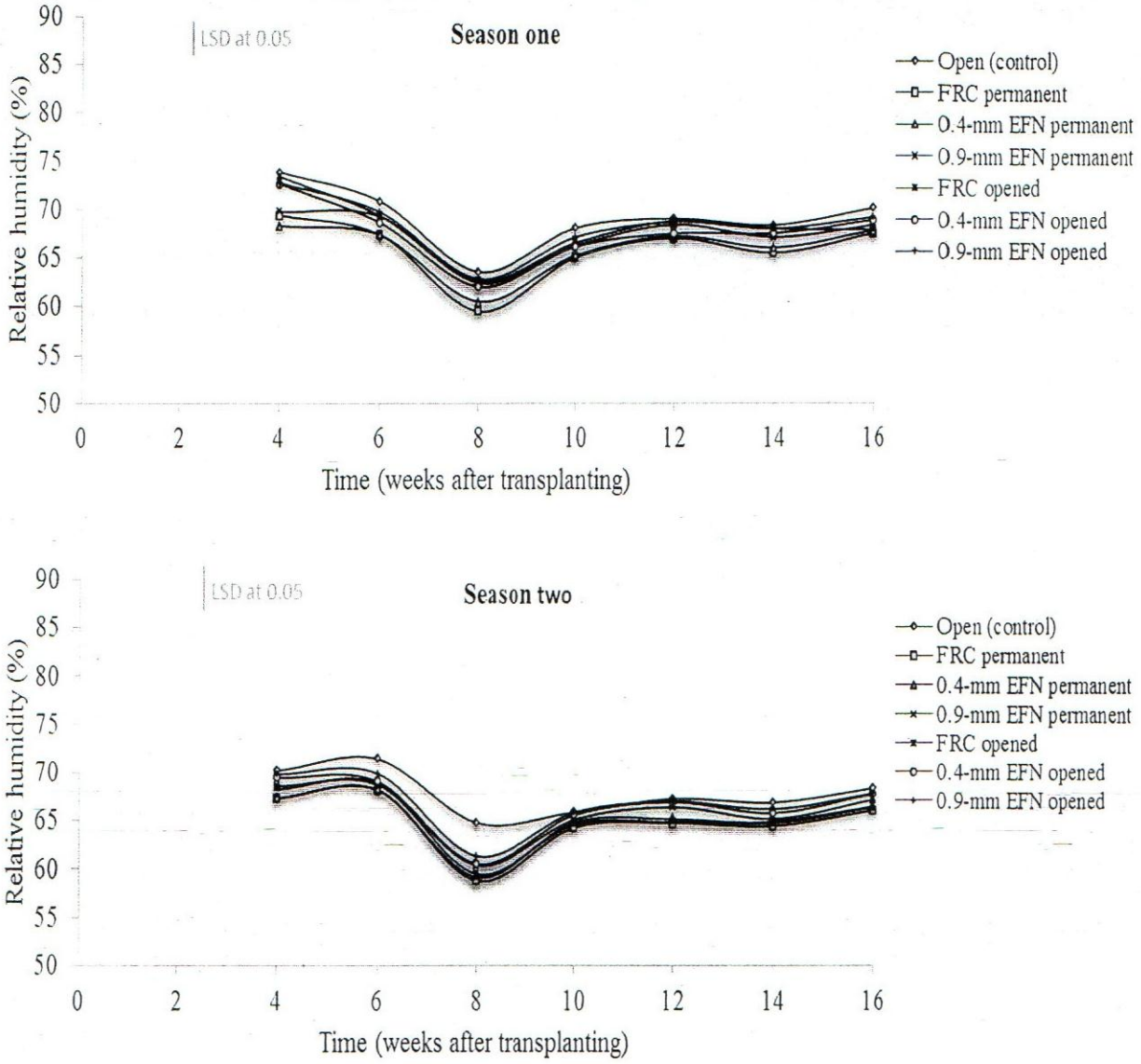


Fig. 8. Effects of floating row covers and eco-friendly nets on weekly relative humidity during tomato production in season 1(May to Oct. 2011) and season 2 (Oct. 2011 to Mar. 2012). Control treatment was left uncovered; permanent is where the FRC or EFN were covered throughout except during crop maintenance periods, and opened is where the FRC or EFN were opened thrice a week from 9.00 am to 3.00 pm.

respectively. Among the two seasons, relative humidity was higher in season 1 (67.5%) than in season 2 (66.1%).

(iii) Soil Moisture

Use of FRC and EFN maintained higher soil moisture content (measured in volumetric water content) throughout the study period in both seasons (Fig. 9). In season 1, FRC used permanently maintained the highest soil moisture in most of the weeks except for 4, 6 and 8 weeks after transplanting (WAT) when plots under the 0.4-mm net covered permanently recorded higher moisture content. The lowest moisture content was obtained under the control treatment throughout the study. Averaged within the each season, the 0.4-mm net covered permanently had a higher soil moisture content of 33.1% followed by FRC used permanently, FRC opened thrice a week, 0.9-mm net covered permanently, 0.4-mm net opened thrice a week, 0.9-mm net opened thrice a week and the control with mean moisture contents of 33.0, 31.4, 30.3, 29.8, 29.0 and 23.4%, respectively.

In season 2, FRC used permanently had more soil moisture content in all the weeks of data collection recording a season mean of 34.4%. On the other hand, the 0.4-mm net covered permanently, FRC opened thrice a week, 0.9-mm net covered permanently, 0.4-mm net opened thrice a week, 0.9-mm net opened thrice a week and the control had mean moisture contents of 33.5, 33.6, 32.1, 31.7, 31.0 and 21.5 %, respectively. In season one, a mean season soil moisture content of 30.0% was recorded compared with 31.1% in the second season.

(iv) Photosynthetic Active Radiation

Floating row covers and EFN covering affected photosynthetic active radiation (PAR). Generally PAR reaching the crop was reduced by the use of FRC or EFN (Fig. 10). In both seasons, tomato plants under the control treatments received higher PAR levels in all the weeks data was collected. The mean PAR received by control plants in season 1 was 573.3 $mmol \cdot s^{-1} \cdot m^{-2}$ compared with 549.8, 548.9, 548.9, 548.7, 548.2, and 548.0 $mmol \cdot s^{-1} \cdot m^{-2}$ recorded under FRC used permanently, 0.4-mm net covered permanently, 0.9-mm net covered permanently, 0.9-mm

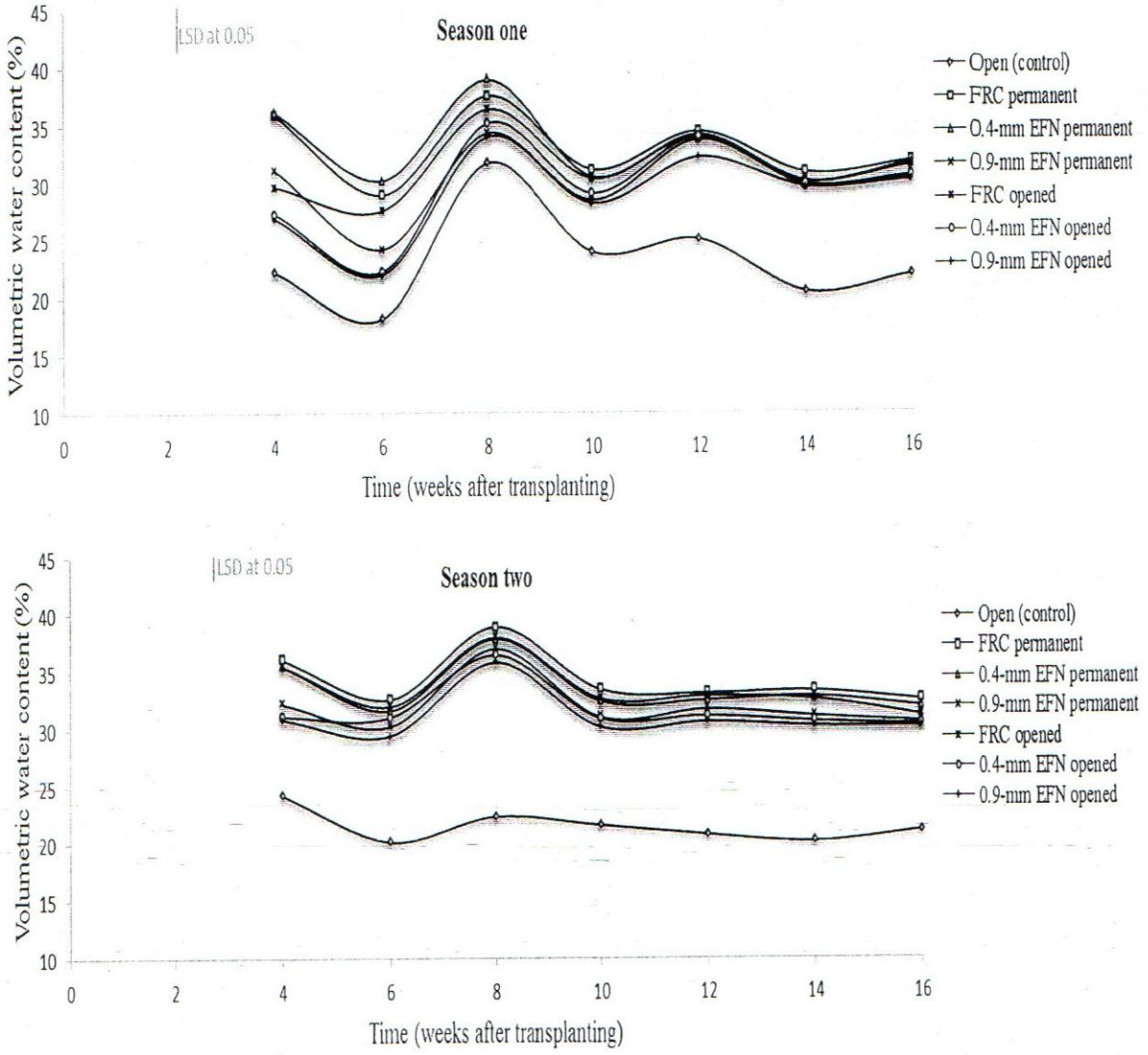


Fig. 9. Effects of floating row covers and eco-friendly nets on soil moisture content (volumetric water content) during tomato production in season 1 (May to Sept. 2011) and season 2 (Oct. 2011 to Mar. 2012). Control treatment was left uncovered; permanent is where the FRC or EFN were covered throughout except during crop maintenance periods and opened is where the FRC or EFN were opened thrice a week from 9.00 am to 3.00 pm.

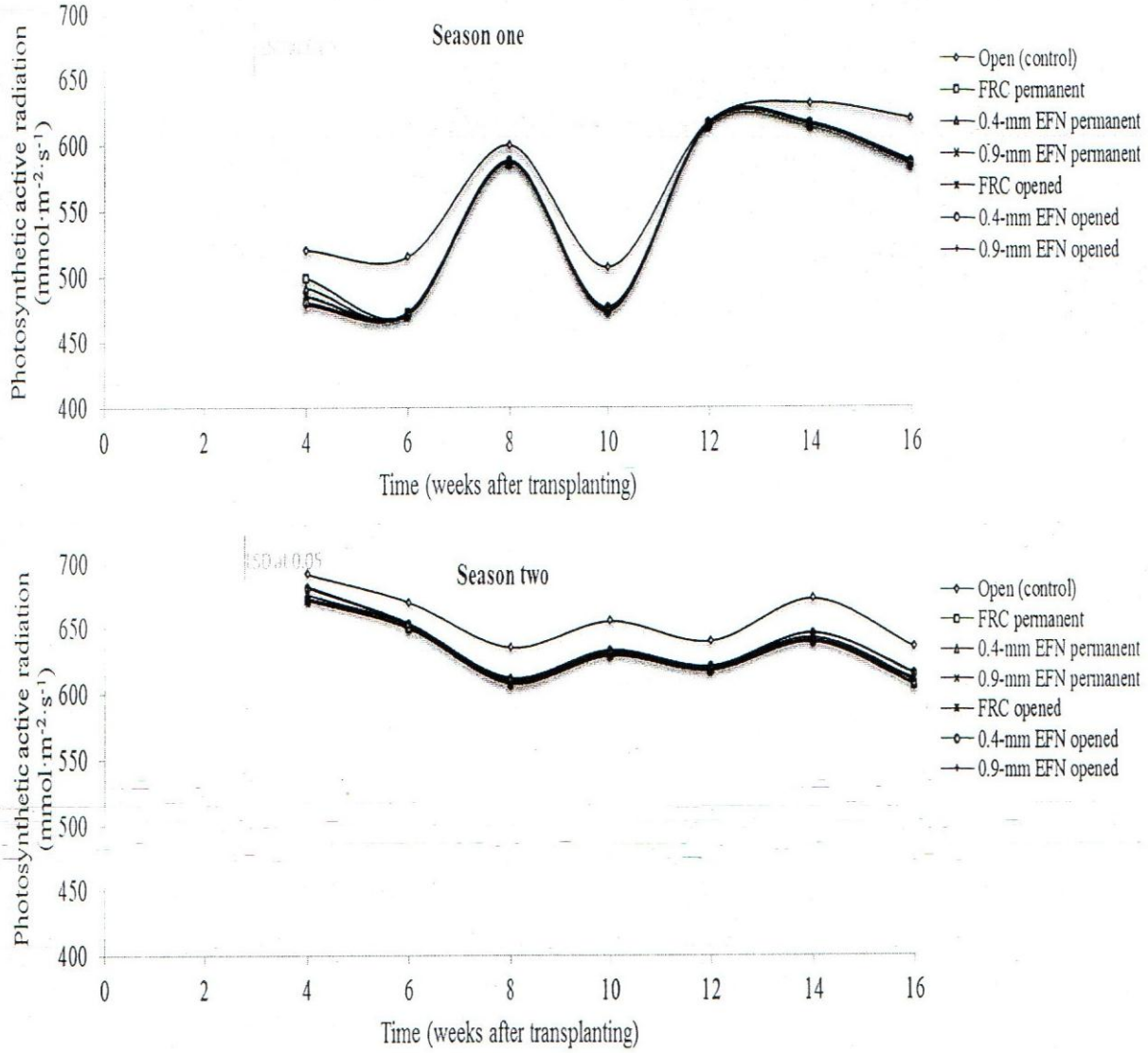


Fig. 10. Effects of floating row covers and ecofriendly nets on photosynthetic active radiation during tomato production in season 1 (May to Oct. 2011) and season 2 (Oct. 2011 to Mar. 2012). Control treatment was left uncovered; permanent is where the FRC or EFN were covered throughout except during crop maintenance periods and opened is where the FRC or EFN were opened thrice a week from 9.00 am to 3.00 pm.

opened thrice a week, 0.4-mm net opened thrice a week, and FRC opened thrice a week, respectively.

In the second season, similar trend was observed with the control having the highest PAR of 657.4 $mmol \cdot s^{-1} \cdot m^{-2}$ against 638.0, 637.0, 634.6, 633.4, 632.3, and 631.8 $mmol \cdot s^{-1} \cdot m^{-2}$ for the 0.9-mm net opened thrice a week, 0.4-mm net opened thrice a week, 0.9-mm net covered permanently, FRC opened thrice a week, 0.4-mm net covered permanently, and FRC used permanently, respectively. In all the treatments, between the two seasons, higher PAR levels were recorded in season 2 achieving a mean of 637.8 $mmol \cdot s^{-1} \cdot m^{-2}$ compared with 552.2 $mmol \cdot s^{-1} \cdot m^{-2}$ in season 1.

(v) Light Quantity

Use of FRC and EFN reduced the light quantity that reached the tomato crop (Fig. 11). In both seasons, control plants received more light compared with plants under FRC or EFN in all the weeks that data was collected. Averaged within a season, control plants received 41.6 $mol \cdot d^{-1}$ compared with 33.8, 33.6, 33.5, 33.0, 32.9, and 32.9 $mol \cdot d^{-1}$ under 0.9-mm net opened thrice a week, 0.4-mm net opened thrice a week, 0.9-mm net covered permanently, 0.4-mm net covered permanently, FRC opened thrice a week, and FRC used permanently, respectively in season 1.

A similar trend was observed in season 2, where a mean light quantity of 44.8 $mol \cdot d^{-1}$ was recorded under the control treatment against 37.7, 37.1, 36.7, 36.1, 36.1, and 35.7 $mol \cdot d^{-1}$ under 0.9-mm net opened thrice a week, 0.4-mm net opened thrice a week, 0.9-mm net covered permanently, FRC opened thrice a week, 0.4-mm net covered permanently, and FRC used permanently, respectively. Generally, season 2 registered higher light quantity with a mean of 37.7 $mol \cdot d^{-1}$ compared with 34.4 $mol \cdot d^{-1}$ in season 1.

(vi) Diurnal Temperature Range

The use of FRC and EFN covering helped in narrowing the diurnal temperature range (Fig. 12). In season 1, FRC used permanently and 0.4-mm net covered permanently had the lowest diurnal temperature ranges of 3.4°C compared with the control, 0.9-mm net opened thrice a week, 0.9-mm net covered permanently, 0.4-mm net opened thrice a week, and FRC

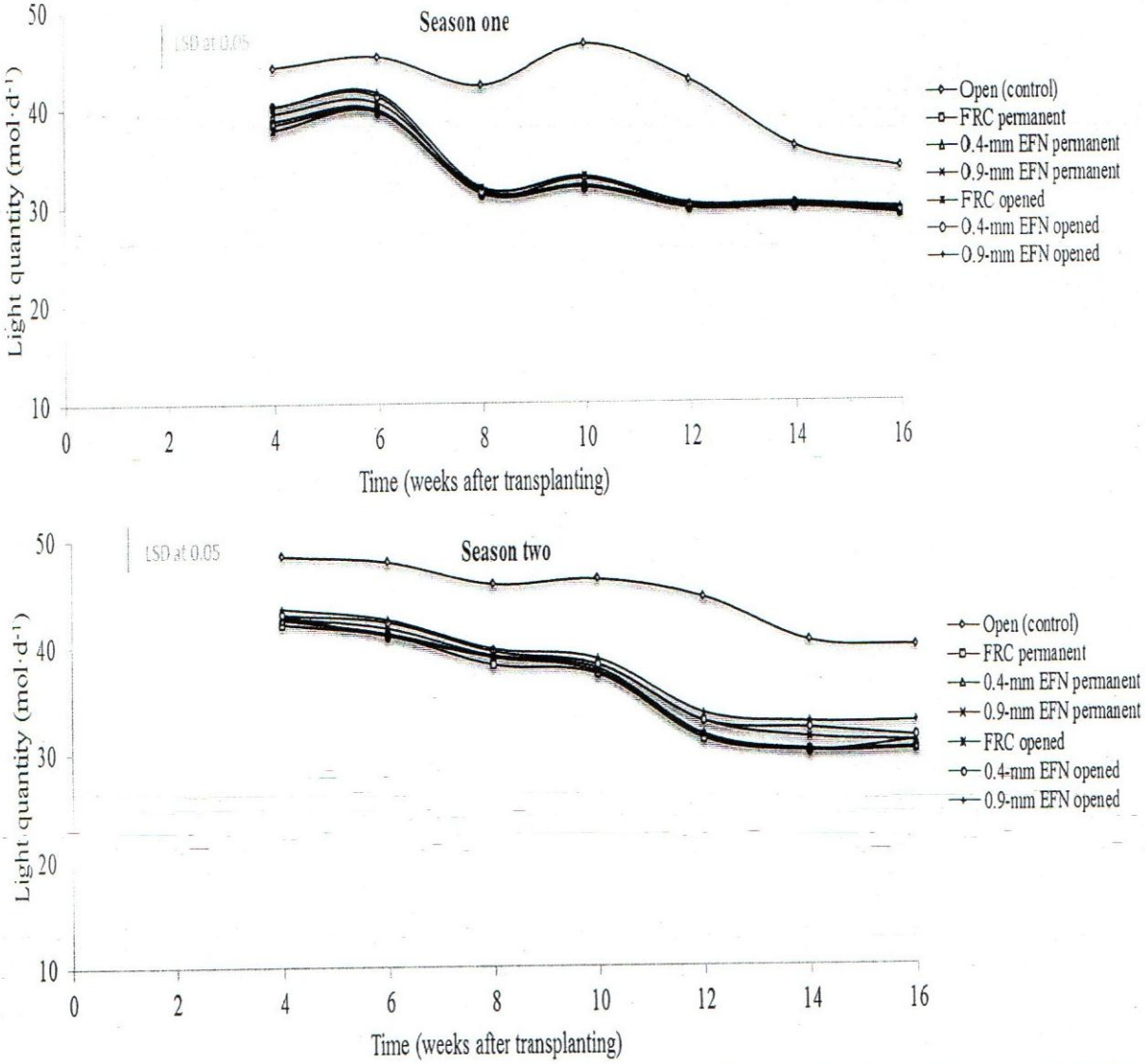


Fig. 11. Effects of floating row covers and eco-friendly nets on light quantity during tomato production in season 1 (May to Oct. 2011) and season 2 (Oct. 2011 to Mar. 2012). Control treatment was left uncovered; permanent is where the FRC or EFN were covered throughout except during crop maintenance periods and opened is where the FRC or EFN were opened thrice a week from 9.00 am to 3.00 pm.

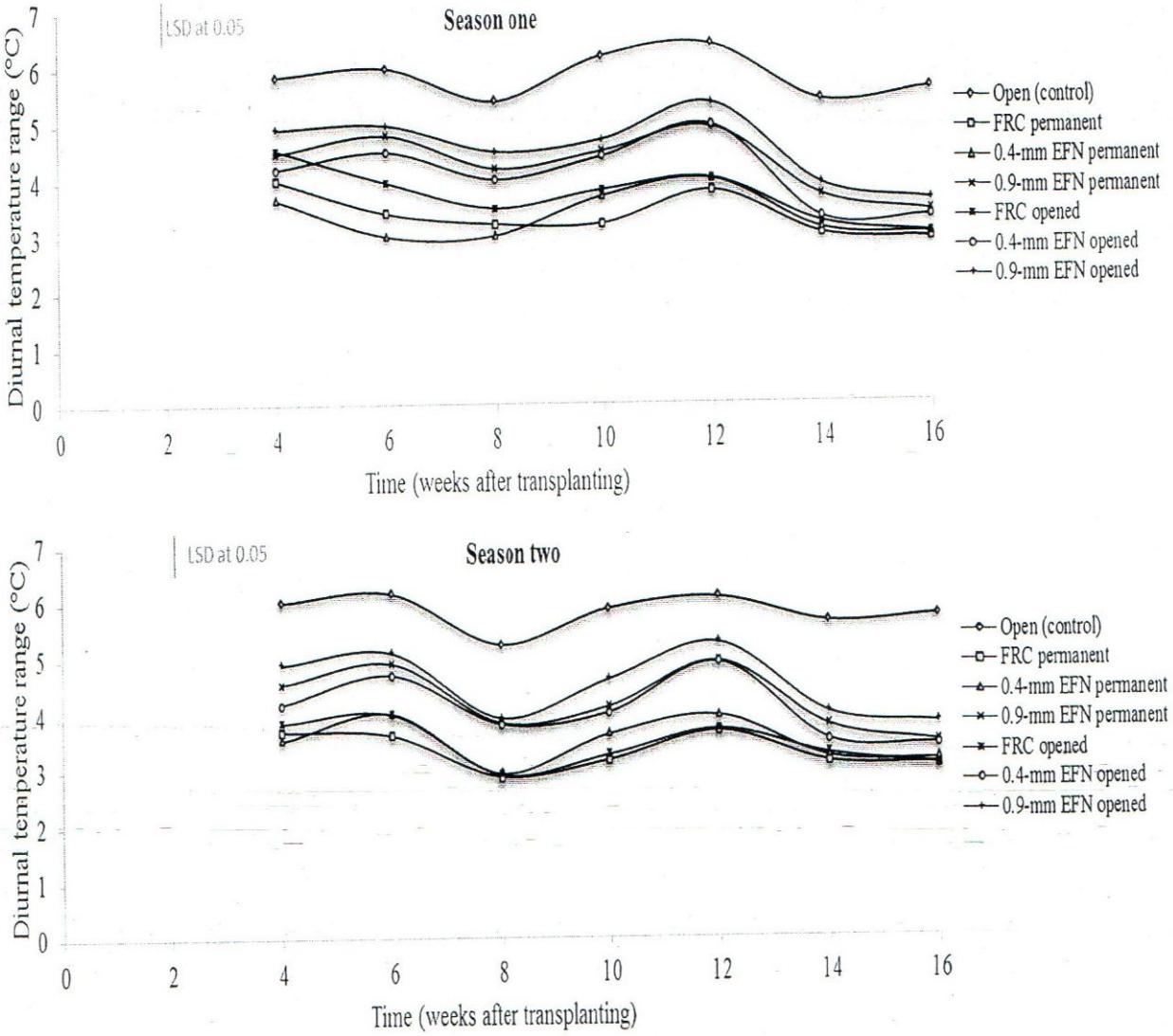


Fig. 12. Effects of floating row covers and eco-friendly nets on diurnal temperature range during the production of tomato in season 1 (May to Oct. 2011) and season 2 (Oct. 2011 to Mar. 2012). Control treatment was left uncovered; permanent is where the FRC or EFN were covered throughout except during crop maintenance periods and opened is where the FRC or EFN were opened thrice a week from 9.00 am to 5.00 pm.

opened thrice a week control that registered mean diurnal temperature ranges of 5.8, 4.6, 4.3, 4.1, and 3.7°C, respectively.

In season 2, a similar trend was observed with the control recording a higher diurnal temperature range (5.8°C) in all the weeks that data was collected compared with 0.9-mm net opened thrice a week, 0.9-mm net covered permanently, 0.4-mm net opened thrice a week, 0.4-mm net covered permanently, FRC opened thrice a week, and FRC used permanently that recorded mean diurnal temperature ranges of 4.5, 4.2, 4.1, 3.5, 3.4, and 3.3°C, respectively. FRC used permanently had the lowest diurnal temperature range in all the weeks of data collection in this season except for 4 WAT when diurnal temperature range was lowest under the 0.4-mm net covered permanently.

4.2.1.2 Effects of Floating Row Covers and Eco-friendly Nets on Tomato Leaf Stomatal Conductance and Chlorophyll Content

The physiological attributes measured were i) tomato leaf stomatal conductance and ii) tomato leaf chlorophyll content.

(i) Leaf Stomatal Conductance

Leaf stomatal conductance was not significantly affected by the use of FRC or EFN covering in both seasons (Table 6). As expected, stomatal conductance increased as the crop aged with the highest stomatal conductance recorded at 82 DAT in all the treatments in both seasons.

(ii) Leaf Chlorophyll Content

Use of FRC and EFN affected the leaf chlorophyll content in both seasons (Table 7). Although a trend of treatment effect could be established, the differences amongst the treatments were not significant in all the data collection days except at 82 DAT in both seasons. Similar to the trend displayed for stomatal conductance, chlorophyll concentration index units (CCIs) increased with plant age reaching a maximum at 82 DAT in both seasons. Leaves of plants under FRC or EFN tended to have higher CCIs throughout the seasons. Although not significantly different except at 82 DAT, leaf chlorophyll content tended to be highest and lowest in plants under FRC used permanently and control plants, respectively in all data collection dates in both

e 6. Leaf stomatal conductance ($mmol \cdot m^{-2} \cdot s^{-1}$) of tomato as influenced by floating row covers (FRC) and eco-friendly nets (EFN) covering in season 1 (May to Oct. 2011) and season 2 (Oct. 2011 to Mar. 2012).

ment*	Season	Time (days after transplanting) 26	40	54	68	82
trol	1	367.54**	395.06	403.30	404.87	407.86
mical	1	437.52	467.03	473.03	476.97	478.89
C permanent	1	553.38	588.99	608.44	611.60	614.53
-mm EFN permanent	1	534.44	578.16	591.54	594.67	595.99
-mm EFN permanent	1	484.69	500.28	510.15	515.94	516.16
C opened	1	520.40	552.98	560.77	561.50	567.67
-mm EFN opened	1	487.60	506.87	509.68	513.53	515.04
-mm EFN opened	1	459.86	496.21	503.55	506.60	509.13
ntrol	2	384.14	401.66	407.05	409.76	410.24
emical	2	445.52	474.43	478.03	480.28	480.52
RC permanent	2	574.61	601.21	614.24	615.78	619.13
4-mm EFN permanent	2	553.84	582.16	596.34	596.88	599.64
9-mm EFN permanent	2	489.88	508.88	516.15	519.59	520.22
RC opened	2	531.20	557.32	565.37	566.20	570.81
4-mm EFN opened	2	495.51	507.89	513.78	517.51	520.21
9-mm EFN opened	2	467.96	500.21	506.85	511.13	512.67

*Control had no pesticide applied, chemical treatment was sprayed with alphacypermethrine, permanent is where the FRC or EFN were covered throughout except during crop maintenance periods and opened is where the FRC or EFN were opened thrice a week from 9.00 am to 3.00 pm.

**Means not followed by a letter within a column are not significantly different significant difference according to F-test at $P \leq 0.05$.

Table 7. Leaf chlorophyll content (CCI) as influenced by floating row covers (FRC) and eco-friendly nets (EFN) covering during tomato production in season 1 (May to Oct. 2011) and season 2 (Oct. 2011 to Mar. 2012).

		Time (days after transplanting)				
Treatment*	Season	26	40	54	68	82
Control	1	42.10**	49.92	53.32	56.53	57.94 j***
Chemical	1	53.97	60.18	62.93	65.23	66.79 hi
FRC permanent	1	67.23	72.49	74.66	78.05	80.61 ab
0.4-mm EFN permanent	1	62.50	71.56	72.20	75.77	77.53 c
0.9-mm EFN permanent	1	55.63	62.87	64.92	67.54	68.56 fghi
FRC opened	1	62.28	65.82	67.68	69.97	71.06 def
0.4-mm EFN opened	1	59.45	63.72	64.15	68.31	70.05 efg
0.9-mm EFN opened	1	55.90	60.37	62.27	65.12	65.91 i
Control	2	48.41	54.08	56.45	59.86	60.61 j
Chemical	2	57.37	62.17	65.75	67.70	67.81 ghi
FRC permanent	2	70.23	74.89	78.40	81.03	83.44 a
0.4-mm EFN permanent	2	65.44	73.48	78.14	79.36	80.53 b
0.9-mm EFN permanent	2	62.45	64.21	66.84	70.05	72.94 de
FRC opened	2	67.07	68.99	69.82	74.00	76.78 c
0.4-mm EFN opened	2	62.19	65.09	67.14	69.18	73.07 d
0.9-mm EFN opened	2	57.63	61.91	65.50	67.26	69.25 fgh

*Control had no pesticide applied, chemical treatment was sprayed with alphacypermethrine, permanent is where the FRC or EFN were covered throughout except during crop maintenance periods and opened is where the FRC or EFN were opened thrice a week from 9.00 am to 3.00 pm.

**Means not followed by a letter are not significantly different according to F-test at $P \leq 0.05$.

***Means followed by the same letter within a column are not significantly different according to Tukey's Honestly Significant Difference (THSD) at $P \leq 0.05$.

seasons. Generally, plants in season 2 had higher chlorophyll content with a mean of 67.9 CCIs than those of season 1 (64.8 CCIs).

4.2.1.3 Effects of Floating Row Covers and Eco-friendly Nets on Tomato Growth

Tomato growth variables measured in this study were i) transplant survival ii) plant height iii) collar diameter iv) number of leaves and v) days to maturity.

(i) Transplant Survival

Use of FRC or EFN significantly enhanced the survival of tomato transplants (Table 8). In both seasons, transplant survival was lowest under the control and chemical treatments. In season 1, significantly higher transplant survival was obtained under the 0.4-mm net covered permanently followed by FRC used permanently. Transplant survival under the other covered treatments was not any different in this season. In season 2, FRC used permanently resulted in the highest transplant survival followed by the 0.4-mm net covered permanently. Transplant survival under FRC and 0.4-mm net opened three times a week was also not statistically different from those of 0.4-mm net and FRC used permanently. Use of FRC or EFN had improved transplant survival for the treatment means. Both the control and chemical treatments recorded the lowest transplant survival while 0.4-mm net used permanently had the highest transplant survival rate. Among the other treatments, FRC used permanently had the highest transplant survival followed by 0.9-mm net used permanently, 0.4-mm net opened thrice a week, FRC opened thrice a week and 0.9-mm net opened thrice a week. Generally transplant survival rate was higher in season 2 for all the treatments than in season 1.

(ii) Plant Height

Tomato plant height was significantly influenced by the use of FRC or EFN covers (Table 9). Significant differences in plant height were realized amongst the different treatments in all data collection days except at 22, 43 and 85 DAT. In season 1, the shortest plants were obtained under the control while the tallest plants were obtained under the FRC used permanently in all data collection days. Among the other treatments, plants were also shorter in the chemical treatment compared with the covered treatments; 0.4-mm net covered permanently,

Table 8. Effects of floating row covers (FRC) and eco-friendly nets (EFN) on survival (%) of tomato transplants at 3 days after transplanting in season 1 (May to Oct. 2011) and season 2 (Oct. 2011 to Mar. 2012).

Treatment*	Season 1	Season 2	**Treatment Means****
Control	40.00 r***	65.71 pq	**52.86 e**
Chemical	41.43 r	70.00 op	**55.71 e**
FRC permanent	71.43 nop	94.29 l	**82.86 ab**
0.4-mm EFN permanent	87.14 lm	92.86 l	**90.00 a**
0.9-mm EFN permanent	70.00 op	82.86 lmn	**76.43 bc**
FRC opened	62.86 pq	87.14 lm	**75.00 c**
0.4-mm EFN opened	65.71 pq	85.71 lm	**75.71 bc**
0.9-mm EFN opened	54.29 q	78.51 mno	**66.43 d**
Season Means	**82.14 h**	**61.61 i**	

*Control had no pesticide applied, chemical treatment was sprayed with alphacypermethrine, permanent is where the FRC or EFN were covered throughout except during crop maintenance periods and opened is where the FRC or EFN were opened thrice a week from 9.00 am to 3.00 pm.

**Data for transplant survival was transformed using arcsine transformation before ANOVA and mean separation but means presented are the original means.

***Means followed by the same letter within a letter series are not significantly different according to Tukey's Honestly Significant Difference (THSD) at $P \leq 0.05$.

Table 9. Effects of floating row covers (FRC) and eco-friendly nets (EFN) on tomato plant height (cm) in season 1 (May to Oct. 2011) and season 2 (Oct. 2011 to Mar. 2012).

		Time (days after transplanting)									
Treatment*	Season	22	29	36	43	50	57	64	71	78	85
Control	1	21.17**	23.57 f***	29.71 g	35.68	39.97 hi	42.41 gh	42.94 h	43.46 g	44.37 g	44.52
Chemical	1	23.67	28.76 c	31.30 de	39.57	42.03 g	43.53 f	44.04 g	45.41 f	46.61 f	46.82
FRC permanent	1	29.40	39.66 a	46.67 a	55.67	60.17 a	62.27 a	62.90 a	64.15 a	67.65 a	67.86
0.4-mm EFN permanent	1	28.81	38.17 ab	42.35 b	52.29	54.02 c	55.61 b	56.09 c	57.50 b	58.44 b	58.65
0.9-mm EFN permanent	1	24.49	24.76 e	31.51 de	44.37	51.15 de	54.51 c	54.92 d	56.45 c	57.51 c	57.73
FRC opened	1	23.91	29.10 c	32.38 cd	47.17	51.14 de	53.49 d	53.99 e	56.49 c	58.49 b	58.71
0.4-mm EFN opened	1	24.40	27.52 cd	30.96 ef	42.77	50.84 de	53.50 d	53.97 e	55.41 d	56.42 d	56.61
0.9-mm EFN opened	1	24.30	27.87 cd	30.12 fg	38.76	48.68 f	52.42 e	52.93 f	54.52 e	55.29 e	55.45
Control	2	21.96	23.56 f	29.67 g	35.94	39.41 i	42.25 h	42.95 h	43.46 g	44.37 g	44.58
Chemical	2	23.66	26.99 d	30.71 efg	37.99	41.04 gh	43.14 fg	43.97 g	45.41 f	46.61 f	46.82
FRC permanent	2	29.57	38.93 ab	46.15 a	54.62	58.25 b	62.04 a	62.90 a	64.63 a	67.65 a	67.86
0.4-mm EFN permanent	2	29.24	37.53 b	42.40 b	52.02	53.83 c	56.42 b	56.77 b	57.47 b	58.32 b	58.65
0.9-mm EFN permanent	2	24.77	26.24 de	31.36 de	43.24	50.26 e	54.04 cd	54.73 d	56.28 c	57.22 c	57.65
FRC opened	2	25.46	29.21 c	33.07 c	48.52	51.69 d	54.45 c	54.93 d	56.49 c	58.41 b	58.74
0.4-mm EFN opened	2	24.76	27.92 cd	31.36 de	43.33	50.65 de	54.09 cd	54.57 de	56.02 cd	56.64 d	57.02
0.9-mm EFN opened	2	24.13	26.60 d	30.61 efg	40.06	48.58 f	52.51 e	52.93 f	54.49 e	55.29 e	55.45

*Control had no pesticide applied, chemical treatment was sprayed with alphacypermethrine, permanent is where the FRC or EFN were covered throughout except during crop maintenance periods and opened is where the FRC or EFN were opened thrice a week from 9.00 am to 3.00 pm.

**Means not followed by a letter are not significantly different according to F-test at $P \leq 0.05$.

***Means followed by the same letter within a column are not significantly different according to Tukey's Honestly Significant Difference (THSD) at $P \leq 0.05$.

0.9-mm net covered permanently, FRC opened thrice a week, 0.4-mm net opened thrice a week and 0.9-mm net open thrice a week. In season 2, the same trend was observed with tallest plants also observed under the FRC used permanently and shortest under the control with a trend similar to that of season 1 displayed by the other treatments. On average, plants from the 2 seasons were not any different in height.

(iii) Collar Diameter

Use of FRC and the EFN cover affected the collar diameter of tomato plants (Table 10). Significant differences in collar diameter were observed at 29, 43, 50, 57, 64, and 85 DAT. In most data collection dates, collar diameter was thickest under FRC used permanently and thinnest in the control treatment in both seasons. Amongst the other treatments, collar diameter was higher under 0.4-mm net covered permanently followed by FRC opened thrice a week, 0.4 mm net opened thrice a week, 0.9-mm net covered permanently, 0.9-mm net open thrice a week and lowest under the chemical treatment. Overall, thicker stems were recorded in season 2 (12.2 mm) than in season 1 (11.9 mm).

(iv) Number of Leaves

Tomato leaf numbers were significantly influenced by the use of FRC and EFN (Table 11). In both seasons plants under FRC used permanently produced the highest number of leaves while the control plants had the least number of leaves. Like with collar diameter, leaf numbers were higher under 0.4-mm net covered permanently followed by FRC opened thrice a week, 0.4-mm net opened thrice a week, 0.9-mm net covered permanently, 0.9-mm net open thrice a week and lowest under the chemical treatment among the other treatments during most data collection dates. Overall, plants in season 2 produced more leaves (11.5 leaves/plant) than those of season 1 (10.8 leaves/plant).

(v) Days to Maturity

Using FRC and EFN in tomato production significantly influenced the time taken to fruit maturity (Table 12). In season 1, tomato fruits under the FRC used permanently took less days to

Table 10. Effects of floating row covers (FRC) and eco-friendly nets (EFN) on tomato collar diameter (mm) during production in season 1 (May to Oct. 2011) and season 2 (Oct. 2011 to Mar. 2012).

		Time (days after transplanting)									
Treatment*	Season	22	29	36	43	50	57	64	71	78	85
Control	1	6.05**	6.59 g***	7.51	9.45 f	10.42 g	11.48 g	11.98 g	12.53	13.19	13.19 g
Chemical	1	6.34	7.51 f	9.00	10.57 e	11.53 e	12.44 f	12.98 f	14.34	15.12	15.20 ef
FRC permanent	1	6.93	10.51 a	12.24	14.16 a	15.45 a	16.29 a	16.41 a	16.79	17.21	17.27 a
0.4-mm EFN permanent	1	6.85	10.20 b	11.47	13.07 b	14.51 b	15.28 b	15.47 b	15.72	16.44	16.52 b
0.9-mm EFN permanent	1	6.45	7.79 e	8.99	11.56 c	12.49 cd	13.53 c	13.97 c	14.72	15.36	15.43 d
FRC opened	1	6.35	8.17 cd	9.48	11.16 d	12.42 cd	13.52 c	13.96 c	15.51	16.11	16.23 c
0.4-mm EFN opened	1	6.29	8.15 d	9.22	10.62 e	11.42 e	12.47 f	12.96 f	14.40	15.09	15.12 f
0.9-mm EFN opened	1	6.26	8.07 d	8.90	10.51 e	11.32 f	12.64 ef	12.93 f	14.36	15.05	15.12 f
Control	2	6.05	6.64 g	7.53	9.58 f	10.47 g	11.50 g	11.99 g	12.54	13.15	13.16 g
Chemical	2	6.33	7.52 ef	9.22	10.61 e	11.53 e	12.44 f	12.99 f	14.36	15.12	15.13 f
FRC permanent	2	6.93	10.51 a	12.24	14.16 a	15.45 a	16.29 a	16.41 a	16.79	17.22	17.22 a
0.4-mm EFN permanent	2	6.85	10.21 b	11.48	13.06 b	14.51 b	15.28 b	15.47 b	15.72	16.44	16.45 b
0.9-mm EFN permanent	2	6.50	8.13 d	9.00	11.56 c	12.47 cd	13.14 d	13.73 d	14.72	15.36	15.36 de
FRC opened	2	6.42	8.44 c	9.54	11.81 c	12.60 c	13.71 c	14.00 c	15.52	16.11	16.13 c
0.4-mm EFN opened	2	6.36	8.20 cd	9.22	11.57 c	12.33 d	12.96 de	13.44 e	14.52	15.25	15.26 def
0.9-mm EFN opened	2	6.26	8.07 d	8.90	10.65 e	11.55 e	12.65 ef	13.02 f	14.37	15.15	15.17 f

*Control had no pesticide applied, chemical treatment was sprayed with alphacypermethrine, permanent is where the FRC or EFN were covered throughout except during crop maintenance periods and opened is where the FRC or EFN were opened thrice a week from 9.00 am to 3.00 pm.

**Means not followed by a letter are not significantly different according to F-test at $P \leq 0.05$.

***Means followed by the same letter within a column are not significantly different according to Tukey's Honestly Significant Difference (THSD) at $P \leq 0.05$.

Table 11. Effects of floating row covers (FRC) and eco-friendly nets (EFN) on tomato leaves no./plant during season 1 (May to Oct. 2011) and season 2 (Oct. 2011 to Mar. 2012).

		Time (days after transplanting)									
Treatment*	Season	22	29	36	43	50	57	64	71	78	85
Control	1	4.27 e**	5.63 e	6.53 j	7.59 j	8.30 i	8.74 j	9.16 l	9.92 l	10.20 j	10.39 i
Chemical	1	5.49 bc	6.29 d	7.67 gh	7.97 i	8.86 h	11.37 h	11.91 jk	12.86 gh	13.21 h	13.43 g
FRC permanent	1	6.41 a	7.66 b	9.58 b	10.84 ab	13.62 a	15.48 b	15.70 bc	16.26 b	17.42 bc	17.58 b
0.4-mm EFN permanent	1	6.42 a	7.67 b	8.60 de	10.20 c	12.63 b	13.53 d	14.24 d	15.79 bc	16.47 de	16.62 cd
0.9-mm EFN permanent	1	5.64 bc	6.44 d	7.79 fgh	8.64 efg	10.39 d	11.57 h	12.24 ij	14.36 e	15.41 fg	15.43 f
FRC opened	1	5.07 d	6.39 d	7.63 gh	8.63 fg	9.87 e	12.51 e	13.18 efg	14.43 e	15.99 ef	16.30 de
0.4-mm EFN opened	1	5.36 cd	6.16 d	7.60 gh	8.35 gh	9.65 ef	11.60 h	12.33 hij	14.16 ef	15.17 g	15.33 f
0.9-mm EFN opened	1	5.86 b	6.10 d	7.37 hi	7.59 gh	9.32 fg	11.41 h	12.26 ij	14.14 ef	15.14 g	15.34 f
Control	2	4.36 e	6.11 d	7.01 i	7.96 i	8.77 h	10.01 i	11.31 k	12.21 h	12.47 i	12.61 h
Chemical	2	5.29 cd	6.43 d	7.81 fgh	8.23 hi	9.07 gh	11.60 h	12.74 ghi	13.53 fg	13.76 h	13.87 g
FRC permanent	2	6.41 a	8.50 a	10.09 a	11.17 a	13.87 a	16.06 a	17.13 a	17.39 a	18.23 a	18.36 a
0.4-mm EFN permanent	2	6.42 a	8.14 a	9.13 c	10.76 b	12.93 b	14.46 c	16.34 b	17.39 a	17.62 ab	17.74 ab
0.9-mm EFN permanent	2	5.59 bc	6.88 c	7.99 fg	8.93 ef	10.54 cd	12.06 fg	13.67 def	15.34 cd	15.59 fg	15.71 ef
FRC opened	2	5.57 bc	7.57 b	8.73 cd	9.66 d	10.83 c	13.28 d	15.27 c	16.46 b	16.86 cd	17.03 bc
0.4-mm EFN opened	2	5.61 bc	7.04 c	8.21 ef	8.99 e	10.37 d	12.33 ef	13.84 de	15.36 cd	15.58 fg	15.71 ef
0.9-mm EFN opened	2	5.36 cd	6.41 d	7.83 fg	8.49 gh	9.52 ef	11.70 gh	13.06 fgh	14.69 de	14.94 g	15.01 f

*Control had no pesticide applied, chemical treatment was sprayed with alphacypermethrine, permanent is where the FRC or EFN were covered throughout except during crop maintenance periods and opened is where the FRC or EFN were opened thrice a week from 9.00 am to 3.00 pm.

**Means followed by the same letter within a column are not significantly different according to Tukey's Honestly Significant Difference (THSD) at $P \leq 0.05$.

Table 12. Effects of floating row covers (FRC) and eco-friendly nets (EFN) on tomato fruit maturity (days) during production in season 1 (May to Oct. 2011) and season 2 (Oct. 2011 to Mar. 2012).

Treatment*	Season 1	Season 2	**Treatment Means**
Control	82.00 o**	83.20 no	**82.60 e**
Chemical	86.20 n	81.40 op	**83.80 bcd**
FRC permanent	80.40 opq	72.60 t	**76.50 e**
0.4-mm EFN permanent	91.00 m	75.20 rst	**83.10 cd**
0.9-mm EFN permanent	93.60 lm	76.80 rs	**85.20 abc**
FRC opened	83.40 no	73.80 st	**78.60 e**
0.4-mm EFN opened	94.20 lm	77.20 qrs	**85.70 ab**
0.9-mm EFN opened	95.00 l	78.20 pqr	**86.60 a**
Season Means	**88.23 h**	**77.30 i**	

*Control had no pesticide applied, chemical treatment was sprayed with alphacypermethrine, permanent is where the FRC or EFN were covered throughout except during crop maintenance periods and opened is where the FRC or EFN were opened thrice a week from 9.00 am to 3.00 pm.

**Means followed by the same letter within in a letter series are not significantly different according to Tukey's Honestly Significant Difference (THSD) at $P \leq 0.05$.

reach the pink stage maturity while those under 0.9-mm net opened thrice a week took the most days to mature compared with the control, chemical treatment, 0.4-mm net covered permanently, 0.9-mm net covered permanently, FRC opened thrice a week, and 0.4-mm net opened thrice.

In the second season, however, fruits under the control took the most days to mature but fruits under the FRC used permanently were still the earliest to mature. Among the other treatments, fruits under the chemical treatment took more days to mature followed by 0.9-mm net opened thrice a week, 0.4-mm net opened thrice a week, 0.9-mm net covered permanently, 0.4-mm net covered permanently, and FRC opened thrice a week. On average, early fruit maturity was observed in the second season compared with the first season.

4.2.1.4 Effects of Floating Row Covers and Eco-friendly Nets on Pest Population and Disease Incidences

This section presents the results on i) weed population, ii) population of leafminers iii) population of cotton bollworms iv) population of onion thrips v) population of mites vi) population of silverleaf whiteflies vii) population of aphids and viii) incidences of late blight.

The use of FRC and EFN in tomato production influenced pest population and late blight incidences (Table 13). Major weeds observed during the study were oxalis (*Oxalis latifolia*), blackjack (*Bidens pilosa*), and gallant soldier (*Galinsoga parviflora*). The main insect pests were leafminers (*Lyriomyzer* sp.), cotton bollworms (*Helicoverpa armigera*), onion thrips (*Thrips tabaci*), mites (*Tetranychus* sp.), silverleaf whiteflies (*Bemisia tabaci*), and aphids (*Aphis* sp.) while the major disease experienced was late blight (*Phytophthora infestans*).

(i) Weed Population

The use of FRC and EFN influenced monthly weed population (Fig. 13). In the first season, the control and chemical treatment had the lowest weed population at 15 and 45 DAT while. FRC used permanently had the lowest weed population at 75 and 105 DAT. In the second season, the chemical and control treatments had the lowest weed population while FRC used permanently had the highest at 15 DAT. At 45 through 105 DAT FRC used permanently had the

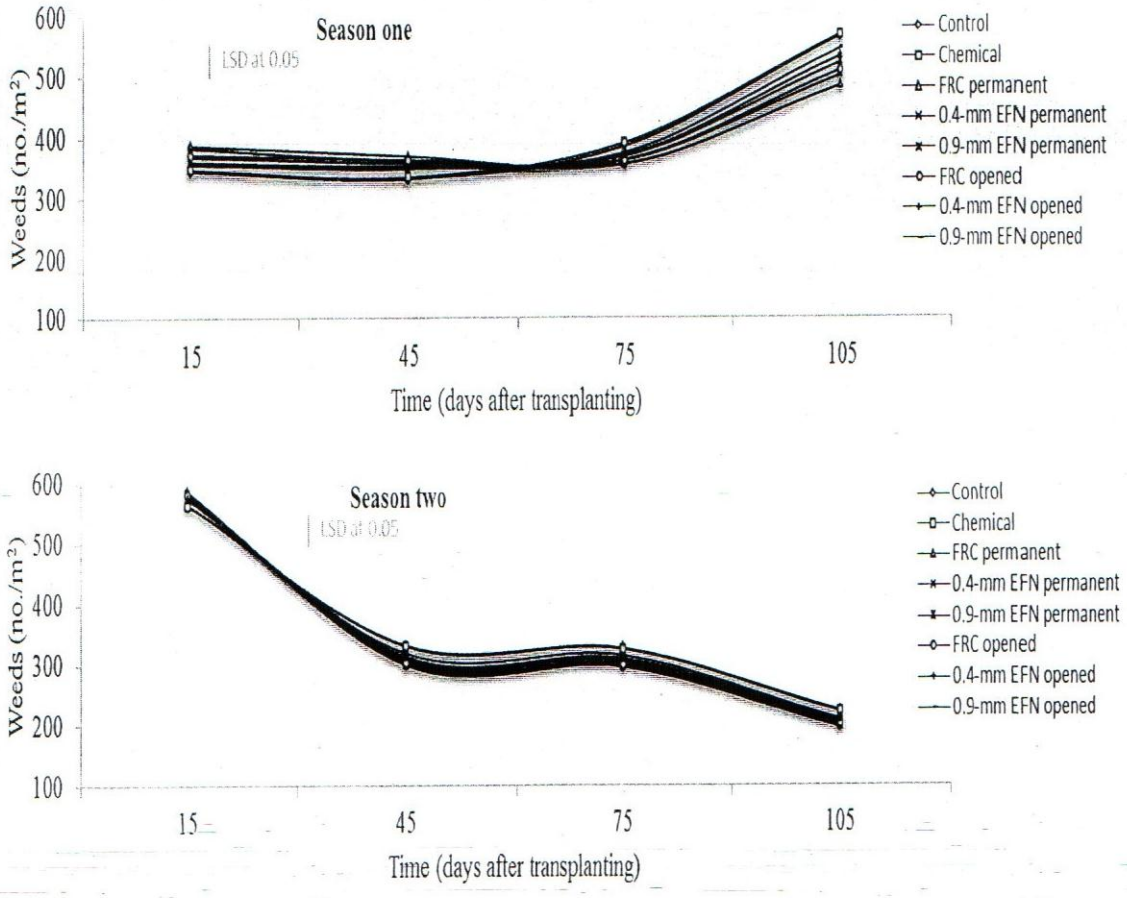


Fig. 13. Effects of floating row covers and eco-friendly nets on monthly weed population during tomato production in season 1 (May. to Oct. 2011) and season 2 (Oct. 2011 to Mar. 2012). Control had no pesticide applied, chemical treatment was sprayed with alphacypermethrine, permanent is where the FRC or EFN were covered throughout except during crop maintenance periods, and opened is where the FRC or EFN were opened thrice a week from 9.00 am to 3.00 pm.

lowest weed population while the control and chemical treatments had the highest weed population.

FRC and EFN had significant influence on weed population (Table 13). The control and chemical treatments had higher weed population while FRC used permanently had the lowest weed population in both seasons. Among other treatments, FRC opened thrice a week had lower weed population followed by 0.4-mm net covered permanently, 0.4-mm net opened thrice a week, 0.9-mm net covered permanently, and 0.9-mm net opened thrice a week. Higher weed population was recorded in the first season compared with the second season.

(ii) Population of Leafminers

The use of FRC and EFN influenced weekly population of leafminers (Fig. 14). The control had the highest leafminers population while FRC used permanently had the lowest throughout the study in both seasons. Among other treatments, 0.4-mm net covered permanently had lower leafminers population followed by the chemical treatment, FRC opened thrice a week, 0.9-mm net covered permanently, 0.4-mm net opened thrice a week, and 0.9-mm net opened thrice a week most of the days data was obtained.

Use of FRC and EFN significantly influenced the population of leafminers (Table 13). The control had the highest leafminers population in both seasons while the chemical treatment, FRC used permanently and 0.4-mm net covered permanently had the lowest leafminers population. In the second season, FRC used permanently and 0.4-mm net covered permanently had the lowest population of leafminers. For the other treatments, 0.9-mm net covered permanently and FRC opened thrice a week had lower leafminers population followed by 0.4-mmn net and 0.9-mm net opened thrice a week. Higher leafminers population was observed in the second season compared with the first season.

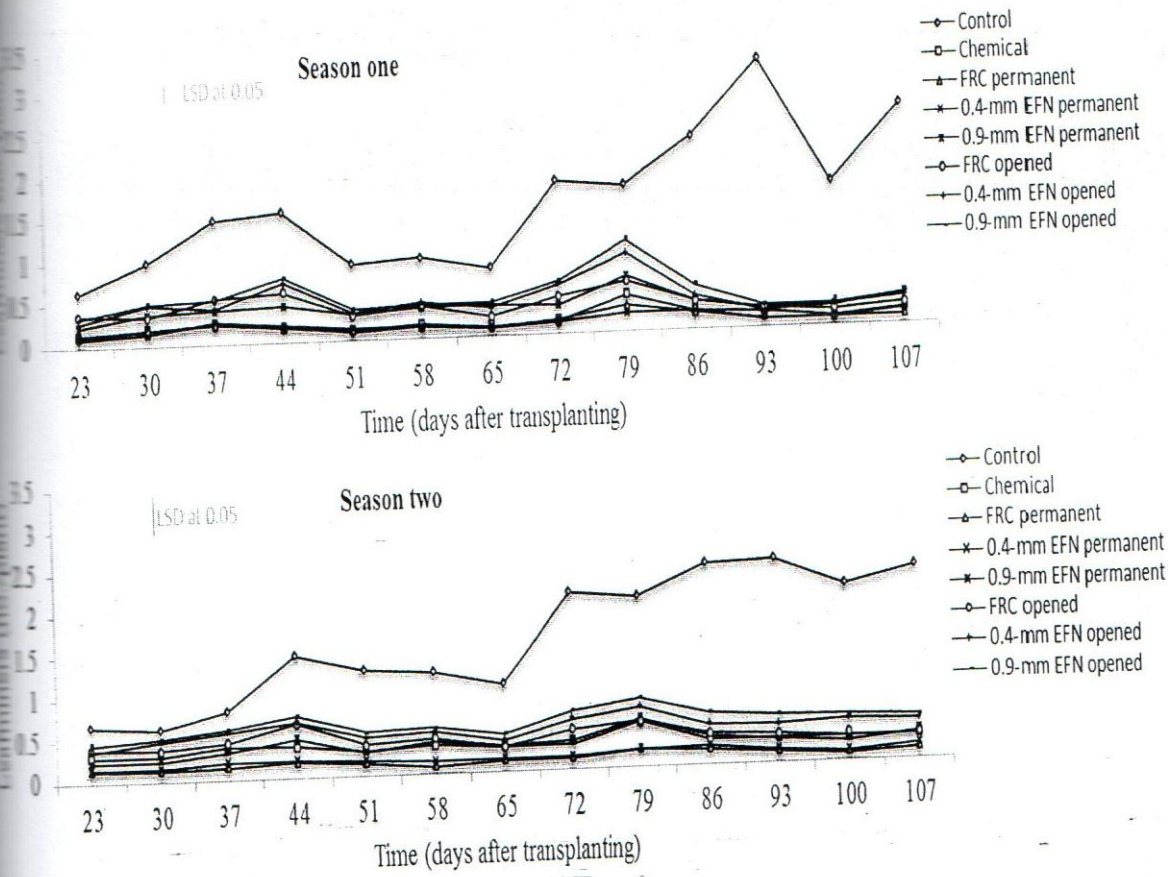
Table 13. Effects of floating row covers (FRC) and eco-friendly nets (EFN) on pest population during production of tomato in season 1 (May to Oct. 2011) and season 2 (Oct. 2011 to Mar. 2012).

Treatment*	Season	Weeds (no./m^2)**	Leafminers (no./plant)	Cotton bollworms (no./plant)	Onion thrips (no./plant)	Mites (no./plant)	Silverleaf whiteflies (no./plant)	Aphids (no./plant)	Late blight (%)
Control	1	407.05 ab	1.61 a***	1.50 a	3.22 b	3.46 b	4.40 b	5.30 b	42.53 b
Chemical	1	410.70 a	0.19 e	0.19 f	0.26 hi	0.39 fg	0.28 ij	0.31 hi	23.19 fg
FRC permanent	1	400.30 c	0.16 e	0.18 f	0.24 i	0.22 h	0.21 j	0.24 i	13.19 j
0.4-mm EFN permanent	1	402.85 bc	0.16 e	0.15 f	0.26 hi	0.25 gh	0.32 ij	0.39 gh	15.38 ij
0.9-mm EFN permanent	1	405.40 abc	0.35 d	0.33 e	0.52 fg	0.44 f	0.61 g	0.62 ef	19.56 gh
FRC opened	1	401.45 de	0.37 d	0.34 de	0.51 fg	0.46 f	0.60 g	0.51 fg	22.64 fg
0.4-mm EFN opened	1	404.20 de	0.45 cd	0.41 cde	0.68 de	0.64 de	0.84 f	0.87 d	23.08 fg
0.9-mm EFN opened	1	406.65 ab	0.50 bc	0.46 c	0.86 c	0.82 c	1.08 cd	1.08 c	25.16 ef
Control	2	361.00 d	1.57 a	1.45 a	4.32 a	3.80 a	6.16 a	6.89 a	46.92 a
Chemical	2	360.50 d	0.34 d	0.36 ed	0.42 gh	0.43 f	0.64 g	0.54 f	34.29 c
FRC permanent	2	344.85 f	0.13 e	0.12 f	0.23 i	0.20 h	0.28 ij	0.25 hi	13.85 ij
0.4-mm EFN permanent	2	347.95 ef	0.16 e	0.16 f	0.28 hi	0.25 gh	0.43 hi	0.36 hi	17.03 hi
0.9-mm EFN permanent	2	350.90 e	0.34 d	0.34 de	0.47 fg	0.44 f	0.86 ef	0.53 f	25.38 ef
FRC opened	2	346.95 ef	0.41 cd	0.42 cd	0.47 fg	0.46 f	0.57 gh	0.53 f	27.80 de
0.4-mm EFN opened	2	349.60 ef	0.50 bc	0.48 c	0.62 ef	0.62 de	1.01 de	0.75 de	30.88 cd
0.9-mm EFN opened	2	352.65 e	0.58 b	0.58 b	0.79 cd	0.73 cd	1.19 c	0.82 d	32.97 c

*Control had no pesticide applied, chemical treatment was sprayed with alphacypermethrine, permanent is where the FRC or EFN were covered throughout except during crop maintenance periods and opened is where the FRC or EFN were opened thrice a week from 9.00 am to 3.00 pm.

**Data for pest population and late blight incidences were transformed using square root and arcsine transformation, respectively before ANOVA and mean separation but means presented are original means.

***Means followed by the same letter within a column and a parameter are not significantly different according to Tukey's Honestly Significant Difference (THSD) at $P \leq 0.05$.



14. Effects of floating row covers and eco-friendly nets on weekly population of leafminers during tomato production in season 1 (May to Oct. 2011) and season 2 (Oct. 2011 to Mar. 2012). Control had no pesticide applied, chemical treatment was sprayed with alphacypermethrine, permanent is where the FRC or EFN were covered throughout except during crop maintenance periods, and opened is where the FRC or EFN were opened thrice a week from 9.00 am to 3.00 pm.

(iii) Population of Cotton Bollworms

The use of FRC and EFN influenced weekly population of cotton bollworms on tomato plants (Fig. 15). In both seasons, the control had the highest cotton bollworms population while FRC used permanently had the lowest cotton bollworms population throughout the study. Among other treatments, 0.4-mmm net covered permanently had lower cotton bollworms population followed by the chemical treatment, FRC opened thrice a week, 0.9-mm net covered permanently, 0.4-mm net opened thrice a week, and 0.9-mm net opened thrice a week in most of the weeks of data collection. Averaged within each season, the use of FRC and EFN cover significantly reduced the population of cotton bollworms on tomato plants (Table 13). The control had the highest cotton bollworms population in both seasons while the chemical treatment, FRC used permanently and 0.4-mm net covered permanently had the lowest cotton bollworms population. In the second season, FRC used permanently and 0.4-mm net covered permanently had the lowest population of cotton bollworms. For the other treatments, 0.9-mm net covered permanently and FRC opened thrice a week had lower cotton bollworms population followed by 0.4-mmn net opened thrice a week and 0.9-mm net opened thrice a week. Generally, higher cotton bollworms populations were observed in the season two than in season one.

(iv) Population of Onion Thrips

The use of FRC and EFN influenced weekly population of onion thrips (Fig. 16). In both seasons, the control had higher population of onion thrips throughout the study. FRC used permanently had the lowest onion thrips population in most of the data collection days. Compared with other treatments, the chemical treatment had lower onion thrips population followed by 0.4-mm net covered permanently, FRC opened thrice a week, 0.9-mm net covered permanently, 0.4-mm net opened thrice a week, and 0.9-mm net opened thrice a week in both seasons. Averaged within each season, the use of FRC or EFN significantly reduced population of onion thrips (Table 13). The control and FRC used permanently had the highest and lowest population of onion thrips, respectively in the first season. Among other treatments, 0.4-mm net covered permanently had a lower population followed by the chemical treatment, 0.9-mm net covered permanently, FRC opened thrice a week, 0.4-mm net opened thrice, and 0.9-mm

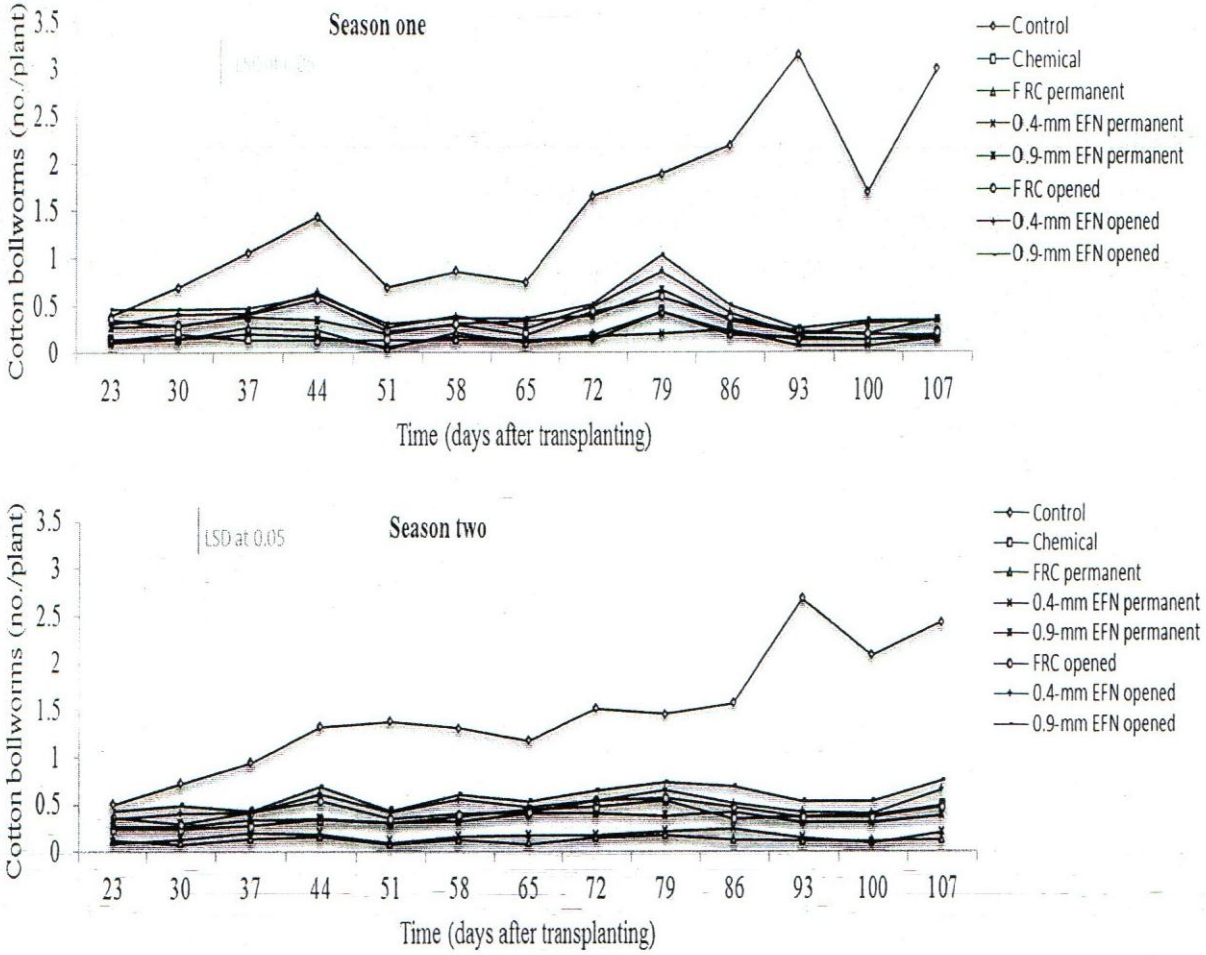


Fig. 15. Effects of floating row covers and eco-friendly nets on weekly cotton bollworm population during tomato production in season 1 (May to Oct. 2011) and season 2 (Oct. 2011 to Mar. 2012). Control had no pesticide applied, chemical treatment was sprayed with alphacypermethrine, permanent is where the FRC or EFN were covered throughout except during crop maintenance periods and opened is where the FRC or EFN were opened thrice a week from 9.00 am to 3.00 pm.

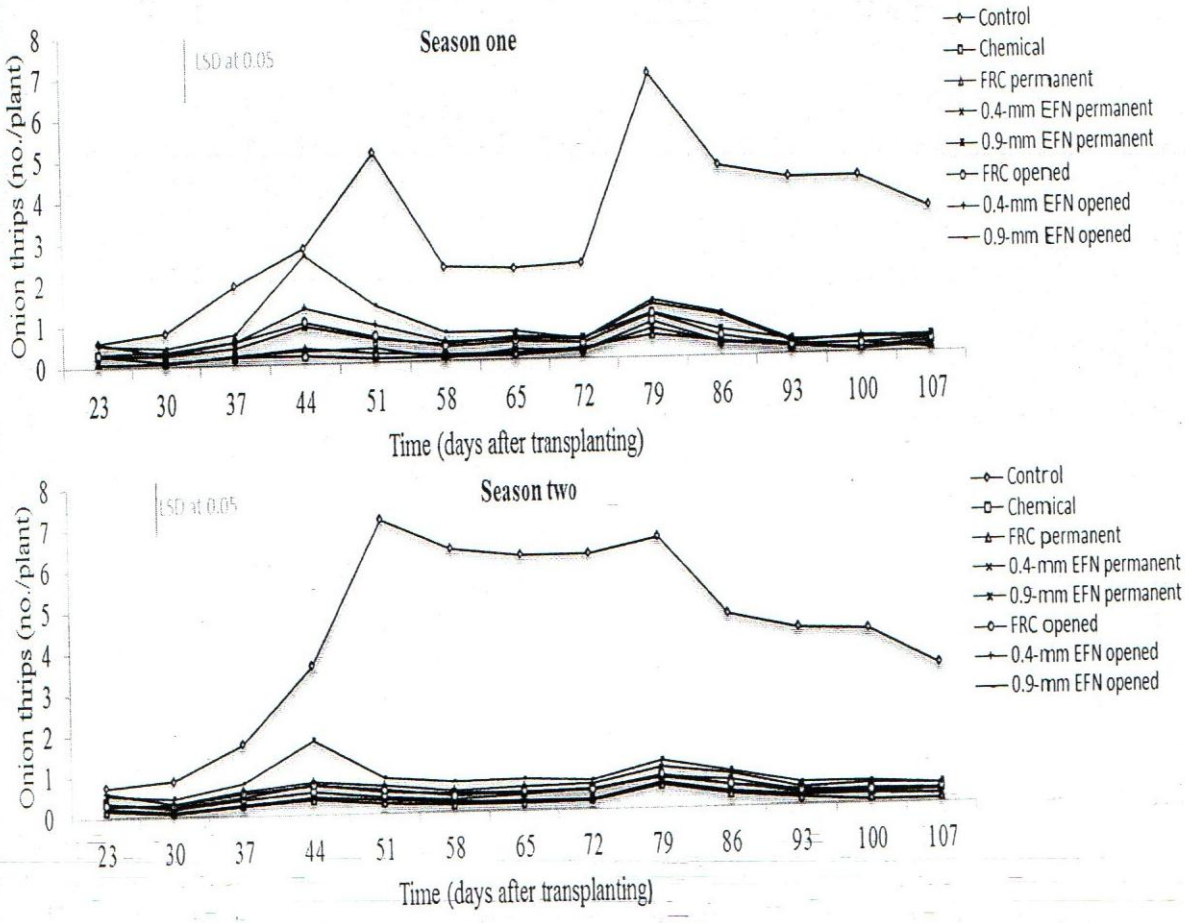


Fig. 16. Effects of floating row covers and eco-friendly nets on weekly population of onion thrips during tomato production in season 1 (May to Oct. 2011) and season 2 (Oct. 2011 to Mar. 2012). Control had no pesticide applied, chemical treatment was sprayed with alphacypermethrine, permanent is where the FRC or EFN were covered throughout except during crop maintenance periods and opened is where the FRC or EFN were opened thrice a week from 9.00 am to 3.00 pm.

net opened thrice a week. Generally, season two had higher population of onion thrips compared with season one.

v) Population of Mites

The use of FRC and EFN also influenced the weekly population of mites on tomato plants (Fig. 17). In both seasons, the control and FRC used permanently had the highest and lowest population of mites throughout the study, respectively. Among other treatments, 0.4-mm net covered permanently had a lower mite population, followed by the chemical treatment, 0.9-mm net covered permanently, FRC opened thrice a week, 0.4-mm net opened thrice a week, and 0.9-mm net opened thrice a week. Averaged within each season, the population of mites was significantly reduced by the use of FRC and EFN cover on tomato plants (Table 13). The control had the highest population of mites while the FRC treatment had the lowest population in both seasons. Among other treatments, 0.4-mm net covered permanently had lower population of mites followed by the chemical treatment, 0.9-mm net covered permanently and FRC opened thrice a week which were not significantly different, 0.4-mm net opened thrice a week, and 0.9-mm net opened thrice a week. In the general, season two had more mites recorded compared with season one.

(vi) Population of Silverleaf Whiteflies

The use of FRC and EFN affected the weekly population of silverleaf whiteflies (Fig. 18). In both seasons, the control and FRC used permanently had the highest and the lowest population of silverleaf whiteflies, respectively throughout the season. Among other treatments, 0.4-mm net covered permanently had lower population of silverleaf whiteflies followed by the chemical treatment, 0.9-mm net covered permanently, FRC opened thrice a week, 0.4-mm net opened thrice a week, and 0.9-mm net opened thrice a week. Averaged within each season, population of silverleaf whiteflies on tomato plants was significantly reduced by use of FRC and EFN covers (Table 13). In both seasons, the control and FRC used permanently had the lowest and the highest population of silverleaf whiteflies, respectively throughout the study. Among other treatments, the chemical treatment and 0.4-mm net covered permanently had lower

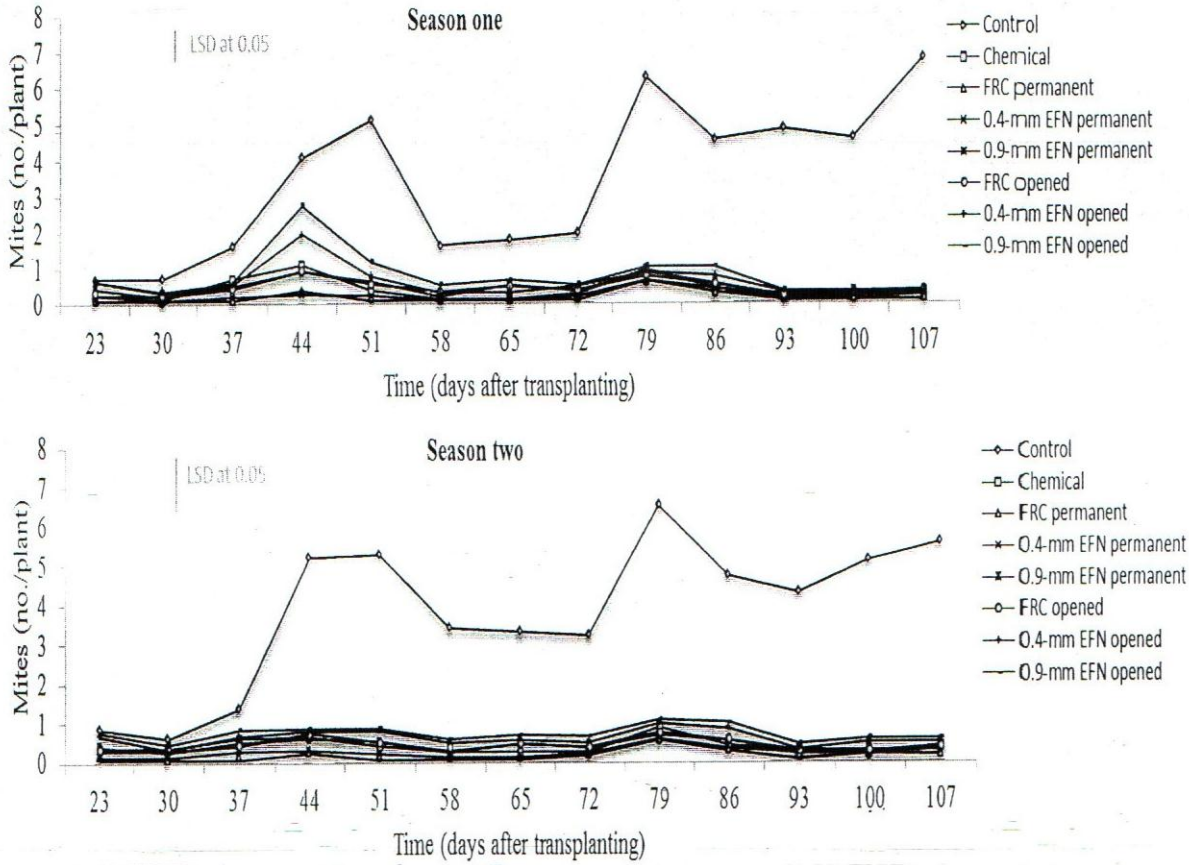


Fig. 17. Effects of floating row covers and eco-friendly nets on weekly mites population during tomato production in season 1 (May to Oct. 2011) and season 2 (Oct. 2011 to Mar. 2012). Control had no pesticide applied, chemical treatment was sprayed with alphacypermethrine, permanent is where the FRC or EFN were covered throughout except during crop maintenance periods and opened is where the FRC or EFN were opened thrice a week from 9.00 am to 3.00 pm.

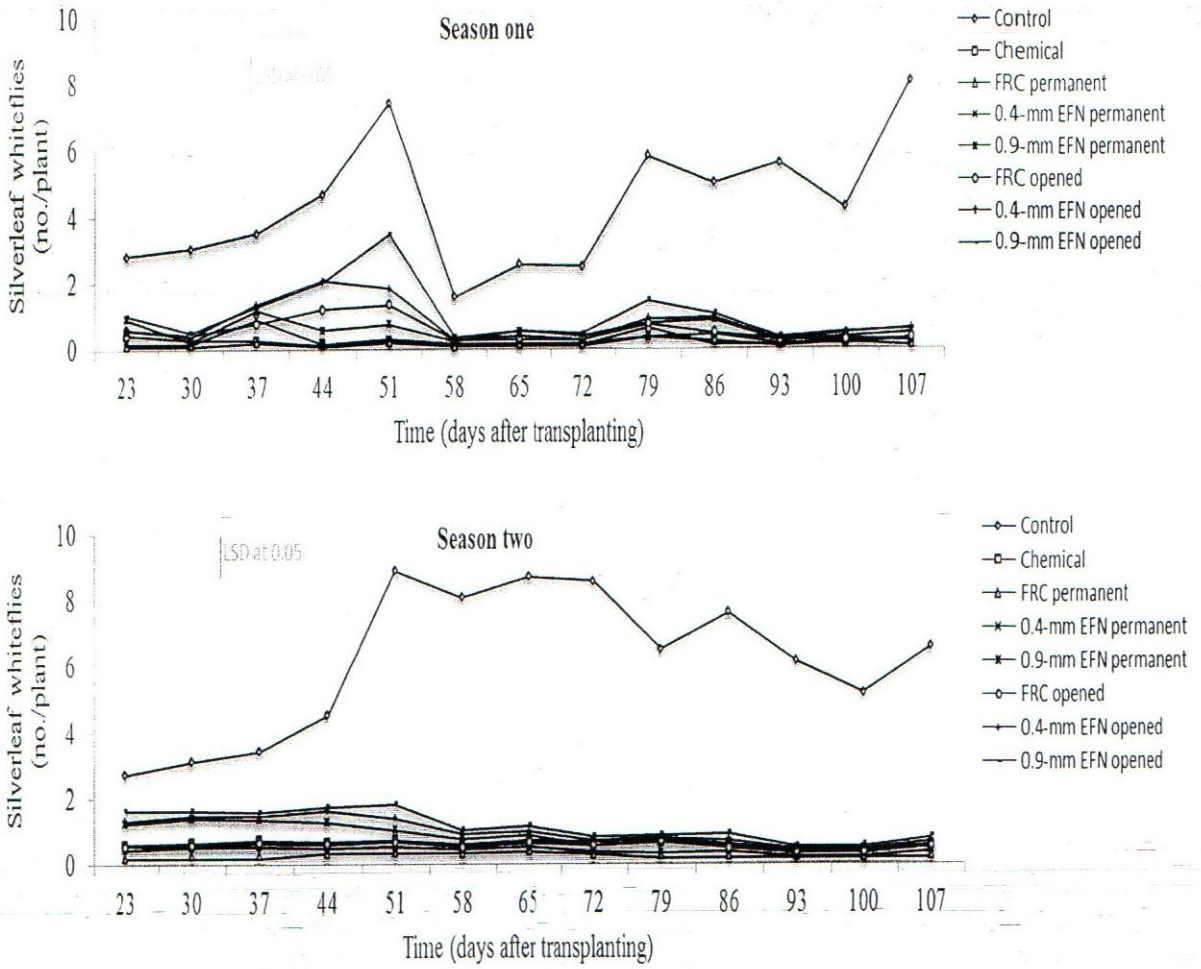


Fig. 18. Effects of floating row covers and eco-friendly nets on weekly silverleaf whiteflies population during tomato production in season 1 (May to Oct. 2011) and season 2 (Oct. 2011 to Mar. 2012). Control had no pesticide applied, chemical treatment was sprayed with alphacypermethrine, permanent is where the FRC or EFN were covered throughout except during crop maintenance periods and opened is where the FRC or EFN were opened thrice a week from 9.00 am to 3.00 pm.

population of silverleaf whiteflies followed by 0.9-mm net covered permanently and FRC opened thrice a week which were not statistically different, 0.4-mm net opened thrice a week and 0.9-mm net opened thrice a week. In general, season 2 had more silverleaf whiteflies recorded compared with season one.

(vii) Population of Aphids

The use of FRC and EFN influenced weekly population of aphids (Fig. 19). In both seasons, the control had the highest population of aphids while FRC used permanently had the lowest population of aphids throughout the study. Among other treatments, the chemical treatment had lower population of aphids, followed by 0.4-mm net covered permanently, 0.9-mm net covered permanently, FRC opened thrice a week, 0.4-mm net opened thrice a week and 0.9-mm net opened thrice a week in most of the data collection days. Averaged within season, FRC and EFN significantly reduced the population of aphids on tomato plants (Table 13). The control had the highest population in both seasons. The chemical treatment and FRC used permanently had the lowest population of aphids in the first season while FRC used permanently and 0.4-mm net covered permanently had the lowest population of aphids in the second season. Among other treatments, FRC opened thrice a week had lower population of aphids followed by 0.9-m net used permanently, 0.4-mm net opened thrice a week, and 0.9-mm net opened thrice a week. Generally, season two had more aphids recorded than in season one.

(viii) Late Blight Incidences

The use of FRC and EFN covering affected the weekly incidences of late blight (Fig. 20). In the first season, the control had the highest late blight incidences throughout the study while in the second season; it had the highest late blight incidences from 23 through 72 DAT with 0.9-mm net opened thrice a week recording highest incidences from 79 through 107 DAT. FRC used permanently had the lowest incidences of late blight in both seasons throughout the study. Among other treatments, 0.4-mm net covered permanently had lower late blight incidences followed by 0.9-mm net covered permanently FRC opened thrice a week, 0.4-mm net opened

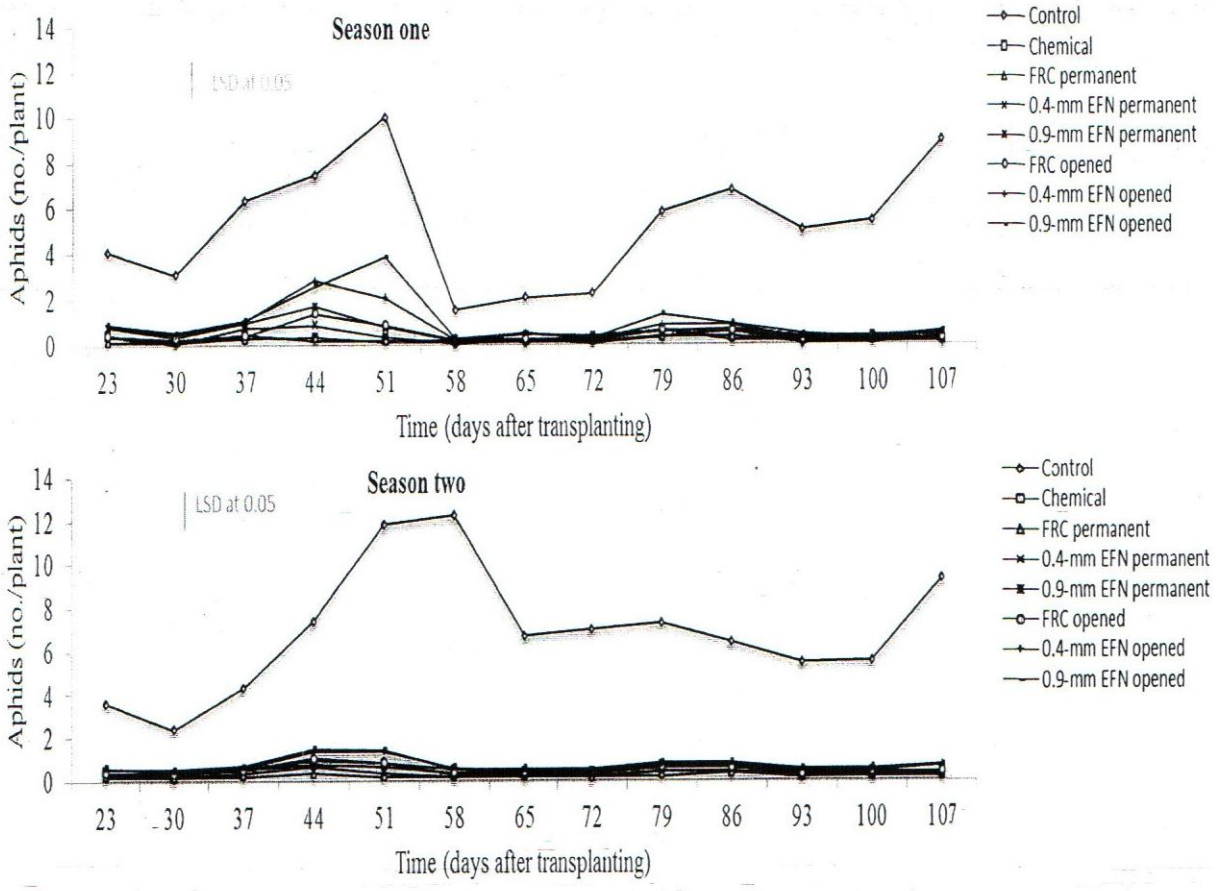


Fig. 19. Effects of floating row covers and eco-friendly nets on weekly aphid population during tomato production in season 1 (May to Oct. 2011) and season 2 (Oct. 2011 to Mar. 2012). Control had no pesticide applied, chemical treatment was sprayed with alphacypermethrine, permanent is where the FRC or EFN were covered throughout except during crop maintenance periods and opened is where the FRC or EFN were opened thrice a week from 9.00 am to 3.00 pm.

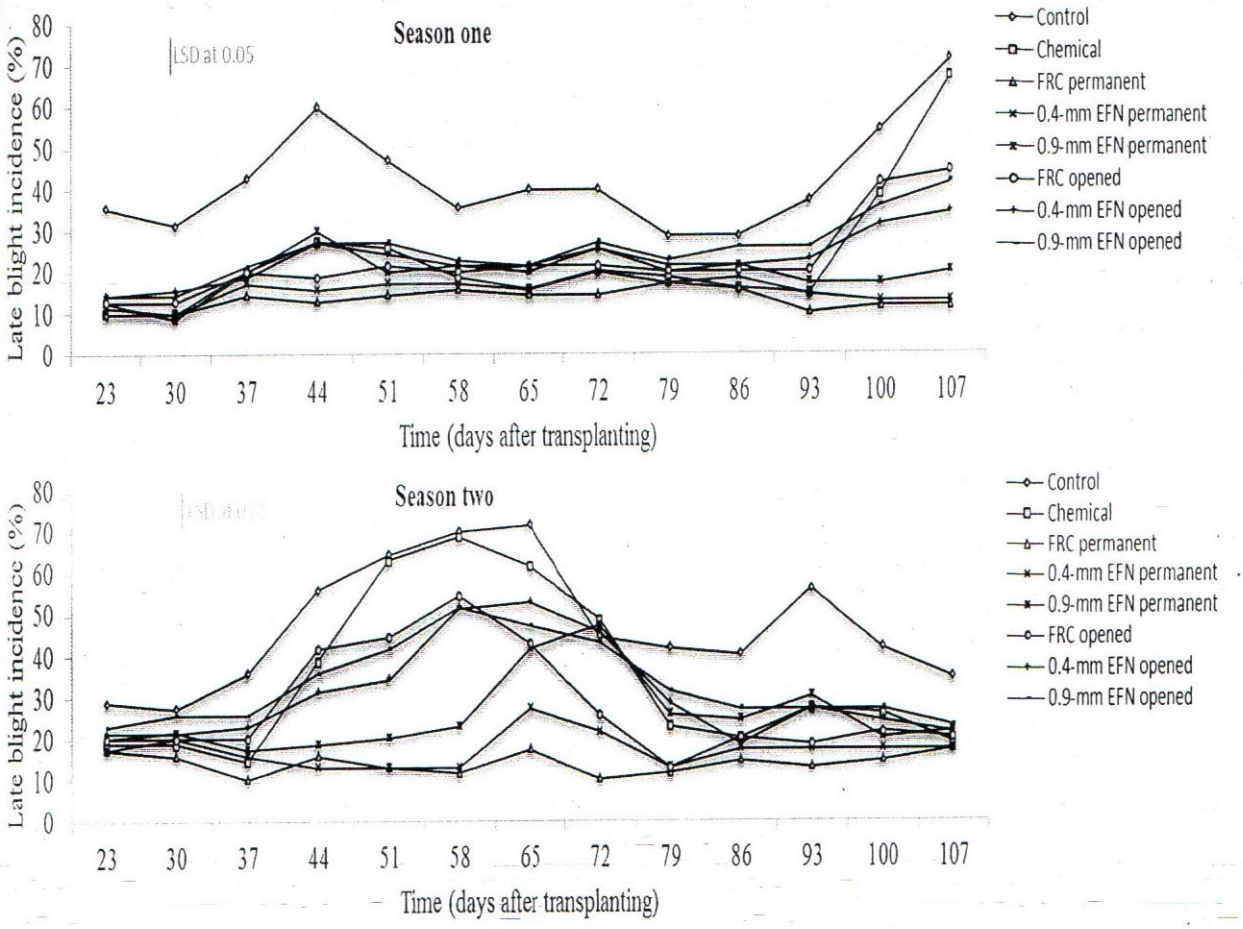


Fig. 20. Effects of floating row covers and eco-friendly nets on weekly late blight incidences during tomato production in season 1 (May to Oct. 2011) and season 2 (Oct. 2011 to Mar. 2012). Control had no pesticide applied, chemical treatment was sprayed with alphacypermethrine, permanent is where the FRC or EFN were covered throughout except during crop maintenance periods and opened is where the FRC or EFN were opened thrice a week from 9.00 am to 3.00 pm.

thrice a week, the chemical treatment, and 0.9-mm net opened thrice a week. Averaged across each season, the use of FRC and EFN significantly reduced late blight incidences (Table 13).

The control and FRC used permanently had the highest and lowest incidences of late blight, respectively in both seasons. Among other treatments, 0.4-mm net covered permanently had lower incidences of late blight followed by 0.9-mm net covered permanently, FRC opened thrice a week, 0.4-mm net opened thrice a week, the chemical treatment and 0.9-mm net opened thrice a week. Generally, season two had higher incidences of late blight compared with season one.

4.2.2 Effects of Cover Pore Diameter and Opening on Microclimate Modification, Tomato Performance, Pest and Disease Incidences

This section presents the results of how the pore diameter of the cover used and whether the cover was opened or maintained permanently covered influenced i) microclimate ii) tomato physiology iii) tomato growth and iv) pest population and disease incidences.

4.2.2.1 Effects of Cover Pore Diameter and Cover Opening on Microclimate Modification during Tomato Field Production

Microclimate variables covered under this section include i) temperature ii) relative humidity iii) soil moisture iv) photosynthetic active radiation v) light quantity and vi) diurnal temperature range.

(i) Temperature

The air temperature around the crop was influenced by the main effects of cover pore diameter as well as cover opening. In both seasons, temperatures tended to be higher under the FRC (0.1-mm pore diameter) compared with the 0.4-mm and 0.9-mm EFN pore diameters (Fig. 21). Among the EFN covers, the smaller mesh size (0.4-mm pore diameter) also recorded higher air temperature than the larger pore diameter (0.9-mm pore diameter) cover in both seasons. Cover opening also affected air temperature within the vicinity of the crop. Using the cover permanently resulted in a higher mean temperature in both seasons compared with when the covers were opened thrice a week. For any given cover pore diameter, temperatures were higher

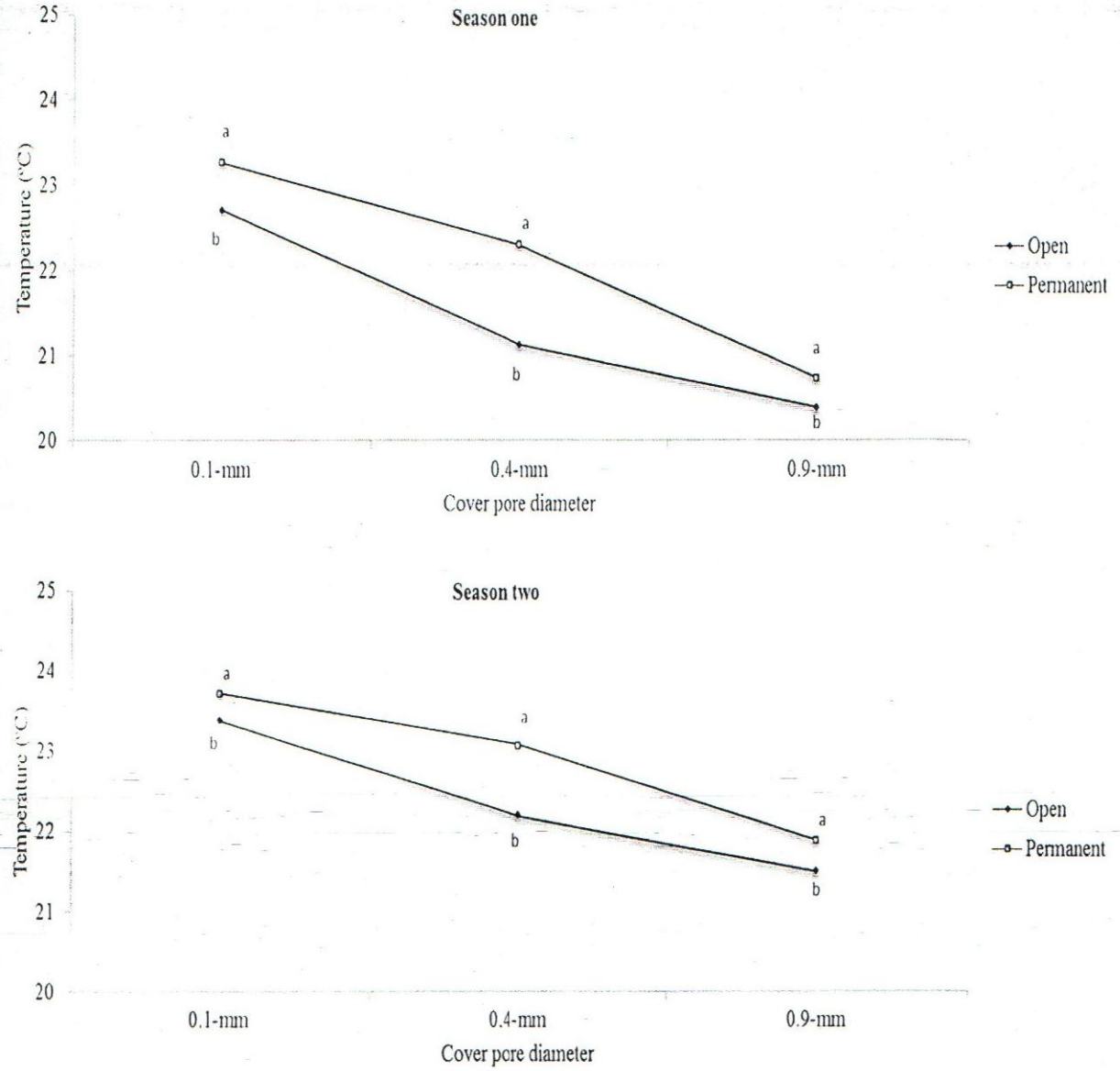


Fig 21. Effects of cover pore diameter and opening on air temperature during tomato production in season 1 (May to Oct. 2011) and season 2 (Oct. 2011 to Mar. 2012). 0.1-mm was the pore diameter size for FRC used while 0.4-mm and 0.9-mm were the pore diameters for EFN used. Covers were either used permanently unless during maintenance and data collection or opened thrice a week from 9.00 am to 3.00 pm. For a specific season and pore diameter, data points followed by the same letter are not significantly different according to Tukey's Honestly Significant Difference (THSD) at $P \leq 0.05$.

when the crop was maintained under permanent cover than when the cover was opened thrice every week.

(ii) Relative Humidity

Both cover pore diameter and cover opening did not have much effect on the relative humidity content of the immediate crop environment. Relative humidity, however, tended to be slightly higher under the 0.9-mm mesh cover and lowest under the 0.1-mm FRC in both seasons (Fig. 22). In both seasons, opening of covers tended to result in higher relative humidity within the cover than maintaining the nets or FRC permanently covered. For any given cover pore diameter, relative humidity also tended to be higher when the cover was opened thrice a week than when it was maintained permanently covered.

(iii) Soil Moisture

Soil moisture was also influenced by the main effect of cover pore diameter and cover opening in both seasons (Fig. 23). During the first season, FRC maintained a higher mean soil moisture content compared with 0.4-mm net and 0.9-mm net. In this season, maintaining the nets or FRC permanently covered also resulted in higher soil moisture content than when the covers were opened thrice a week. The trend was not any different in season 2 where FRC recorded a higher mean soil moisture content during the season compared with 0.4-mm and 0.9-mm nets. Similarly, permanent covering resulted in higher soil moisture than opening the covers thrice a week. For any given cover pore diameter, soil moisture also tended to be higher when the cover was maintained permanently covered than when it was opened thrice a week.

(iv) Photosynthetic Active Radiation

Both the cover pore diameter and cover opening did not have much influence on the photosynthetic active radiation (PAR). However, PAR tended to be slightly higher under the 0.1-mm FRC compared with 0.4-mm and 0.9-mm EFN in both seasons (Fig. 24). In the first season, no much difference was observed on PAR. Cover opening did not have much influence in the first season. However, during the second season, covers opened thrice a week had higher PAR compared with those used permanently.

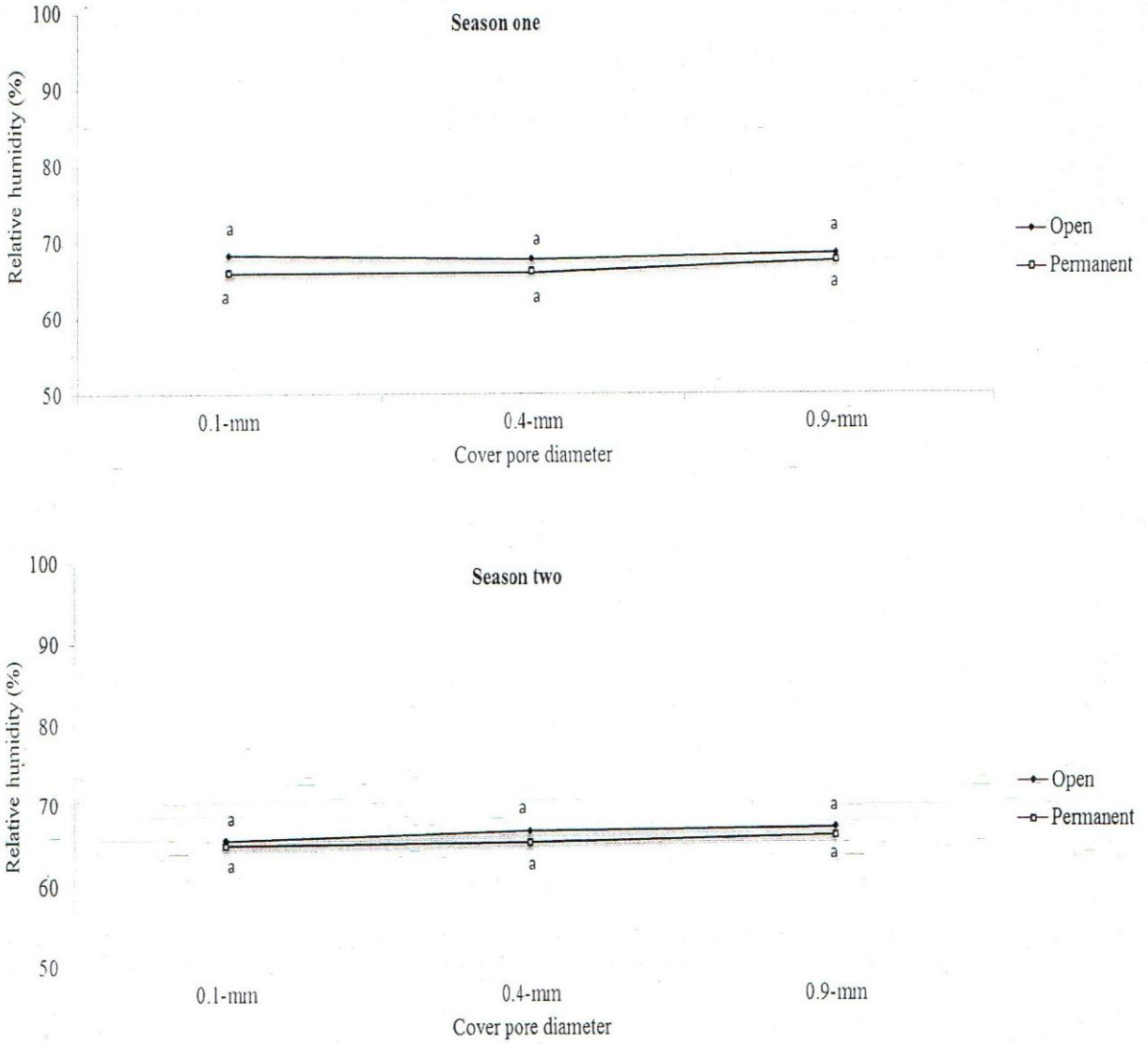


Fig. 22. Effects of cover pore diameter and opening on the relative humidity during tomato production in season 1 (May to Oct. 2011) and season 2 (Oct. 2011 to Mar. 2012). 0.1-mm was the pore diameter size for FRC used while 0.4-mm and 0.9-mm was the pore diameter for EFN used. Covers were either used permanently unless during maintenance and data collection or opened thrice a week from 9.00 am to 3.00 pm. For a specific season and pore diameter, data points followed by the same letter are not significantly different according to Tukey's Honestly Significant Difference (THSD) at $P \leq 0.05$.

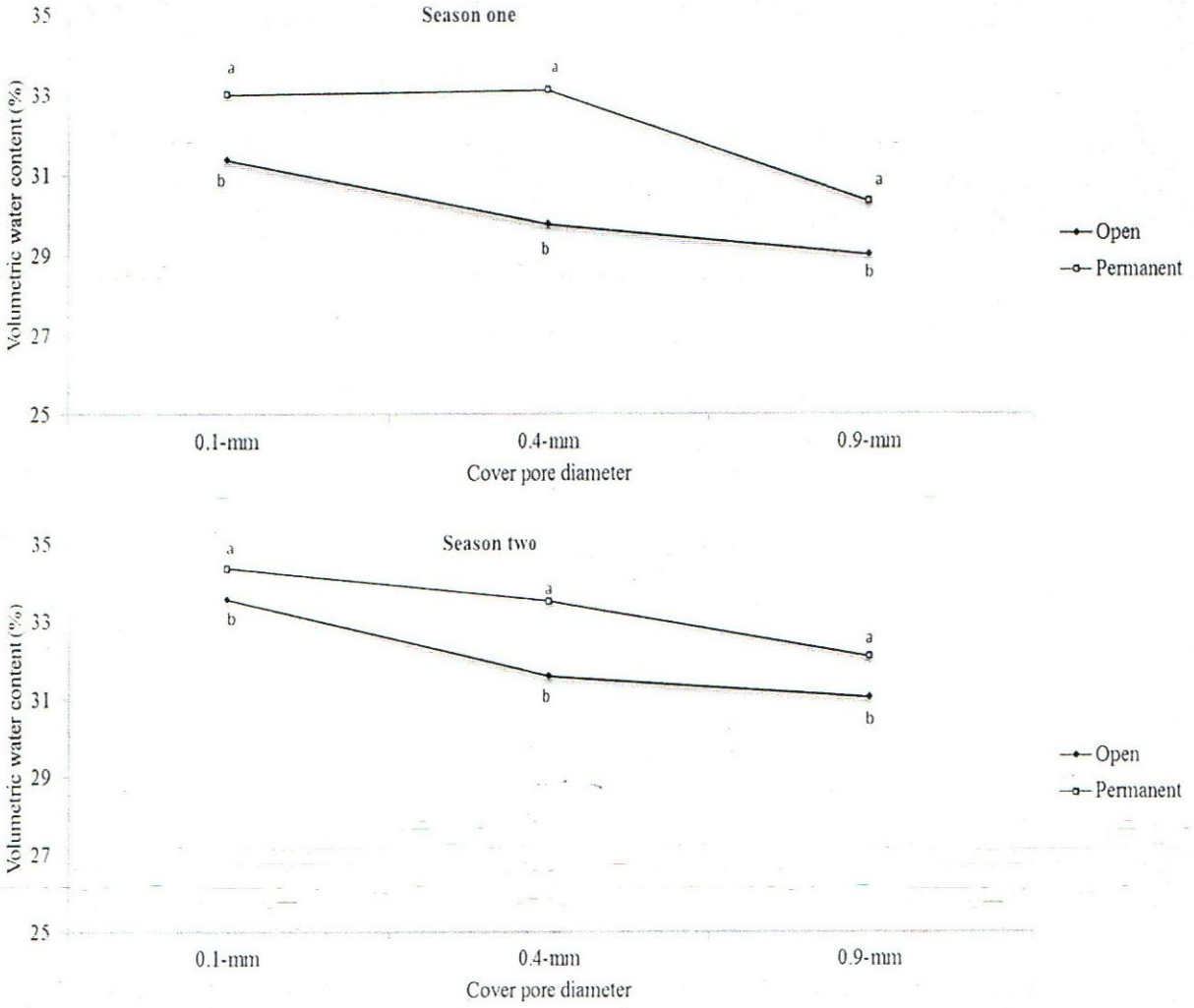


Fig. 23. Effects of cover pore diameter and opening on soil moisture content (volumetric water content) during tomato production in season 1 (May to Oct. 2011) and season 2 (Oct. 2011 to Mar. 2012). 0.1-mm was the pore diameter size for FRC used while 0.4-mm and 0.9-mm was the pore diameter for EFN used. Covers were either used permanently unless during maintenance and data collection or opened thrice a week from 9.00 am to 3.00 pm. For a specific season and pore diameter, data points followed by the same letter are not significantly different according to Tukey's Honestly Significant Difference (THSD) at $P \leq 0.05$.

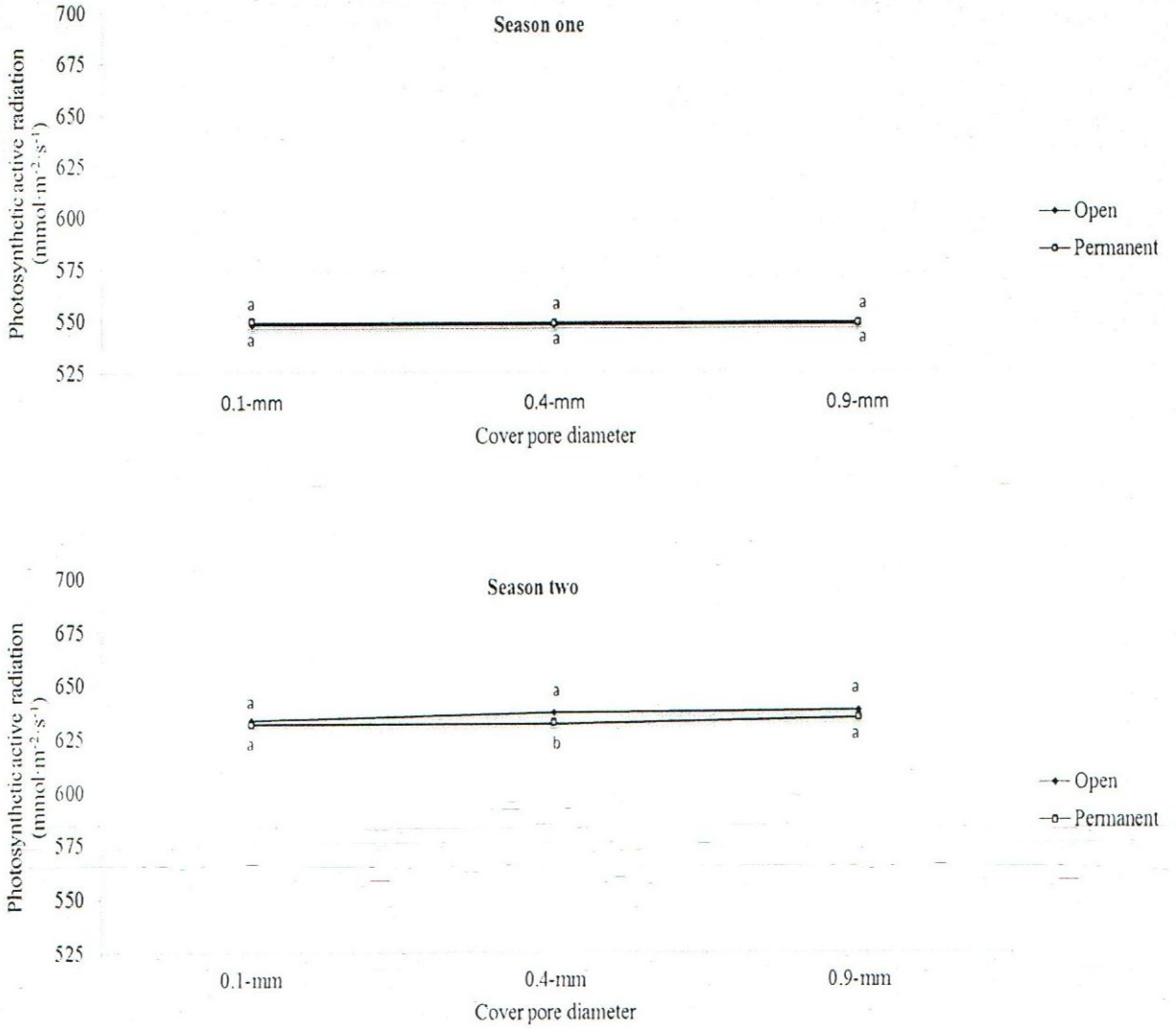


Fig. 24. Effects of cover pore diameter and opening on photosynthetic active radiation during tomato production in season 1 (May to Oct. 2011) and season 2 (Oct. 2011 to Mar. 2012). 0.1-mm was the pore diameter size for FRC used while 0.4-mm and 0.9-mm was the pore diameter for EFN used. Covers were either used permanently unless during maintenance and data collection or opened thrice a week from 9.00 am to 3.00 pm. For a specific season and pore diameter, data points followed by the same letter are not significantly different according to Tukey's Honestly Significant Difference (THSD) at $P \leq 0.05$.

(v) Light Quantity

Light quantity was influenced by the main effect of cover pore diameter and opening (Fig. 25). In both seasons, lower light quantity was recorded under the 0.1-mm FRC compared with the 0.4-mm and 0.9-mm nets. Covers opened thrice a week allowed in more light compared with those maintained permanently covered, in both seasons. For any given cover pore diameter, light quantity also tended to be higher when the cover was opened thrice a week than when it was maintained permanently covered.

(vi) Diurnal Temperature Range

Both the cover pored diameter and opening influenced the diurnal temperature range (Fig. 26). In both seasons, the 0.1-mm FRC had lower diurnal temperature range compared with 0.4-mm and 0.9-mm nets. Covers used permanently had lower diurnal temperature range compared with those opened thrice a week in both seasons. For any given cover pore diameter, diurnal temperature range also tended to be lower when the cover was maintained permanently covered than when it was opened thrice a week.

4.2.2.2 Effects of Cover Pore diameter and Cover Opening on Tomato Leaf Stomatal Conductance and Chlorophyll Content

Tomato physiological characteristics covered under this section include i) tomato leaf stomatal conductance and ii) tomato leaf chlorophyll content.

(i) Leaf stomatal conductance

Tomato leaf stomatal conductance was significantly influenced by the main effects of cover pore diameter and cover opening in both seasons (Table 14). Throughout the sampling dates of both seasons, tomato plants grown under the 0.1-mm FRC recorded higher leaf stomatal conductance than those grown under 0.4-mm or 0.9-mm nets. The lowest leaf stomatal conductance was obtained in leaves of tomato grown under the larger pore diameter net (0.9-mm) in both seasons. Cover opening also significantly effected stomatal conductance throughout the study with plants that were permanently covered recording significantly higher stomatal conductance compared with those grown under cover that was opened thrice a week. The

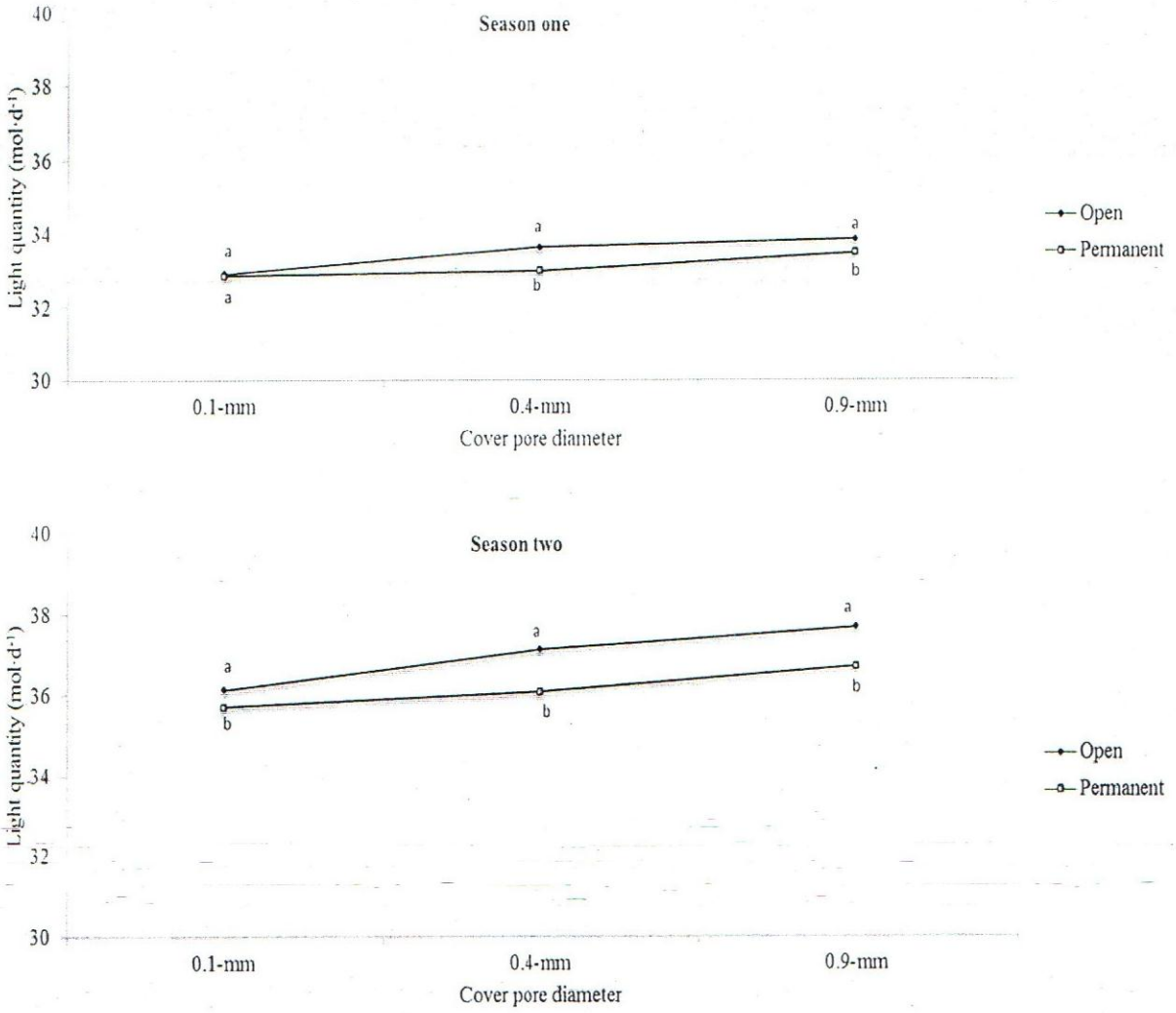


Fig. 25. Effects of cover pore diameter and opening on light quantity during tomato production in season 1 (May to Oct. 2011) and season 2 (Oct. 2011 to Mar. 2012). 0.1-mm was the pore diameter size for FRC used while 0.4-mm and 0.9-mm was the pore diameter for EFN used. Covers were either used permanently unless during maintenance and data collection or opened thrice a week from 9.00 am to 3.00 pm. For a specific season and pore diameter, data points followed by the same letter are not significantly different according to Tukey's Honestly Significant Difference (THSD) at $P \leq 0.05$.

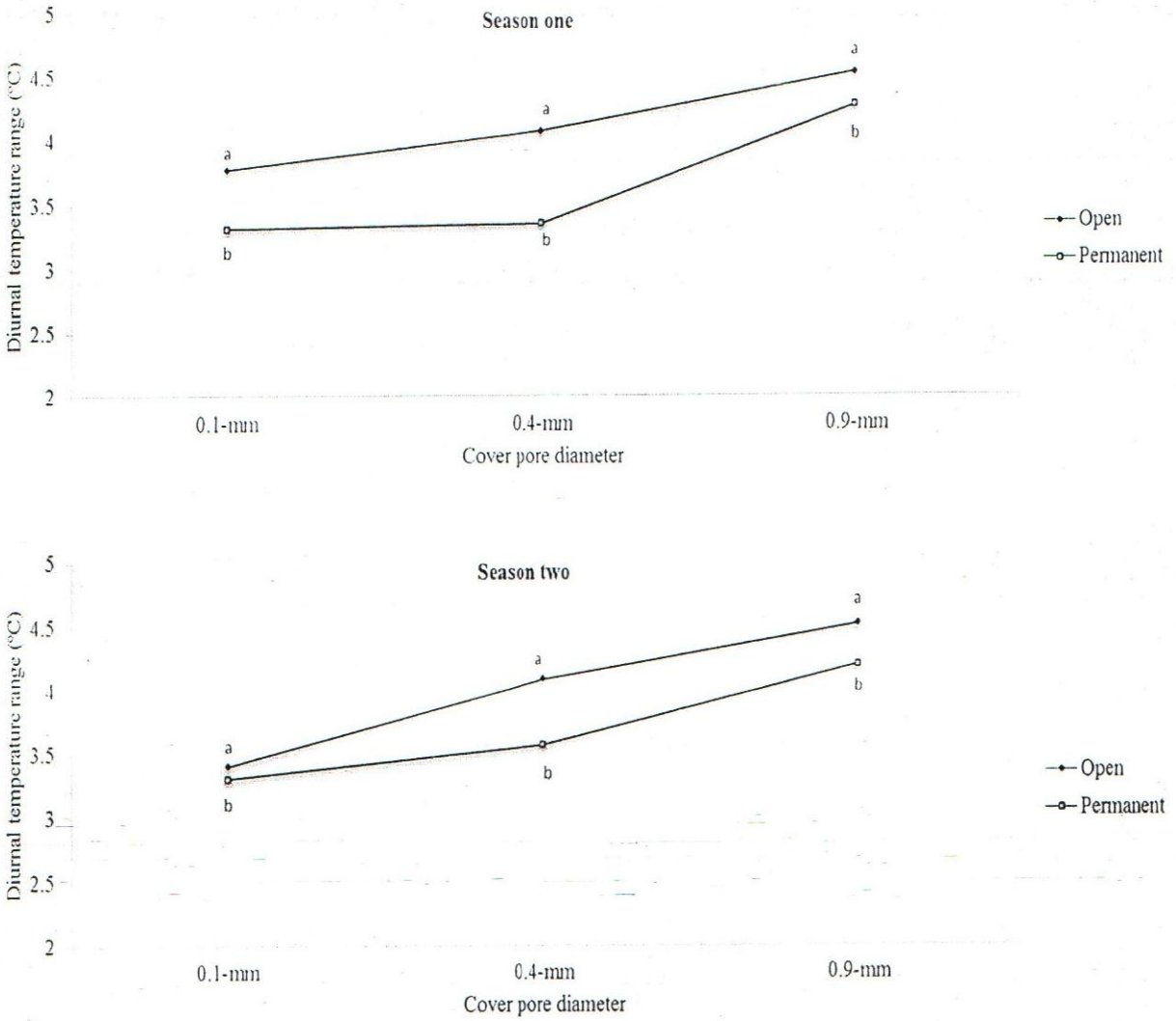


Fig. 26. Effects of cover pore diameter and opening on diurnal temperature range during tomato production in season 1 (May to Oct. 2011) and season 2 (Oct. 2011 to Mar. 2012). 0.1-mm was the pore diameter size for FRC used while 0.4-mm and 0.9-mm was the pore diameter for EFN used. Covers were either used permanently unless during maintenance and data collection or opened thrice a week from 9.00 am to 3.00 pm. For a specific season and pore diameter, data points followed by the same letter are not significantly different according to Tukey's Honestly Significant Difference (THSD) at $P \leq 0.05$.

Table 14. Effects of cover pore diameter and opening on stomatal conductance ($mmol \cdot m^{-2} \cdot s^{-1}$) during production of tomato in season 1 (May to Oct. 2011) and season 2 (Oct. 2011 to Mar. 2012).

	Time (days after transplanting)								
	26			54			82		
	Cover opening*			Cover opening			Cover opening		
Cover pore diameter	Opened	Permanent	**Pore diameter means**	Opened	Permanent	**Pore diameter means**	Opened	Permanent	**Pore diameter means**
				A. Season one					
0.1-mm FRC	520.40**	553.38	**536.89 a*** **	560.77 l	608.44 j	**584.61 a**	567.67 l	614.53 j	**591.10 a**
0.4-mm EFN	487.60	534.44	**511.02 b**	509.68 mn	591.54 k	**550.61 b**	515.04 m	595.99 k	**555.52 b**
0.9-mm EFN	459.86	484.69	**472.28 c**	503.55 n	510.15 m	**506.85 c**	509.13 n	516.16 m	**512.64 c**
Cover opening means	**489.29 g**	**524.17 f**		**524.66 g**	**570.04 f**		**530.62 g**	575.56 f	
				B. Season two					
0.1-mm FRC	531.20 l	574.61 j	**552.90 a**[v]	565.37 l	614.24 j	**589.81 a**	570.81 l	619.13 j	**594.97 a**
0.4-mm EFN	495.51 m	553.84 k	**524.68 b**	513.78 m	596.34 k	**555.06 b**	520.21 m	599.64 k	**559.93 b**
0.9-mm EFN	467.96 n	489.88 m	**478.92 c**	506.85 n	516.15 m	**511.50 c**	512.67 n	520.22 m	**516.45 c**
Cover opening means	**498.22 g**	**539.44 f**		**528.67 g**	**575.58 f**		**534.56 g**	**579.67 f**	

*Covers were either maintained permanently or opened thrice a week from 9.00 am to 3.00 pm.

**Means not followed by a letter are not significantly different according to F-test at $P \leq 0.05$.

***Means followed by the same letter in a letter series within a specific date and a season are not significantly different according to Tukey's Honestly Significant Difference (THSD) at $P \leq 0.05$.

interaction between cover pore diameter and cover opening was significant at 54 and 82 DAT but not at 26 DAT with FRC used permanently and 0.9-mm net opened thrice a week having the highest and the lowest stomatal conductance, respectively. However, in all sampling dates, a common trend could be established whereby for any given cover pore diameter, leaf stomatal conductance tended to be higher when the plants were maintained under permanent cover as compared with when the cover was opened thrice a week.

(ii) Leaf chlorophyll content

The effects of cover pore diameter and cover opening on tomato leaf chlorophyll content followed a trend similar to that of leaf stomatal conductance. Tomato leaf chlorophyll content was significantly influenced by the main effects of cover pore diameter and cover opening in both seasons (Table 15). Throughout the sampling dates of both seasons, tomato plants grown under the 0.1-mm FRC recorded higher leaf chlorophyll content than those grown under 0.4-mm or 0.9-mm nets. The lowest leaf chlorophyll content was obtained in leaves of tomato plants grown under the larger pore diameter net (0.9-mm) in both seasons. Cover opening also significantly effected chlorophyll content throughout the study with plants that were permanently covered recording significantly higher chlorophyll content compared with those grown under cover that was opened thrice a week. The interaction between cover pore diameter and cover opening was also significant at 54 and 82 DAT but not at 26 DAT with plants under FRC covered permanently recording the highest chlorophyll content while those under 0.9-mm net recording the lowest chlorophyll content. However, in all sampling dates, a common trend could be established whereby for any given cover pore diameter, leaf chlorophyll content tended to be higher when the plants were maintained under permanent cover as compared with when the cover was opened thrice a week.

4.2.2.3 Effects of Cover Pore Diameter and Opening on Tomato Growth

Tomato growth variables covered in this study included i) transplant survival, ii) tomato height, iii) collar diameter, iv) tomato leaf numbers and v) days to maturity.

Table 15. Effects of cover pore diameter and opening on chlorophyll content (CCI) during tomato production in season 1 (May to Oct. 2011) and season 2 (Oct. 2011 to Mar. 2012).

	Time (days after transplanting)								
	26			54			82		
	Cover opening*			Cover opening			Cover opening		
Cover pore diameter	Opened	Permanent	**Pore diameter means**	Opened	Permanent	**Pore diameter means**	Open	Permanent	**Pore diameter means**
				A. Season one					
0.1-mm FRC	62.28**	67.23	**64.75 a*** **	67.68 kl	74.66 j	**71.17 a**	71.06 l	80.61 j	**75.84 a**
0.4-mm EFN	59.45	62.50	**60.97 ab**	64.15 kl	72.20 jk	**68.17 b**	70.05 lm	77.53 k	**73.79 b**
0.9-mm EFN	55.90	55.63	**55.77 b**	62.27 m	64.92 kl	**63.59 c**	65.91 o	68.56 n	**67.23 c**
Cover opening means	**59.21**	**61.79**		**64.70 g**	**70.59 f**		**69.00 g**	**75.57 f**	
				B. Season two					
0.1-mm FRC	67.07	70.23	**68.65 a**	69.82 j	78.40 i	**74.11 a**	76.78 k	83.44 i	**80.11 a**
0.4-mm EFN	62.19	65.44	**63.82 ab**	67.14 jk	78.14 i	**72.64 a**	73.07 l	80.53 j	**76.80 b**
0.9-mm EFN	57.63	62.45	**60.03 c**	65.50 k	66.84 jk	**66.17 b**	69.25 m	72.94 l	**71.10 c**
Cover opening means	**62.30**	**66.04**		**67.49 f**	**74.46 e**		**73.03 g**	**78.97 f**	

*Covers were either maintained permanently or opened thrice a week from 9.00 am to 3.00 pm.

**Means not followed by a letter are not significantly different according to F-test at $P \leq 0.05$.

***Means followed by the same letter in a letter series within a specific date and a season are not significantly different according to Tukey's Honestly Significant Difference (THSD) at $P \leq 0.05$.

(i) Transplant Survival

Transplant survival in the main field was affected by both the cover pore diameter and whether the cover was maintained permanently or opened thrice a week (Table 16). In both seasons, more transplants survived under the finer pore diameter cover provided by the 0.4-mm net compared with the other treatments, although this was not statistically different with 0.1-mm FRC in the second season. Among the net treatments, transplant survival was also higher under the finer 0.1-mm FRC compared with the larger 0.9-mm net cover in both seasons, although the difference in the two treatments was significant only in season 2. The survival of transplants was also influenced by cover opening. In both seasons, maintaining the plants under a permanent cover resulted in a higher transplant survival than when the cover was opened thrice a week. A significant interaction between cover pore diameter and cover opening was also observed in season 1. Within each cover pore diameter, transplant survival, however, tended to be higher when the cover was maintained permanently compared with when it was opened thrice a week.

(ii) Tomato Plant Height

Tomato height was significantly influenced by the cover pore diameter and cover opening in both seasons at all sampling dates (Table 17). At 22 DAT, the 0.1-mm FRC and 0.4-mm net had taller tomato plants compared with the 0.9-mm net in both seasons. In the other sampling dates (57 and 85 DAT), the 0.1-mm FRC had significantly taller plants while 0.9-mm net had the shortest plants in both seasons. Cover opening also significantly affected tomato plant height. Tomato plants under covers used permanently were taller compared with those under covers opened thrice a week, throughout the study in both seasons. Significant interactions were observed between the cover pore diameter and cover opening throughout the study in both seasons. An analysis of this interaction showed it in terms of magnitude of the difference in plant height of tomato plants grown under opened or permanent cover at any given cover pore diameter. 0.1-mm FRC used permanently had the tallest plants while 0.9-mm net opened thrice a week had the shortest plants. However, a trend could be established where under any given cover pore diameter, tomato plants tended to be taller when the plants were maintained under permanent cover compared to when the cover was opened thrice a week.

Table 16. Effects of cover pore diameter and opening on tomato transplant survival (%) during production in season 1 (May to Oct. 2011) and season 2 (Oct. 2011 to Mar. 2012).

Cover pore diameter	Cover opening*		Pore diameter means
	Opened	Permanent	
		A. Season one	
0.1-mm FRC	62.86 j***	71.43 j	**67.14 b**
0.4-mm EFN	65.71 j	87.14 i	**76.43 a**
0.9-mm EFN	54.29 k	70.00 j	**62.15 b**
Cover opening means	**60.95 f**	**76.19 e**	
		B. Season two	
0.1-mm FRC	87.14**	94.29	**90.72 a**
0.4-mm EFN	85.71	92.86	**89.29 a**
0.9-mm EFN	78.51	82.86	**80.70 b**
Cover opening means	**83.79 f**	**90.00 e**	

*Covers were either maintained permanently or opened thrice a week from 9.00 am to 3.00 pm.
**Means not followed by a letter are not significantly different according to F-test at $P \leq 0.05$.
***Data for transplant survival was transformed using arcsine transformation before ANOVA and mean separation but means presented are the original means.
****Means followed by the same letter in a letter series within a season are not significantly different according to Tukey's Honestly Significant Difference (THSD) at $P \leq 0.05$.

Table 17. Effects of cover pore diameter and opening on tomato plant height (cm) during season 1 (May to Oct. 2011) and season 2 (Oct. 2011 to Mar. 2012).

	Time (days after transplanting)								
	22			57			85		
	Cover opening*			Cover opening			Cover opening		
Cover pore diameter	Opened	Permanent	**Pore diameter means**	Opened	Permanent	**Pore diameter means**	Opened	Permanent	**Pore diameter means**
				A. Season one					
0.1-mm FRC	23.91 j**	29.40 i	**26.66 a**	53.49 k	62.27 j	**57.88 a**	58.72 k	67.86 j	**63.29 a**
0.4-mm EFN	24.40 j	28.81 i	**26.61 a**	53.50 k	55.61 k	**54.56 b**	56.61 m	58.65 k	**57.63 b**
0.9-mm EFN	24.30 j	24.49 j	**24.39 b**	52.42 m	54.51 l	**53.47 c**	55.45 n	57.73 l	**56.59 c**
Cover opening means	**24.21 f**	**27.57 e**		**53.14 g**	**57.46 f**		**56.93 g**	**61.41 f**	
				B. Season two					
0.1-mm FRC	25.46 j	29.57 i	**27.52 a**	54.45 k	62.04 i	**58.25 a**	58.74 k	67.86 j	**63.30 a**
0.4-mm EFN	24.76 j	29.24 i	**27.00 a**	54.09 k	56.42 j	**55.26 b**	57.02 m	58.65 k	**57.84 b**
0.9-mm EFN	24.13 j	24.77 j	**24.45 b**	52.51 l	54.04 k	**53.27 b**	55.45 n	57.65 l	**56.55 c**
Cover opening means	**24.78 f**	**27.86 e**		**53.68 f**	**57.50 e**		**57.07 g**	**61.39 f**	

*Covers were either maintained permanently or opened thrice a week from 9.00 am to 3.00 pm.

**Means followed by the same letter in a letter series within a specific date and a season are not significantly different according to Tukey's Honestly Significant Difference (THSD) at $P \leq 0.05$.

(iii) Collar Diameter

Cover pore diameter and cover opening influenced tomato plant collar diameter in both seasons throughout the study (Table 18). At 22 DAT, the 0.1-mm FRC and 0.4-mm net had thicker tomato stems compared with 0.9-mm net in both seasons. At 57 and 85 DAT, the 0.1-mm FRC had the thickest stems while 0.9-mm net had the thinner tomato plants compared with 0.4-mm net in both seasons. Cover opening also significantly affected collar diameter. Tomato plants under permanent covers had thicker stems compared with those under cover that were opened thrice a week, throughout the study in both seasons. Significant interactions were observed between the cover pore diameter and cover opening throughout the study in both seasons. Similar to the trend displayed by plant height, an analysis of the interaction showed it in terms of magnitude of the difference in collar diameter of tomato plants grown under opened or permanent cover at any given cover pore diameter. Tomato plants under 0.1-mm FRC and 0.9-mm net opened thrice a week had the thickest and thinnest collar diameter, respectively. However, for any given cover pore diameter, tomato stems tended to be thicker when the plants were maintained under permanent cover than when the cover was opened thrice a week.

(iv) Leaf Numbers

Cover pore diameter and opening influenced tomato plant leaf numbers (Table 19). Tomato leaf numbers were significantly influenced by cover pore diameter in all sampling dates except at 22 DAT in season 1 when differences were observed amongst the tomato leaf numbers recorded from the different cover pore diameters were not statistically different. In all sampling dates, plants with the highest and lowest leaf numbers were recorded under the 0.1-mm FRC and 0.9-mm net. Cover opening also significantly influenced tomato leaf numbers. Covers used permanently had higher leaf numbers compared with those opened thrice a week in both seasons throughout the study. Significant cover pore diameter x cover opening was also observed in both seasons. The interaction was also in terms of magnitude of the difference in plant leaf numbers of plants grown under opened or permanent cover at any given cover pore diameter. Tomato plants under 0.1-mm FRC used permanently had the highest leaf numbers while 0.9-mm net opened thrice a week had the lowest leaf numbers. However, for any given cover pore diameter,

Table 18. Effects of cover pore diameter and opening on tomato collar diameter (mm) during production in season 1 (May to Oct. 2011) and season 2 (Oct. 2011 to Mar. 2012).

	Time (days after transplanting)								
	22			57			85		
	Cover opening*			Cover opening			Cover opening		
Cover pore diameter	Opened	Permanent	**Pore diameter means**	Opened	Permanent	**Pore diameter means**	Opened	Permanent	**Pore diameter means**
				A. Season one					
0.1-mm FRC	6.35 j**	6.94 i	**6.65 a**	13.52 l	16.29 j	**14.91 a**	16.23 l	17.27 j	**16.75 a**
0.4-mm EFN	6.29 j	6.85 i	**6.57 a**	12.47 m	15.28 k	**13.87 b**	15.12 m	16.52 k	**15.82 b**
0.9-mm EFN	6.26 j	6.45 j	**6.36 b**	12.64 m	13.53 l	**13.09 c**	15.12 m	15.43 l	**15.27 c**
Cover opening means	**6.30 f**	**6.75 e**		**12.87 g**	**15.03 f**		**15.49 g**	**16.41 f**	
				B. Season two					
0.1-mm FRC	6.42 jk	6.93 i	**6.68 a**	13.71 l	16.29 j	**15.00 a**	16.13 l	17.22 j	**16.68 a**
0.4-mm EFN	6.36 jk	6.85 i	**6.60 a**	12.96 m	15.28 k	**14.12 b**	15.26 mn	16.45 k	**15.86 b**
0.9-mm EFN	6.26 k	6.50 j	**6.38 b**	12.65 n	13.14 m	**12.89 c**	15.17 n	15.36 m	**15.26 c**
Cover opening means	**6.35 f**	**6.76 e**		**13.11 g**	**14.90 f**		**15.52 g**	**16.35 f**	

*Covers were either maintained permanently or opened thrice a week from 9.00 am to 3.00 pm.

**Means followed by the same letter in a letter series within a specific date and a season are not significantly different according to Tukey's Honestly Significant Difference (THSD) at $P \leq 0.05$.

Table 19. Effects of cover pore diameter and opening on tomato leaves (no./plant) during season 1 (May to Oct. 2011) and season 2 (Oct. 2011 to Mar. 2012).

	Time (days after transplanting)								
	22			57			85		
	Cover opening*			Cover opening			Cover opening		
Cover pore diameter	Opened	Permanent	**Pore diameter means**	Opened	Permanent	**Pore diameter means**	Opened	Permanent	**Pore diameter means**
				A. Season one					
0.1-mm FRC	5.07 h***	6.41 e	**5.74****	12.51 l	15.48 j	**14.00 a**	16.30 l	17.58 j	**16.94 a**
0.4-mm EFN	5.36 gh	6.42 e	**5.89**	11.60 m	13.53 k	**12.56 b**	15.33 m	16.62 k	**15.97 b**
0.9-mm EFN	5.86 f	5.64 fg	**5.75**	11.41 m	11.57 m	**11.49 c**	15.34 m	15.43 m	**15.37 c**
Cover opening means	**5.43 b**	**6.16 a**		**11.84 g**	**13.53 f**		**15.66 g**	**16.54 f**	
				B. Season two					
0.1-mm FRC	5.57 j	6.41 i	**6.01 a**	13.28 l	16.06 j	**14.67 a**	17.03 k	18.36 j	**17.69 a**
0.4-mm EFN	5.61 j	6.42 i	**5.99 a**	12.33 m	14.46 k	**13.39 b**	15.71 l	17.74 j	**16.73 b**
0.9-mm EFN	5.36 j	5.59 j	**5.47 b**	11.70 n	12.06 mn	**11.88 c**	15.01 m	15.71 l	**15.36 c**
Cover opening means	**5.51 f**	**6.14 e**		**12.44 g**	**14.19 f**		**15.92 g**	**17.27 f**	

*Covers were either maintained permanently or opened thrice a week from 9.00 am to 3.00 pm.

**Means not followed by a letter are not significantly different according to F-test at $P \leq 0.05$.

***Means followed by the same letter in a letter series within a specific date and a season are not significantly different according to Tukey's Honestly Significant Difference (THSD) at $P \leq 0.05$.

tomato plants tended to have more leaves when the plants were maintained under permanent cover as compared with when the covers were opened thrice a week.

(v) Days to Maturity

The main effects of cover pore diameter and cover opening significantly influenced the maturity of tomato fruits (Table 20). Tomato fruits under the 0.9-mm net matured earlier compared with those under the 0.1-mm FRC and 0.4-mm net which had no significant difference from each other in the first season. In the second season, tomato fruits under the 0.1-mm FRC matured earliest while those under the 0.9-mm net matured latest. Cover opening had significant influence on the maturity of tomato fruits. In the first season, tomato fruits under cover opened thrice a week matured earlier compared with those maintained under permanent cover. However, in the second season, tomato fruits under permanent cover matured earlier than those under covers opened thrice a week. The cover pore diameter x cover opening interaction was, however, not significant in both seasons.

4.2.2.4 Effects of Cover Pore Diameter and Opening on Pest Population and Disease Incidences

The pest population and disease incidences variables studied include i) weed population, ii) population of leafminers, iii) population of cotton bollworms, iv) population of onion thrips, v) population of mites, vi) population of silverleaf whiteflies, vii) population of aphids, and viii) late blight incidences.

(i) Weed Population

Cover pore diameter and cover opening significantly influenced the population of weeds in the tomato fields (Table 21). The effect of cover pore diameter and cover opening on weed population, however, depended on the time from transplanting of the crop. During the initial weed evaluation period (15 DAT), the 0.1-mm FRC plots had the highest weed population while the 0.9-mm net had the lowest weed populations in both seasons. Covers used permanently also had higher weed population compared with covers opened thrice a week during these early growth stages of the crop. In the advanced stage of tomato growth (105 DAT), the 0.1-mm FRC had the lowest weed population while 0.9-mm net had the highest weed population in both

Table 20. Effects of cover pore diameter and opening on tomato fruit maturity (days from transplanting) during season 1 (May to Oct. 2011) and season 2 (Oct. 2011 to Mar. 2012).

Cover pore diameter	Cover opening*		
	Opened	Permanent	**Pore diameter means**
		A. Season one	
0.1-mm FRC	95.00**	93.60	**94.30 a*** **
0.4-mm EFN	94.20	91.00	**92.60 a**
0.9-mm EFN	83.40	80.40	**81.90 b**
Cover opening means	**88.33 f**	**90.87 e**	
		B. Season two	
0.1-mm FRC	73.80	72.60	**73.20 c**
0.4-mm EFN	77.20	75.20	**76.20 b**
0.9-mm EFN	78.20	73.80	**77.50 a**
Cover opening means	**76.40 f**	**74.87 g**	

*Covers were either maintained permanently or opened thrice a week from 9.00 am to 3.00 pm.
**Means not followed by a letter are not significantly different according to F-test at $P \leq 0.05$.
***Means followed by the same letter in a letter series within a season are not significantly different according to Tukey's Honestly Significant Difference (THSD) at $P \leq 0.05$.

Table 21. Effects of cover pore diameter and opening on weed population (no/m^2) during tomato production in season 1 (May to Oct. 2011) and season 2 (Oct. 2011 to Mar. 2012).

	Time (days after transplanting)					
	15			105		
	Cover opening*			Cover opening		
Cover pore diameter	Opened	Permanent	**Pore diameter means**	Opened	Permanent	**Pore diameter means**
			A. Season one			
0.1-mm FRC	372.0**	389.0	**380.5 a*** **	510.0	486.0	**498.0 c**
0.4-mm EFN	359.0	383.0	**371.0 b**	534.6	503.2	**518.9 b**
0.9-mm EFN	356.4	369.4	**362.9 c**	547.2	524.2	**535.7 a**
Cover opening means	**362.47 g**	**380.47 f**		**530.6 f**	**504.5 g**	
			B. Season two			
0.1-mm FRC	582.8	586.4	**584.6 a**	201.6	196.8	**199.2 c**
0.4-mm EFN	576.8	583.0	**579.9 b**	205.4	200.0	**202.7 b**
0.9-mm EFN	573.2	579.6	**576.4 c**	207.0	204.4	**205.7 a**
Cover opening means	**577.6 g**	**583.0 f**		**204.7 f**	**200.4 g**	

*Covers were either maintained permanently or opened thrice a week from 9.00 am to 3.00 pm.

**Means not followed by a letter are not significantly different according to F-test at $P \leq 0.05$.

***Means followed by the same letter in a letter-series within a season are not significantly different according to Tukey's Honestly Significant Difference (THSD) at $P \leq 0.05$.

seasons. Covers used permanently maintained lower weed population compared with covers opened thrice a week throughout the study. No significant interaction was observed between cover pore diameter and cover opening in both seasons.

(ii) Population of Leafminers

Population of leafminers was significantly affected by cover pore diameter and cover opening. In both seasons, tomato plants grown under the 0.1-mm FRC had the least leafminers while those under the 0.9-mm net had the highest population of leafminers (Table 22). Cover opening also influenced the population of leafminers. Tomato plants under permanent covers had less leafminers compared with those under covers opened thrice a week. A significant cover pore diameter x cover opening was also observed. The interaction was, however, in terms of magnitude of the difference in leafminer populations on plants grown under opened or permanent cover at any given cover pore diameter. Tomato plants under 0.1-mm FRC covered permanently had the lowest leafminers while those under 0.9-mm net had the highest leafminers For any given cover pore diameter; plants grown in covers used permanently had less leafminers compared with those under covers opened thrice a week.

(iii) Population of Cotton bollworms

The main effects of cover pore diameter and cover opening significantly influenced the population of cotton bollworms (Table 23). In the first season, the 0.1-mm FRC and 0.4-mm net had lower cotton bollworm populations compared with the 0.9-mm net treatment. A similar trend was observed in the second season with tomato plants under the 0.1-mm FRC having the lowest population of cotton bollworms and those under 0.9-mm net had the highest population. Cover opening also significantly influenced the population of cotton bollworm on tomato plants. Plants under permanent cover had less cotton bollworms compared with those under covers opened thrice a week in both seasons. The cover pore diameter x cover opening interaction was significant in both seasons with 0.1-mm FRC used permanently and 0.9-mm net opened thrice a week having the lowest and the highest population of cotton bollworms, respectively. However,

Table 22. Effects of cover pore diameter and opening on population of leafminers (no./plant) during tomato production in season 1 (May to Oct. 2011) and season 2 (Oct. 2011 to Mar. 2012).

Cover pore diameter	Cover opening*		**Pore diameter means**
	Opened	Permanent	
		A. Season one**	
0.1-mm FRC	0.37 k***	0.16 j	**0.27 b**
0.4-mm EFN	0.44 j	0.16 j	**0.30 a**
0.9-mm EFN	0.50 i	0.35 k	**0.43 a**
Cover opening means	**0.44 e**	**0.23 f**	
		B. Season two	
0.1-mm FRC	0.41 l	0.13 n	**0.27 c**
0.4-mm EFN	0.50 k	0.16 n	**0.33 b**
0.9-mm EFN	0.60 j	0.34 m	**0.46 a**
Cover opening means	**0.50 f**	**0.21 g**	

*Covers were either maintained permanently or opened thrice a week from 9.00 am to 3.00 pm.

**Data were transformed using square root before ANOVA and mean separation but means presented are the original means.

***Means followed by the same letter in a letter series within a season are not significantly different according to Tukey's Honestly Significant Difference (THSD) at $P \leq 0.05$.

Table 23. Effects of cover pore diameter and opening on population of cotton bollworms (no./plant) during tomato production in season 1 (May to Oct. 2011) and season 2 (Oct. 2011 to Mar. 2012).

Cover pore diameter	Cover opening*		
	Opened	Permanent	**Pore diameter means**
		A. Season one**	
0.1-mm FRC	0.34 k***	0.18 l	**0.26 b**
0.4-mm EFN	0.41 j	0.15 l	**0.28 b**
0.9-mm EFN	0.46 i	0.33 k	**0.40 a**
Cover opening means	**0.40 e**	**0.22 f**	
		B. Season two	
0.1-mm FRC	0.42 l	0.12 o	**0.27 c**
0.4-mm EFN	0.49 k	0.16 n	**0.32 b**
0.9-mm EFN	0.60 j	0.34 m	**0.46 a**
Cover opening means	**0.49 f**	**0.20 g**	

*Covers were either maintained permanently or opened thrice a week from 9.00 am to 3.00 pm.

**Data were transformed using square root before ANOVA and mean separation but means presented are the original means.

***Means followed by the same letter in a letter series within a season are not significantly different according to Tukey's Honestly Significant Difference (THSD) at $P \leq 0.05$.

for any given pore diameter, covers used permanently had a lower population of cotton bollworms compared with those under covers that were opened thrice week.

(iv) Population of Onion Thrips

Cover pore diameter and cover opening main effects significantly influenced the population of onion thrips (Table 24). In both seasons, tomato plants under the 0.1-mm FRC had the lowest population of onion thrips while those under the 0.9-mm net had the highest population. Cover opening also significantly influenced the population of onion thrips on tomato plants in both seasons. Using covers permanently resulted in lower population of onion thrips on tomato plants compared with when the covers were opened thrice a week. The interaction between the cover pore diameter and cover opening was not significant in the first season. However, a significant interaction between the two factors was observed in the second season with tomato plants under 0.1-mm FRC used permanently recording the lowest population while 0.9-mm net opened thrice a week having the highest population. Overall, for any given cover pore diameter; plants under permanent covers had less onion thrips population compared with those under covers opened thrice a week.

(v) Population of Mites

The main effects of cover pore diameter and cover opening significantly influenced the population of mites (Table 25). In both seasons, tomato plants grown under the 0.1-mm FRC had the lowest population of mites while those under 0.9-mm net had the highest mite population. Cover opening also significantly influenced the population of mites on tomato plants. Covers maintained permanently covered resulted in less population of mites compared with when the covers were opened thrice a week in both seasons. The interaction between the cover pore diameter and cover opening was also significant with the lowest and highest population of mites being recorded under 0.1-mm FRC used permanently and 0.9-mm net opened thrice a week, respectively. Generally, for any given pore diameter, covers used permanently had lower population of mites compared with covers opened thrice a week.

Table 24. Effects of cover pore diameter and opening on population of onion thrips (no./plant) during tomato production in season 1 (May to Oct. 2011) and season 2 (Oct. 2011 to Mar. 2012).

Cover pore diameter	Cover opening*		
	Opened	Permanent	**Pore diameter means**
		A. Season one**	
0.1-mm FRC	0.51 k****	0.24 j	**0.37 c**
0.4-mm EFN	0.68 l	0.26 j	**0.47 b**
0.9-mm EFN	0.86 m	0.52 k	**0.69 a**
Cover opening means	**0.68 f**	**0.34 g**	
		B. Season two	
0.1-mm FRC	0.47***	0.23	**0.35 c**
0.4-mm EFN	0.62	0.28	**0.45 b**
0.9-mm EFN	0.79	0.47	**0.63 a**
Cover opening means	**0.63 f**	**0.33 g**	

*Covers were either maintained permanently or opened thrice a week from 9.00 am to 3.00 pm.

**Data were transformed using square root before ANOVA and mean separation but means presented are the original means.

***Means not followed by a letter are not significantly different according to F-test at $P \leq 0.05$.

****Means followed by the same letter in a letter series within a season are not significantly different according to Tukey's Honestly Significant Difference (THSD) at $P \leq 0.05$.

Table 25. Effects of cover pore diameter and opening on population of mites (no./plant) during tomato production in season 1 (May to Oct. 2011) and season 2 (Oct. 2011 to Mar. 2012).

Cover pore diameter	Cover opening*		Pore diameter means
	Opened	Permanent	
		A. Season one**	
0.1-mm FRC	0.46 l ***	0.22 m	**0.34 c**
0.4-mm EFN	0.64 k	0.25 m	**0.44 b**
0.9-mm EFN	0.82 j	0.50 l	**0.66 a**
Cover opening means	**0.64 f**	**0.32 g**	
		B. Season two	
0.1-mm FRC	0.46 l	0.20 m	**0.33 c**
0.4-mm EFN	0.62 k	0.25 m	**0.43 b**
0.9-mm EFN	0.73 j	0.44 l	**0.58 a**
Cover opening means	**0.60 f**	**0.29 g**	

*Covers were either maintained permanently or opened thrice a week from 9.00 am to 3.00 pm.

**Data were transformed using square root before ANOVA and mean separation but means presented are the original means.

***Means followed by the same letter in a letter series within a season are not significantly different according to Tukey's Honestly Significant Difference (THSD) at $P \leq 0.05$.

(vi) Population of Silverleaf Whiteflies

Cover pore diameter and cover opening significantly influenced the population of silverleaf whiteflies (Table 26). In both seasons, plants under the 0.1-mm FRC had the lowest population of silverleaf whiteflies while the 0.9-mm net had the highest population. Cover opening also significantly affected the population of whiteflies. Tomato plants grown under permanent covers had less silverleaf whiteflies compared with those under covers that were opened thrice a week. A significant interaction was also observed between the cover pore diameter and cover opening. Tomato plants under 0.1-mm FRC used permanently had the lowest population of silver leaf whiteflies while those under 0.9-mm net opened thrice a week had the highest population. However, for any given pore diameter, covers used permanently resulted in a lower population of leafminers compared with opening of the cover thrice a week.

(vii) Population of Aphids

Cover pore diameter and cover opening significantly influenced the population of aphids (Table 27). In both seasons, plants under the 0.1-mm FRC had the lowest population of aphids while 0.9-mm net had the highest population. Cover opening also affected the population of aphids. Plants under permanent covers had a lower population of aphids compared with those under covers opened thrice a week. In both seasons, significant interactions between the cover pore diameter and cover opening were observed. Tomato plants under 0.1-mm FRC used permanently had the lowest population of aphids while those under 0.9-mm net opened thrice a week had the highest population However, for any given cover pore diameter, permanent use of covers resulted in a lower aphid populations compared with opening of covers thrice a week.

(viii) Late blight incidences

Cover pore diameter and cover opening main effects significantly influenced late blight incidences (Table 28). In the first season, tomato plants grown under the 0.1-mm FRC suffered less incidences of late blight compared with 0.4-mm and 0.9-mm nets which were not significantly different from each other. Similar observations were observed in the second season with tomato plants grown under the 0.1-mm FRC suffering less late blight incidences while those

Table 26. Effects cover pore diameter and opening on the population of silverleaf whiteflies during tomato production in season 1 (May to Oct. 2011) and season 2 (Oct. 2011 to Mar. 2012).

Cover pore diameter	Cover opening*		
	Opened	Permanent	**Pore diameter means**
		A. Season one**	
0.1-mm FRC	0.60 ***	0.21	**0.40 c****
0.4-mm EFN	0.84	0.32	**0.58 b**
0.9-mm EFN	1.08	0.61	**0.85 a**
Cover opening means	**0.84 f**	**0.38 g**	
		B. Season two	
0.1-mm FRC	0.57 m	0.28 o	**0.43 c**
0.4-mm EFN	1.01 k	0.43 n	**0.72 b**
0.9-mm EFN	1.19 j	0.86 l	**1.03 c**
Cover opening means	**0.92 f**	**0.53 g**	

*Covers were either maintained permanently or opened thrice a week from 9.00 am to 3.00 pm.

**Data were transformed using square root before ANOVA and mean separation but means presented are the original means.

***Means not followed by a letter are not significantly different according to F-test at $P \leq 0.05$.

****Means followed by the same letter in a letter series within a season are not significantly different according to Tukey's Honestly Significant Difference (THSD) at $P \leq 0.05$.

Table 27. Effects of cover pore diameter and opening on the population of aphids (no./plant) during tomato production in season 1 (May to Oct. 2011) and season 2 (Oct. 2011 to Mar. 2012).

Cover pore diameter	Cover opening*		**Pore diameter means**
	Opened	Permanent	
		A. Season one**	
0.1-mm FRC	0.51 m***	0.24 o	**0.37 c**
0.4-mm EFN	0.87 k	0.39 n	**0.63 b**
0.9-mm EFN	1.08 j	0.62 l	**0.85 a**
Cover opening means	**0.82 f**	**0.41 g**	
		B. Season two	
0.1-mm FRC	0.53 k	0.25 m	**0.39 c**
0.4-mm EFN	0.75 j	0.36 l	**0.55 b**
0.9-mm EFN	0.82 j	0.53 k	**0.68 a**
Cover opening means	**0.70 f**	**0.38 g**	

*Covers were either maintained permanently or opened thrice a week from 9.00 am to 3.00 pm.

**Data were transformed using square root before ANOVA and mean separation but means presented are the original means.

***Means followed by the same letter in a letter series within a season are not significantly different according to Tukey's Honestly Significant Difference (THSD) at $P \leq 0.05$.

Table 28. Effects of cover pore diameter and opening on late blight incidences (%) during production of tomato in season 1 (May to Oct. 2011) and season 2 (Oct. 2011 to Mar. 2012).

Cover pore diameter	Cover opening*		
	Opened	Permanent	**Pore diameter means**
		A. Season one**	
0.1-mm FRC	22.64 i***	13.19 k	**17.91 b**
0.4-mm EFN	23.08 i	15.38 k	**19.23 a**
0.9-mm EFN	25.16 i	19.56 j	**22.36 a**
Cover opening means	**23.63 e**	**16.04 f**	
		B. Season two	
0.1-mm FRC	27.80 k	13.85 m	**20.82 c**
0.4-mm EFN	30.88 j	17.03 l	**23.96 b**
0.9-mm EFN	32.97 j	25.38 k	**29.17 a**
Cover opening means	**30.55 f**	**18.75 g**	

*Covers were either maintained permanently or opened thrice a week from 9.00 am to 3.00 pm.

**Data were transformed using arcsine before ANOVA and mean separation but means presented are the original means.

***Means followed by the same letter in a letter series within a season are not significantly different according to Tukey's Honestly Significant Difference (THSD) at $P \leq 0.05$.

under 0.9-mm net had a higher late blight incidences compared with those under the 0.4-mm net cover. Cover opening also significantly influenced late blight incidences. Covers used permanently resulted in lower late blight incidences compared with those opened thrice a week in both seasons. Significant interactions between the cover pore diameter and cover opening were also observed in both seasons with tomato plants under 0.1-mm FRC having the lowest incidences of late blight while those under 0.9-mm net opened thrice a week recording the highest incidences of late blight. Generally, for any given cover pore diameter, covers used permanently helped reduce incidences of late blight compared with covers opened thrice a week.

4.2.3 Effects of Floating Row Covers and Eco-friendly Nets on Tomato Yield Components and Yield

Tomato yield component and yield variables measured in this study were i) number of flower trusses per plant, ii) number of fruits per plant, iii) number of marketable fruits iv) number of fruits non-marketable v) marketable fruit weight and vi) marketable unit fruit weight.

(i) Number of Flower Trusses Per Plant

- Use of FRC and EFN influenced weekly production of flower trusses. In both seasons, the highest number of trusses was produced under FRC used permanently and the lowest number under the control compared with the 0.4-mm net used permanently, FRC opened thrice a week, 0.9-mm net used permanently, 0.4-mm net opened thrice a week, 0.9-mm net opened thrice a week and the chemical treatment (Fig. 27).

Using FRC and EFN significantly influenced the number of flower trusses produced by tomato plants (Table 29). Significant differences in the number of flowers amongst the different treatments were observed. In both seasons FRC had the highest number of flower trusses while the control had the lowest. Among other treatments, 0.4-mm net covered permanently had more flower trusses followed by FRC opened thrice a week, 0.9-mm net covered permanently, 0.4-mm net opened thrice a week, 0.9-mm net opened thrice a week and the chemical treatment. In general, plants in season two produced more trusses compared with those of season one.

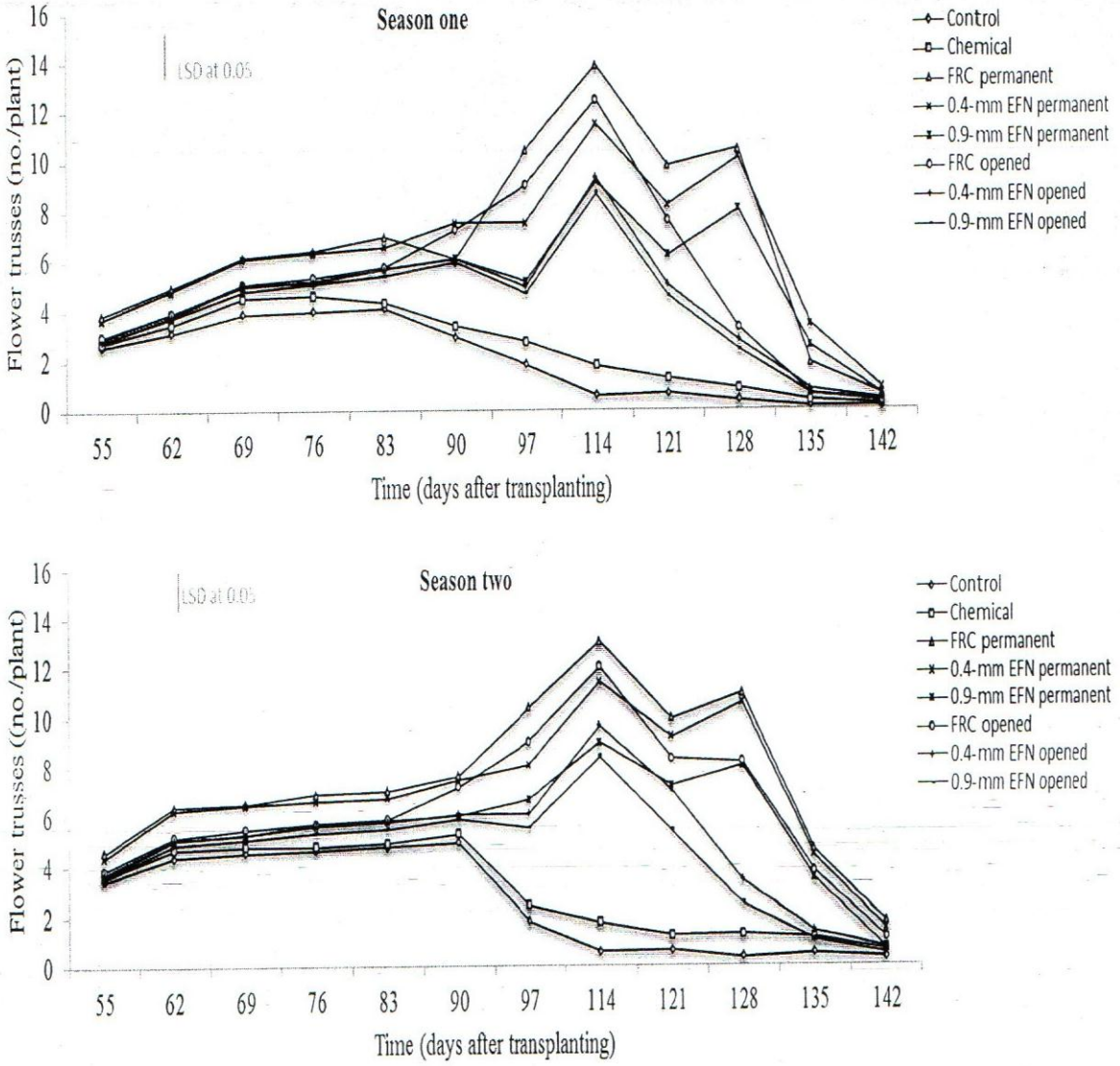


Fig. 27. Effects of floating row covers and eco-friendly nets on tomato flower trusses during production in season 1 (May to Oct. 2011) and season 2 (Oct. 2011 to Mar. 2012). Control had no pesticide applied, chemical treatment was sprayed with alphacypermethrine, permanent is where the FRC or EFN were covered throughout except during crop maintenance periods and opened is where the FRC or EFN were opened thrice a week from 9.00 am to 3.00 pm.

Table 29. Effects of floating row covers (FRC) and eco-friendly nets (EFN) on tomato flower trusses (no./plant) and fruits (no./plant) during production in season 1 (May to Oct. 2011) and season 2 (Oct. 2011 to Mar. 2012).

Treatment*	Season	Flower trusses (no./plant)	Fruits (no./plant)
Control	1	1.91 j**	7.92 i
Chemical	1	2.36 i	11.00 h
FRC permanent	1	6.28 b	17.60 e
0.4-mm EFN permanent	1	5.92 c	17.49 e
0.9-mm EFN permanent	1	4.69 e	14.67 g
FRC opened	1	4.94 e	17.29 e
0.4-mm EFN opened	1	4.03 fg	13.91 g
0.9-mm EFN opened	1	3.79 g	13.50 g
Control	2	2.53 i	15.62 f
Chemical	2	2.96 h	17.24 e
FRC permanent	2	7.06 a	27.89 a
0.4-mm EFN permanent	2	6.53 b	25.81 b
0.9-mm EFN permanent	2	5.25 d	22.79 c
FRC opened	2	5.98 e	25.87 b
0.4-mm EFN opened	2	4.77 e	22.72 c
0.9-mm EFN opened	2	4.27 f	20.60 d

*Control had no pesticide applied, chemical treatment was sprayed with alphacypermethrine, permanent is where the FRC or EFN were covered throughout except during crop maintenance periods and opened is where the FRC or EFN were opened thrice a week from 9.00 am to 3.00 pm.

**Means followed by the same letter within a column are not significantly different according to Tukey's Honestly Significant Difference (THSD) at $P \leq 0.05$.

(ii) Number of Fruits per Plant

Using FRC and EFN influenced weekly production of tomato fruits. In both seasons, FRC used permanently had more fruits recorded followed by 0.4-mm net covered permanently, FRC opened thrice a week, 0.9-mm net covered permanently, 0.4-mm net opened thrice a week, 0.9-mm net opened thrice a week, the control and chemical treatments in most of the evaluation days (Fig. 28).The use of FRC and EFN covers significantly enhanced tomato fruit numbers (Table 29). Plants in the FRC used permanently, 0.4-mm net covered permanently, and FRC opened thrice a week treatments, produced the highest fruit number while the control produced the lowest number of fruits in the first season. In the same season, 0.9-mm net covered permanently, 0.4-mm and 0.9-mm net opened thrice a week had higher fruits compared with the chemical treatment. However, FRC used permanently had the highest fruits while the control produced the lowest fruits. 0.4-mm net covered permanently had higher fruits than FRC opened thrice a week and 0.9-mm net covered permanently which were statistically different, 0.4-mm net opened thrice a week and the chemical treatment. On average, plants in season 2 produced more fruits compared with those of season 1.

(iii) Marketable Fruit Number

The use of FRC and EFN covering influenced the weekly trends of marketable fruits harvested (Fig. 29). In season 1, the control produced more marketable fruits in the first two harvests (118 and 125 DAT). In the later harvests, the permanent FRC treatment yielded more marketable fruits compared with the other treatments except during the last two weeks of harvesting (142 and 153 DAT) when the 0.4-mm covered permanently registered more marketable fruits. In season 2, the permanent FRC treatment yielded more marketable fruits in all weeks of harvesting. The control on the other hand had the least number of marketable fruits on all the weeks except at 118 and 139 DAT when the 0.9-mm net opened thrice a week recorded the least number of marketable fruits. Summed up within each season, FRC and EFN cover significantly increased the number of marketable fruits (Table 30). In the first season, the highest marketable fruit numbers were obtained from the permanent FRC treatment compared with the control that had the lowest. Among other treatments, 0.4-mm net covered permanently had

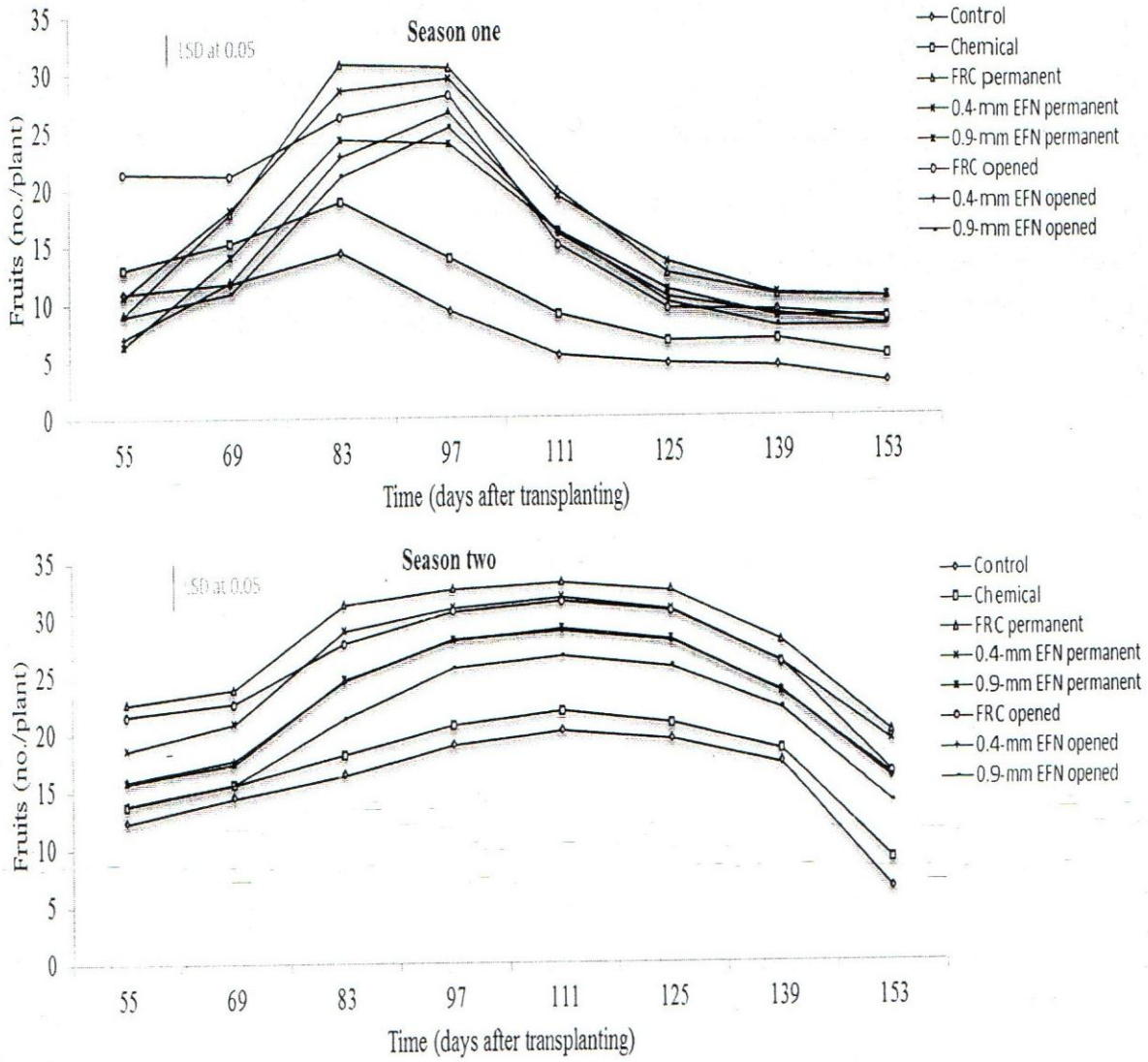


Fig. 28. Effects of floating row covers and eco-friendly nets on tomato fruits during production in season 1 (May to Oct. 2011) and season 2 (Oct. 2011 to Mar. 2012). Control had no pesticide applied, chemical treatment was sprayed with alphacypermethrine, permanent is where the FRC or EFN were covered throughout except during crop maintenance periods, and opened is where the FRC or EFN were opened thrice a week from 9.00 am to 3.00 pm.

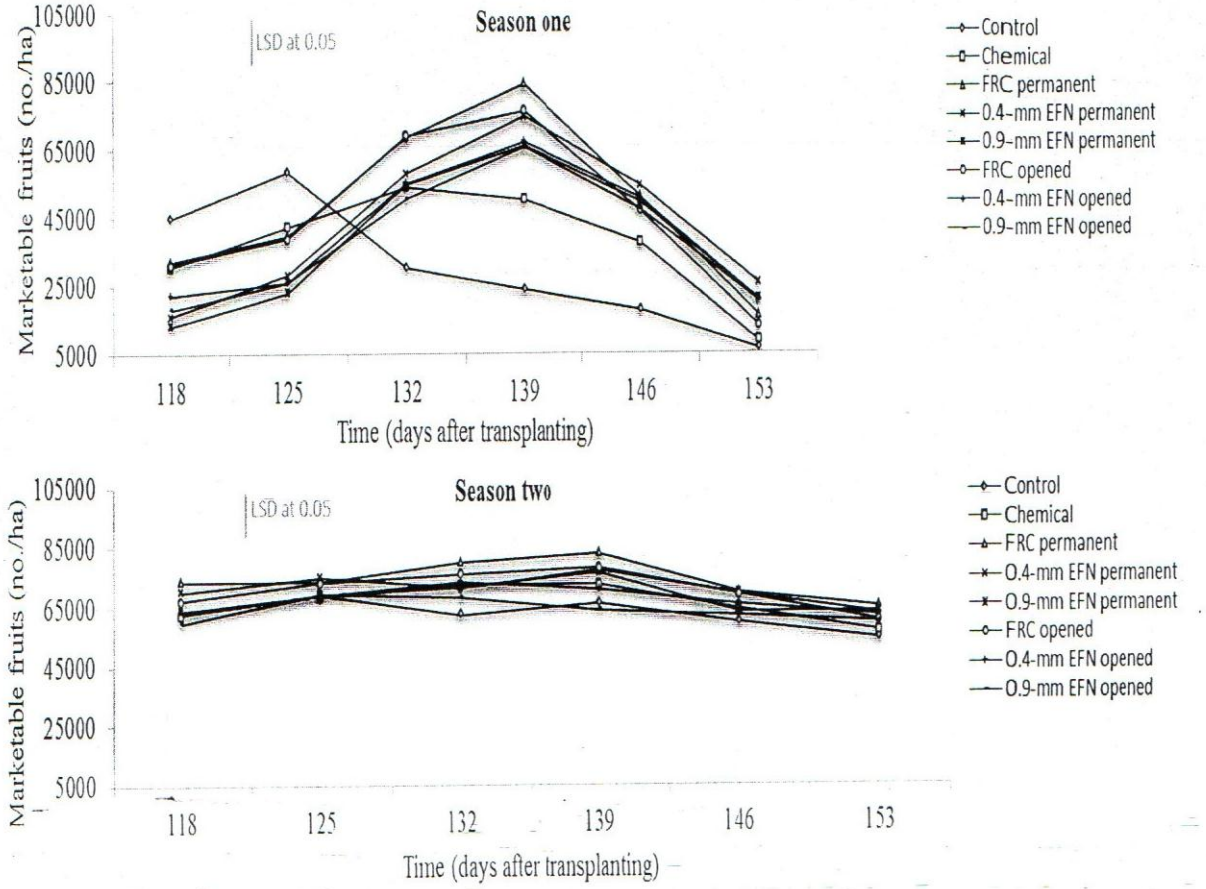


Fig. 29. Effects of floating row covers and eco-friendly nets weekly harvest of marketable fruits during tomato production in season 1 (May to Oct. 2011) and season 2 (Oct. 2011 to Mar. 2012). Control had no pesticide applied, chemical treatment was sprayed with alphacypermethrine, permanent is where the FRC or EFN were covered throughout except during crop maintenance periods, and opened is where the FRC or EFN were opened thrice a week from 9.00 am to 3.00 pm.

Table 30. Effects of floating row covers (FRC) and eco-friendly nets (EFN) on tomato fruit yield during production in season 1 (May to Oct. 2011) and season 2 (Oct. 2011 to Mar. 2012).

Treatment*	Season	Marketable fruit number (no./ha)	Non-marketable fruit number (no./ha)	Marketable fruit weight (t/ha)	Marketable Unit fruit weight (g/fruit)
Control	1	181750 h**	74750 g	10.63 h	56.29 k
Chemical	1	223250 g	20750 bc	15.78 g	83.58 j
FRC permanent	1	292000 d	2000 a	28.25 d	149.67 cd
0.4-mm EFN permanent	1	256500 ef	6750 a	23.48 ef	124.37 g
0.9-mm EFN permanent	1	227000 g	21250 bc	20.03 g	106.09 hi
FRC opened	1	275500 de	21250 bc	25.70 de	136.16 efg
0.4-mm EFN opened	1	242250 fg	29750 de	21.10 fg	111.79 h
0.9-mm EFN opened	1	227250 g	36000 ef	18.58 g	98.41 i
Control	2	373750 c	89750 h	24.95 c	132.19 fg
Chemical	2	397000 b	38750 f	27.50 b	145.70 cde
FRC permanent	2	443500 a	16000 bc	38.68 a	204.90 a
0.4-mm EFN permanent	2	425000 a	22250 bc	34.80 a	184.50 b
0.9-mm EFN permanent	2	400000 b	29250 de	29.78 b	157.75 c
FRC opened	2	423500 a	25000 cd	34.83 a	184.50 b
0.4-mm EFN opened	2	402250 b	34250 ef	29.10 b	154.17 cd
0.9-mm EFN opened	2	382500 bc	37750 f	27.00 bc	143.05 def

*Control had no pesticide applied, chemical treatment was sprayed with alphacypermethrine, permanent is where the FRC or EFN were covered throughout except during crop maintenance periods and opened is where the FRC or EFN were opened thrice a week from 9.00 am to 3.00 pm.

**Means followed by the same letter within a column and a parameter are not significantly different according to Tukey's Honestly Significant Difference (THSD) at $P \leq 0.05$.

higher marketable fruits harvested followed by FRC opened thrice a week, 0.9-mm net covered permanently, 0.4-mm net opened thrice a week, 0.9-mm net opened thrice a week, and the chemical treatment. In the second season, a similar trend was observed with FRC used permanent recording more marketable fruits which was not significantly different from that of 0.4-mm net covered permanently and FRC opened thrice a week. The control similarly had the least number of marketable fruits amongst all the treatments. Marketable fruits were on average more in season 2 than in season 1.

(iv) Non-marketable Fruit Numbers

The use of FRC and EFN influenced weekly harvest of non-marketable tomato fruits (Fig. 30). The control and FRC used permanently had the highest and the lowest non-marketable fruits harvested, respectively, throughout the harvesting period in both seasons. Among the other treatments, 0.4-mm net covered permanently, had less non-marketable fruits harvested followed by the chemical treatment, FRC opened thrice a week, 0.9-mm net covered permanently, 0.4-mm net opened thrice a week, and 0.9-mm net opened thrice a week in most of the harvesting days. Summed up for each treatment within a season, non-marketable fruit numbers showed an opposite trend to that of marketable fruit yields (Table 30). Most treatments that registered higher marketable fruit numbers had lower numbers of non-marketable fruits. Covering tomato plants with FRC or EFN generally resulted in less non-marketable fruit numbers compared with growing tomato in the open. In season 1, the use of FRC and the 0.4-mm net permanently significantly reduced the number of non-marketable fruits. Similar results were recorded in the second season with FRC and 0.4-mm net used permanently giving significantly less non-marketable fruits compared with all other treatments. In both seasons, the highest number of non-marketable fruits was obtained under the control treatment. Among the other treatments, non-marketable fruit numbers were highest under the control followed by 0.9-mm net opened thrice a week, 0.4-mm net opened thrice a week, FRC opened thrice a week, 0.9-mm net covered permanently, and the chemical treatment. On average, more non-marketable fruits were obtained in the second season compared with the first the season.

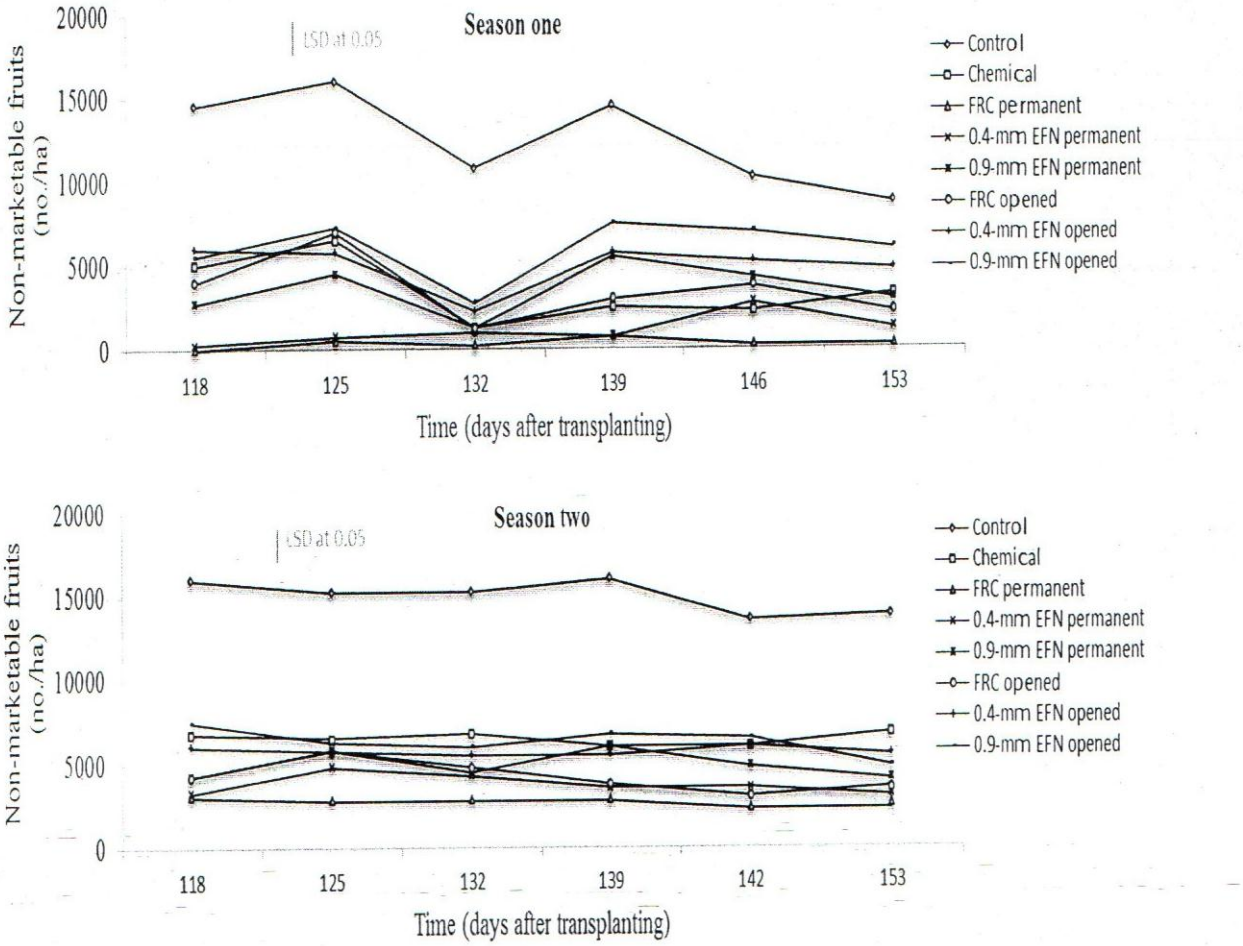


Fig. 30. Effects of floating row covers and eco-friendly nets on weekly harvest of non-marketable fruits during production of tomato in season 1 (May to Oct. 2011) and season 2 (Oct. 2011 to Mar. 2012). Control had no pesticide applied, chemical treatment was sprayed with alphacypermethrine, permanent is where the FRC or EFN were covered throughout except during crop maintenance periods, and opened is where the FRC or EFN were opened thrice a week from 9.00 am to 3.00 pm.

(v) Marketable Fruit Weight

Using FRC and EFN affected the weekly harvested marketable fruit weight (Fig. 31). In the first two harvests (118 and 125 DAT), 0.9-mm net had the lowest harvested fruit weight while in the remaining days, the control had the lowest marketable fruit weight harvested. Permanent FRC treatment had the highest marketable fruit weight harvested throughout the harvesting period. Compared with other treatments, FRC opened thrice a week had more marketable fruit weight followed by 0.4-mm net covered permanently, 0.4-mm net opened thrice a week, 0.9-mm net covered permanently, 0.9-mm net opened thrice a week, and the chemical treatment in most of the harvesting dates. Summed up within each season, FRC and EFN covering significantly improved on the marketable fresh fruit weight of tomato (Table 30). In both seasons, the lowest marketable fruits weight harvested were obtained from the control while the permanent FRC treatment had highest harvested marketable fruit weight which was not statistically different from 0.4-mm net covered permanently and FRC opened thrice a week in the second season. Among other treatments, 0.4-mm net covered permanently had higher harvested marketable fruit weight followed by FRC opened thrice a week, 0.4-mm net opened thrice a week, 0.9-mm net used permanently, 0.9-mm net opened thrice a week and the chemical treatment. Generally, season two obtained higher marketable fruit weight compared with season one.

(vi) Marketable Unit Fruit Weight

The use of FRC and EFN significantly affected the weight of individual tomato fruit (Table 30). In both seasons, individual fruits weighed more under the permanent FRC treatment and less under the control. Among the other treatments, 0.4-mm net covered permanently had heavier individual fruits followed by FRC opened thrice a week, 0.4-mm net opened thrice a week, 0.9-mm net covered permanently, 0.9-mm net opened thrice a week, and the chemical treatment. Higher individual fruit weight was recorder in the second season compared with the first season.

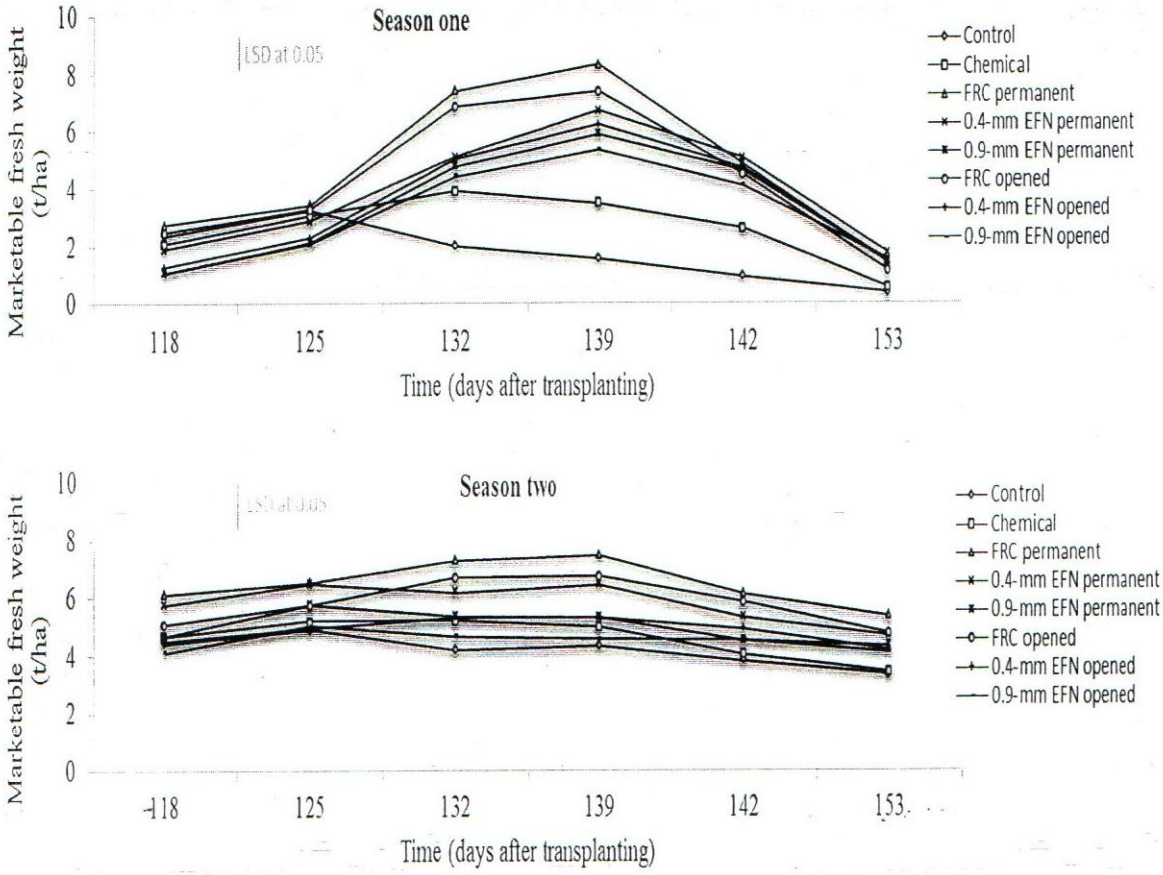


Fig. 31. Effects of floating row covers and eco-friendly nets on harvested fresh weight during tomato production in season 1 (May to Oct. 2011) and season 2 (Oct. 2011 to Mar. 2012). Control had no pesticide applied, chemical treatment was sprayed with alphacypermethrine, permanent is where the FRC or EFN were covered throughout except during crop maintenance periods and opened is where the FRC or EFN were opened thrice a week from 9.00 am to 3.00 pm.

4.2.4 Effects of Floating Row Covers and Eco-friendly Nets on Tomato Fruit Quality

Fruit quality aspects covered in this study are i) firmness, ii) total soluble solids (TSS), iii) titratable acidity (TA), and iv) sugar acid ratio (TSS:TA) at the red ripe stage of the fruit.

(i) Fruit Firmness

The use of FRC and EFN in tomato growing significantly influenced tomato fruit quality (Table 31). In general, the use of FRC and EFN resulted in firmer fruits in both seasons. Growing tomato under FRC permanently covered yielded firmer fruits compared with all the other treatments in both seasons. The least firm fruits were obtained in the control and chemical treatments in both seasons. Among the other treatments, fruits were more firm from the 0.4-mm net covered permanently followed by FRC opened thrice a week, 0.9-mm net covered permanently, 0.4-mm opened thrice a week, and lowest in the 0.9-mm net opened thrice a week. Generally, fruits of season 2 tended to be more firm compared with season 1.

(ii) Total Soluble Solids

Tomato fruit total soluble solids (TSS) were significantly influenced by the use of FRC and EFN in both seasons (Table 31). In both seasons, fruits under FRC used permanently had the highest sugars while the lowest sugars were obtained from fruits under the control. For the other treatments, fruits under FRC opened thrice a week and 0.4-mm net covered permanently had more sugars in the first and second season, respectively, followed by 0.4-mm net opened thrice a week, 0.9-mm net covered permanently, 0.9-mm net opened thrice a week, and the chemical treatment. Generally, fruits of season 1 tended to have more total soluble solids compared with season 2.

(iii) Titratable Acidity

The use of FRC and EFN significantly influenced tomato fruits titratable acidity (TA) (Table 31). The control had fruits with the highest TA which was not different from the chemical treatment in the second season while fruits under FRC used permanently, 0.4-mm net covered permanently, had the lowest TA in both seasons. Among other treatments, fruits under 0.4-mm net covered permanently, 0.9-mm net covered permanently and FRC opened thrice a week were

Table 31. Tomato fruit quality attributes at harvest as influenced by floating row covers (FRC) and eco-friendly nets (EFN) in season 1 (May to Oct. 2011) and season 2 (Oct. 2011 to Mar. 2012).

Treatment*	Season	Firmness (KgF)	TSS (%)	TA (%)	Sugar acid ratio
Control	1	3.39 e**	2.94 i	4.02 ab	0.74 ef
Chemical	1	3.39 e	3.21 h	3.79 bc	0.85 e
FRC permanent	1	5.93 a	6.22 a	3.40 de	1.84 a
0.4-mm EFN permanent	1	5.44 bc	5.93 b	3.45 de	1.73 ab
0.9-mm EFN permanent	1	5.23 cd	5.23 fg	3.65 cd	1.44 d
FRC opened	1	5.50 b	5.94 b	3.60 cde	1.65 bc
0.4-mm EFN opened	1	5.22 cd	5.24 fg	3.57 cde	1.47 d
0.9-mm EFN opened	1	5.15 d	5.07 g	3.64 cde	1.43 d
Control	2	3.08 g	2.89 i	4.15 a	0.70 f
Chemical	2	3.13 fg	2.99 hi	4.18 a	0.70 f
FRC permanent	2	5.79 a	5.81 bc	3.31 de	1.76 ab
0.4-mm EFN permanent	2	5.47 bc	5.61 cd	3.37 de	1.67 bc
0.9-mm EFN permanent	2	5.15 d	5.37 def	3.45 de	1.56 cd
FRC opened	2	5.45 bc	5.54 cde	3.36 de	1.65 bc
0.4-mm EFN opened	2	5.09 d	5.28 efg	3.51 cde	1.49 d
0.9-mm EFN opened	2	5.05 d	5.25 fg	3.53 cde	1.49 d

*Control had no pesticide applied, chemical treatment was sprayed with alphacypermethrine, permanent is where the FRC or EFN were covered throughout except during crop maintenance periods and opened is where the FRC or EFN were opened thrice a week from 9.00 am to 3.00 pm.

**Means followed by the same letter within a column and a parameter are not significantly different according to Tukey's Honestly Significant Difference (THSD) at $P \leq 0.05$.

not statistical different in the second season while 0.4-mm net opened thrice a week, 0.9-mm net opened thrice a week, and the treated control had lower TA. Generally, fruits of season 1 and season 2 had no differences in TA with a mean of 3.64 and 3.61%, respectively.

(iv) Sugar:acid Ratio

Sugar: acid ratio (TSS:TA) was significantly influenced by FRC and EFN (Table 31). In both seasons, the control and chemical treatments had the lowest TSS:TA while fruits under FRC used permanently had the highest TSS:TA ratio. Among other treatments, fruits from the 0.4-mm net covered permanently had higher TSS:TA followed by FRC opened thrice a week, 0.4-mm net opened thrice a week, 0.9-mm net covered permanently, and 0.9-mm net opened thrice a week. Generally, fruits of season 1 and season 2 had no differences in TSS:TA.

4.2.5 Effects of Cover Pore Diameter and Opening on Yield Components and Yield of Tomato

Yield components and yield variables studied were i) flower trusses per plant, ii) number of fruits per plant , iii) marketable fruit numbers, iv) non-marketable fruit numbers v) marketable fruit weight and (vi) marketable unit fruit weight.

(i) Tomato Flower Trusses per Plant

The main effects of cover pore diameter and cover opening significantly influenced the production of flower trusses (Table 32). In the initial days of data collection (55 and 97 DAT), tomato plants grown under the 0.1-mm FRC had the highest number of trusses while the 0.9-mm net had the lowest number of trusses in both seasons. However, as the season advanced (at 142 DAT), plants under the 0.9-mm net had more flower trusses compared with those under both the 0.1-mm FRC and 0.4-mm net in the first season. In the second season, plants under the 0.1-mm FRC had the highest number of flower trusses while 0.9-mm net had the lowest number of flower trusses in all sampling dates. Cover opening also influenced the number of flower trusses. Throughout the study, tomato plants under permanent covers had more flower trusses compared with those under covers opened thrice a week in both seasons. A significant interaction was observed between cover pore diameter and cover opening in all sampling dates except at 142 DAT in the first season and 97 DAT in the second season. Tomato plants under 0.1-mm FRC

Table 32. Effects of cover pore diameter and opening on tomato flower trusses (no./plant) during production in season 1 (May to Oct. 2011) and season 2 (Oct. 2011 to Mar. 2012).

	Time (days after transplanting)								
	55			97			142		
	Cover opening*			Cover opening			Cover opening		
Cover pore diameter	Opened	Permanent	**Pore diameter means**	Opened	Permanent	**Pore diameter means**	Opened	Permanent	**Pore diameter means**
				A. Season one					
0.1-mm FRC	2.96 k***	3.80 j	**3.38 a**	9.00 k	10.37 j	**9.68 a**	0.26**	0.54	**0.40 b**
0.4-mm EFN	2.77 k	3.64 j	**3.21 b**	4.90 m	7.46 l	**6.18 b**	0.36	0.79	**0.41 b**
0.9-mm EFN	2.76 k	2.87 k	**2.81 c**	4.60 m	5.09 m	**4.84 c**	0.29	0.54	**0.57 a**
Cover opening means	**2.83 g**	**3.44 f**		**6.17 g**	**7.64 f**		**0.30 f**	**0.63 e**	
				B. Season two					
0.1-mm FRC	3.89 l	4.60 j	**4.24 a**	9.05	10.27	**9.69 a**	1.09 l	1.74 j	**1.41 a**
0.4-mm EFN	3.77 lm	4.37 k	**4.07 b**	6.09	8.06	**7.07 b**	0.70 mn	1.46 k	**1.07 b**
0.9-mm EFN	3.59 m	3.63 m	**3.61 c**	5.53	6.64	**6.09 c**	0.47 no	0.69 mn	**0.58 c**
Cover opening means	**3.75 g**	**4.20 f**		**6.87 g**	**8.36 f**		**0.75 g**	**1.30 f**	

*Covers were either maintained permanently or opened thrice a week from 9.00 am to 3.00 pm.

**Means not followed by a letter are not significantly different according to F-test at $P \leq 0.05$.

***Means followed by the same letter in a letter series within a specific date and a season are not significantly different according to Tukey's Honestly Significant Difference (THSD) at $P \leq 0.05$.

used permanently had the highest number of flower trusses while those under 0.9-mm net opened thrice a week had the lowest trusses. In general, for any given cover pore diameter, tomato plants under permanent covers produced more flower trusses compared with those under covers opened thrice a week.

(ii) Number of Tomato Fruits per Plant

Cover pore diameter and cover opening main effects significantly influenced tomato fruit numbers (Table 33). In both seasons, tomato plants grown under the 0.1-mm FRC had the highest number of fruits per plant while those grown under the 0.9-mm net had the lowest fruit numbers in both seasons. Cover opening also significantly influenced tomato fruit numbers per plant. In the first season, plants grown under covers opened thrice a week produced more fruits per plant compared with those grown under permanent covers at 55 DAT. In all other dates, plants grown under permanent covers yielded more fruits than those grown under covers opened thrice a week in both seasons. A significant interaction between cover pore diameter and cover opening was only observed in at 55 and 153 DAT in the first season with plants under 0.1-mm FRC having the highest number of fruits per plant while 0.9-mm net opened thrice a week recorded the lowest number of fruits per plant.

(iii) Marketable Fruit Numbers

The main effects of cover pore diameter and cover opening significantly influenced the harvested marketable tomato fruit numbers (Table 34). In both seasons, the highest number of marketable fruits was harvested from the 0.1-mm FRC while the 0.9-mm net yielded the lowest number of marketable fruits harvested. Cover opening also had a significant influence on the number of marketable fruits harvested. More marketable fruits were harvested from tomato plants grown under permanent covers compared with those grown under covers opened thrice a week. The interaction between cover pore diameter and cover opening was not significant in both seasons.

Table 33. Effects of cover pore diameter and opening on tomato fruits '(no./plant) during production in season 1 (May to Oct. 2011) and season 2 (Oct. 2011 to Mar. 2012).

	Time (days after transplanting)								
	55			111			153		
	Cover opening*			Cover opening			Cover opening		
Cover pore diameter	Opened	Permanent	**Pore diameter means**	Opened	Permanent	**Pore diameter means**	Opened	Permanent	**Pore diameter means**
				A. Season one					
0.1-mm FRC	21.27 i***	9.10 j	**15.19 a**	14.91***	19.70	**17.31 a**	8.46 j	10.26 i	**9.36 a**
0.4-mm EFN	6.99 kl	10.59 j	**8.79 b**	15.89	19.13	**17.51 a**	7.91 j	10.27 i	**9.09 a**
0.9-mm EFN	8.94 jk	6.33 j	**7.64 b**	16.13	16.13	**14.79 b**	7.99 j	8.60 j	**8.29 b**
Cover opening means	**12.40 e**	**8.67 f**		**14.75 f**	**18.32 e**		**8.12 f**	**9.71 e**	
				B. Season two					
0.1-mm FRC	21.53	22.57	**22.05 a**	31.41	33.06	**32.24 a**	16.39	19.84	**18.11 a**
0.4-mm EFN	15.84	18.53	**17.19 b**	28.73	31.69	**30.21 b**	15.89	19.11	**17.50 a**
0.9-mm EFN	14.01	15.77	**14.89 c**	26.66	29.00	**27.83 c**	13.80	16.13	**14.96 b**
Cover opening means	**17.13 g**	**18.96 f**		**28.93 g**	**31.25 f**		**15.36 f**	**18.36 e**	

*Covers were either maintained permanently or opened thrice a week from 9.00 am to 3.00 pm.

**Means not followed by a letter are not significantly different according to F-test at $P \leq 0.05$.

***Means followed by the same letter in a letter series within a specific date and a season are not significantly different according to Tukey's Honestly Significant Difference (THSD) at $P \leq 0.05$.

Table 34. Effects of cover pore diameter and opening on marketable tomato fruits (no./ha) during production in season 1 (May to Oct. 2011) and season 2 (Oct. 2011 to Mar. 2012).

Cover pore diameter	Cover opening*		**Pore diameter means**
	Opened	Permanent	
		A. Season one	
0.1-mm FRC	275500**	292000	**283750 a*** **
0.4-mm EFN	242250	256500	**249375 b**
0.9-mm EFN	227250	227000	**227125 c**
Cover opening means	**248333.3 g**	**258500.0 f**	
		B. Season two	
0.1-mm FRC	423500	443500	**433500 a**
0.4-mm EFN	402250	425000	**413625 b**
0.9-mm EFN	382500	400000	**391250 c**
Cover opening means	**402750.0 g**	**422833.3 f**	

*Covers were either maintained permanently or opened thrice a week from 9.00 am to 3.00 pm.
**Means not followed by a letter are not significantly different according to F-test at $P \leq 0.05$.
***Means followed by the same letter in a letter series within a season are not significantly different according to Tukey's Honestly Significant Difference (THSD) at $P \leq 0.05$.

(iv) Non-marketable Fruit Numbers

The effect of cover pore diameter and cover opening showed a trend opposite to that of marketable fruit numbers. In both seasons, the highest number of non-marketable fruits was obtained from the 0.9-mm net while the lowest was obtained from the 0.1-mm FRC (Table 35). Cover opening also significantly influenced the non-marketable fruits harvested. More non-marketable fruits were obtained from tomato plants grown under covers opened thrice a week compared with plants grown under permanent cover in both seasons. A significant interaction between the cover pore diameter and cover opening was observed in the second season but not in the first season with the lowest and the highest number of non-marketable fruits obtained under 0.1-mm FRC used permanently and 0.9-mm net opened thrice a week. Generally, for any given pore diameter, covers used permanently yielded less non-marketable fruits compared with those opened thrice a week.

(v) Marketable Fruit Weight

Cover pore diameter and cover opening significantly influenced the weight of marketable tomato fruits (Table 36). In the first season, the 0.1-mm FRC yielded the highest marketable fruit weight while the 0.9-mm net gave the lowest marketable fruit weight. In the second season, however, both the 0.1-mm FRC and 0.4-mm net yielded statistically higher marketable fruit weight compared with the 0.9-mm net. Cover opening also influenced the weight of marketable fruits harvested. In both seasons, using covers permanently yielded more marketable fruit weight compared with opening covers thrice a week. No significant interaction was observed between the cover pore diameter and cover opening.

(vi) Marketable Unit fruit weight

Cover pore diameter and cover opening main effects significantly influenced tomato unit fruit weight (Table 37). In both seasons, fruits harvested from the 0.1-mm FRC had the highest unit fruit weight while those harvested from the 0.9-mm net had the lowest unit fruit weight. Cover opening also had an influence on tomato unit fruit weight. In both seasons individual tomato fruits harvested from covers used permanently weighed more compared with those

Table 35. Effects of cover pore diameter and opening on non-marketable tomato fruits (no./ha) during production in season 1 (May to Oct. 2011) and season 2 (Oct. 2011 to Mar. 2012).

Cover pore diameter	Cover opening*		Pore diameter means
	Opened	Permanent	
		A. Season one	
0.1-mm FRC	21250**	2000	**11625 c*** **
0.4-mm EFN	29750	6750	**18250 b**
0.9-mm EFN	36000	21250	**28625 a**
Cover opening means	**29000.0 f**	**10000.0 g**	
		B. Season two	
0.1-mm FRC	25000 m	16000 n	**20500 c**
0.4-mm EFN	34250 k	22250 m	**28250 b**
0.9-mm EFN	37750 j	29250 l	**33500 a**
Cover opening means	**32333.3 f**	**22500.0 g**	

*Covers were either maintained permanently or opened thrice a week from 9.00 am to 3.00 pm.
**Means not followed by a letter are not significantly different according to F-test at $P \leq 0.05$.
***Means followed by the same letter in a letter series within a season are not significantly different according to Tukey's Honestly Significant Difference (THSD) at $P \leq 0.05$.

Table 36. Effects of cover pore diameter and opening on marketable tomato fruit weight (t/ha) during production in season 1 (May to Oct. 2011) and season 2 (Oct. 2011 to Mar. 2012).

Cover pore diameter	Cover opening*		**Pore diameter means**
	Opened	Permanent	
		A. Season one	
0.1-mm FRC	25.70**	28.25	**26.98 a*** **
0.4-mm EFN	21.10	23.48	**22.29 b**
0.9-mm EFN	18.58	20.03	**19.30 c**
Cover opening means	**21.79 g**	**23.92 f**	
		B. Season two	
0.1-mm FRC	34.83	38.68	**36.75 a**
0.4-mm EFN	29.10	34.80	**31.95 a**
0.9-mm EFN	27.00	29.78	**28.39 b**
Cover opening means	**30.30 f**	**34.42 e**	

*Covers were either maintained permanently or opened thrice a week from 9.00 am to 3.00 pm.
**Means not followed by a letter are not significantly different according to F-test at $P \leq 0.05$.
***Means followed by the same letter in a letter series within a season are not significantly different according to Tukey's Honestly Significant Difference (THSD) at $P \leq 0.05$.

Table 37. Effects of cover pore diameter and opening on tomato marketable unit fruit weight (g/fruit) during production in season 1 (May to Oct. 2011) and season 2 (Oct. 2011 to Mar. 2012).

Cover pore diameter	Cover opening*		
	Opened	Permanent	**Pore diameter means**
		A. Season one	
0.1-mm FRC	136.16 k**	149.67 j	**142.92 a**
0.4-mm EFN	111.79 m	127.37 kl	**119.58 b**
0.9-mm EFN	98.41 n	106.09 l	**102.25 c**
Cover opening means	**115.45 g**	**127.71 f**	
		B. Season two	
0.1-mm FRC	184.50 k	204.90 j	**194.70 a**
0.4-mm EFN	154.17 m	184.50 k	**169.34 b**
0.9-mm EFN	143.05 n	157.75 l	**150.40 c**
Cover opening means	**160.57 g**	**182.38 f**	

*Covers were either maintained permanently or opened thrice a week from 9.00 am to 3.00 pm.

**Means followed by the same letter in a letter series within a season are not significantly different according to Tukey's Honestly Significant Difference (THSD) at $P \leq 0.05$.

harvested from covers opened thrice a week. Cover pore diameter and cover opening had interacted significantly in influencing tomato unit fruit weight in both seasons. Tomato plants under 0.1-mm FRC used permanently had the highest unit fruit weight while those under 0.9-mm net opened thrice a week had the lowest unit fruit weight. In general, for any given pore diameter, individual fruits harvested from covers used permanently were heavier than those harvested from covers opened thrice a week.

4.2.6 Effects of Cover Pore Diameter and Opening on Tomato Fruit Quality

Tomato fruit quality attributes were determined at the red ripe stage. The variables measured were i) fruit firmness, ii) total soluble solids (TSS), iii) titratable acidity (TA) and iv) sugar acid ratio (TSS:TA).

(i) Fruit Firmness

The main effects of cover pore diameter and cover opening significantly influenced tomato fruit firmness (Table 38). In both seasons, tomato fruits harvested from the 0.1-mm FRC were firmer compared with those fruits harvested from the 0.4-mm and 0.9-mm nets. Among the EFN treatments, the 0.9-mm net yielded the least firm fruits. Cover opening also significantly affected the firmness of tomato fruits. In both seasons, tomato fruits obtained from covers used permanently were more firm compared with those harvested from covers opened thrice a week. A significant interaction between the cover pore diameter and cover opening was also observed in both seasons. Tomato fruits harvested from 0.1-mm FRC used permanently were the most firm while those obtained from 0.9-mm net opened thrice a week were the least firm. However, a general trend could be established where for any given cover pore diameter, fruits obtained from covers used permanently were firmer than those harvested from covers opened thrice a week.

(ii) Total Soluble Solids

Cover pore diameter and cover opening significantly influenced the total soluble solids (TSS) of tomato fruits (Table 39). In both seasons, tomato fruits harvested from the 0.1-mm FRC had the highest TSS content while those harvested from the 0.9-mm net had the lowest TSS content. Cover opening also influenced TSS in tomato fruits. Covers used permanently resulted

Table 38. Effects of cover pore diameter and opening on tomato fruit firmness (KgF) during production in season 1 (May to Oct. 2011) and season 2 (Oct. 2011 to Mar. 2012).

Cover pore diameter	Cover opening*		
	Opened	Permanent	**Pore diameter means**
		A. Season one	
0.1-mm FRC	5.49 j**	5.93 i	**5.71 a**
0.4-mm EFN	5.22 kl	5.44 jk	**5.33 b**
0.9-mm EFN	5.15 l	5.23 kl	**5.19 b**
Cover opening means	**5.29 f**	**5.54 e**	
		B. Season two	
0.1-mm FRC	5.45 j	5.79 i	**5.62 a**
0.4-mm EFN	5.09 k	5.47 j	**5.28 b**
0.9-mm EFN	5.05 k	5.15 k	**5.10 c**
Cover opening means	**5.20 g**	**5.47 f**	

*Covers were either maintained permanently or opened thrice a week from 9.00 am to 3.00 pm.

**Means followed by the same letter in a letter series within a season are not significantly different according to Tukey's Honestly Significant Difference (THSD) at $P \leq 0.05$.

Table 39. Effects of cover pore diameter and opening on tomato total soluble solids (%) during production in season 1 (May to Oct. 2011) and season 2 (Oct. 2011 to Mar. 2012).

Cover pore diameter	Cover opening*		
	Opened	Permanent	**Pore diameter means**
		A. Season one	
0.1-mm FRC	5.94 k**	6.22 j	**6.08 a**
0.4-mm EFN	5.24 l	5.93 k	**5.58 b**
0.9-mm EFN	5.07 l	5.23 l	**5.15 c**
Cover opening means	**5.42 g**	**5.79 f**	
		B. Season two	
0.1-mm FRC	5.54***	5.81	**5.67 a**
0.4-mm EFN	5.28	5.61	**5.45 b**
0.9-mm EFN	5.25	5.37	**5.31 c**
Cover opening means	**5.36 g**	**5.60 f**	

*Covers were either maintained permanently or opened thrice a week from 9.00 am to 3.00 pm.
**Means not followed by a letter are not significantly different according to F-test at $P \leq 0.05$.
***Means followed by the same letter in a letter series within a season are not significantly different according to Tukey's Honestly Significant Difference (THSD) at $P \leq 0.05$.

in fruits with more TSS compared with those from covers opened thrice a week. A significant interaction between the cover pore diameter and cover opening was observed in the first season but not in the second season with fruits obtained from 0.1-mm FRC used permanently having the highest TSS while those obtained from 0.9-mm net opened thrice a week had the lowest TSS levels. Generally, for any given pore diameter, tomato fruits harvested from covers used permanently had more TSS than those from covers opened thrice a week.

(iii) Titratable Acidity

The main effects of cover pore diameter and cover opening significantly influenced titratable acidity (TA) of tomato fruits. In the first season, fruits harvested from the 0.1-mm FRC and 0.4-mm net had lower TA compared with those harvested from the 0.9-mm net. In the second season, fruits from the 0.1-mm FRC had the lowest TA while those from the 0.9-mm net still had the highest TA (Table 40). Cover opening also significantly influenced TA of tomato fruits. Fruits obtained from covers used permanently had lower TA compared with those obtained from covers opened thrice a week. No significant interaction was observed between the cover pore diameter and cover opening.

(iii) Sugar Acid Ratio

Cover pore diameter and cover opening significantly influenced sugar acid ratio (TSS:TA) of tomato fruits (Table 41). In both seasons, tomato fruits from the 0.1-mm FRC had the highest TSS:TA while those from the 0.9-mm net had the lowest TSS:TA. Tomato fruits harvested from covers used permanently also had significantly higher TSS:TA compared with those obtained from covers opened thrice a week. In both seasons, a significant interaction was observed between the cover pore diameter. Fruits harvested from 0.1-mm FRC used permanently had the highest TSS:TA while those from 0.9-mm net opened thrice a week had the lowest TSS:TA. Generally, for any given cover pore diameter, tomato fruits obtained from permanent covers had higher TSS:TA compared with those from covers opened thrice a week.

Table 40. Effects of cover pore diameter and opening on tomato fruit titratable acidity (%) during production in season 1 (May to Oct. 2011) and season 2 (Oct. 2011 to Mar. 2012).

Cover pore diameter	Cover opening* Opened	Permanent	**Pore diameter means**
		A. Season one	
0.1-mm FRC	3.60**	3.40	**3.50 b*** **
0.4-mm EFN	3.57	3.45	**3.51 b**
0.9-mm EFN	3.64	3.65	**3.64 a**
Cover opening means	**3.60 e**	**3.50 f**	
		B. Season two	
0.1-mm FRC	3.36	3.31	**3.33 b**
0.4-mm EFN	3.51	3.37	**3.44 a**
0.9-mm EFN	3.53	3.45	**3.49 a**
Cover opening means	**3.47 e**	**3.38 f**	

*Covers were either maintained permanently or opened thrice a week from 9.00 am to 3.00 pm.
**Means not followed by a letter are not significantly different according to F-test at $P \leq 0.05$.
***Means followed by the same letter in a letter series within a season are not significantly different according to Tukey's Honestly Significant Difference (THSD) at $P \leq 0.05$.

Table 41. Effects of cover pore diameter and opening on tomato fruit sugar acid ratio during production in season 1 (May to Oct. 2011) and season 2 (Oct. 2011 to Mar. 2012).

Cover pore diameter	Cover opening*		**Pore diameter means**
	Opened	Permanent	
		A. Season one	
0.1-mm FRC	1.65 k**	1.84 j	**1.75 a**
0.4-mm EFN	1.47 l	1.73 jk	**1.60 b**
0.9-mm EFN	1.43 l	1.44 l	**1.43 c**
Cover opening means	**1.52 g**	**1.67 f**	
		B. Season two	
0.1-mm FRC	1.65 k	1.76 j	**1.70 a**
0.4-mm EFN	1.49 l	1.67 k	**1.58 b**
0.9-mm EFN	1.49 l	1.56 l	**1.52 c**
Cover opening means	**1.54 g**	**1.66 f**	

*Covers were either maintained permanently or opened thrice a week from 9.00 am to 3.00 pm.
**Means followed by the same letter in a letter series within a season are not significantly different according to Tukey's Honestly Significant Difference (THSD) at $P \leq 0.05$.

4.2.7 Relationships between Microclimate Variables, Yield, and Quality of Tomato

Using residual plots and R^2 values as the basis for selecting the best models, the relationships between microclimate, yield and fruit quality could best be described by second order polynomial equations. A significant relationship was noted between temperature and tomato fruit numbers per plant ($p<0.0001$) and temperature and marketable fruit yield ($p=0.0002$) (Fig. 32). The regression models fitted were; ***Fruits (no./plant)*** $= 8.25 + 3.08X + 0.18X^2$ with $R^2=0.73$, where X is temperature (°C) and ***Fruit marketable yield (t/ha)*** $= 13.15 + 4.08X + 0.18X^2$ with $R^2=0.79$, where X is temperature (°C). This therefore implies that temperature changes during tomato production could explain 73% of the fruits formed per plant and 79% of the marketable fruit yield harvested.

The relationship between temperature and fruit firmness and volumetric water content and fruit firmness was also established (Fig. 33). The relationships could best be described by the models; ***Fruit firmness (KgF)*** $= 3.25 + 0.47X + 0.01X^2$ with $R^2=0.61$, where X is temperature (°C) and ***Fruit firmness (KgF)*** $= 2.13 + 0.18X + 0.01X^2$ with $R^2=0.95$, where X is volumetric water content (%). A highly significant relationship between temperature and tomato fruit firmness ($p<0.0001$) and volumetric water content and tomato fruit firmness ($p<0.0001$) was established. According to these observations, temperature or volumetric water content during tomato production could explain 61% and 95%, respectively of tomato fruit firmness. The relationships between volumetric water content and total soluble solids and diurnal temperature range and total soluble solids were also established (Fig. 34). The regression models fitted were; ***Total soluble solids (%)*** $= 1.43 + 0.22X - 0.01X^2$ with $R^2=0.94$, where X is volumetric water content (%) and ***Total soluble solids (%)*** $= 5.80 + 0.96X - 0.28X^2$ with $R^2=0.96$, where X is diurnal temperature range (°C). These models show a highly significant positive relationship between volumetric water content and negative relationship between total soluble solids ($p<0.0001$) and diurnal temperature range and total soluble solids ($p<0.0001$). Based on the fitted models, volumetric water content could explain 94% of the variations in tomato total soluble solids with an increase in fruit total soluble solids expected with an increase in the volumetric water content of these soil. On the other hand, diurnal temperature range could explain 96% of

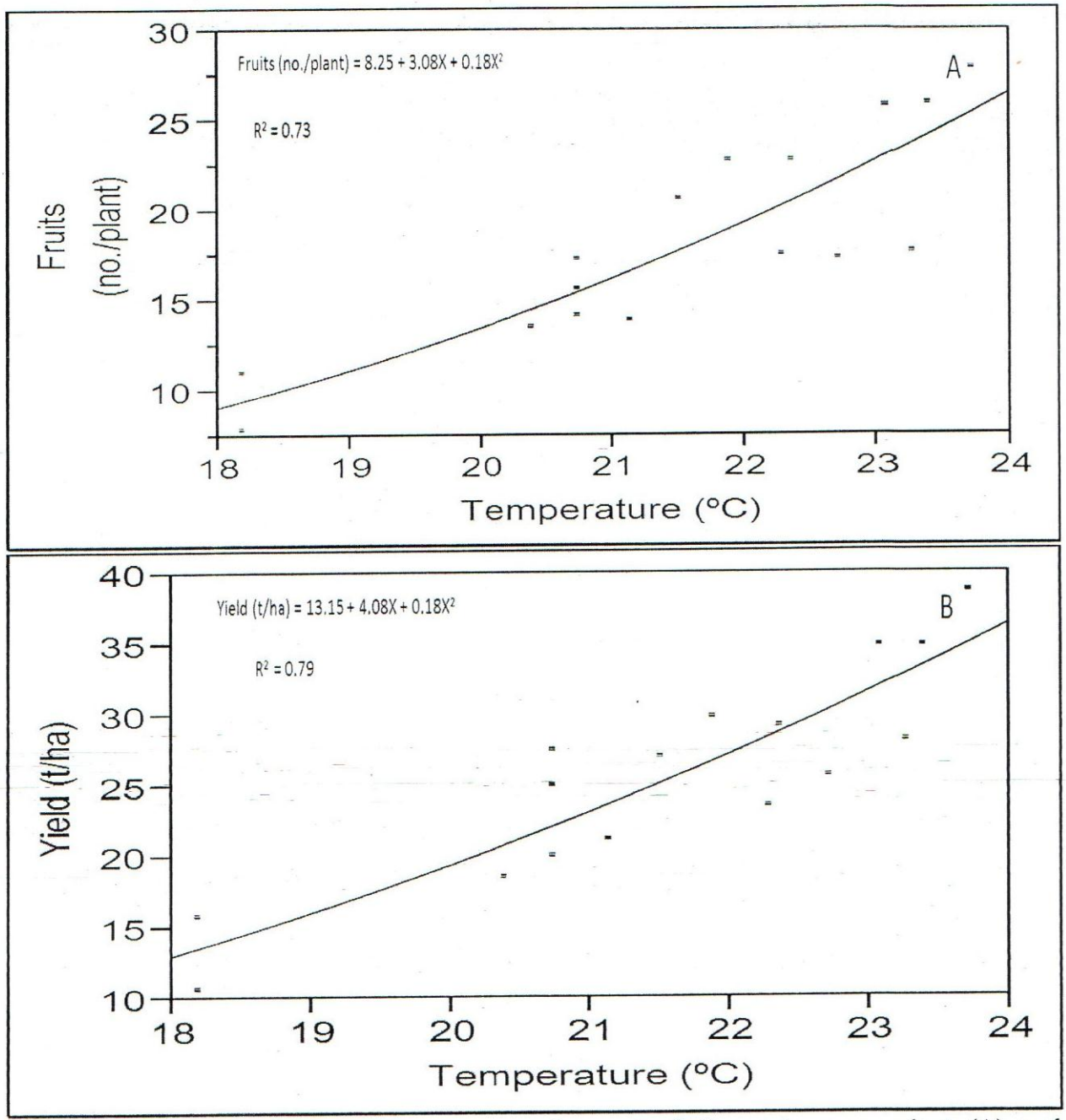


Fig. 32. Relationship between temperature and tomato fruit numbers per plant (A) and temperature and tomato marketable fruit yield (B).

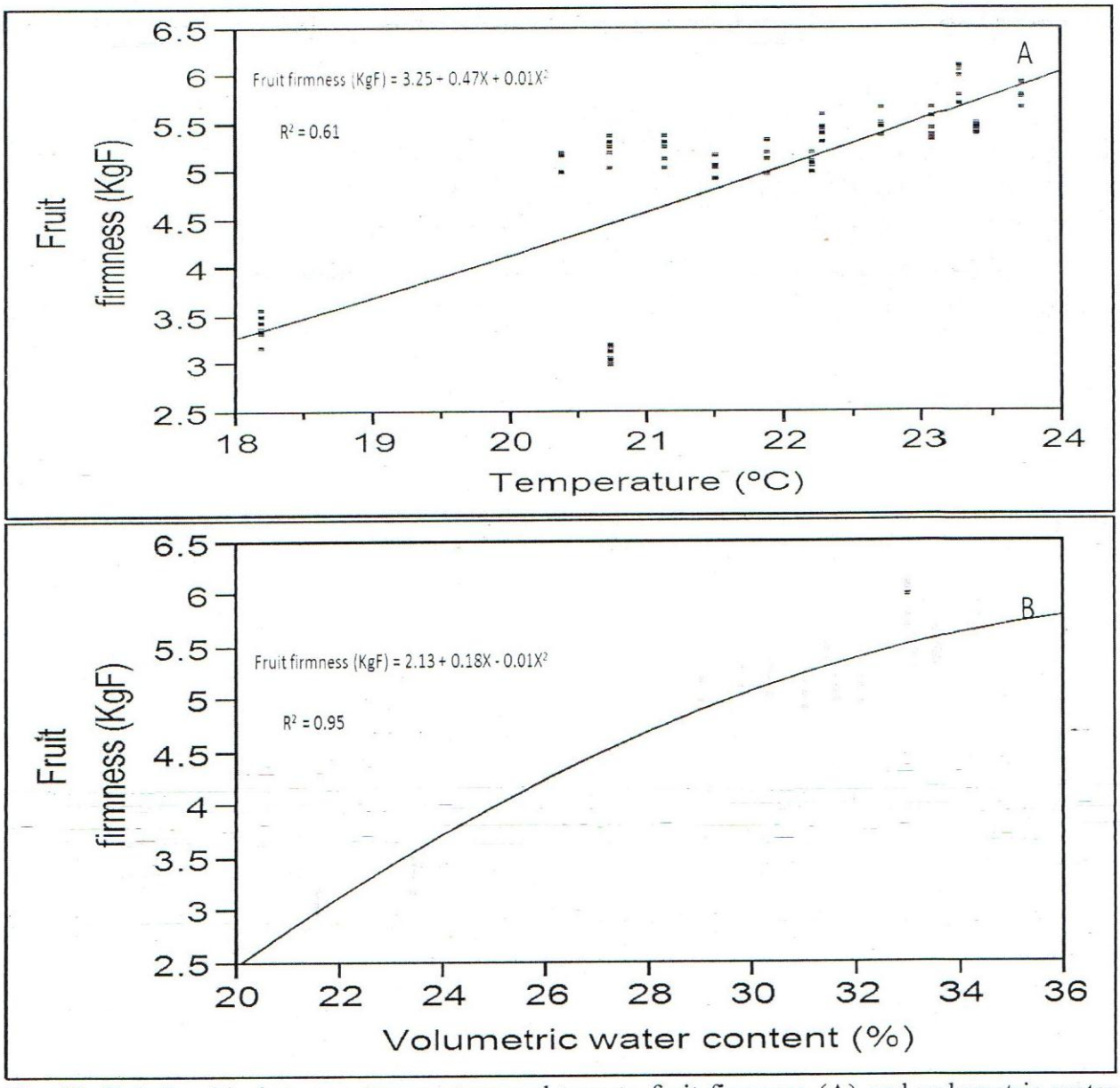


Fig. 33. Relationship between temperature and tomato fruit firmness (A) and volumetric water content and tomato fruit firmness (B).

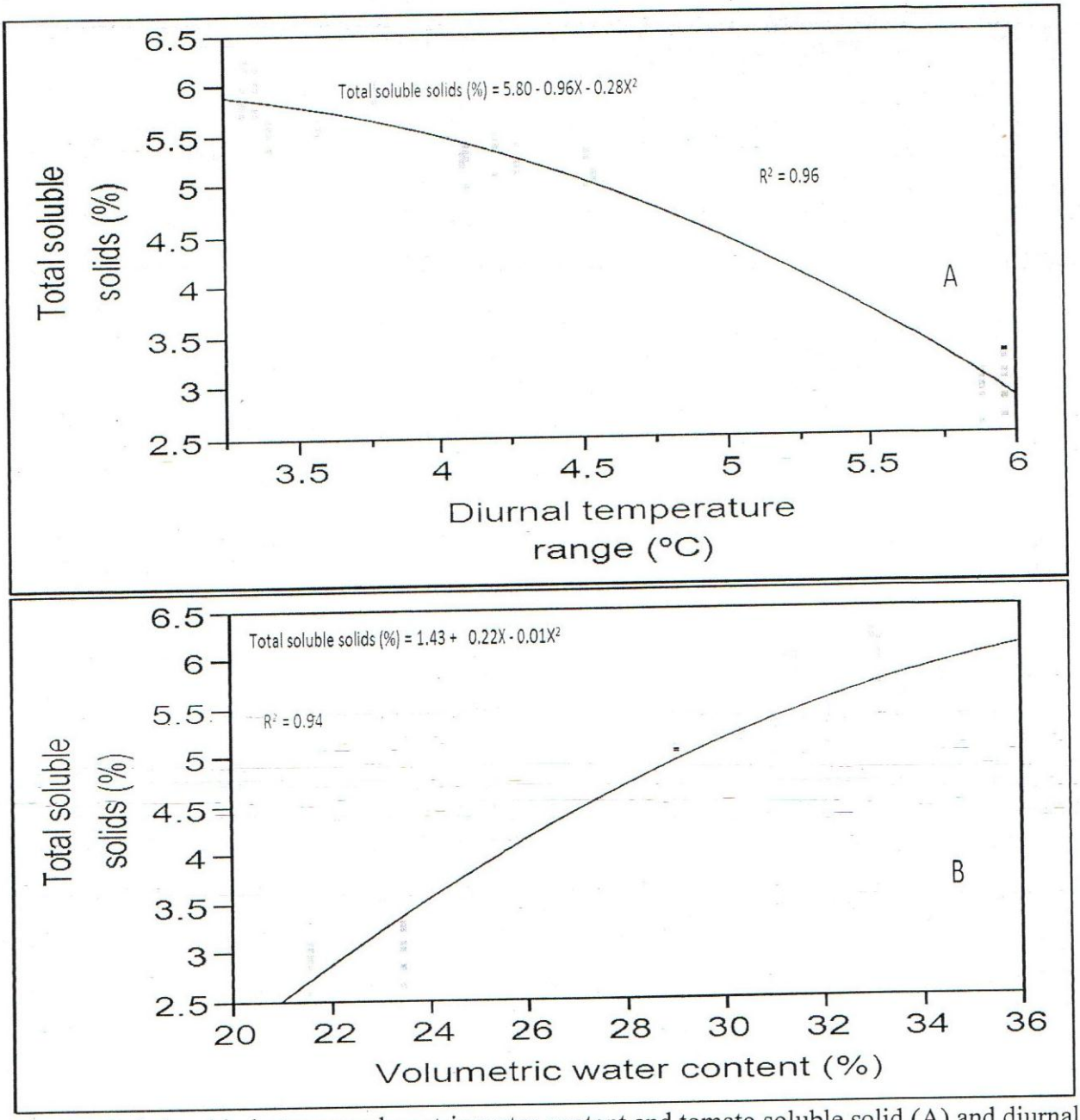


Fig. 34. Relationship between volumetric water content and tomato soluble solid (A) and diurnal temperature range and tomato total soluble solids (B).

the variations in the tomato total soluble solids with a decrease in total soluble solids expected with every increase in diurnal temperature range.

CHAPTER FIVE

5.0 DISCUSSION

This chapter presents a discussion of the results of both the tomato transplant production and the tomato field production experiments. The chapter layout follows the order in which the results were presented in chapter 4 of this document.

5.1 Effects of Floating Row Covers (FRCs), Eco-friendly Nets (EFNs) and Cover Pore Diameter and Opening on Microclimate Modification

Using FRC or EFN in the current study effectively modified the microclimate around the growing tomato seedlings and plants. Covering the seedlings or plants with FRC or EFN increased the temperature around the seedlings or plants compared with the uncovered treatments (control). Under the covered plots, air temperatures tended to increase with a decrease in cover pore diameter with the use of covers with smaller pore diameter resulting in higher temperature compared with those with larger pore diameters. Air temperature also remained consistently higher under permanent covers compared with when the covers were opened thrice a week.

The use of netting and any other type of covering has been shown to restrict air movement around the growing crop resulting in higher temperature (Majumdar, 2010; Nair and Ngouajio, 2010). Opening of nets during the growing period of plant has, on the other hand, been shown to enhance air movement within the vicinity of the crop, leading to lower air temperatures under opened nets (Harmanto et al., 2006). In their study with mesh of different sizes, Antignus et al. (1998) showed that the use of smaller mesh size nets in crop production results in higher air temperatures than the use of large mesh size nets. Higher temperatures recorded for covered tomato plots compared with uncovered plots: finer mesh covers compared to larger mesh covers as well as under permanent cover compared with covers opened thrice a week in the current study could therefore be attributed to the differences in the levels of the restriction in air movement around the growing tomato crop amongst the different treatments leading to a temperature build up.

Covering the tomato crop with either FRC or EFN during production also reduced the diurnal temperature range. Greater reduction in diurnal temperature range were achieved under permanent cover compared with opened covers and uncovered treatments. The diurnal temperature range also tended to decrease with the decrease in cover pore diameter. Shahak et al.

(2004) and Weerakkody and Peiris (1998) reported similar results while working with coloured nets in flower production and tomato plants, respectively. Uses of covers lead to temperature build up (Waterer et al., 2003) by restricting air movement (Majumdar, 2010). Higher temperatures under covers and reduction in air movement results to an increase in vapour pressure deficit (Nair and Ngouajio 2010) leading to lower diurnal temperature range. Higher air temperatures recorded under covers, increased vapour pressure deficit and reduction in air movement could probably have contributed to narrowing the diurnal temperature under covers in the current study.

Different authors have reported contradictory results on the effects of plant covers on relative humidity levels. Parvej et al. (2010) reported lower relative humidity under polyethylene-covered tomatoes while according to Lamont (1996) and Moreno et al. (2002); relative humidity tends to be higher under covers as a result of reduced evapotranspiration and condensation of water within the covers under field conditions. The use of EFN covers during transplant production in the current study led to increased relative humidity levels under the covers. The higher relative humidity under the net covering could be attributed to the reduction in air movement and evapotranspiration (Mutwiwa et al., 2007), temperature build up (Jourbert and Poissonier, 1991) and shading (Shahak et al., 2004) under covers that could have probably led to an increase in relative humidity around the growing seedlings. In the field experiment, however, relative humidity was slightly lower under covered compared with the uncovered plots. It has been documented that high temperature under covers may also reduce relative humidity by increasing vapor pressure deficit (Nair and Ngouajio, 2010) which could lend a possible explanation for the lower relative humidity levels recorded under covered treatments in the current study. Height of tunnels affects relative humidity under covers with higher tunnels having lower humidity compared with lower tunnels as a result of increased air circulation under covers (Waterer et al., 2003). Relative humidity levels also tended to be lower in permanently covered than in opened plots in the current study. It also showed a decreasing trend with a decrease in cover pore diameter. Higher reduction in air movement and temperature build up in permanently covered than opened plots as well as under finer pore diameter covers could

possibly have led to a greater decline in vapour pressure deficit in these treatments leading to lower relative humidity levels.

Soil moisture content was higher in all covered compared with uncovered plots in the field. Permanent use of FRC or EFN also maintained a higher soil moisture content than when covers were opened thrice a week. Generally, soil moisture content remained higher under smaller pore diameter covers than under larger pore diameter covers during the study. Covering crops reduces instantaneous solar radiation through shading (Waterer et al., 2003) resulting to lower evaporation from the ground thus maintaining higher soil moisture contents (Moreno et al., 2002). This argument lends an explanation to the higher moisture content observed under covered plots in the current study. Majumdar (2010) also reported higher soil moisture under net covered plots than uncovered plots.

The use of FRC and EFN reduced PAR and light quantities that reached the tomato crop. Although PAR was also lower under covered plots, it still remained within the 400 – 700 nm range that favours photosynthetic activities within plants. Photosynthetic active radiation and light quantity was also reduced by permanent covering and lowering cover pore diameter in the current study. Covers have been shown to block the light from entering as well as reduce the light quality (Antignus et al., 1998). The reduction in PAR and light quantity under FRC or EFN observed in the current study could therefore be attributed to the light blocking properties of the materials used with more light being blocked when covers of smaller pore diameter are used or when the covers are maintained permanently covered.

5.2 Effects of Floating Row Covers, Eco-friendly Nets and Cover Pore Diameter and Opening on Tomato Leaf Stomata Conductance and Chlorophyll Content

The use of FRC or EFN influenced physiological characteristics of tomato. Tomato seedlings under nets had higher leaf stomatal conductance and leaf chlorophyll content. Chlorophyll content was measured in chlorophyll concentration index units which are an estimate of chlorophyll concentration on tomato leaves with higher units representing higher chlorophyll content. In the field, tomato plants grown under FRC or EFN had better physiological performance compared with uncovered treatments. Tomatoes under covers with finer pore diameter and used permanently had higher leaf stomatal conductance and leaf

chlorophyll content. Higher temperatures and lower diurnal temperature range enhance tomato physiological development (Weerakkody, 1998). Tomato is a warm season crop (Waterer et al., 2003) thus temperature increase would favour several physiological and biochemical processes like photosynthetic enzyme activity, stomatal conductance, carbon dioxide diffusion, and photoassimilate translocation. Elevated air temperatures and improved moisture status and root development reported in current study could have enhanced uptake of nutrients such as potassium and nitrogen, thereby favouring leaf stomatal conductance and chlorophyll content.

5.3 Effects of Floating Row Covers, Eco-friendly Nets and Cover Pore Diameter and Opening on Tomato Growth

Higher transplant success is ideal for any grower (El-Aidy and Sidaros, 1996). In the current study, tomato grown inside the nets emerged earlier than those under the control. In addition, the final emergence percentage was higher under netting compared with the control. Temperature and water are among the important factors affecting germination and survival of transplants in the field (Adams et al., 2001). The modified internal temperature and higher soil moisture conditions observed under netting and covering in the current study could have favoured biochemical and physiological processes necessary for germination within the seeds resulting in early and higher emergence. These findings are in line with results of previous study on advantages of growing tomatoes under protected culture with higher transplant success noted under row covers compared with the control (Weerakkody and Peiris, 1998).

Upon emergence, seedlings under netting showed a relatively better growth than the control seedlings. Tomato seedlings under nets had more leaves, thicker and taller stems, and better root development (more and longer lateral roots) compared with those grown in the outside. After transplanting, covering transplants with FRC or EFN enhanced seedling survival rate compared with uncovered treatments. Covers with finer pore diameter and used permanently had better survival than those with lager pore diameters and opened thrice a week. Higher temperature and soil moisture have been reported to enhance the survival of seedlings (Waterer et al., 2003). Higher temperature, narrow diurnal temperature range and higher soil moisture noted under FRC or EFN may have enhanced root development resulting to higher survival rate.

Every farmer would prefer to reduce production costs while maximizing profits; the use of netting in seedling production showed a greater reduction in cost of seed compared with the control. A farmer using nets for protection may save on the cost of buying seed compared with the one starting seeds in the open. This is supported by higher transplant success under the nets compared with the control, and requiring less seed and potentially increasing economic returns.

Use of FRC or EFN also resulted to better growth of tomato in the field than uncovered treatments. Tomato plants under cover with smaller pore diameter had better growth with more leaves, thicker collar diameter, taller plants and earlier maturing than those with larger pore diameter with covers maintained permanently, and performing better than covers opened thrice a week. Growth and development of crops is dependent on the microclimate within the growing crop (Aoki, 1995). Adams et al. (2001) demonstrated that tomato growth and development largely dependent on temperature, with higher temperatures favouring growth by encouraging the physiological activities of the crop (Weerakkody, 1998). These results can be attributed to the microclimate modified (higher internal temperature, lower diurnal temperature range and higher soil moisture) under FRC or EFN that could have favoured batter physiological development of tomato crop, with higher stomatal conductance and leaf chlorophyll content noted in the present study. Higher stomatal conductance and leaf chlorophyll content enhances photosynthetic activities (Adams et al., 2001). As a result, more photosynthates are translocated to the growing points leading to better growth. These results are in agreement with El-Aidy and Sidaros (1996) who reported better growth of tomato under protected culture compared with non-protected.

5.4 Effects of Floating Row Covers, Eco-friendly Nets and Cover Pore Diameter and Opening on Pest Population and Disease Incidences

Using FRC or EFN significantly influenced pest and disease incidences. During the initial stages of tomato growth, control had fewer weed population compared with the covered treatments. Covers with smaller pore diameter also had more weeds compared with covers with lager pore diameter. More weeds were also noted under covers used permanently compared with those opened thrice a week. Higher temperature and soil moisture under covers encourage weed development (Aoki, 1995). Higher weed population observed in the initial stages of tomato growth could be attributed to higher internal temperature and soil moisture that favoured the

growth of weeds under covered treatments. However, in the later stages fewer weeds were observed under covered treatments compared with the control. Weed population under covered treatments dependent on the cover pore diameter and opening with finer pore diameter and used permanently having less weed population. Vegetation cover has been reported to smoother weeds thus discouraging their growth (Gordon, 2006). Faster growth of tomato under covered treatments may have smothered the weeds in the later stages of tomato growth thus depriving them from space, light and nutrients leading to lower weed population.

Use of FRC or EFN in tomato production considerably reduced populations of leafminers, cotton bollworms, onion thrips, mites, silverleaf whiteflies, and aphids. Covers with smaller pore diameter and used permanently had less pest population compared with covers with lager pore diameter opened thrice a week. FRC or EFN offer physical barrier to pests (Majumdar 2010; Martin et al., 2006; Bextine and Wayandande, 2001). Therefore, covers used may have protected tomato through physical exclusion of pests. In addition, the white nets and floating row cover used could also be a visual barrier for flying pests such as leafminers, onion thrips, moths (Lepidoptera), and silverleaf whiteflies distracting their feeding and mating, hence lowering their population under covered treatments. Cover pore diameter also affects entry of insect pests into the crops. (Majumdar, 2010). This could probably explain the lower population of pest under covers with finer pore diameter. In their field tests, Licciardi et al. (2007) and Martin et al. (2006) observed a delay in the infestation of cabbage by aphids under netting. Although the incidence of viral diseases was not evaluated in the nursery and field, it is likely that the use of FRC or EFN could provide significant benefits in management of those diseases. The reduction of the silverleaf whitefly population noted in the current study could reduce and delay the risk of begomovirus transmission such as tomato yellow leaf curl virus to the plant (Berlinger et al., 2002).

Using FRC or EFN effectively managed late blight incidence compared with the control. Covers with smaller pore diameters had better late blight management compared with covers with lager pore diameter. Tomato plants under covers used permanently also had lower incidences of late blight compared with covers opened thrice a week. This may be attributed to the effectiveness of the FRC or EFN in the reduction of the impact of rain drop thus reducing the

spread of late blight via rain splashes. These results confirm those of Kashyap and Dhiman (2010) while working with nylon nets in the management of alternaria blight and black rot in cauliflower seedlings.

5.5 Effects of Floating Row Covers, Eco-friendly Nets and Cover Pore Diameter and Opening on Tomato Yield Components and Yield

Use of FRC or EFN improved tomato yield components and yield compared with uncovered plots. Yield components and yield tended to increase with a decrease in cover pore diameter. Covers maintained permanently also resulted to more flower trusses, more fruits per plant, more marketable fruits, higher fruit weight and less non-marketable fruits compared with covers opened thrice a week. Covers have been reported to modify internal temperature, soil moisture and diurnal temperature range inside protected culture (Adams et al., 2001). This favours physiological processes (higher stomatal and chlophyll content) of plants leading to better growth and development, leading to more flowers, more fruits per plant and subsequently higher yields (Weerakkody, 1998). In the current study, higher air temperature, higher soil moisture, lower diurnal temperature range was noted under covered treatments. This could probably lead to higher leaf stomatal conductance, higher chlorophyll content noted under covers. Better physiological development can be translated to higher photosynthetic activities (Gerber et al., 1989). When photosynthesis is enhanced, more food is manufactured and translocated to sink. This probably encouraged the growth and development of tomato leading to higher yields. Weerakkody et al. (1999) also noted more tomato fruits, higher marketable yield and quality fruits under protected tomatoes, compared with the uncovered treatments.

Less non-marketable fruits were also noted under covered treatments, compared with the uncovered treatments. The numbers of non-marketable fruits harvested increased with decreasing cover pore diameter. Covers used permanently had lower non-marketable fruits harvested. Higher infestation from pest and diseases on crops lead to non-marketable products (Gaye et al., 1992). Covering crops physically excludes pest and diseases (Majumdar, 2010; Martin et al., 2006). Lower population of pests noted under the present study may have reduced the attack on tomato leading to lower non-marketable fruits. Modified microclimate under covered treatments also may have reduced physiological disorders leading to more marketable and less non-

marketable fruits. El-Aidy and Sidaros (1996) reported higher marketable yield and less non-marketable fruits under protected tomato compared with the non-protected ones. Although lower PAR and light quantity was noted under FRC or EFN, Heinze and Borthwick (1952) demonstrated that tomato plants are highly affected by reduction in temperature compared with light. Therefore, it is possible that the yield of tomato may not be affected with little reduction in light.

5.6 Effects of Floating Row Covers, Eco-friendly Nets and Cover Pore Diameter and Opening on Tomato Fruit Quality

Use of FRC or EFN had higher tomato fruit firmness, TSS, TSS:TA and lower TA, compared with uncovered treatments. Fruits obtained from covers used permanently had better quality compared with those from covers opened thrice a week with quality increasing with the decreasing pore diameter. Fruits from covered treatments were more firm, had more total soluble solids, less titratable acidity and more sugar to acid ratio. Temperature and water are among the preharvest factors affecting quality of fruits (Weerakkody et al., 1999). Heinze and Borthwick (1952) reported that temperature and water play important role in the quality development of fruits. When tomato plants are grown under covers, their quality tends to be enhanced (Waterer et al., 2003). Modified internal temperature and high soil moisture under covers may have encouraged cell wall development, leading to firm fruits under covered treatments. Higher stomatal conductance and chlorophyll content enhance photosynthesis leading to more starch storage on fruits under covered treatments. During ripening process, starch is converted to sugars, leading to high total soluble solids, lower titratable acidity and subsequently higher sugar acid ratio; an important indicator of flavour. These therefore indicate that such fruits are good for fresh market consumption both as salad and cooking. Similar results were observed by Weerakkody et al. (1999).

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

Based on the findings in this study, it can be concluded that:

a) Eco-friendly nets (EFN) influence tomato transplant growth and quality. Seeds started under EFN have faster growth giving healthier seedlings than seeds started under conventional farmer practice.

b) Floating row covers and EFN modify microclimate within the grown tomato crop; reduce pest population and disease incidences, leading to better growth, higher yield and quality tomato fruits, compared with the control.

c) Cover pore diameter affects microclimate, tomato growth, pest population and disease incidences, yield and quality of tomato. The smaller the pore diameter, the better the microclimate modification, plant growth, yield and quality of fruits, while at the same time maintaining lower pest population and disease incidences around the crop.

d) Cover opening influences microclimate, tomato growth, pest population and disease incidences, and yield and quality of tomato. Permanent use of covers results in better microclimate modification, faster tomato growth higher yield and quality, while at the same time maintaining lower pest population and disease incidences around the crop.

e) Microclimate modification as a result of floating row cover (FRC) and eco-friendly net (EFN) coverings influences yield and quality of tomato.

Based on the findings of this study, the following recommendations can be made:

a) Growers will benefit from use of EFN for improved tomato transplant production.

b) Floating row covers and EFN may be used in the field under highland conditions to improve tomato production.

c) In areas with the climatic conditions similar to where the study was done, opening of FRC or EFN is not necessary as it does not lead to any appreciable advantages. If anything, it would only increase the cost of labour.

d) When choosing FRC or EFN for ecological zones similar to those where this study was conducted, farmers should choose those with smaller pore diameters as these have proven to perform better than those with larger pore diameters in tomato production.
e) In choosing a type of cover to use in the production of tomato, the response of the crop to the effect of the cover on microclimate modification, pest and disease incidences and the ultimate crop performance should serve as the guiding principle to farmers.

While the findings from the present study provide a good foundation to understanding the influence of FRC and EFN on microclimate modification, pest population and disease incidences and tomato performance, it is further recommended that:

a) The technology be tested in different agro-ecological regions since ambient conditions affect the changes in the microclimate that results from the use of the technology.
b) Full economic analysis factoring in the cost of FRC or EFN purchase, installation and management will be useful.

REFERENCES

Abate, T., A. van Huis and J. K. O. Ampofo. 2000. Pest Management. Review of Entomology 45:631-659.

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

Al-Helal, I. M. and A. M. Abdel-Ghany. 2010. Responses of plastic shading nets to global and diffuse PAR transfer: Optical properties and evaluation. NJAS -Wageningen Journal of Life Sciences 57:125-132.

Anonymous. 1968. National Canners Association Laboratory Manual Food Canners and Processors. AVI Publishing Co., Westport, CT. 300 pp.

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

Aoki, H. 1995. Present and Future Protected Horticulture of Vegetables. Famling Japan 29:20-24.

Avilla, C., J. L. Collar, M. Duque, P. Perez and A. Fereres. 1997. Impact of Floating Row Covers on Bell Pepper Yield and Virus Incidence. HortScience 32:882-883.

Berger, R. D. 1980. Measuring Disease Intensity. In: Proceedings of E. C. Stakman Commemorative Symposium on Crop Loss Assessment. Univ. of Minnesota Misc. Publ. 7, St Paul. pp. 28-31.

Berlinger, M. J., R. A. J. Taylor, S. Lebiush-Mordechi, S. Shalhevet and I. Spharim. 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 A. Wayadande. 2001. Effect of Insect Exclusion on the Incidence of Yellow Vine Disease and of the Associated Bacterium in Squash. Plant Diseases 85:875-878.

Boisclair, J. and E. Bernard. 2006. Insect Pest Management in Organic Agriculture: Acting in Harmony with Complexity. Phytoprotection 87:83-90.

Britannica, C. 1990. The 'New Encyclopedia Britannica'. Encyclopedia Inc. (Chicago) 11:135-137.

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

FAO. 2012. FAOSTAT: Statistical Database. http://faostat.fao.org. 11th January 2013.

Gaye, M. M. and A. R. Maurer. 1991. Modified Transplant Production Techniques to Increase Yield and Improve Earliness of Brussels Sprouts. J. Amer. Soc. Hort. Sci. 116:210-214.

Gaye, M. M., P. A. Jolliffe and A. R. Maurer. 1992. Row Cover and Population Density Effects on Yield of Bell Peppers in South Coastal British Columbia. Journal of Plant Science 72:901-909.

Gerber, J. M., W. E. Splittstoesser and G. Choi. 1989. A heat System for Predicting Optimum Row Tunnel Removal Time for Bell Peppers. Scientia Hort. 40:99-104.

Gielen T., T. Ultzen, S. Bontems, W. Loots, A. van Schepen, A.Westerbroek, T. de Haan, M. Suzuki and H. Kaneno. 1996. Coat Protein-Mediated Protection to Cucumber Mosaic Virus Infections in Cultivated Tomato. Euphytica 88:139-149.

Gordon, G. G. 2006. Effects of Color Plastic Mulches and Row Covers on the Growth and Production of Okra and Summer Squash. M.Sc. Thesis, Auburn University, Auburn, Alabama, USA.

Gormley, T. R. and M. J. Maher. 1990. Tomato Fruit Quality-an Interdisciplinary. Professional Horticulture 4:7-12.

Harmanto, H., J. Tantau and V. M. Salokhe. 2006. Microclimate and Air Exchange Rates in Greenhouses Covered with Different Nets in the Humid Tropics. Biosystems Engineering 94:239-253.

HCDA. 2006. Fruits and Vegetables. Agricultural Information Resource Centre, Nairobi, Kenya. 150 pp.

HCDA. 2011. Horticulture Validated Report. Agricultural Information Resource Centre, Nairobi, Kenya. 87 pp.

Heinze, P. H. and H. A. Borthwick. 1952. The Light Controlled Production of a Pigment in the Skins of Tomato Fruit. Program American Society of Plant Physiolgists, Ithaca, New York. 37 pp.

Iqbal, M. 1987. Evaluation of Vegetable Production in Plastic Covered Greenhouses in Fiji. Fiji Agricultural Journal 49:9-16.

Joubert, G. and J. Poissonier. 1991. Tomatoes: Production under Nets. Infos-Paris 69:37-42.

Kashyap, P. L. and S. J. Dhiman. 2010. Eco-Friendly Strategies to Suppress the Development of Alternaria Blight and Black Rot of Cauliflower. World Applied Sciences Journal 9:345-350.

Kassilly, F. N. 2002. The fence as a moderator of wildlife menace in Kenya. African Journal of Ecology 40:407-409.

Kaur, S., S. S. Bal, G. Singh, A. S. Sindhu and T. S. Dhillon. 2004. Management of Brinjal Shoot and Fruit Borer through Nethouse Cultivation. Acta Horticulturae 659:345-350.

Klose, F. and H. J. Tantau. 2004. Test of Insect Screens–Measurement and Evaluation of the Air Permeability and Light Transmission. European Journal of Horticultural Science 69:235-243.

Lamont, W. J., Jr. 1996. What are the Components of a Plasticulture Vegetable System? HortTechnology 6:150-154.

Lanny, G. 2001. Fruit vegetables. Crop Production in Tropical Africa. Brussels, Belgium. 1540 pp.

Licciardi, S., F. Assogba-Komlan, I. Sidick, F. Chandre, J. M. Hougard and T. Martin. 2007. 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.

Majumdar, A. 2010. Large-Scale Net-house for Vegetable Production: Pest Management Successes and Challenges for a New Technology. Alabama Cooperative Extension System, Auburn University, Alabama, USA. 350 pp.

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

Ministry of Agriculture and Rural Development. 2003. Fruits and Vegetable technical hand book. Agricultural Information Resource Centre, Nairobi, Kenya. 250 pp.

Moreno, D. A., G. Vı´llora, M. T. Soriano, N. Castilla and L. Romero. 2002. Floating Row Covers Affect the Molybdenum and Nitrogen status of Chinese Cabbage Grown under Field Conditions. Funct. Plant Biol. 29:585-593.

Mungai J., J. Ouko and M. Heiden. 2000. Processing of fruits and vegetables in Kenya. Agricultural Information Resource Centre, Nairobi, Kenya. 180 pp.

Mutwiwa, U. N., J. J. N. Max and H. J. Tantau. 2007. Effect of Greenhouse Cooling Method on the Growth and Yield of Tomato in the Tropics, p. 10-15. In: Leibniz, G. W. (Ed.). Conference on International Agricultural Research for Development held from 9th to 11th October at Hannover, Germany.

Naika, S., J. de Jeude, M. de Goffau, M. Hilmi and B. van Dam. 2005. Cultivation of Tomato: Production, Processing and Marketing. Agromisa Foundation and CTA, Wageningen, Netherlands. 91 pp.

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

Nkondjock, A., P. Ghadirian, K. C. Johnson and D. Krewski. 2005. Dietary Intake of Lycopene is Associated with Reduced Pancreatic Cancer Risk. Journal of Nutrition 135:592-597.

Oren-Shamir, M., E. E. Gussakovsky, E. Spiegel, A. Nissim-Levi, K. Ratner, R. Ovadia, Y. E. Giller and Y. Shahak. 2001. Coloured Shade Nets can improve the Yield and Quality of Green Decorative Branches of Pittosporum variegatum. J. Hort. Sci. Biotech. 76:353-361.

Ortiz, R. and P. Hartmann. 2003. Beyond Crop Technology: The challenge for African rural development. International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. 46 pp.

Parvej, M. R., M. A. H. Khan and M. A. Awal. 2010. Phenological development and production potentials of tomato under polyhouse climate. J. of Agr. Sci. 5:19-31.

Peterson, R. H. and H. G. Taber. 1991. Tomato Flowering and Early Yield Response to Heat Build-up under Row Covers. J. Amer. Soc. Hort. Sci. 116:206-209.

Rekika, D., K. A. Stewart, G. Boivin and S. Jenni. 2008. Floating Row Covers Improve Germination and Reduce Carrot Weevil Infestations in Carrot. Hortscience 43:1619-1622.

Rekika, D., K. A. Stewart, G. Boivin and S. Jenni. 2008. Reduction of Insect Damage in Radish with Floating Row Covers. International Journal of Vegetable Science 14:177-193.

Rojas, E. S., M. L. Gleason, J. C. Batzer and M. Duffy. 2011. Feasibility of Delayed Removal of Row Covers to Suppress Bacterial Wilt of Muskmelon (*Cucumis melo*) Plant Disease 95:729-734.

Shahak, Y., E. E. Gussakovsky, E. Gal and R. Ganelevin. 2004. ColorNets: Crop Protection and Light Quality Manipulation in One Technology. Acta Hort. 659:143-151.

Shahak, Y., T. Lahav, E. Spiegel, S. Philosoph-Hadas, S. Meir, H. Orenstein, E. E. Gussakovsky, K. Ratner, Y. Giller, S. Shapchisky, N. Zur, I. Rosenberger, Z. Gal and R. Ganelevin. 2002. Growing Aralia and Monstera under Colored Shadenets. Olam Poreah 13:60-62.

Soltani, N., J. L. Anderson and A. R. Hamson. 1995. Growth Analysis of Watermelon Plants Grown with Mulches and Row Covers. J. Amer. Soc. Hort. Sci. 120:1001-1004.

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

Thériault, F., K. A. Stewart and P. Seguin. 2009. Incidence of Pieris rapae in Organic Broccoli Grown with Living Mulches under Floating Row Cover. International Journal of Vegetable Science 15:218-225.

Tigchelaar, E. C. 1986. Tomato Breeding, p.135-171. In: Basset, M. J. (Ed.). Breeding Vegetable Crops. Intercept, Andover, UK.

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

Turhan, A. and V. Seniz. 2009. Estimation of Certain Chemical Constituents of Fruits of Selected Tomato Genotypes Grown in Turkey. African Journal of Agricultural Research 4:1086-1092.

Wamache, A. 2005. Vegetable Seeds Handbook. Regina Seeds Seminis. Bizone ltd. Nairobi, Kenya. 200 pp.

Waterer, D. 1995. Multiseason Use of Plastic Soil Mulches in Vegetable Production. University of Saskatchewan, Canada. 245 pp.

Waterer, D., J. Bantle and K. Leray. 2001. Plant Growth Control by Photoselective Filters. Saskatchewan Agriculture and Food. University of Saskatchewan, Saskatchewan, Canada. 200 pp.

Waterer, D., T. Sander, R. Spencer and J. Bantle. 2002. CO_2 levels in Low Tunnels. Saskatchewan Agriculture and Food. University of Saskatchewan, Saskatchewan, Canada. 250 pp.

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

Weerakkody,W.A.P. 1998. Evaluation and manipulation of the major environmental influences of tomato during the rainy season. PhD. Thesis, Postgraduate Institute of Agriculture, Paradeniya, Sri Lanka.

Weerakkody, W.A.P. and B.C.N. Peiris. 1998. Yield and quality of tomato as affected by rainfall during growth stages. Trop. Agr. Res. 9:158–167.

Weerakkody, W.A.P., B.C.N. Peiris, and P.H. Karunananda. 1999. Fruit formation, marketable yield and fruit quality of tomato varieties grown under protected culture in two agro-ecological zones during the rainy season. J. Natl. Sci. Foundation Sri Lanka 27:177–186.

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

Wells, O. S. and J. B. Loy. 1985. Intensive Vegetable Production with Row Covers. HortScience 20:822-826.

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