EVALUATION OF AGRONETS ON MICROCLIMATE MODIFICATION, INSECT PEST CONTROL AND CABBAGE (*Brassica oleraceae var.capitata*) CROP PERFORMANCE

By

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EGERTON UNIVERSITY

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DECLARATION AND RECOMMENDATION

DECLARATION

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

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DEDICATION

This work is dedicated to my parents Dr. and Mrs Muleke, brothers; Albert Muleke, Price Muleke, the late Elphas Muleke and sister, Christine Muleke.

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ABSTRACT

This study was done to evaluate the effects of agronets on insect pests and crop performance on cabbage production under Kenyan conditions. Two experiments were conducted over a span of two seasons at the Horticulture Research and Teaching Field, Egerton University. The objectives were to determine the effects of agronets on (1) microclimate modification, (2) insect pest population and damage, and (3) the subsequent effect on seedling performance, crop growth, yield and quality of cabbage. A Randomized Complete Block Design with two treatments and five replications was used for the nursery transplant production experiment, while six treatments and five replications were used for the field production experiment. For the nursery experiment, the treatments comprised of; (i) open transplant production (control) and (ii) production of transplants under a 0.4mm mesh size net cover used permanently. In the field production experiment, the treatments comprised of; (i) covering crop with a net with fine mesh (0.4mm mesh size) used permanently, (ii) covering the crop with a net with large mesh (0.9mm mesh size) used permanently, (iii) covering the crop with a net with fine mesh (0.4mm mesh size) opened thrice a week (iv) covering the crop with a net with large mesh (0.9mm mesh size) opened thrice a week (v) uncovered crop sprayed with chemicals and (iv) uncovered control with no chemical sprays.

Agronet cover increased both temperature and relative humidity, enhanced seedling growth, and reduced pest damage. Seedling emergence was significantly earlier and higher under the net covering, compared to the control. Seedlings grown under the nets had higher stomatal conductance and leaf chlorophyll content. Similarly, in the field experiment, net covering generally modified the microclimate characterized by higher temperatures, relative humidity and volumetric water content compared to the control. However, the amount of photosynthetic active radiation and diurnal air temperature were reduced under net treatments. Crops covered with 0.9mm agronet generally showed faster growth, high plant dry weight and enhanced stomatal conductance and chlorophyll content.

Permanent cover with 0.4mm and 0.9mm nets resulted in significantly lower pest populations and crop damage. Cabbage yield and the number of marketable heads per hectare were highest in the 0.9mm mesh size agronet. Based on the findings of this study, the use of 0.4mm and 0.9mm net for cabbage transplant and crop production, respectively offer a potentially sustainable technology for profitable cabbage production in Kenya.

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LIST OF ABBREVIATIONS AND ACRONYMS

AVRDC-	Asian Vegetable and Research Development Centre
DAT-	Days after Transplanting
FAO-	Food and Agricultural Organization of the United Nations.
FAOSTAT-	Food and Agricultural Organization Statistics
HCDA-	Horticultural Crops Development Authority
PAR-	Photosynthetic Active Radiation
RCBD-	Randomized Complete Block Design
UPVP-	Urban and Peri-urban Vegetable Production
VPD-	Vapour Pressure Deficit
WAT-	Weeks After Transplanting
TSS-	Total Soluble Solids

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Cabbage, (*Brassica oleracea* var. *capitata* (L) Alef) is a popular member of the family Brassicaceae. It is a herbaceous, biennial, dicotyledonous flowering plant distinguished by a highly reduced stem upon which is a crowded mass of overlapping leaves, which while mature form a characteristic compact, globular cluster the 'cabbage head'. The plant is therefore called head cabbage or heading cabbage. The part of the plant that is normally consumed is the leafy head; more precisely, the spherical cluster of immature leaves, excluding the partially unfolded outer leaves.

Cabbage is a rich source of vitamins and minerals when used as a vegetable by humans and as fodder for animals, in addition to having medicinal values (Fahey et al., 2001). In humans, the "cabbage head" is widely consumed raw or cooked. Semi-intensive production systems - often the batch rearing of cross-breed cattle (local and exotic) use cabbage as a fodder crop forming one of the principle dietary components (Radul, 2008).

The high nutrient content and numerous medicinal properties of cabbage make it popular throughout the world. Cabbage is an excellent source of mineral nutrients including calcium, iron and phosphorous among others (De Lannoy, 2001) and vitamins, fibre, folate and omega-3 fatty acids (Hubpages, 2010). The vegetable has also been documented to have multiple uses as an effective herbal medicine offering good protection against free radicals thus working against aging process. It also has significant amounts of glutamine, an amino acid that has anti-inflammatory properties. Cabbage is considered a low calorie food, and as such, can be included in dieting programs (Herbal Remedies, 2009).

In Kenya, cabbage is an important vegetable mainly grown by resource poor smallholder farmers for food and as a source of income. Farming and marketing of cabbage provides a secure source of continuous income to support the family needs and enable small farms to remain financially viable, especially in the rapid growing peri-urban farming sector (Wambani et al., 2007). It is estimated that nearly half a million families in the countryside derive substantial on-farm earning through the cultivation of cabbage in Africa (FAO, 2009). Kenya is among the undisputed leaders in cabbage production alongside Egypt (FAOSTAT, 2011). In the year 2011, the country harvested more than 523,000 metric tonnes accounting for about 28.3% of total production in the African market (HCDA, 2012). Cabbage production in the country is estimated to occupy an area of about 40,000 hectares with an average yield of 13 tons ha^{-1}. This yield falls far below worldwide average production of 40 tons ha^{-1} (Otieno et al., 2000).

Cabbage crop production in Kenya is constrained by numerous factors including adverse ecological conditions and pest infestation. Cabbage is a high water requiring, cool season crop. The optimum temperature range for production is 15 to 20°C with growth and yields greatly reduced under low moisture and high temperature. In most parts of the country, cabbage is grown in open fields where it is exposed to pest attack, supra-optimal solar radiation of the tropics, low moisture conditions and thermal fluctuations. During its growing period of about 16 weeks, the crop is also exposed to a number of insect pests belonging to different orders, including Lepidoptera, Homoptera, Diptera and Coleoptera (Sengonca et al., 2001). Losses due to these pests amount generally to between 10% and 30% reaching over 80% in severe infestations (Liu and Yu, 1996). To minimize output losses, farmers widely use synthetic pesticides with many of them solely dependent on their use (Varela et al., 2003).

Broad-spectrum insecticides like methomyl and permethrin sprays have been used by many farmers in monoculture cabbage production. However, according to Gelernter and Lomer (2000) and Ninsin et al. (2000), extensive application does not suppress cabbage pests, but to the contrary, the pests quickly develop resistances leading to a build-up of the pests with repeated use of the pesticides. Tests conducted in Kenya for example showed organophosphates, carbamates and pyrethroids to have lost effectiveness against diamondback moth (*Plutella xylostella*) and aphids (*Brevicoryne brassicae*) in most brassicas (Kibata, 1996; Cooper, 1999). Although this poses a challenge to many farmers, chemical overuse marked by high quantity and spray frequencies, as well as application of pesticide cocktails is expected to continue if alternative control methods are not sort (Varela et al., 2003). Besides increasing cost of production, other potential implications associated with the high usage of pesticides would be a further reduction in the already small populations of natural enemies, a decline in land and water quality through accumulation of pesticide residues and human and animal health problems (Brethour and Weersink, 2001; Margni et al., 2002).

High cost of seed and the subsequent poor seed germination and seedling performance in the nursery has also been a major constraint to many commercial nursery owners and cabbage growers in Kenya; substantially increasing on cost of seed and production of the crop. Seed germination and early seedling vigour are important attributes that impact on the success of any crop. The germination of most seeds is affected by environmental factors such as temperature and moisture (Chachalis and Reddy, 2000; Taylorson, 1987). While temperature affects capacity for germination and rate of germination (Bewley and Black, 1994), soil moisture availability is known to be an essential factor for seed germination. Moisture content of the immediate surrounding environment also influences early seedling and transplant survival. Insufficient moisture results in poor germination and transplant survival, which can be costly to growers considering the high cost of seed. Relative humidity has been shown to be of considerable importance in influencing seedling growth especially of most F1 hybrid annuals (Went, 1958).

Like in the field production, successful transplant production in the tropics is also constrained by pest and disease attack. Aphids and leaf miners have been documented among major pests of cabbage seedlings in Kenya (Oduor et al., 1997). The sucking of seedling sap by aphids creates a lack of vigour in the seedlings marked by a variety of symptoms, including decreased growth rates, mottled leaves, yellowing, stunted growth, curled leaves, browning, wilting which affect the physiology of seedlings and eventual plant growth in the field. Aphids may also transmit disease causing organisms like cabbage mosaic virus to their hosts while the coating of plants with honeydew also contributes to the spread of fungi which can damage the plants (Gillman 2005; Reynolds and Volk, 2007). Leaf miners on the other hand cause damage through the mining of leaves by the larvae of the pest resulting in destruction of leaf mesophyll. Leaf mining greatly depresses the level of photosynthesis in the plant, thereby reducing plant vigour and growth. An indirect effect of the wounding of the foliage is that the wounds created can serve as avenues for entry of bacterial and fungal pathogens (Info-net Biovision, 2012).

Information on profitable cabbage production is lacking in many sub-Saharan countries, with little known on cost effective environmental friendly production technologies with the potential of enhancing cabbage transplant production and increasing cabbage production through microclimate modification and insect pest exclusion. Net-covering by itself has been shown to mitigate extreme climatic fluctuations and improve canopy vitality (Shahak, 2006), while at the same time providing physical exclusion of the insects, which reduces the incidence of direct crop damage and also of insect-transmitted viral diseases (Teitel, 2008). With chemical control measures becoming increasingly difficult and uneconomical, alternative physical control measures are gaining attention (Lubulwa, 1997; Hajek, 2004). The use of agronets represents a technology, which has a potential of not only providing resource-poor farmers with low-cost pest control but also for better crop performance through modified microclimate around the crop. Nets have been used to protect crops from excessive solar radiation or other environmental hazards in the developed countries (Majumdar, 2010). The use of nets in protected cultivation has also been tested and proved effective against certain pests on cabbage in Benin (Martin et al., 2006). Using nets in crop production reduces the use of pesticides thus offering environmentally friendly means of controlling insect pests. They are also relatively affordable to resource poor farmers compared to other protected structures like greenhouses (Martin et al., 2006; Majumdar, 2010). As a result of microclimate improvement and pest exclusion, nets have been reported to improve seedling performance, increase yields and enhance quality of crops.

1.2 Statement of the Problem

Despite the economic importance of cabbage, many growers in Kenya are not able to achieve high productivity and good quality cabbage owing to various biotic and abiotic constraints. Cabbage transplant and the subsequent crop production are mostly done in open field subject to erratic weather characterized by fluctuating temperatures, humidity, wind flow and moisture. High incidences of insect pests also prevail under the open field production leading to reduced seedling quality. Cabbage yield and quality is also greatly reduced under these conditions. In Kenya, there is no documented use of protected cropping structures to modify microclimate for improved cabbage yield and/or quality. Moreover, most cabbage farmers solely depend on the use of insecticides, which are often applied extensively to control the prevalent pests of cabbage; the result of which has been loss of effectiveness, increased cost of production and environmental degradation. The use of agronets as an inexpensive and environmentally friendly alternative pest control and microclimate modification method has given favourable results in other parts of the world. The potential use of agronets in controlling cabbage pests and improving microclimate for improved seedling and crop yield and quality under Kenyan conditions, however, remained to be established.

1.3 Justification of the Study

In the era of commercial and high value agriculture, horticultural crops such as cabbage are front runners for betterment of small and marginal farmers in Kenya. Utilization of affordable scientific innovation and intervention in horticultural sector is therefore becoming imperative for sustainable agricultural development of these fragile farmers. Moreover, approaches to safe and affordable pest and environmental management have become relevant and necessary to control crop pests and increase quality and yield so that small scale farmers can benefit from farming. Cabbage crop is highly susceptible to bad weather and insect pest damage. Netting technologies have not only been tested and found to be effective against insect pests but also regulate microclimate for better growth, yield and quality of crops. The use of netting technologies in cabbage production reduces the need for pesticides and other chemicals, thus improving the yield while maintaining environment quality. Elucidating microclimate changes and insect pest dynamics under agronets and their subsequent impact on cabbage plant growth and development goes a long way in ensuring good use of the technology. Findings of this study will provide farmers with information on a protected cropping system for cabbage that is affordable with not only improved microclimate conditions but also reduced pest incidences and the need for chemical sprays. Hence better, cabbage yields and quality with minimum negative impact to the environment.

1.4 Objectives of the Study

1.4.1 General Objective

The main objective of this study was to improve cabbage transplant production, crop yields and quality through providing a protected cropping system that is environmentally friendly and relatively affordable to small scale farmers.

1.4.2 Specific Objectives

The specific objectives for this study were to:

a) Determine the effects of agronets on cabbage seedling performance.
b) Evaluate the effects of agronets on the microclimate around a cabbage crop.
c) Document the effects of agronets on insect pest infestation on cabbage.
d) Quantify the effects of agronets on growth, yield and quality of cabbage.
e) Test the effects of mesh size and net management on the microclimate, insect pest population, growth, yield and quality of cabbage.
f) Determine if a relationship exists between microclimate conditions, pest infestation, growth and yield of cabbage.

1.5 Research Hypotheses

The following research hypotheses were tested in the study;

a) The use of agronets enhances cabbage seedling performance.
b) The use of agronets modifies the microclimate around a cabbage crop.
c) The use of agronets affects insect pest infestation on cabbage.
d) The use of agronets improves growth, yield and quality of cabbage.
e) Mesh size and net management affect the microclimate, insect pest population, growth, yield and quality of cabbage.
f) A relationship exists between microclimate conditions, pest infestation, growth and yield of cabbage.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 An Overview of Protected Vegetable Culture

Protected vegetable production systems offer farmers enhanced market opportunities with better economic returns. These systems significantly contribute to food supplies, especially to urban and peri-urban areas (Olufunke et al., 2003). The impact of vegetable production systems is limited by a number of factors including climatic, insect pests and disease problems. Insects are developing resistance to many of the most widely used pesticides in vegetable production (Palada, 2006) prompting many farmers to grow vegetables under protected culture, which block the entry of pest and prevent crop infestations.

Protected culture is a technology that encompasses all various systems and practices ranging from plastic low tunnels to hydroponic greenhouses and growing rooms used to modify the environment for better crop production. Protected culture technology dates back to 1437A.D when Romans used hydrous magnesium silicate to cover windows, with the objective of screening out light in order to extend growth of plants.

Since its inception, the production of crops under protection has expanded in many countries as a result of the increasing demand for better yields and high-quality fresh produce (Garnaud, 1988). Growers who cannot afford the high initial construction costs of more sophisticated structures like net houses or plastic greenhouses grow vegetables under temporary structures like net tunnels or shade nets. Net tunnels can be constructed with U-shaped iron or aluminium bars, which are covered with nylon netting over each bed (Talekar et al., 2003). The use of netted sheets lay directly over horticultural field crops and supported by the crop as it grows or by a frame, has also increased rapidly in many countries. Such covers have mainly been used to modify microclimate for the early production of field crops such as potato (*Solanum tuberosum*), carrot (*Daucus carota*) and salad vegetables. In addition, with the growing demand for pesticide-free produce, direct covers are also being used to protect crops from insect pests.

2.2 Effects of Net Coverings on Microclimate Modification

Covering crops with screens is a common practice used to attain a number of objectives including shading from supra-optimal solar radiation, sheltering from wind and hail, and improving the thermal climate. The existence of a screen modifies the exchange of radiation, momentum and mass between the crop and the atmosphere, and hence, modifies the crop microclimate (Lloyd et al., 2004). One potential benefit of shading crops is the possibility of saving irrigation water due to the reduced radiation and wind speed. In studying the effects of shading screens on the microclimate, an apple orchard was covered with 23 patches of screens with four shading levels, 0% (control, without shading), 16%, 30% and 60%. Wind speed under the screen was 9% lower than that in the uncovered plot. The screens reduced air temperature during the day (maximum of 1.5^{0}C at noon) and increased air temperature at night (maximum of 0.5^{0}C), when compared to the uncovered plot, resulting in a 2^{0}C reduction in daily temperature range. In this study, the effect of the screens on temperature increased with increasing shading percentage. During daytime, vapour pressure deficit (VPD) under the screens was lower than that in the uncovered plot but no significant effect of the screens on VPD was observed at night. Shading enhanced atmospheric stability as compared to the uncovered orchard where direct solar heating of the ground presumably induced a more unstable atmosphere suggesting a potential reduction of the atmospheric water demand and possible saving of irrigation water under shading (Tanny et al., 2003).

Research has also demonstrated that netting could provide the benefits of conventional net protection as well as effectively modifying the crops enclosed microclimate. Lloyd et al. (2004) measured environmental and crop growth parameters under netting in low-chill stone fruit and under conventional bird and bat netting. Netting increased maximum temperature by 4.4^{0}C and decreased minimum temperature by 0.5^{0}C. Although exclusion netting reduced irradiance by approximately 20%, it enhanced fruit development by 7-10 days and improved fruit quality by increasing sugar concentration by 20-30% and colour intensity by 20%. In a study with tomatoes (*Lycopersicon esculentum*) grown with or without shade nets conducted in Riyadh, Saudi Arabia, Abdel-Mawgoud et al. (1994) observed that air and leaf temperatures under shade conditions were lower by 2^{0}C than those of the open field during day time and higher under shade conditions by 3^{0}C than of the open field during the night.

Net coverings around a crop also influence composition of the surrounding air. In a study done with different types of low tunnel covering materials, CO_2 levels in the tunnels varied with the time of day, outside conditions and the type of cover used. In general, CO_2 levels peaked just before dawn and then declined through the mid-point of the day only to rebuild up later during the day. At mid-day, CO_2 levels were well below ambient levels, reflecting the photosynthetic activity of the plants within the confines of the tunnels. By contrast, at night, CO_2 levels in the tunnels were well above ambient reflecting the tunnel materials' ability to trap the CO_2 generated at night by the respiration of the plants and the soil micro-organisms. The extent of the diurnal fluctuation in CO_2 levels depended on the porosity of the covering material used with the extent of fluctuation more noticeable when the tunnels were constructed of non-perforated clear polyethylene than when constructed of the more porous woven materials (Waterer et al., 2002).

In a field experiment carried out to study the microclimate and air exchange rate of an insect-exclusion fine mesh for commercial pepper (*Capsicum frutense*) cultivation in central Israel, diurnal courses of plant transpiration, and internal temperature and humidity at three heights were measured . Results showed that the upper region of the screen house interacted strongly with the ambient air, but that during most of the day a temperature inversion inside the screen house stabilized the air and reduced mixing of outside and inside air. Humidity and temperature profiles showed that within the screen house, temperature increased and absolute humidity decreased with increasing height of the screen (Tanny et al., 2003).

2.3 Effects of Net Coverings on Insect Pest Populations and Crop Damage

The use of screens to reduce insect invasion in crops has become a common practice in many countries. The screens act as a mechanical barrier, aimed at preventing migratory insects from reaching the plants. The physical exclusion of the insects reduces the incidence of direct crop damage and also of insect-transmitted viral diseases (Teitel, 2008). The screens allow growers to follow international mandatory regulations, enable the use of biological control agents as well as the use of insect pollinators and contribute to the protection of the environment by reducing the need for pesticide application. Different mesh sizes are used for various insect pests. For instance, coarser net (16 to 32 mesh size) has been demonstrated to be effective against larger sized insects, such as lepidopteran moths, whereas finer net (50- or 60-mesh size) can be used to exclude smaller insects, such as thrips, whiteflies, and aphids (Talekar et al., 2003; Harmanto, 2006; Shahak et al., 2008; Palada and Wu, 2009).

In a study done by Martin et al. (2006) to compare the efficacy of mosquito netting and foliar insecticide spray in protecting cabbage against pests in Benin, West Africa, the number of all lepidopteran larvae including diamondback moth (*Plutella xylostella* (L.)) was significantly lower with netting protection and foliar insecticide sprays than under the unprotected control. Nets treated with deltamethrin gave total protection of young plants against the aphid *Lipaphis erysimi* (Kaltenbach)). In this study, polyester nets were used to cover the plants at night by using a wood armature and the nets removed during the day to prevent overheating and excessive shade, both problems of insect-proof screens used under tropical conditions.

Insect-proof screens have been developed in collaboration with, and produced by Polysack Plastics Industries, Nir-Yitzhak, Israel under the trade mark OptiNet®. When cucumber was grown under OptiNet® screens, the number of thrips (mainly *Thrips tabaci*) found on cucumber leaves in tunnels covered with the OptiNet® screen were significantly lower by 3-9 folds compared to the populations under standard screens. Similarly, fewer thrips were observed (about 5 folds) in tunnels of chive covered by OptiNet® compared to the standard screen (Antignus and Ben-Yakir, 2004).

Vernon (2003), showed that low-flying dipteran pests, including the cabbage maggot fly (*Delia radicum* (L.)), the onion maggot fly (*D. antiqua* (Meigen)), the seed corn maggot fly (*D. Platura*), and the carrot rust fly (*Psila rosae* (F.)) could be impeded from entering their host crops by erecting screen fences around the field perimeters. Exclusion fences 0.9m in height with downward-sloping screen overhangs about 25cm long prevented more than 80% of cabbage fly females from entering enclosed plantings of rutabaga. The associated maggot damage was also significantly reduced relative to unfenced controls. Similarly, Linda et al. (2009) observed fewer cabbage fly females captured inside a fence enclosure containing radish than in an unfenced adjacent area of equal size. In a different study, seedling bed netted with mosquito net barrier against red pumpkin beetle (*Aulacophora foveicollis* (Lucas)) in sweet gourd was evaluated against other chemical, mechanical, and botanical approaches of controlling pest. Among the six treatments studied, results indicated that seedling bed of sweet gourd covered with mosquito net barrier up to 45 days before planting was most effective against the pest providing 97.59% to 100% protection with higher benefit cost ratio of 21.99 compared to 9.74 when Furadan 5G was applied into soil and 4.35 when neem seed oil was applied against red pumpkin beetle (Khorsheduzzaman et al., 2010). Similarly, in another study four materials (black, white, silver and grey) were tested and compared against the standard shade cloth and an uncovered control, the average number of *Bemisia tabaci* caught inside the test field cages was extremely low, not exceeding 0.7 whiteflies per trap per day compared to catches under the shade cloth screen tunnel (30.4 whiteflies per trap per day) and the unscreened control (88.5 whiteflies per trap per day) (Shahak et al., 2008).

Photoselective shade nets have also been shown to differentially affect vegetable pest infestation. Whiteflies and thrips preferred landing on yellow and blue nets, respectively. Nevertheless, the number of pests trapped inside chambers or tunnels covered by these nets were similar to, or lower than the equivalent black net. The number of whiteflies found on traps and plants under the yellow net was 2-3 folds lower than under the black net

(Bukovinszky et al., 2005). Yellow shade nets were previously reported to affect aphids in a similar manner (Harpaz, 1982). The red net did not differ from the black shade net, while the white and pearl shade nets significantly lowered both aphid infestation and the incidence of Potato virus Y and Cucumber Mosaic Virus (Harpaz, 1982), probably due to their reflectivity of sunlight, deterring pest landing.

2.4 Effects of Net Covering on Growth, Yield and Quality of Crops

Nets have been shown to improve growth, yield and quality of most crops. Results from a study done by Song et al. (2012) indicated that, shade-net covering reduced light intensity and temperature, and increased air humidity of the seedling environment, compared with the control. Shade-net covering increased plant height, stem diameter, leaf area and biomass of Chieh-qua (*Benincasa hispida* Cogn.var. *chieh-qua How*.) seedlings, among which covering with blue and silver shading-nets were superior to the red net and ordinary black net. Root/shoot ratio and strong seedling index were highest under blue net treatment. Specific leaf weight of Chieh-qua seedlings was reduced by shade-net covering. In addition to silver net, leaf chlorophyll and carotenoids content were significantly increased by red, blue and ordinary covering shading-nets.

It has also been demonstrated that 15 cycles of various leafy vegetables could be produced free of any pesticide use without losing yield or quality over a two-year period under nets. In addition to leafy vegetables, tomato, eggplant, cabbage, cauliflower, broccoli, yard-long bean, and bitter gourd can also be grown successfully in nethouses (Talekar et al., 2003). A study done on broccoli revealed that plants raised in two-and three layer shading nets were least attacked by insect pest and hence, had the least mortality rate than under other treatments. Although the number of days from transplanting to flowering and harvesting, height of plants at heading and harvesting, circumference and weight of head, and plot yield was not affected by different layers of shade nets, the trend of the data revealed that broccoli raised under two or three layers of shade net flowered and matured earlier, had more leaves, were taller at heading and harvesting, had bigger and heavier heads and higher yield per unit area of production (Prado and Raga-as, 2008). In another study with cabbage, Martin et al. (2006) observed that the number of marketable cabbages protected with untreated mosquito netting was significantly higher at harvest compared with the production with foliar insecticide sprays.

Bell pepper (*Capsicum annum*) is commercially grown under shade nets of 30-40% shading for production of high-quality fruit, avoiding sunburns, and saving on irrigation

(Abdel-Mawgoud et al., 1994). Pepper cultivation under coloured shade nets increased productivity of 5 different cultivars tested during 3 successive years. Depending on the year and cultivar, the total fruit yields under the coloured nets were higher by 115-135%, relative to the equivalent black shade net. The higher fruit yield resulted mostly from enhanced rates of fruit production, especially the number of fruits produced per plant but the average fruit size was not significantly affected in most cases. However, in tomato (*Lycopersicon esculentum* (Mill.)) cv. Prigade, applying 30% shade to the plants did not only consistently have any effect on fruit yield under the experiment conditions but also reduced total dry matter production (Abdel-Mawgoud et al., 1994).

In the production of leafy vegetables such as *Brassica rapa* var *chinensis, B. oleracea* var. *alboglabra*, *B. rapa* var. *parachinensis,* and *B. juncea,* it was consistently noted that vegetables grown under tunnels were less damaged by heavy rain and insect pests resulting in a reduced number of insecticide applications, better produce quality, and higher marketable yield (Talekar et al., 2003). Tripled *Amaranthus* yields have also been recorded under net tunnels in Vietnam compared to the control (AVRDC, 2007). Insect populations on cauliflower under net tunnels were greatly reduced by 80% in Cambodia with marketable yields 1.5 to 2.0 times greater obtained under net tunnels than in the open field (Palada and Ali, 2007). Growing head cabbage under net tunnels in the Solomon Islands reduced insect pest incidence by 38-72%, and resulted in significantly higher economic returns (Neave et al., 2011). In tomato, Abdel-Mawgoud et al. (1994) observed that shade net covering has a significant effect on main stem length and leaf area but not on leaf number or intercepted photosynthetic active radiation (PAR).

The use of photoselective netting has also been tested on foliage crops including *Pittosporum variegatum, Fatsia japonica, Monstera deliciosa* traditionally cultured under black shade nets of 50-80% shading. Compared with black nets of the same shading factor, the red and yellow nets were found to specifically stimulate vegetative growth rate and vigour, the blue net caused dwarfing, and the grey net specifically enhanced branching and bushiness and also reduced leaf size and variegation in Pittosporum (Oren-Shamir et al., 2001; Shahak, 2008). The effects of the blue, yellow and red nets result from their enriching/reducing the relative content of blue, yellow and red spectral bands of the transmitted light illumination while the effects of the grey net might relate to its distinct absorption in the infra-red range (Rajapakse and Shahak, 2007).

Several cultivars of Lisianthus (*Eustoma grandiflorum*), sunflower (*Helianthus annuus*) and *Trachelium* were also found to develop longer and thicker flowering stems under the red and yellow nets, while shorter stems were noted under the blue, compared with their equivalent black shade net. Additionally, the red net induced shorter time to flowering in some species with the extent of responsiveness varying amongst the different species and cultivars (Oren-Shamir et al., 2003; Rajapakse and Shahak, 2007). The highly dispersive pearl net was recently reported to enhance branching of *Myrtus communis* pot plants, while in *Crowea* ‘Poorinda Extasy’ it increased the number of flowers per branch compared with a black net of the same shading capacity (Nissim-Levi et al., 2008). In the west-Negev area of Israel, lettuce (*Lactuca sativa*) grown in walk-in tunnels covered by clear plastic films plus 30% shading nets produced lettuce heads, which were 20 -30% larger (‘Noga’ variety), or 40-50% larger (‘Iceberg’ variety), when the red or pearl nets were used instead of the equivalent blue, black or Aluminet (Shahak, 2008).

CHAPTER THREE

3.0 MATERIALS AND METHODS

The study comprised of two parts; i) a cabbage seedling production experiment and ii) a cabbage field production experiment

3.1 Experimental Site Description

The study was conducted at the Horticulture Research and Teaching Field, Egerton University, Njoro. The farm lies at a Latitude of 0^{o} 23' South, Longitudes $35^{o}35$' East in the Lower Highland III Agro Ecological Zone (LH3) (Jaetzold and Schmidt, 1983) at an altitude of approximately 2,238 meters a.s.l. Average maximum and minimum temperatures ranges from $19^{o}C$ to $22^{o}C$ and $5^{o}C$ to $8^{o}C$, respectively with a total annual rainfall ranging from 900 to 1200mm (Egerton Meteorological Station, 2009). The soils are predominantly mollic Andosols (Egerton Meteorological Station, 2009).

3.2 Planting Materials

Cabbage variety Gloria F1 hybrid was used in both the seedling and field production experiments. This variety is one of the preferred varieties by growers due to its high yields, superior taste, resistance to head bursting and good keeping quality (HCDA, 2007). The seeds used for the seedling production experiment were sourced from Kenya Seed Company suppliers in Nakuru. Strong and healthy seedlings produced in the seedling experiment were then selected and used as the planting material for the field experiment.

3.3 Cabbage Seedling Production Experiment

This study was a two-season experiment conducted between Mar.–Apr., 2011 and Sept.–Oct., 2011.

3.3.1 Land Preparation, Design Layout and Seedling Establishment

Land for the seedling production experiment was prepared manually using hoes and rakes to a fine tilth. The experiment was then laid in a Randomized Complete Block Design (RCBD) with five replications and two treatments. Each block measured 4.5m by 1m with a 1m buffer separation between single blocks. Individual blocks comprised of two nursery beds each measuring 1m by 2m of which one bed was protected with 0.4mm mesh size net used permanently, while the other bed (control) used grower standard practice which consisted of shading the bed with grass mulch. The layout of the experiment was as illustrated in Fig. 1. In protected beds, ordinary mild steel was used to make arches to support the nets. Hoops used were 1m wide and 0.3m high after being secured 0.2m into the soil. Two such arches were used per plot mounted in the 1m opposite ends of the plot (Fig. 2). Plots within a block were separated by a 0.5m buffer. On each plot, cabbage seeds were sown in rows 10 cm apart by

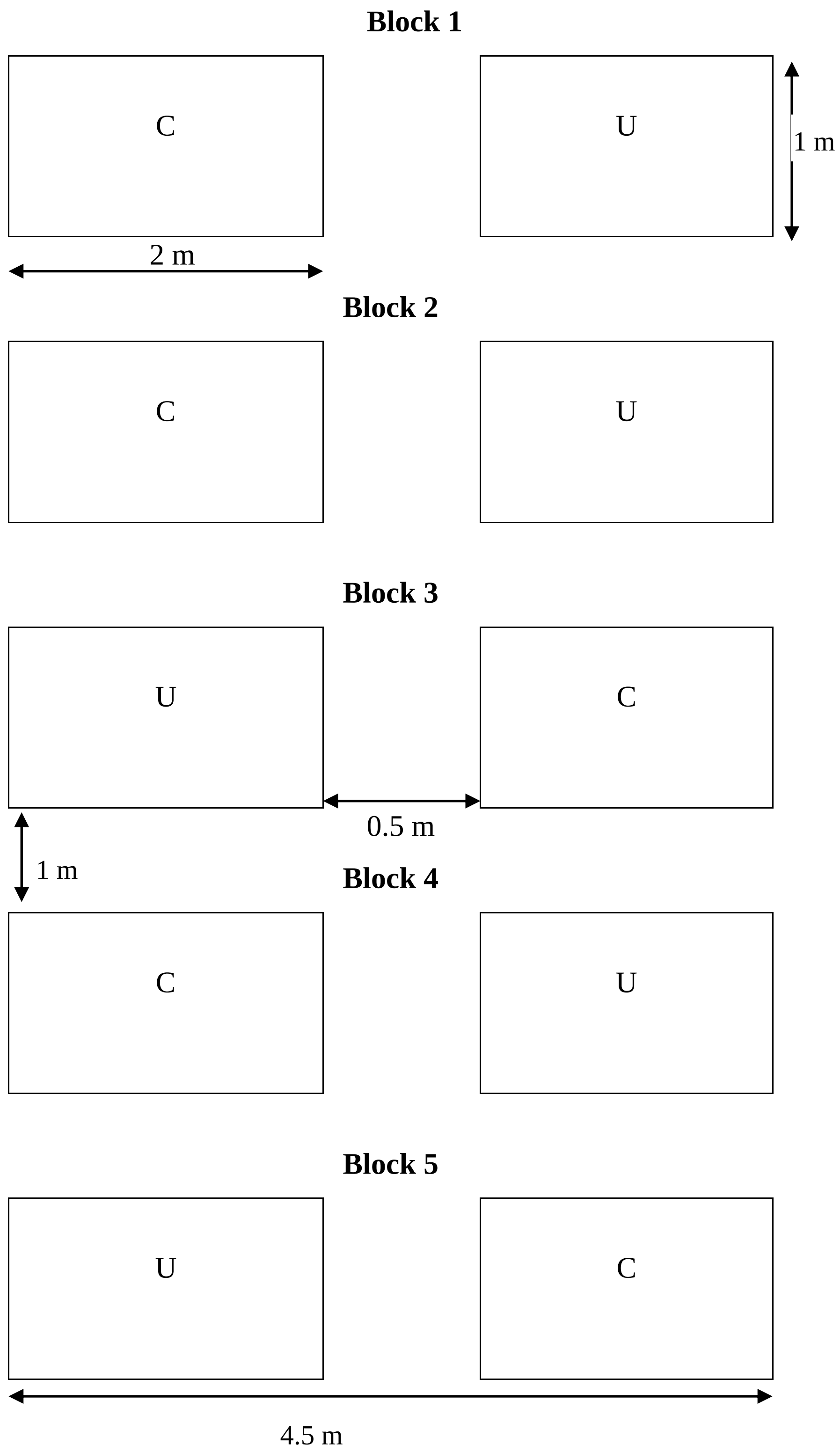


Fig. 1: Experimental layout of the nursery experiment

Key: U - Unprotected nursery bed (control) and C- Nursery bed covered with fine mesh net(0.4mm mesh size) used permanently.

Fig. 2: Cabbage nursery ordinary mild steel arches

1cm within the rows giving 20 lines of 1m length in each bed. Hand weeding was done to control weeds and loosen the soil. Watering was also done as needed during dry spells.

3.3.2 Data Collection

Data collection commenced three days after sowing and continued for a period of four weeks. The variables measured were:

3.3.2.1 Cabbage Nursery Microclimate Variables

Microclimate data collected included daily temperature and relative humidity both measured three times a day; at 8.00 am, noon and 4.00 pm. A thermo-Hygrometer (HM9, Shangai Precision and Scientific Instrument Co. Ltd. Shangai, China) was used to measure both temperature and relative humidity. Daily mean temperature and relative humidity were obtained by computing the mean of the three readings collected for each parameter in each day.

3.3.2.2 Cabbage Seedling Emergence Variables

The emergence variables measured were days to first emergence and percent emergence. Days to emergence was determined by counting the number of days from sowing to first seedling emergence for each treatment in each block. The mean days to first emergence was then obtained by computing the average number of days to first seedling emergence for each treatment for the five blocks. The total number of emerged seedlings was determined on the eleventh day after sowing and germination percentage computed by dividing the total number of emerged seedlings by the total number of sown seeds and the result multiplied by a hundred (ISTA, 1985).

3.3.2.3 Cabbage Seedling Physiology Variables

Physiological variables measured were leaf chlorophyll content and stomatal conductance**.** Leaf chlorophyll content estimates in chlorophyll concentration index units (CCI) was taken on a weekly basis from a recently fully expanded leaf of 20 tagged cabbage seedling in the inner rows of each treatment using a chlorophyll meter (CCM-200 Plus, Opti-Sciences, Inc. NH, USA). Stomatal conductance was also taken from the same leaf used to estimate the chlorophyll content using a steady state leaf porometer (SC-1, Decagon Devices, Inc. Hopkins Court Pullman, USA) and readings recorded in $\mu molm^{-2}s^{-1}$.

3.3.2.4 Cabbage Seedling Growth Variables

Once weekly, leaves were physically counted and plant height measured using a ruler from the 20 tagged cabbage seedlings in each plot. Seedling height was recorded in centimetres (cm). At the same time, the collar diameter of the 20 tagged seedlings was also measured using a vernier calliper (Series 530 Standard model, Mitutoya America Corporation, IL, USA) and recorded in millimetres (mm).

3.3.2.5 Insect Pests and Disease Counts on Cabbage Seedlings

The number and type of pests were counted weekly from each of the 20 tagged seedlings and the counts recorded. The number of diseased seedlings among the 20 tagged seedlings were also counted and recorded.

3.3.3 Data Analysis

Data collected from the nursery experiment were subjected to Analysis of Variance (ANOVA) and where significant, means were separated using the Tukey's Honestly Significant Difference Test at $P \leq 0.05$**.** The RCBD model fitted was:

$$Y_{ijk} = \mu + \rho_i + ß_k + \alpha_j + \eta_l + ß\alpha_{kj} + ß\eta_{kl} + \alpha\eta_{jl} + \varepsilon_{ijl}..$$

Where, Y_{ijk} is the cabbage seedling response, μ is the grand mean, ρ_i is the ith blocking effect (i = 1, 2, 3, 4, 5), αj is the jth season effect (j=1, 2), $ß_k$ is the kth treatment effect (k = 1, 2), η_l is the lth age effect, $ß\alpha_{kj}$ is the kjth season by treatment interaction effect, $ß\eta_{kl}$ is the klth treatment by age interaction effect, $\alpha\eta_{jl}$ is the jlth season by age effect and ε_{ijk} is the random error component which are normally and independently distributed about zero means with a common variance $\sigma^{2.}$ Data for percent emergence was transformed to arcsine for ANOVA and mean separation but the means presented are original means. Data for the pests were subjected to square root transformation before ANOVA and mean separation but values presented are the original means.

3.4 Cabbage Field Production Experiment

The field cabbage experiment was conducted over a span of two seasons (May–Aug., 2011 and Oct.–Jan., 2012)

3.4.1 Land Preparation, Field Layout and Seedling Establishment

Land for the field experiment was prepared using a disc plough and harrowed to a fine tilth using a disc harrow. The experimental design used was a Randomized Complete Block Design (RCBD) with five replications (Fig 3). Healthy cabbage seedlings grown under nets in the nursery were transplanted under the following treatments; (1) uncovered plot with no chemical spray as the control, covered with (2) 0.4mm mesh size net used permanently (3) 0.9mm mesh size net used permanently (4) 0.4mm mesh size net opened thrice a week from

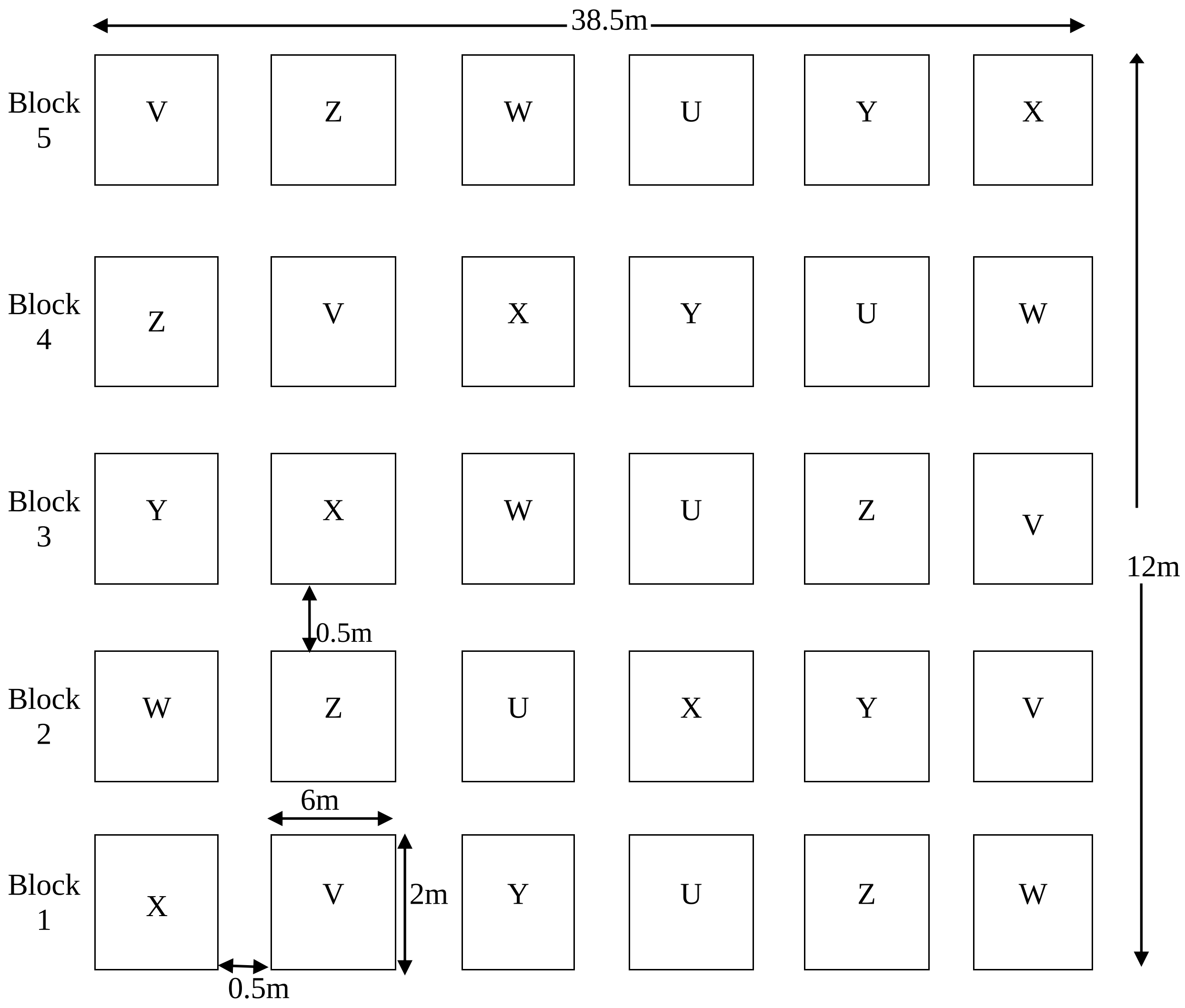


Fig 3: Experimental layout for the field experiment

Key: U-Uncovered, unsprayed V- Uncovered sprayed (control), W- 0.4mm mesh size net used permanently, X -0.9mm mesh size net used permanently, Y-0.4mm mesh size net opened thrice weekly, Z-0.9mm mesh size net opened thrice weekly

9 am to 3 pm (5) 0.9mm mesh size net opened thrice a week from 9 am to 3 pm and (6) uncovered plot sprayed with a broad spectrum insecticide (Duduthrin). There were 5 blocks each measuring 2m by 38.5m separated by a 1m buffer. In each block there were 6 plots each measuring 2m by 6m giving a total of 30 plots. Out of 6 plots in each block, 4 plots were therefore protected by net covers (3m x 7m) and the other 2 remained uncovered. Where nets were used to cover cabbage crops, wooden plunks were used to make arches to support the nets. Hoops used were 2m wide and 0.3m high after being secured 0.2m into the soil. Four such arches were used per plot, mounted at equidistance across the 2m (width) of the plot (Fig. 4).

At transplanting of seedlings to the main field, only seedlings grown under net covering in the nursery were used to ensure uniform growth in the field. Transplanting was done at a spacing of 40cm by 40cm which is recommended by the Ministry of Agriculture, giving a total of 75 plants per plot. Triple supper phosphate (TSP) fertilizer (46 % p_2o_5) was used at transplanting at the rate of 275 kg/ha and later calcium ammonium nitrate (CAN, 26 % N) was applied as a top dress at 200 kg/ha, in two equal splits; at three and six weeks after transplanting. Thereafter, cabbage maintenance activities were done uniformly on all treatments.

3.4.2 Data Collection

Twenty central plants from the inner rows of each plot were randomly picked and marked for data collection on the first day of data collection. From each plant, the following data were collected and recorded;

3.4.2.1 Cabbage Field Microclimate Variables

WatchDog Plant Growth Station data loggers model 2475 (Spectrum Technologies, Inc.) were used to collect microclimate data. The data loggers were programmed to take data hourly which was averaged daily. Each data logger was screwed on a wooden post, 10 cm high at the centre of each plot. Accumulated data was downloaded on a weekly basis to ensure safety. The loggers were used to collect data on; air temperature, diurnal temperature range, relative humidity, quantum light (PAR), and volumetric soil water content.

3.4.2.2 Cabbage Plant Physiological Variables

Physiological parameters measured were chlorophyll content and leaf stomatal conductance. Leaf chlorophyll content estimates in chlorophyll concentration index units (CCI) were taken from a recently fully expanded leaf of the 20 tagged cabbage plants in the inner rows of each treatment using a chlorophyll meter (CCM-200 Plus, Opti-Sciences, Inc. NH, USA) every two weeks beginning 5 weeks after planting to the end of the experiment.

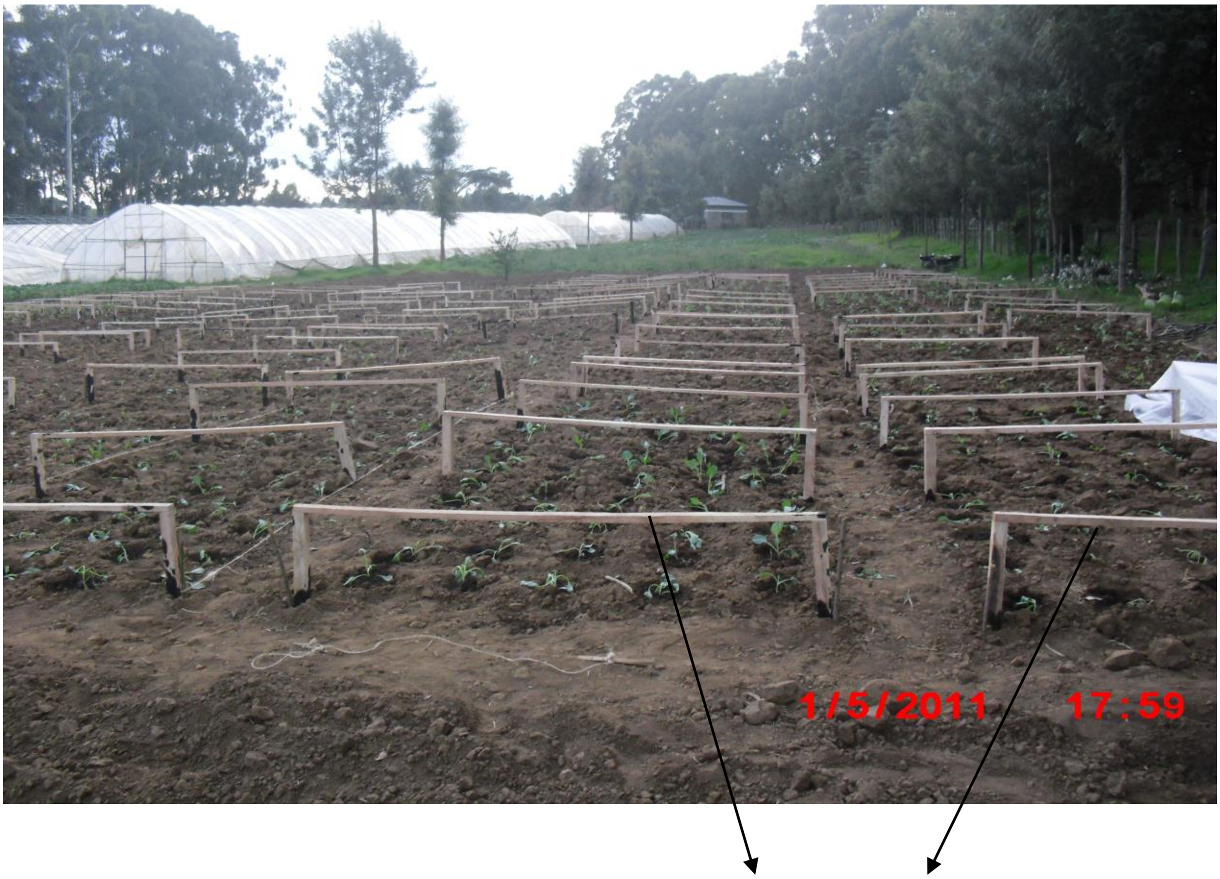


Fig. 4: Wooden arches used for agronet support in the field experiment.

Stomatal conductance (µmol$m^{-2}s^{-1}$) of the 20 middle cabbage plants from each treatment was also measured on the same leaf on which chlorophyll was measured. Stomatal conductance was measured using a steady state leaf porometer (Decagon SC-1) after every two weeks beginning 5 Weeks After Transplanting (WAT).

3.4.2.3 Cabbage Plant Growth Variables

Height of the tagged 20 cabbage plants from the central lines of each plot was measured weekly using a ruler (cm) from the ground level to the top of the shoot and recorded in cm. The number of fully expanded leaves of the same plants was also counted weekly beginning 5 WAT. A vernier calliper (Series 530 Standard model, Mitutoya America Corporation, IL, USA) was also used to measure collar diameter of the stems of the same 20 plants every week.

3.4.2.4 Insect Pests and Diseases Counts on Cabbage Plants

Once a week, the number of insect pests including aphids, diamond back moth, cabbage looper, mites and leaf miners on each plant were counted and recorded. Scouting for diseases was also done once a week and the number of plants presenting disease or virus symptoms noted and recorded. The collection of data on these parameters commenced 4 WAT and continued to the end of the experiment.

3.4.2.5 Cabbage Yield and Yield Components

Upon harvest at maturity stage, 20 cabbage plants were selected at random and uprooted from each plot as a representative sample for determination of total fresh head weight using a mechanical weighing pan scale (10kg/40g, 18636 Shenzhen west-Boao Science and technology Co. Ltd). Cabbage fresh head weight was measured in kilograms per plot (kg/plot) and later converted into kilograms per hectare (kg/ha). From the 20 cabbages harvested from each plot, a random sample of 5 cabbages was selected from the harvest of each plot. Head diameter was then determined from the sample of 5 cabbages of each plot by making longitudinal cuts and measuring the equatorial and polar diameter using a ruler. The equatorial diameter was measured at the widest point of each cabbage head. Thereafter, the 5 heads from each plot were separately chopped into smaller pieces, put in clean paper bags and oven dried at 75°C to a constant weight and the weight determined and recorded in grams per head (g/head). From the 15 cabbages that had remained from the harvest of each plot, another sample of 5 cabbages was randomly selected for determination of total plant dry biomass. The stems and roots were washed using clean water to remove any adhered soil particles and wiped dry using a cotton cloth. Total fresh weight of the 5 cabbages from each plot was determined and used to compute total fresh weight in kg/ha for the individual treatments. Samples from the individual plots were then chopped into separate containers using a knife and thoroughly mixed. A sample of 100 grams was then drawn from each container, put in paper bags and oven dried at 75°C to a constant weight. The dry weight for each 100 grams fresh weight sample was then determined and used to compute total plant biomass using the formula:

Total dry weight/plant = Total fresh weight/ plant x Dry weight/100gms fresh weight

From the 10 cabbages that remained above, another 10 cabbage heads picked at random from each plot were added to make a total of 20 cabbage heads. From this sample, marketable heads were separated from unmarketable heads by taking them to a roadside market and allowing customers to choose for themselves. Those cabbages that did not attract a buyer at all were considered as unmarketable. Total marketable head numbers were then computed as the summation of the heads sold out for each treatment converted into numbers per hectare.

3.4.2.6 Cabbage Quality Variables

The head firmness was determined using the random sample of the 5 cabbage heads used to determine head dry weight before they were chopped. The head firmness was then determined using a hand held penetrometer (model FT327, QA Supplies, LLC. U.S.A) probe number 16, by exerting pressure on the head; the reading in kg force, at which the cabbage head was punctured, indicated the head firmness. From the remainder of the chopped up cabbage pieces used to determine head fresh weight, a handful of the chopping was taken for Total soluble solids (TSS) measurement. This was done by wearing clean gloves and hand squeezing out tissue liquid onto a hand held refractometer (model RHB-32atc, Fuzhou Hedao Trade Co. Ltd.China) and the reading recorded in % brix.

3.4.3 Data Analysis

Data collected from the field experiment was subjected to Analysis of Variance (ANOVA) using PROC GLM code of SAS (version 9, 2005) and means for significant treatments separated using the Tukey's Honestly Significant Different Test at $P \leq 0.05$. The RCBD model fitted was:

$$Y_{ijk} = \mu + \rho_i + ß_k + \alpha_j + \eta_l + \beta\alpha_{kj} + ß\eta_{kl} + \alpha\eta_{jl} + \varepsilon_{ijl}..$$

where, $\boldsymbol{Y_{ijk}}$ is the cabbage plant response, $\boldsymbol{\mu}$ is the grand mean, $\boldsymbol{\rho_i}$ is the ith blocking effect (i = 1, 2,3,4,5), $\boldsymbol{\alpha_j}$ is the jth season effect (j=1, 2), $\boldsymbol{ß_k}$ is the kth treatment effect (k = 1, 2,3,4,5,6), $\boldsymbol{\eta}_l$ is the lth age effect, $\boldsymbol{ß\alpha_{kj}}$ is the kjth season by treatment interaction effect, $\boldsymbol{ß\eta}_{kl}$ is the klth treatment by age interaction effect, $\boldsymbol{\alpha\eta}_{jl}$ is the jlth season by age effect and $\boldsymbol{\varepsilon_{ijk}}$ is the random error component which are normally and independently distributed about zero means with a common variance $\sigma^{2.}$ In order to be able to examine the effects of mesh size (0.4 and 0.9mm) and net management system (opened or maintained permanently covered) and their possible interactions on the studied variables during the field production experiment, data for the balanced factorial part of the experiment were extracted and analyzed using the model:

$$\boldsymbol{Y_{ijkl} = \mu + \rho_i + s_j + \alpha_k + ß_l + s\alpha_{jk} + sß_{kl} + \alpha ß_{kl} + s\alpha ß_{jkl} + s\eta_i + \varepsilon_{ijl}}.$$

Where $\boldsymbol{Y_{ijkl}}$ is the cabbage plant response, $\boldsymbol{\mu}$ is the grand mean, $\boldsymbol{\rho_i}$ is the ith blocking effect (1,2,3.4,5), $\boldsymbol{s_j}$ is the jth season effect (1,2), $\boldsymbol{\alpha_k}$ is the kth mesh size effect (1,2) , $\boldsymbol{ß_l}$ is the lth net management effect (1,2) , $\boldsymbol{s\alpha}_{jk}$ is the effect of the jth season and kth mesh size interaction effect, $\boldsymbol{sß_{kl}}$ is effect of the kth season and lth net management interaction, $\boldsymbol{\alpha ß_{kl}}$ is the effect of the kth mesh size and lth net management interaction, $\boldsymbol{s\alpha ß_{jkl}}$ is the season, mesh size and mesh management interaction, $\boldsymbol{s\eta_i}$ is the crop age effect and ε_{ijl} is the random error component. The assumptions made were that the different factors were additive and that experimental errors are independent. It was also assumed that the experimental error was normally distributed with mean zero and a common variance. Regressions were also done to establish relationships between some of the microclimate variables and cabbage insect pests, cabbage growth and cabbage yield and quality. The regression model fitted was:

$\boldsymbol{Y_i = ß_o + ß_1 x_i}$ where $\boldsymbol{ßo}$ is the Y intercept, $\boldsymbol{ß_i}$ the slope of the regression line and $\boldsymbol{x}$ is the independent variable. Data for the pests were subjected to square root transformation before ANOVA and mean separation but values presented are the original means. The results obtained have been presented in chapter 4 and discussed in chapter 5 of this document.

CHAPTER FOUR

4.0 RESULTS

In this section results of both the cabbage seedling production experiment and cabbage field production are presented.

4.1 Cabbage Seedling Production Experiment

This experiment involved two treatments; covering the nursery bed with a 0.4mm mesh size agronet or leaving the nursery bed uncovered as the control. This section presents the results of the effect of these treatments on the cabbage; (i) nursery microclimate (ii) seedling emergence (iii) seedling physiology (iv) seedling growth and (v) insect pest and disease counts on seedlings.

4.1.1 Effects of Agronets on Cabbage Nursery Microclimate

The use of agronet covers influenced the nursery microclimate conditions. Throughout the study, relative humidity and temperature were higher in the agronet-covered treatment compared to the control (Fig 1). The mean temperatures were 23.4^{0}C and 26.7^{0}C under control and agronet, respectively in season 1 and 23.3 ^{0}C and 26.3^{0}C in season 2, respectively, depicting a 14.1% and 12.9% increase in temperatures under agronets in season 1 and 2, respectively. Mean relative humidity was 53.0% and 58.7% under the control and under the agronet, respectively in season 1 and 54.9% and 62.0% under the control and under the agronet, respectively in season 2 depicting a 9.7% and 11.5% increase in relative humidity under nets in season 1 and 2, respectively.

4.1.2 Effects of Agronets on Cabbage Seedling Emergence and Percent Emergence

Starting cabbage seeds under agronets advanced seedling emergence and improved the germination percentage. Cabbage seeds sown under the agronet took a shorter duration to emerge compared to control seeds. While first emergence occurred in an average 3 days after sowing under the agronets, it took 6 days on average under the control treatment in both seasons (Table 1). Sowing cabbage seeds under netting also resulted in a higher final emergence percentage (96.1% and 96.5% in season one and two, respectively) compared to the control (39.1% in season one and 41.6% in season two).

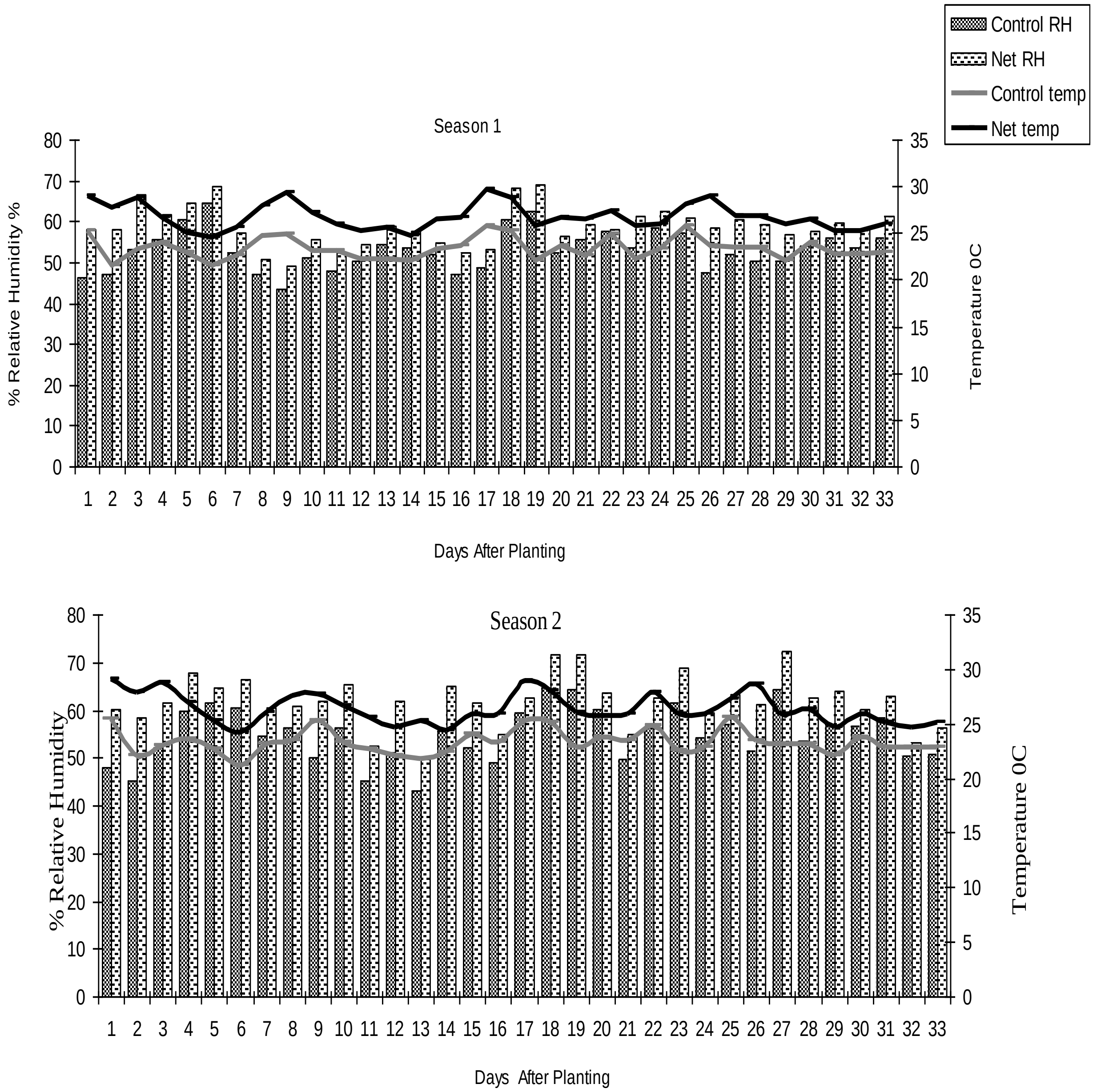


Fig. 5: Effect of agronets on cabbage nursery air temperature and relative humidity during season 1(March-April, 2011) and season 2 (Sept-Oct, 2011). Control RH was relative humidity under the uncovered plots, Net RH was relative humidity under the agronet covers, Control temp was temperature under the uncovered plots. Net temp was temperature under agronet covers.

Table 1: Effects of agronet cover on days to emergence and percent emergence of cabbage during season 1(March-April, 2011) and season 2 (Sept-Oct, 2011).

	Days to emergence	Percent emergence**		
		Days after sowing		
Treatment		7th	9th	11th
		Season 1		
Control	6.6a*	9.1e	31.6d	39.1c
Agronet	3.2b	86.1b	95.1a	96.1a
		Season 2		
Control	6.4a	9.9d	34.2c	41.6c
Agronet	3.0b	89.4b	94.2a	96.5a

* Means followed by the same letter within a parameter and within a season are not significantly different according to Tukey's HSD test (P≤ 0.05).

**Data for percent emergence was transformed to arcsine for ANOVA and mean separation but the means presented are original means.

4.1.3 Effects of Agronets on Cabbage Seedling Stomatal Conductance and Chlorophyll Content

Net protection influenced seedling physiology. Higher stomatal conductance and chlorophyll estimates were recorded in seedlings grown under net covering compared to the control. In both seasons, stomatal conductance under netting was on average higher by 100 $\mu molm^{-1}sec^{-2}$ compared to the unprotected seedlings, at all stages of the seedling growth (Table 2). Seedling stomatal conductance increased with increase in age of the seedling. A similar trend was observed with estimates of chlorophyll content where protected cabbage seedlings recorded 33.7 CCI at four weeks after emergence against 23.8 CCI for unprotected seedlings at the same age. Age of the seedlings was also found to affect the chlorophyll content with higher chlorophyll being obtained with increase in age of the seedlings (Table 2).

4.1.4 Effects of Agronets on Cabbage Seedling Growth

Stem height, leaf numbers and stem diameter were used as the indicators of seedling growth. In general, growing seedlings under agronet improved seedling growth and vigour compared to the unprotected seedlings. As evidenced by the data presented in Table 3, seedlings under the net mostly attained a given plant height at least one week earlier than those under the control in both seasons. Moreover, netting resulted in the tallest seedlings by the fourth week which was the end of the study. At any seedling stage, leaf numbers and seedling collar diameter were also higher for seedlings under the agronet than for unprotected seedlings. While seedlings under the nets took one week after emergence to achieve a collar diameter of 2.1mm and 2.6 leaves per seedling, unprotected seedlings took 3 weeks to achieve similar attributes.

4.1.5 Effects of Agronets on Pest Infestation and Disease Incidences

Starting cabbage seedlings under net covering provided an exclusion barrier against insect pests. This effectively reduced the number and extent of insect pest infestation compared to the control treatment. Seedling disease incidences were also reduced under net protection with a mean of 1.0 seedling infected per 1m x 2m bed against 8.3 seedlings under the control (Table 4). Damping off was the main disease experienced during the study.

Table 2: Selected physiological traits of cabbage seedlings as influenced by agronet cover during season 1(March-April, 2011) and season 2 (Sept-Oct, 2011).

	Stomatal conductance (μmolm-^{1}sec-^{2})			Chlorophyll (CCI)		
	Weeks After Emergence			Weeks After Emergence		
Treatment	2	3	4	2	3	4
			Season 1			
Control	216.1f*	219.6e	224.2d	17.7e	21.6d	23.8c
Agronet	314.7c	319.3b	324.2a	25.2c	29.8b	33.7a
			Season 2			
Control	215.9f	219.2e	223.1d	18.0f	21.6e	24.3d
Agronet	314.9c	318.9b	322.4a	26.5c	30.1b	33.1a

*Means followed by the same letter within a parameter and within a season are not significantly different according to Tukey's HSD test ($P \leq 0.05$).

Table 3: Selected cabbage seedling growth attributes as influenced by agronet cover during season 1(March-April, 2011) and season 2 (Sept-Oct, 2011)

	Collar diameter(mm)				Leaf number(No/plant)				Height (cm)			
	Weeks After Emergence				Weeks After Emergence				Weeks After Emergence			
Treatment	1	2	3	4	1	2	3	4	1	2	3	4
Season 1												
Control	1.2g*	1.7f	2.1de	2.4d	2.0f	2.2e	2.7de	3.0cd	2.4e	3.2de	3.7cd	4.3b
Agronet	2.1e	2.8c	3.5b	3.8a	2.7de	3.6bc	3.8ab	4.1a	3.4cd	3.9bc	4.6b	6.0a
Season 2												
Control	1.2g	1.7f	2.3e	2.4d	1.8b	2.2b	2.6b	2.6b	2.0e	2.5d	3.7c	4.4b
Agronet	2.2e	2.8c	3.5b	3.7a	2.6a	3.5a	3.8a	4.2a	3.1d	3.5c	4.6b	5.5a

*Means followed by the same letter within a parameter and within a season are not significantly different according to Tukey's HSD test ($P \leq 0.05$)

Table 4: Insect pests and disease counts on cabbage seedlings as influenced by agronet cover during season 1(March-April, 2011) and season 2 (Sept-Oct, 2011).

	Aphids** (No/plant)			Leafminers (No/plant)			Diseased*** (No/bed)
	Weeks After Emergence			Weeks After emergence			
Treatment	2	3	4	2	3	4	
				Season 1			
Control	4.99a*	6.94a	5.50a	0.53a	0.50a	0.40a	8.28a
Agronet	0.48b	0.28b	0.15b	0.11b	0.10b	0.07b	1.00b
				Season 2			
Control	9.94a	11.1a	11.64a	0.24a	0.24a	0.24a	8.20a
Agronet	0.44b	0.29b	0.24b	0.08a	0.04b	0.06b	0.80b

* Means followed by the same letter within a parameter and within a season are not significantly different according to Tukey's HSD test (P≤ 0.05).

**Data for the pests were subjected to square root transformation before ANOVA and mean separation but values presented are the original means.

***Diseases data included an average of all seedlings presenting any of the cabbage diseases. Main disease observed was dumping off.

4.2 Cabbage Field Production Experiment

The cabbage field experiment comprised six treatments which included two uncovered treatments: one to which no pesticide was applied (control) while the other was sprayed with a broad spectrum insecticide (duduthrin) and; covering the cabbage crop with a 0.4mm or 0.9mm mesh size agronets used either permanently or opened thrice a week. In the subsequent sections of this chapter, the field experiment results have been presented in the sequence; i) microclimate variables, ii) cabbage plant physiology variables, iii) cabbage crop growth variables, iv) pests and disease counts on the cabbage crop, v) cabbage yield components and yield variables, vi) cabbage quality variables and vii) the relationship between various dependent variables in the study.

4.2.1 Effects of Agronets on the Crop Microclimate

Microclimatic variables measured in the field experiment included temperature, relative humidity, diurnal temperature range, volumetric water content and photosynthetic active radiation.

4.2.1.1 Temperature

In both seasons, temperature was influenced by the use of agronet covers (Fig 6). Throughout the study, temperatures were lower under the control treatments with no net covering and higher under the net covered plots. In season one, mean temperatures were 23.8^{o}C under 0.4mm agronet used permanently, 21.8^{o}C under 0.4mm agronet opened thrice a week, 19.1^{o}C under 0.9mm agronet used permanently; 18.3^{0}C under 0.9mm agronet opened thrice a week and 17.9^{o}C under the control. Although temperatures generally tended to be slightly lower in season two, a similar trend of treatment effect was observed. Mean temperatures were highest under 0.4mm agronet used permanently at 22.9^{o}C followed by 20.5^{o}C under 0.4mm agronet opened thrice a week, 18.8^{o}C under 0.9mm agronet used permanently, 18.4^{o}C under 0.9mm agronet opened thrice a week with the lowest temperature of 18.0^{o}C recorded under the control treatment. Plots covered using the smaller mesh net (0.4mm) tended to exhibited higher temperatures compared to those covered using the larger mesh size (0.9mm) netting throughout the study. Within each mesh size of the agronet, opening the nets thrice a week resulted in lower temperatures compared to where nets were maintained permanently covered.

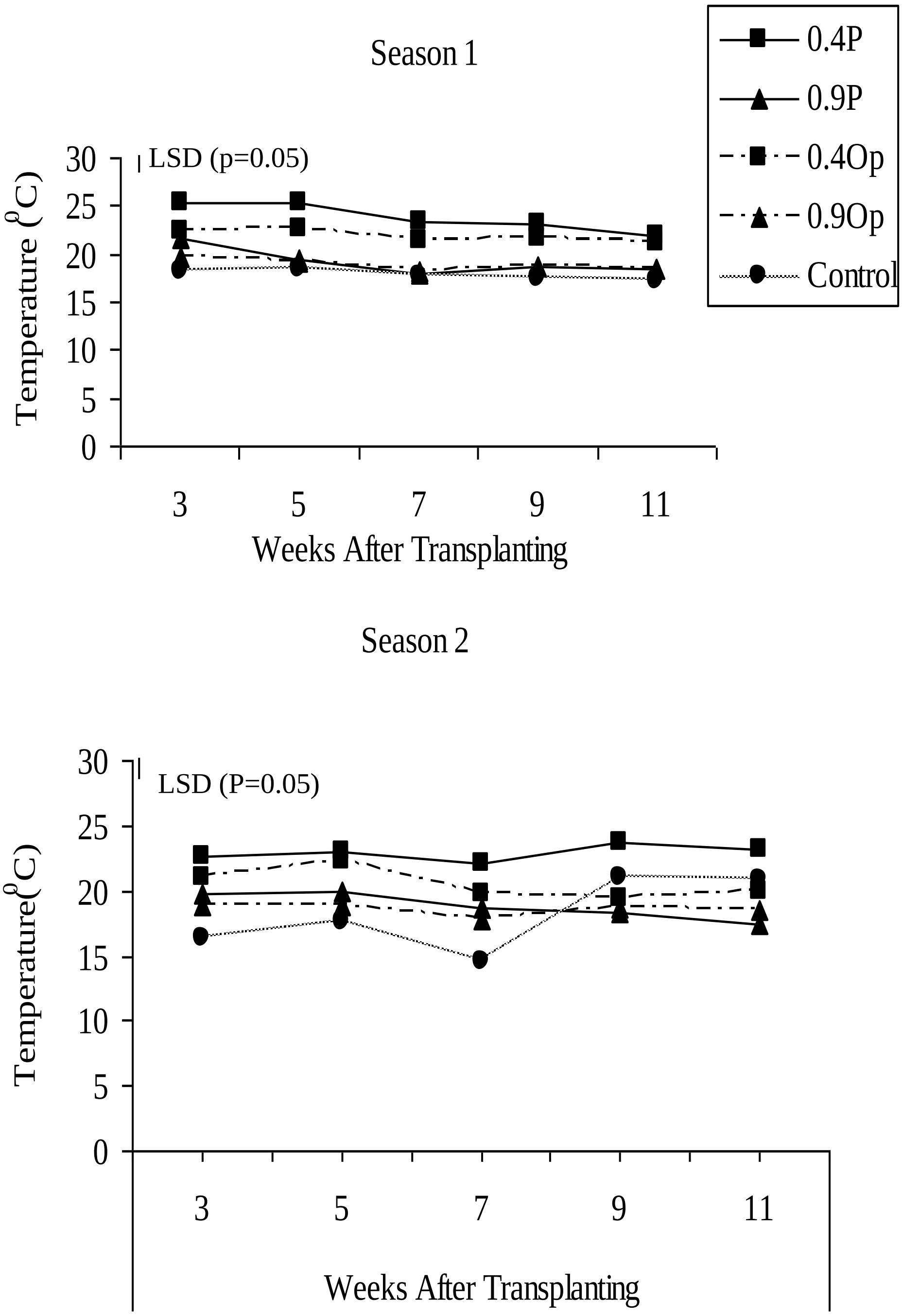


Fig. 6: Air temperature profile as influenced by agronet cover during season 1(May-Aug, 2011) and season 2 (Oct-Jan, 2012) cabbage field production experiment. Control had no agronet cover, Op is where the agronet was opened three times a week, P is where agronet was maintained permanently covered except during maintenance and data collection periods while 0.4 and 0.9 were the different agronet mesh sizes (mm) used**.**

4.2.1.2 Relative Humidity

Relative humidity displayed a trend similar to that of temperature in both seasons being highest under 0.4mm netting used permanently and lowest under the control treatment throughout the study (Fig. 7). Seasonal effects in relative humidity content were evident with season one registering higher relative humidity than season two. In season one, the mean relative humidity for the season was 85.4% under the 0.4mm netting used permanently and 84.7% under the same mesh size netting opened thrice a week against 77.9% relative humidity recorded for the control treatment. This depicted a 7.5% and 6.8% increase in relative humidity when the 0.4mm agronet was used permanently or opened thrice a week, respectively. Relative humidity under the 0.9mm agronets was on the other hand, 81.2% and 79.9% when used permanently and when opened thrice a week, respectively depicting a 3.3 % and 2.0% increase in relative humidity, respectively. A similar trend was established in season two where relative humidity increased from 69.2% under the control to 83.4% under the 0.4mm permanent treatment and 79.6% under the 0.4mm opened treatment depicting a 14.2% and 10.4% increase, respectively. Under the 0.9mm agronet used permanently or opened thrice a week, mean relative humidity was 79.3% and 75.8%, respectively depicting a 10.1% and 6.6% increase, respectively. Within each mesh size, relative humidity tended to be higher in the 0.4mm mesh size than in the 09mm mesh size. Relative humidity was also highest when the net was maintained permanently covered compared to when it was opened thrice a week.

4.2.1.3 Volumetric Soil Water Content (%)

The volumetric soil water content (a measure of soil moisture content) was also influenced by the use of agronet covers in both seasons. Using the 0.4mm agronet permanently resulted in the highest volumetric soil water content in all sampling dates in both seasons. The lowest volumetric soil water content was recorded in soils of uncovered plots in all sampling dates (Fig. 8). Differences in volumetric soil water content due to seasons were also evident with season one recording higher values than season two. The mean volumetric soil water content for the control treatment was 28.3% in the first season and 20.0% in the second season against 36.8% and 34.3% in season one and two, respectively under the 0.4mm agronet used permanently, 33.9% and 31.4% under the 0.4mm agronet opened thrice a week, 30.9% and 28.9% under the 0.9mm agronet net used permanently and 29.0% and 27.3 % under the 0.9mm agronet net opened thrice weekly. Within each agronet mesh size, the volumetric soil water content tended to be higher under the 0.4mm mesh size and when the net remained permanently covered compared to when it was opened thrice a week.

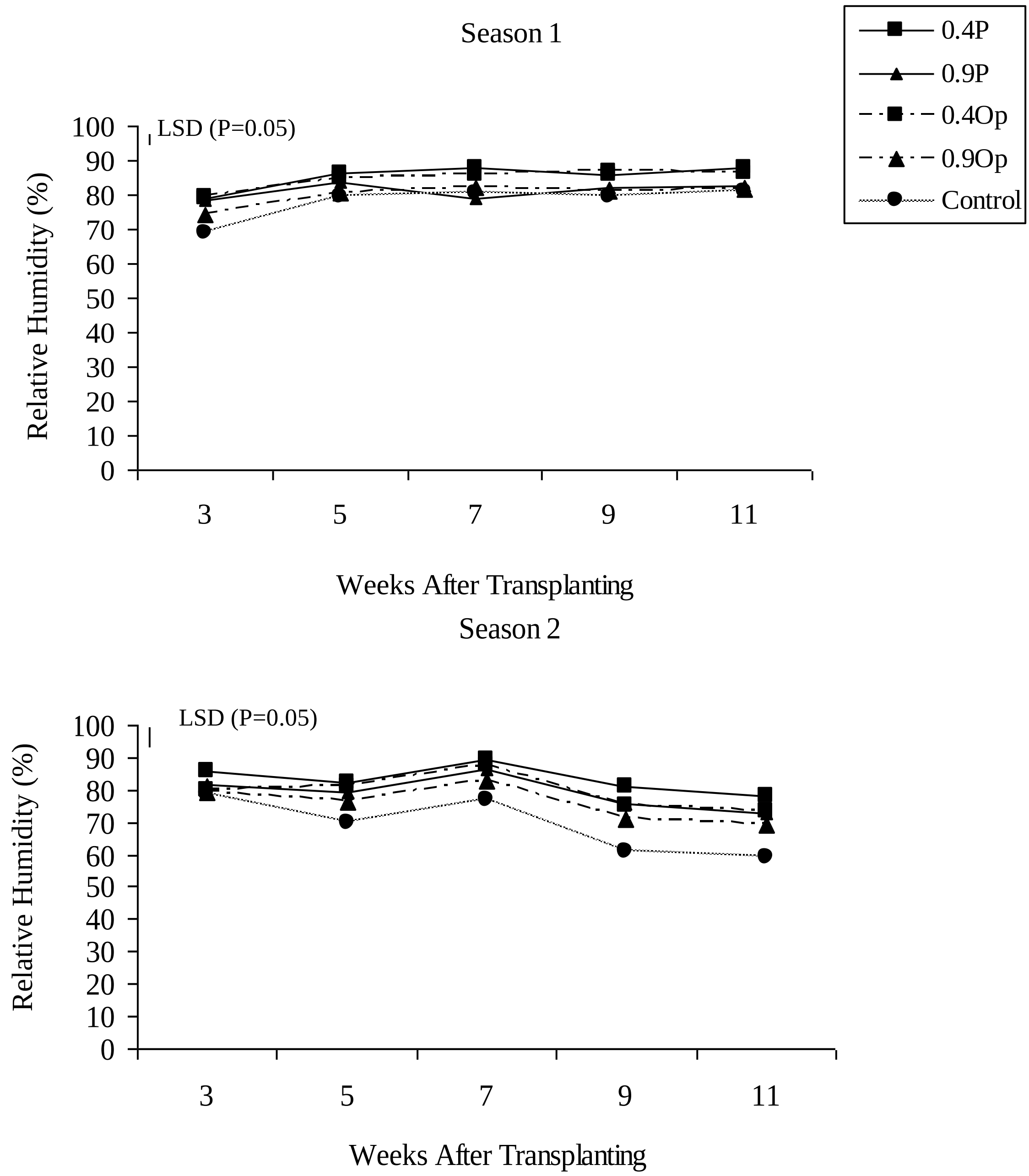


Fig. 7: Relative humidity profile as influenced by agronet cover during season 1(May-Aug, 2011) and season 2(Oct-Jan, 2012)cabbage field production experiment. Control had no agronet cover, Op is where the agronet was opened three times a week, P is where agronet was maintained permanently covered except during maintenance and data collection periods while 0.4 and 0.9 were the different agronet mesh sizes (mm) used.

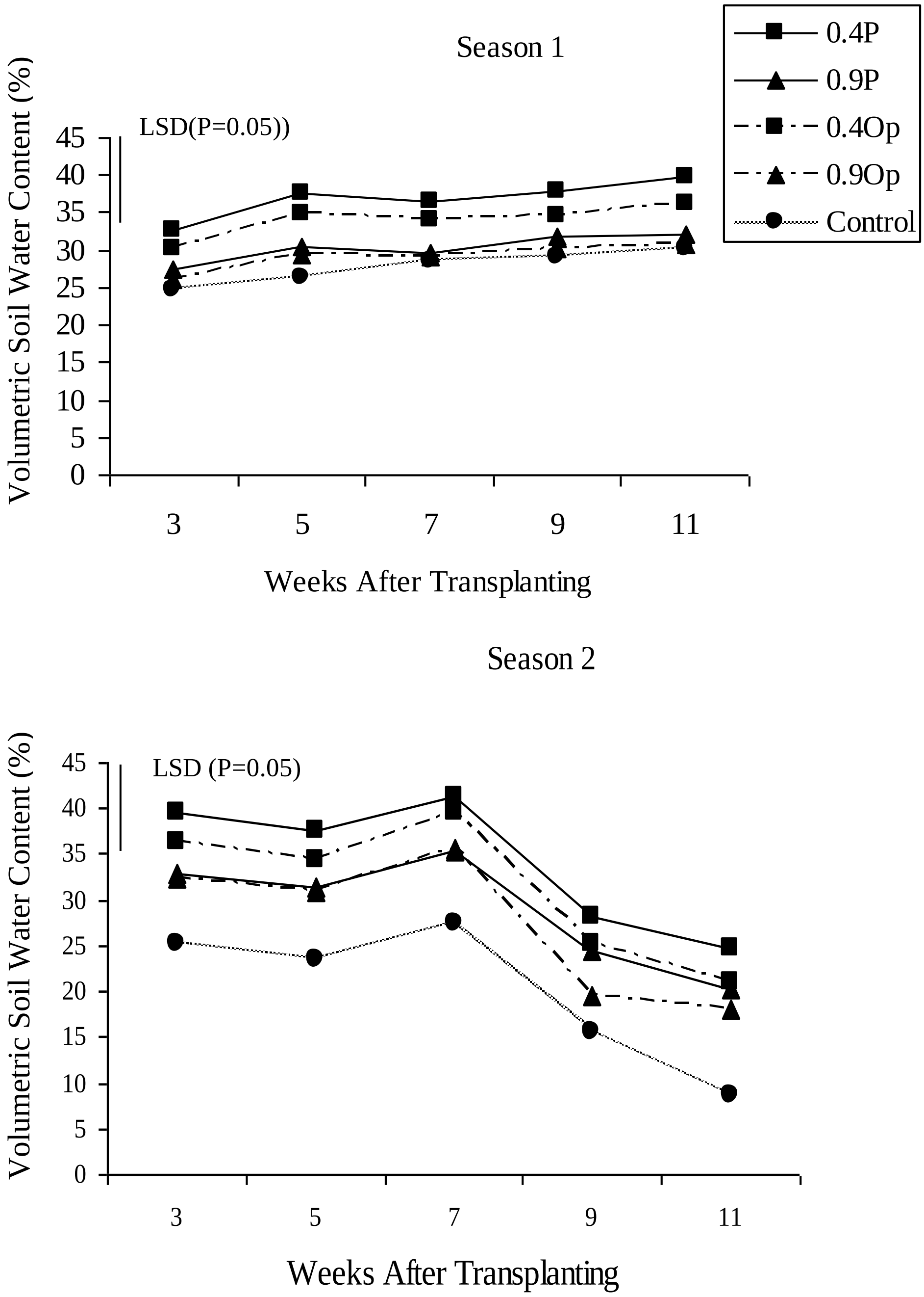


Fig. 8: Volumetric soil water content profile as influenced by agronet cover during season 1(May-Aug, 2011) and season 2(Oct-Jan, 2012)cabbage field production. Control had no agronet cover, Op is where the agronet was opened three times a week, P is where agronet was maintained permanently covered except during maintenance and data collection periods while 0.4 and 0.9 were the different agronet mesh sizes (mm) used.

4.2.1.4 Diurnal Temperature Range

The use of agronet influenced the diurnal temperature range within the vicinity of the crop. In both seasons, diurnal temperature range was widest under the uncovered controls and narrowest under the 0.4mm agronet maintained permanently covered in all sampling dates (Fig.9). Generally, mean diurnal temperature ranges were narrower in season one than in season two. In season one, the 0.4mm mesh agronet maintained permanently covered registered a seasonal mean diurnal temperature range of 3.0^{o}C and 4.1^{o}C when it was opened thrice a week. Mean diurnal temperature ranges were 5.1^{o}C and 5.3^{o}C under the 0.9mm mesh agronet used permanently or opened thrice a week, respectively and 5.8^{o}C under the control treatment. In season two, the 0.4mm netting used permanently resulted in a seasonal mean diurnal temperature of 3.2^{o}C and 4.6^{o}C when managed by opening thrice weekly. The diurnal temperature range was 5.5^{o}C and 5.8^{o}C under the 0.9mm used permanently and when opened thrice a week, respectively against a mean range of 6.4^{o}C under the control in this season. Within each mesh size, the diurnal temperature range tended to be narrower when the cover was maintained permanently covered compared to when it was opened thrice a week

4.2.1.5 Photosynthetic Active Radiation

The use of agronet covers also influenced the Photosynthetic active radiation (PAR) received by the cabbage crop. As expected, covered plots consistently received lower PAR than uncovered treatments. Amongst the agronet-covered treatments, PAR was consistently lower under the 0.4mm netting treatments compared to that under the 0.9mm netting treatments throughout the study (Fig.10). In season one the seasonal mean PAR under the 0.4mm net used permanently and opened thrice a week was 412.0nm and 444.1nm, respectively, while the 0.9mm used permanently registered a PAR of 523.2nm against 587.9nm when opened thrice a week. In season two, permanent use of 0.4mm netting resulted in a seasonal mean PAR of 443.1nm under the net and 476.4nm when opened thrice a week. The 0.9mm netting recorded a mean PAR of 581.1nm when maintained permanently covered and 602.9nm when opened thrice a week in this season. The highest PAR was obtained under the no net cover control in both seasons, registering a mean of 601.2nm and 609.6nm in season one and two, respectively.

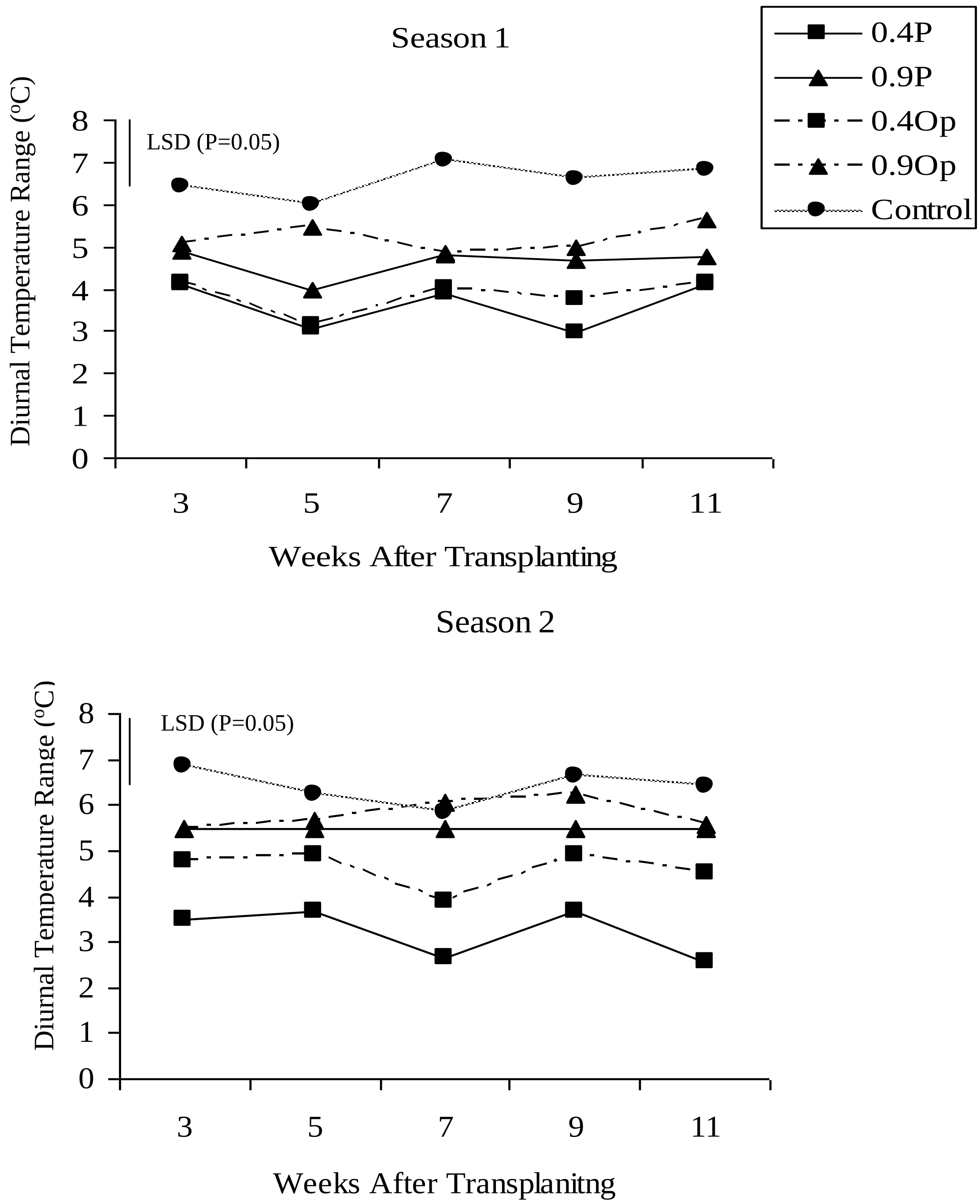


Fig. 9: Diurnal temperature range profile as influenced by agronet cover during season 1 (May-Aug, 2011) and season 2 (Oct-Jan , 2011) cabbage field production. Control had no agronet cover, Op is where the agronet was opened three times a week, P is where agronet was maintained permanently covered except during maintenance and data collection periods while 0.4 and 0.9 were the different agronet mesh sizes (mm) used.

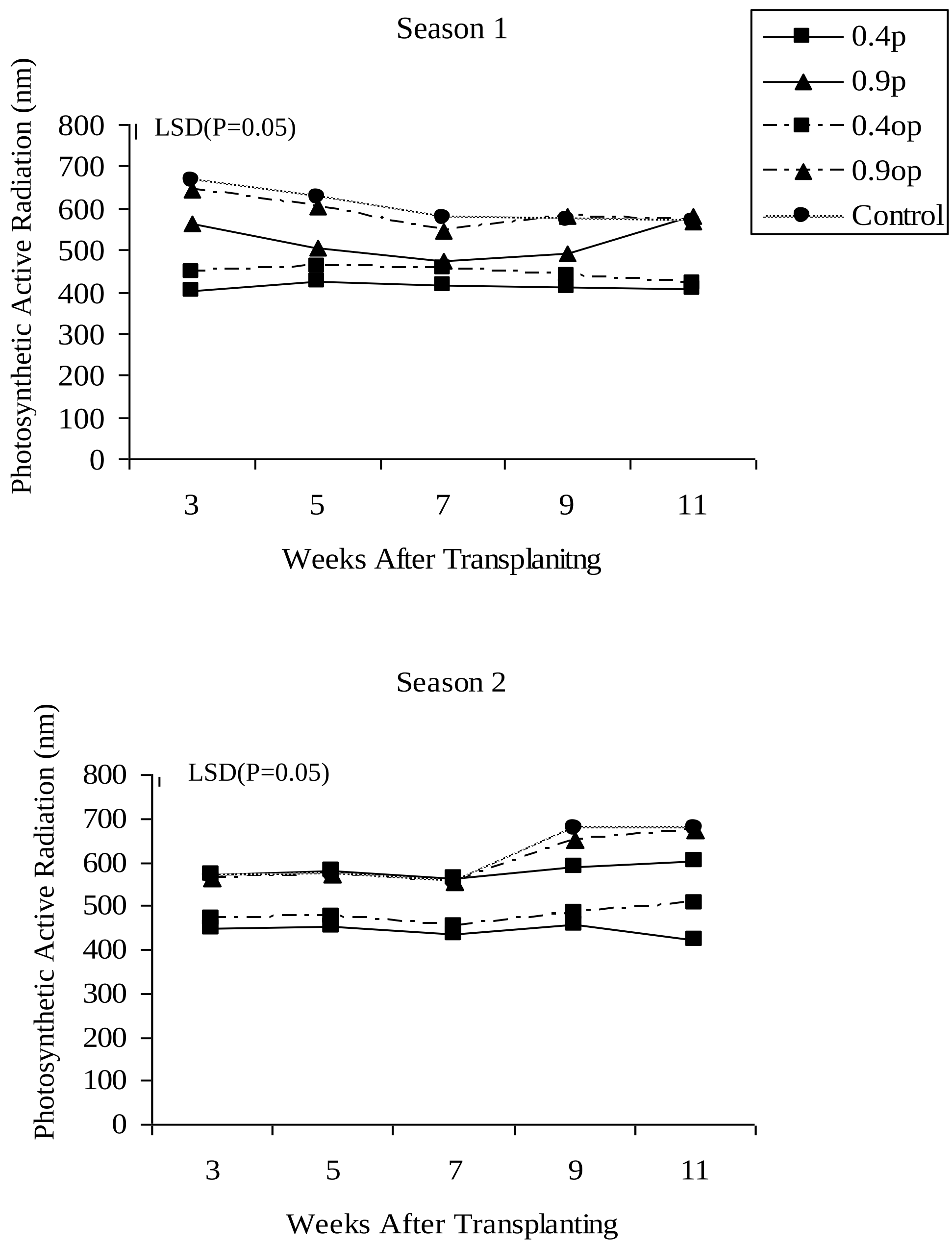


Fig. 10: Photosynthetic active radiation profile as influenced by agronet cover during season 1(May-Aug, 2011) and season 2 (Oct-Jan, 2012) cabbage field experiment. Control had no agronet cover, Op is where the agronet was opened three times a week, P is where agronet was maintained permanently covered except during maintenance and data collection periods while 0.4 and 0.9 were the different agronet mesh sizes(mm) used.

4.2.2 Effects of Agronets on Cabbage Stomatal Conductance and Chlorophyll Content

Physiological aspects of cabbage plants studied were; (a) leaf stomatal conductance and (b) leaf chlorophyll content.

4.2.2.1 Leaf Stomatal Conductance

The stomatal conductance of cabbage leaves was influenced by the use of agronet covers and the age of the crop. In both seasons, leaf stomatal conductance was consistently higher in cabbage plants grown under agronets and lowest under the control at all data collection dates in both seasons (Fig. 11). At 11 weeks after transplanting, cabbage under the permanent use of 0.9mm netting registered significantly higher stomatal conductance followed by that under the 0.9mm net opened thrice a week, 0.4mm net used permanently, 0.4mm net opened thrice a week and chemical sprayed, with the lowest stomatal conductance recorded in the control cabbage in all sampling dates. Generally, stomatal conductance was significantly lower in season two than season one.

Within each mesh size, maintaining the cover permanently covered resulted in a higher leaf stomatal conductance than when the cover was opened thrice a week (Table 5). The use of the larger mesh net of 0.9mm also resulted in higher leaf stomatal conductance compared to the finer 0.4mm mesh netting whether maintained permanently covered or opened thrice a week.

4.2.2.2 Leaf Chlorophyll Content

Estimates of cabbage leaf chlorophyll content displayed a similar trend to that of leaf stomatal conductance. With successive increase in the age of the crop, plants grown under 0.9mm nets presented significantly ($p=0.05$) higher chlorophyll content values than those under 0.4mm net and the uncovered control plants in both seasons (Fig. 12). However, when the crop approached maturity, chlorophyll content reduced significantly. In season one and two, the average chlorophyll content of 0.9mm net covered crops was 74.4 CCI, 70.2 CCI and 72.6 CCI, 69.3 CCI when permanently used and when opened thrice a week, respectively .On the other hand, leaves of cabbage plants grown under the 0.4mm net used permanently and opened thrice a week had chlorophyll contents of 55.6 CCI and 63.6 CCI, respectively in season one and 57.2 and 65.2 CCI in season two. The uncovered treatments registered significantly lower mean chlorophyll contents of 43.4 CCI for the control plants and 52.7 CCI for the insecticide sprayed plants in season one against 47.8 and 48.33 CCI, respectively in season two. Within the two mesh sizes, a higher chlorophyll content was recorded where the cover was used permanently than when it was opened thrice a week in all sampling dates (Table 6). The larger mesh size of 0.9mm resulted in plants with a higher leaf chlorophyll

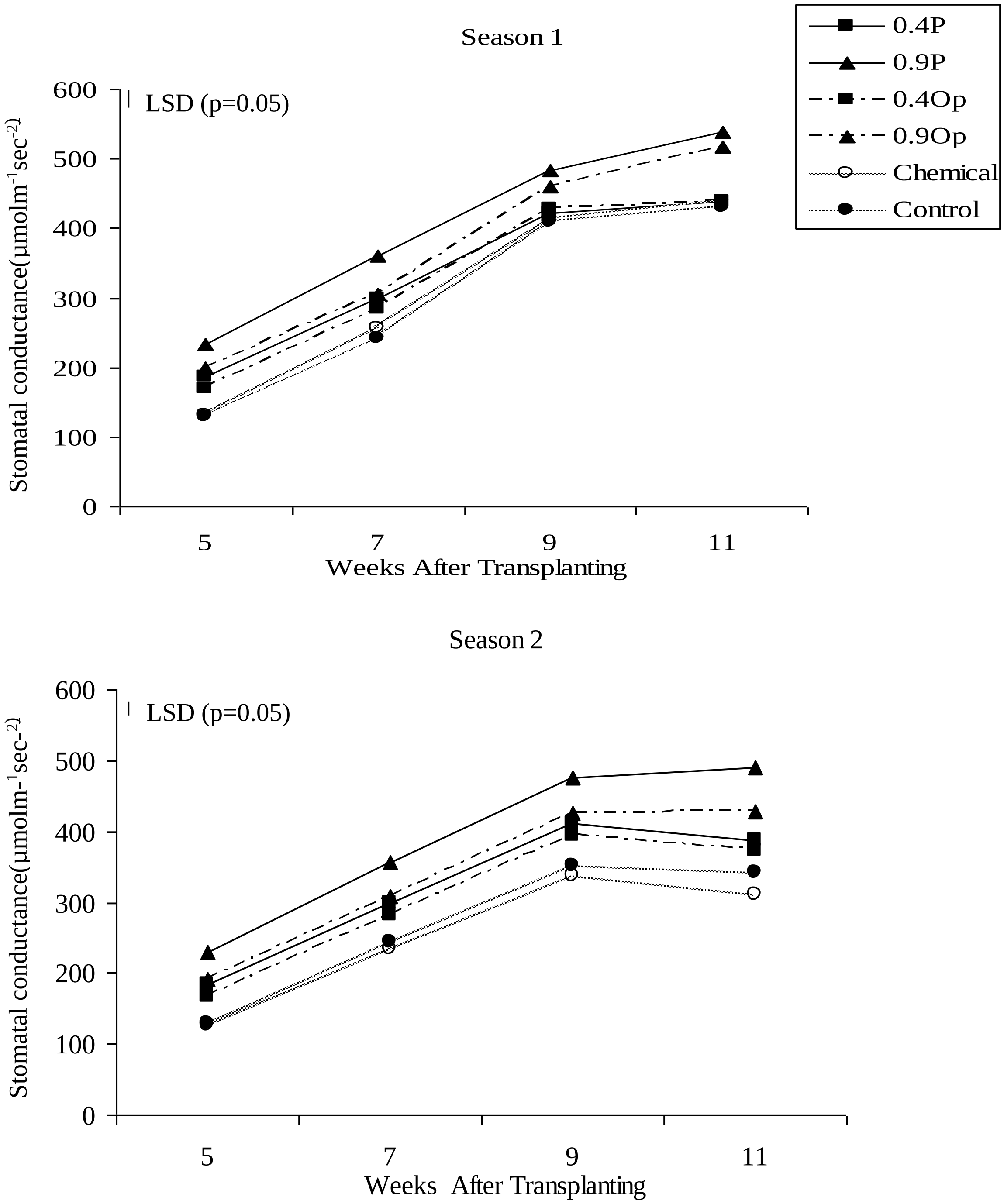


Fig. 11: Effect of agronets on leaf stomatal conductance during season 1(May-Aug, 2011) and season 2 (Oct-Jan, 2012) cabbage field production experiment. Control had no agronet cover, op agronet was opened three times a week, p is where agronet was maintained permanently covered except during maintenance and data collection periods, chemical is where no cover was used and an insecticide was sprayed, while 0.4 and 0.9mm were the different agronet mesh sizes used.

Table 5: Effects of net mesh size and management on stomatal conductance ($\mu molm^{-1}sec^{-2}$) of cabbage leaves during season 1(May-Aug, 2011) and season 2 (Oct-Jan, 2012).

	Weeks after transplanting								
	5		7		9		11		
Management*	Mesh size		Mesh size		Mesh size		Mesh size		**Management Means**
	0.4mm	0.9mm	0.4mm	0.9mm	0.4mm	0.9mm	0.4mm	0.9mm	
				Season 1					
Opened	169.5z**	200.0x	283.4v	305.6u	427.9s	459.1r	438.9rs	517.1p	**350.2l**
Permanent	185.9xz	233.1vw	299.7uv	360.8t	422.2s	483.1q	439.3rs	538.7o	**370.4k**
Mesh size Means	**177.7h**	**216.4g**	**291.8f**	**333.2e**	**425.1d**	**471.1b**	**439.1c**	**527.9a**	
				Season 2					
Opened	167.1k	190.3i	282.3r	308.1p	393.9mn	424.4m	372.8de	429.0m	**321.0k**
Permanent	184.0jk	230.5s	299.4qr	355.9o	412.1lm	475.8l	387.8d	489.1l	**354.3j**
Mesh size mean	**175.6g**	**210.4f**	**290.8e**	**332.0d**	**402.9b**	**450.1a**	**380.3c**	**459.0a**	

***** In opened management the net cover was opened thrice weekly while in permanent management the net cover was used permanently.
**Means followed by the same letter within a letter series and within a season are not significantly different according to the Tukey's HSD test ($p \leq 0.05$).

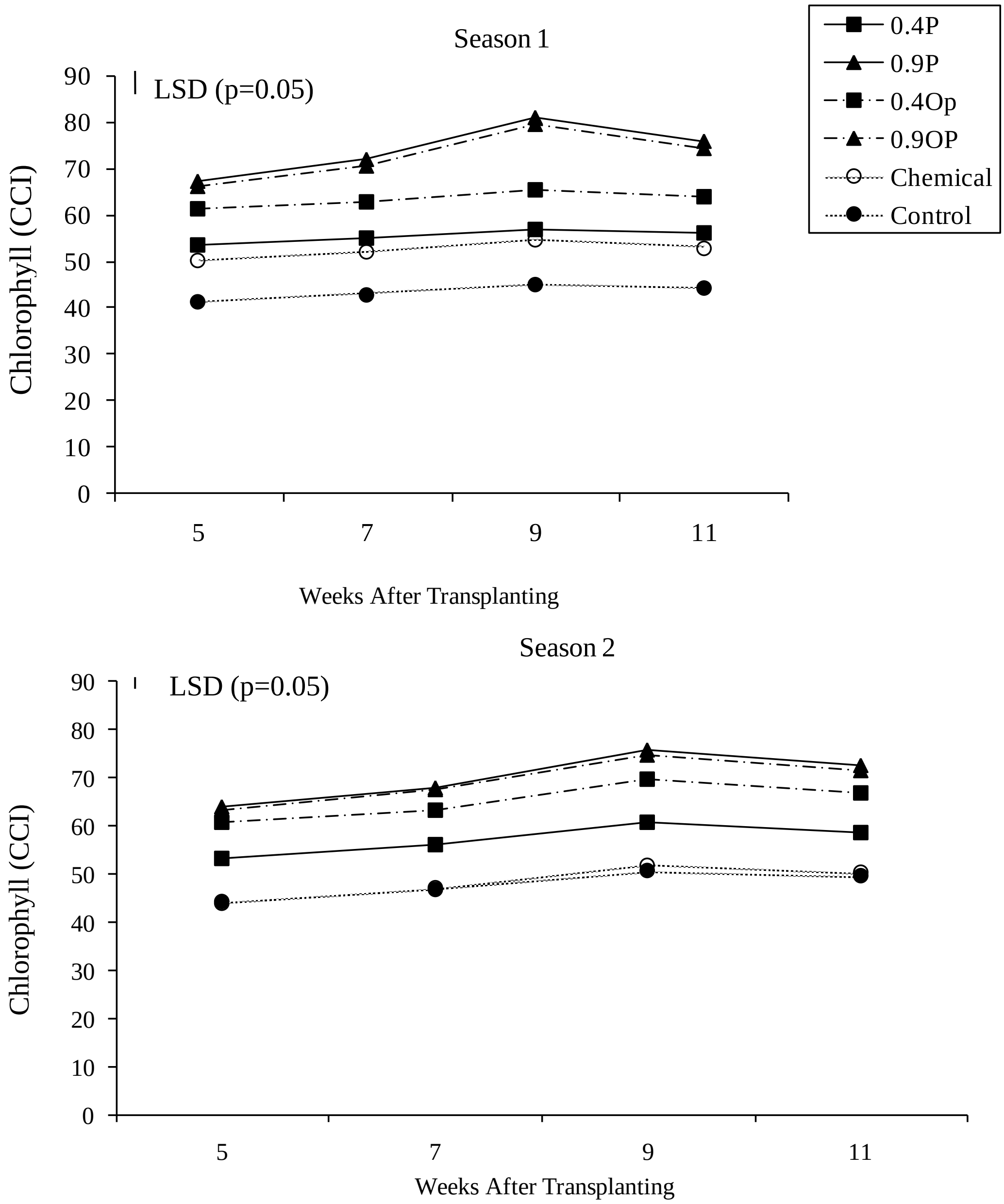


Fig. 12: Effect of agronets on leaf chlorophyll content during season 1(May-Aug, 2011) and season 2 (Oct-Jan, 2012) cabbage filed production experiment. Control had no agronet cover or chemical sprayed, chemical was sprayed with pesticides, opened is where the agronet as opened three times a week, permanent is where agronet was maintained permanently covered except during maintenance and data collection periods while 0.4 and 0.9mm were the different agronet mesh sizes used.

Table 6: Effect of net mesh size and management on Chlorophyll Content (CCI) of cabbage leaves during season 1(May-Aug, 2011) and season 2 (Oct-Jan, 2012) cabbage field experiment

	Weeks after transplanting								
	5		7		9		11		
	Mesh size		Mesh size		Mesh size		Mesh size		**Management**
Management*	0.4mm	0.9mm	0.4mm	0.9mm	0.4mm	0.9mm	0.4mm	0.9mm	**Means**
					Season 1				
Opened	61.5t**	66.1pq	63.1st	70.5o	65.6qr	79.5m	64.0rs	74.3n	**68.1i**
Permanent	53.4v	67.5p	55.2vu	72.2o	57.0i	81.2m	56.1u	76.1n	**64.8j**
Mesh size Means	**57.6f**	**66.8d**	**59.1e**	**71.3c**	**61.3e**	**80.3a**	**60.0e**	**75.2b**	
					Season 2				
Opened	60.8t	63.4s	63.4s	67.4qr	69.7pq	74.6mn	67.0r	71.6op	**67.2i**
Permanent	53.2v	64.1s	56.0u	68.1qr	60.7t	75.8m	58.7h	72.7no	**63.7j**
Mesh size Means	**57.0f**	**63.7de**	**59.7ef**	**67.7c**	**65.2d**	**75.2a**	**62.8e**	**72.2b**	

*****In opened management the net cover was opened thrice weekly while in permanent management the net cover was used permanently.
**Means followed by the same letter within a letter series and a season are not significantly different according to the Tukey's HSD test (p≤0.05).

content compared to the finer 0.4mm mesh netting whether maintained permanently covered or opened thrice a week.

4.2.3 Effects of Agronets on Cabbage Plant Growth

The variables used as indicators of growth in this study were stem height, leaf number and collar diameter.

4.2.3.1 Stem Height

The use of agronets generally resulted in taller plants than when the plants were grown in the open at every stage of the cabbage crop. Season two yielded taller plants than season one under all treatments (Table 7). Throughout the study, the tallest plants were under the 0.4mm net used permanently, at all growth stages of the plant. Cabbage stem height for this treatment was, however, not any statistically different from that of plants under the 0.4mm agronet opened thrice a week in most sampling dates. Cabbage plants were generally shorter in the uncovered plots with the shortest stems obtained under the chemical treatment in most sampling dates. Among the 0.9mm agronet covers, plants tended to be taller under permanent cover than under the covers opened thrice a week. Compared to the chemical and control treatments, plants were significantly taller under both the 0.9mm permanent and 0.9mm opened thrice a week agronet treatments in most sampling dates of the study.

The main effects of mesh size and management on cabbage stem height were also significant in all sampling dates (Table 8). Stem height increased with decrease in mesh size in both seasons. Higher stem heights were also obtained when the nets were maintained permanently covered than when they were opened thrice a week. Generally, maintaining the agronet permanently covered within a given mesh size gave a higher stem height than when the cover was opened thrice a week. Similarly, within a given net management regime, higher stem heights were obtained under the finer mesh (0.4mm) than under the larger mesh (0.9mm) in all sampling dates. In all sampling dates, the tallest stems were therefore obtained under the 0.4mm agronet used permanently while the shortest plants were in the 0.9mm agronet opened thrice a week.

4.2.3.2 Leaf Number

Growing cabbage under agronets contributed to a significant increase in leaf number when compared to open field production. With increase in age of the plants, higher leaf number was recorded for cabbage grown under all agronet treatments compared to those in the open treatments at all sampling dates (Table 9).

Table 7: Effect of agronets on stem height (cm) of cabbage during season 1(May-Aug, 2011) and season 2(Oct-Jan, 2012) cabbage field experiment

	Weeks After Transplanting					
Treatment*	5	6	7	8	9	**Treatment**
			Season 1			
Control	6.3suv**	6.8rt	7.1pq	7.9mno	8.0mno	**7.2E**
Chemical	5.4w	5.7v	6.0tu	6.3pqrs	6.4pqrs	**6.0F**
0.9mm opened	7.3qrt	7.9op	8.4mn	8.8jkl	8.9ijkl	**8.3D**
0.9mm permanent	7.7nop	8.3lm	9.2jk	10.0f'ghI	10.1dfg	**9.1C**
0.4mm opened	8.3klm	9.35hj	10.3fg	11.0cde	11.2ef	**10.0B**
0.4mm permanent	8.7ghIj	9.9ef'	11.1cd	12.2ab	12.3a	**10.8A**
Age	**7.3L**	**8.0K**	**8.7J**	**9.4I**	**9.5I**	
			Season 2			
Control	6.7y	7.7wx	8.8tuv	9.8pqs	10.6klm	**8.7E**
Chemical	6.8xy	7.8w	8.8tuv	9.9pqs	10.8jkl	**8.8E**
0.9mm opened	8.0vw	9.4stu	10.9oq	12.6hij	13.9efg	**10.9D**
0.9mm permanent	8.3u	10.1qr	12.3ijln	14.5f'g	16.1d	**12.2C**
0.4mm opened	9.4qrst	11.7nop	13.9gh	16.1b	17.9de	**13.8B**
0.4mm permanent	9.9nop	12.7ghI	15.8cdef	18.8b	21.2a	**15.7A**
Age	**8.2I**	**9.8K**	**11.7J**	**13.6I**	**15.1H**	

*Control treatment had no agronet cover or chemical sprayed, chemical had no agronet cover but was sprayed with pesticides, opened is where the agronet was opened three times a week, permanent is where agronet was maintained permanently covered except during maintenance and data collection periods while 0.4 and 0.9mm were the different agronet mesh sizes used.

**Values followed by the same letter within a letter series and a season are not significantly different according to the Tukey's HSD test ($p \leq 0.05$).

Table 8: Effects of net mesh size and management on the stem height (cm) of cabbage during season 1(May-Aug, 2011) and season 2(Oct- Jan, 2012) cabbage field experiment.

Management*	Mesh size		Mesh size		Mesh size		Mesh size		Mesh size		Management Means
	0.4mm	0.9mm	0.4mm	0.9mm	0.4mm	0.9mm	0.4mm	0.9mm	0.4mm	0.9mm	
					Season 1						
Opened	8.3tuv**	7.3w	9.4pqr	8.2tuv	10.2op	8.4stuv	11.0no	8.9rstu	11.2n	8.9rst	**9.2j**
Permanent	8.7rstu	7.7vw	9.9pq	7.9uvw	11.0no	9.2qrs	12.2m	10.0pq	12.2m	10.1pq	**9.9i**
Mesh size Means	**8.5de**	**7.5f**	**9.6c**	**8.1ef**	**10.6b**	**8.8d**	**11.6a**	**9.4t**	**11.7a**	**9.5c**	
					Season 2						
Opened	9.5uv	7.9w	11.9st	9.2uvw	14.1pqr	10.7tu	16.3o	12.5rs	18.0n	13.7qr	**12.4j**
Permanent	9.7uv	8.4vw	12.6rs	10.2tu	15.6op	12.4rs	18.6n	14.7opq	21.2m	16.3o	**14.0i**
Mesh size Means	**9.6e**	**8.2f**	**12.2d**	**9.7e**	**14.8c**	**11.6d**	**17.4b**	**13.6d**	**19.5a**	**15.0c**	

***In opened management the net cover was opened thrice weekly while in permanent management the net cover was used permanently.

**Means followed by the same letter within a letter series and within a season are not significantly different according to the Tukey's HSD test ($p \leq 0.05$).

Table 9: Effect of agronets on cabbage leaf numbers (no/plant) during season 1(May-Aug, 2011) and season 2(Oct-Jan, 2012) cabbage field experiment

	Week After Transplanting					
Treatment*	5	6	7	8	9	**Treatment**
			Season 1			
Control	5.1uv**	5.4st	6.2qr	7.4lmno	8.2ghI	**6.4D**
Chemical	5.0v	5.3tu	5.9rs	7.0mno	7.6ghij	**6.2D**
0.9mm opened	6.6pqr	7.3lmno	8.2ghi	9.2ef	9.9bcd	**8.2C**
0.9mm permanent	6.8opq	7.5klmn	8.7g	9.4de	10.2bc	**8.5BC**
0.4mm opened	6.7nop	7.7hijkl	8.6f'g	9.7cde	10.6ab	**8.7B**
0.4mm permanent	7.3ab	8.0b	8.9ef	10.0bc	11.1a	**9.1A**
Age	**6.2K**	**6.9J**	**7.7I**	**8.8H**	**9.6G**	
			Season 2			
Control	5.1rs	5.7cqr	6.3nop	6.9klm	7.7hij	**6.3D**
Chemical	5.2rs	5.9pq	6.6mno	7.2jkl	8.1ghi	**6.6D**
0.9mm opened	6.5lmn	7.2ijk	8.0d	9.2gh	10.1def'	**8.2C**
0.9mm permanent	6.9klm	7.9hij	9.6fgh	10.6de	11.5bc	**9.3B**
0.4mm opened	6.7klm	8.1hij	9.7efg	11.2cd	12.2b	**9.6B**
0.4mm permanent	7.4ijk	9.1efg	10.9cd	12.4b	13.6a	**10.7A**
Age	**6.3K**	**7.3J**	**8.5I**	**9.6H**	**10.6G**	

*Control treatment had no agronet cover or chemical sprayed, chemical had no agronet cover but was sprayed with pesticides, opened is where the agronet was opened three times a week, permanent is where agronet was maintained permanently covered except during maintenance and data collection periods while 0.4 and 0.9mm were the different agronet mesh sizes used.

**Values followed by the same letter within a letter series and within a season are not significantly different according to the Tukey's HSD test ($p \leq 0.05$).

Among the agronet treatments, plants under the 0.4mm agronet maintained permanently covered tended to have more leaves than those under the other agronet treatments. However, the difference of the number of leaves for this treatment and that of the 0.4mm agronet opened thrice a week and 0.9mm agronet maintained permanently covered was not significant in most sampling dates. Although the 0.9mm agronet opened thrice a week yielded the least number of leaves among the agronet treatments, the treatment was still superior to the control and chemical treatments in terms of the number of leaves produced by the plants throughout the study. Overall, plants in season 2 produced more leaves than those in season 1.

The main effects of mesh size and management on cabbage leaf numbers were also significant in all sampling dates (Table. 10). Cabbage plants tended to yield higher leaf numbers when grown under the finer mesh of 0.4mm than when grown under the larger mesh size of 0.9mm in most sampling dates. Higher leaf numbers were also obtained when the nets were maintained permanently covered than when they were opened thrice a week. Generally, maintaining the agronet permanently covered within a given mesh size gave more leaf numbers than opening the net thrice a week. Similarly, within a given net mesh size, more leaves per plant were obtained under the finer mesh (0.4mm) than under the larger mesh (0.9mm) in all sampling dates. In all sampling dates, the highest number of leaves was therefore obtained under the 0.4mm agronet used permanently with the least number of leaves being recorded in plants under the 0.9mm agronet opened thrice a week.

4.2.3.4 Effects of Agronets on Cabbage Plant Collar Diameter

The use of agronet covers in cabbage production enhanced cabbage collar diameter compared to open field production (Table 11). Between the two seasons, cabbage plants in season one generally had thicker stems than those of season two for all treatments. Throughout the study, cabbage plants under the 0.9mm agronet maintained permanently covered had the thickest stems although not statistically different from those of plants under the 0.9mm agronet opened thrice a week in most sampling dates. Cabbage plants were generally thinner in the 0.4mm plots being thinnest in the 0.4mm permanent treatment in most sampling dates. Among the uncovered plants, chemical sprays resulted in thicker stems than when no form of insecticide control was applied. The main effects of mesh size and management on cabbage collar diameter were also significant in all sampling dates (Table. 12). Thicker cabbage stems were obtained under the larger mesh of 0.9mm than under the finer agronet (0.4mm) in all sampling dates. Cabbage stems were also thicker where the nets

Table 10: Effects of net mesh size and management on cabbage leaf numbers (no/plant) during season 1(May-Aug, 2011) and season 2(Oct-Jan,2012) cabbage field experiment.

	Weeks after transplanting										
	5		6		7		8		9		
	Mesh size		Mesh size		Mesh size		Mesh size		Mesh size		**Management**
Management	0.4mm	0.9mm	0.4mm	0.9mm	0.4mm	0.9mm	0.4mm	0.9mm	0.4mm	0.9mm	**Means**
					Season 1						
Opened	6.7xy**	6.6y	7.7vw	7.2wxy	8.6stu	8.1tuv	9.7pq	9.2qrs	10.6no	10.0op	**8.4k**
Permanent	7.3wxy	6.8xy	7.9uvw	7.5vwx	8.9rst	8.7rst	10.0op	9.4pqr	11.1n	10.1op	**8.8j**
Mesh size Means	**7.0fg**	**6.7g**	**7.8e**	**7.3ef**	**8.4d**	**8.7d**	**9.9c**	**9.3d**	**10.8a**	**10.0b**	
					Season 2						
Opened	6.7xy	6.5y	8.1v	7.2vwx	99.7stu	8.0v	11.2q	9.2tu	12.4op	10.1rst	**9.0k**
Permanent	7.4vwx	7.0wxy	9.0u	7.9vw	10.9qr	9.5tu	12.4o	10.6qrs	13.6n	11.5pq	**10.0j**
Mesh size Means	**7.1fg**	**6.7g**	**8.5e**	**7.5f**	**10.3cd**	**8.8e**	**11.8b**	**9.9d**	**13.0a**	**10.8c**	

***In opened management the net cover was opened thrice weekly while in permanent management the net cover was used permanently.
**Means followed by the same letter within a letter series and within a season are not significantly different according to the Tukey's HSD test (p≤0.05).

Table 11: Effect of agronets on cabbage plant collar diameter (mm)during seaon 1(May-Aug, 2011) and season 2(Oct- Jan, 2012) cabbage field experiment.

	Weeks after transplanting					
Treatment*	5	6	7	8	9	**Treatment**
			Season 1			
Control	6.9t**	7.9pqr	8.4nop	8.9klm	10.4efgh	**8.5C**
Chemical	7.0rst	8.5nop	9.2lmno	9.9ijk	11.7defg	**9.3C**
0.9mm opened	9.8hij	11.4def	13.3cd	15.0b	18.7a	**13.6A**
0.9mm permanent	9.7hij	11.4de	13.2cd	15.4b	19.3a	**13.8A**
0.4mm opened	8.3opqr	9.0klm	9.9jkl	10.8ghi	12.9cd	**10.2B**
0.4mm permanent	6.1u	6.6t	7.2st	7.7nop	8.7ghi	**7.3D**
Age	**8.0K**	**9.1J**	**10.2I**	**11.3hH**	**13.6G**	
			Season 2			
Control	6.7wx	7.4stu	8.2pqr	8.7lmn	9.1ik	**8.0D**
Chemical	6.7wx	7.3st	8.2pqr	8.8klm	9.3hij	**8.1D**
0.9mm opened	9.4hi	10.5fg	12.3e	13.5d	14.5bc	**12.0B**
0.9mm permanent	9.8gh	11.1ef	13.4cd	14.9b	16.1a	**13.1A**
0.4mm opened	7.8rst	8.5nop	9.7ijkl	10.6fg	11.3ef’	**9.6C**
0.4mm permanent	5.7y	6.1x	6.6uvw	7.0rs	7.4opq	**6.6E**
Age	**7.7K**	**8.5J**	**9.7I**	**10.6H**	**11.3G**	

*Control treatment had no agronet cover or chemical sprayed, chemical had no agronet cover but was sprayed with pesticides, opened is where the agronet was opened three times a week, permanent is where agronet was maintained permanently covered except during maintenance and data collection periods while 0.4 and 0.9mm were the different agronet mesh sizes used.

**Values followed by the same letter within a letter series and within a season are not significantly different according to the Tukey’s HSD test ($p \leq 0.05$).

Table 12: Effects of net mesh size and management on cabbage plant collar diameter (mm) during season 1(May-Aug, 2011) and season 2(Oct-Jan, 2012) cabbage field experiment.

	Weeks after transplanting										
	5		6		7		8		9		
	Mesh size		Mesh size		Mesh size		Mesh size		Mesh size		**Management Means**
Management*	0.4mm	0.9mm	0.4mm	0.9mm	0.4mm	0.9mm	0.4mm	0.9mm	0.4mm	09mm	
					Season 1						
Opened	8.3uvw**	9.8st	9.0tuv	11.3r	9.9st	13.2q	10.7rs	14.9p	12.9q	18.7o	**11.9k**
Permanent	6.1yz	9.7st	6.6xy	11.3r	7.2wx	13.2q	7.6vwx	15.4p	8.7tuv	19.3o	**10.5l**
Mesh size Means	**7.2h**	**9.7e**	**7.8gh**	**11.3d**	**8.6fg**	**13.2c**	**9.2ef**	**15.2b**	**10.8d**	**18.9a**	
					Season 2						
Opened	6.7u	10.3pqr	7.5stu	11.5op	8.7qrst	12.3nop	9.6qrs	9.5rst	10.3de	15.5mn	**10.8i**
Permanent	6.7u	8.8qrst	7.1tu	10.5qrs	7.66stu	13.3mno	8.0rstu	13.8mno	8.4rstu	15.1m	**10.0j**
Mesh size Means	**6.7f**	**9.6cd**	**7.3ef**	**10.8c**	**8.2def**	**12.8b**	**8.8de**	**14.1ab**	**9.4cd**	**15.3a**	

*****In opened management the net cover was opened thrice weekly while in permanent management the net cover was used permanently.

**Means followed by the same letter within a letter series and within a season are not significantly different according to the Tukey's HSD test ($p \leq 0.05$).

the nets were managed by opening them thrice a week compared to when they were maintained permanently covered. Within a given mesh size, maintaining the agronet permanently covered generally resulted in plants with thinner stems than when the nets were opened thrice a week. Similarly, within a given net management regime, thicker stems were obtained under the larger mesh (0.9mm) than under the finer mesh (0.4mm) in all sampling dates. In all sampling dates, the largest collar diameters were therefore obtained under the 0.9mm agronet opened thrice a week with the smallest collar diameter recorded in plants under the 0.4mm agronet maintained permanently covered.

4.2.4 Effects of Agronets on Cabbage Insect Pests and Disease Incidences

The main pests observed in this study were aphids, cabbage looper, diamond backmoth, mites and leafminers.

4.2.4.1 Cabbage Aphids

The use of agronet and week after transplanting influenced the aphid population on the cabbage crop. In both seasons, aphid populations were highest under the uncovered control and lowest under the 0.4mm and 0.9mm permanent agronet treatments in most sampling dates (Fig.13). Higher aphid populations were also recorded on the insecticide sprayed cabbage than on cabbage grown under the 0.4mm or 0.9mm permanent agronet treatments throughout the study. The population of aphids remained lower in the 0.4mm and 0.9mm agronet opened thrice a week treatments compared to that under the unsprayed treatment in most sampling dates. However, the aphid population for these treatments increased rapidly between week 9 and 10 after transplanting in both seasons surpassing that of the unsprayed control treatment after week 10 in both seasons.

The aphid population on cabbage plants was also influenced by the main effects of mesh size and management (Table 13). More aphids were found on cabbage plants grown under the larger mesh size of 0.9mm than under the finer mesh size of 0.4mm. Higher aphid populations were also recorded when the nets were managed by opening thrice a week than when they were maintained permanently covered. Generally, within a given mesh size, maintaining the agronets permanently covered resulted in a greater reduction on the aphid population on cabbage plants than when the covers were managed by opening them thrice a week.

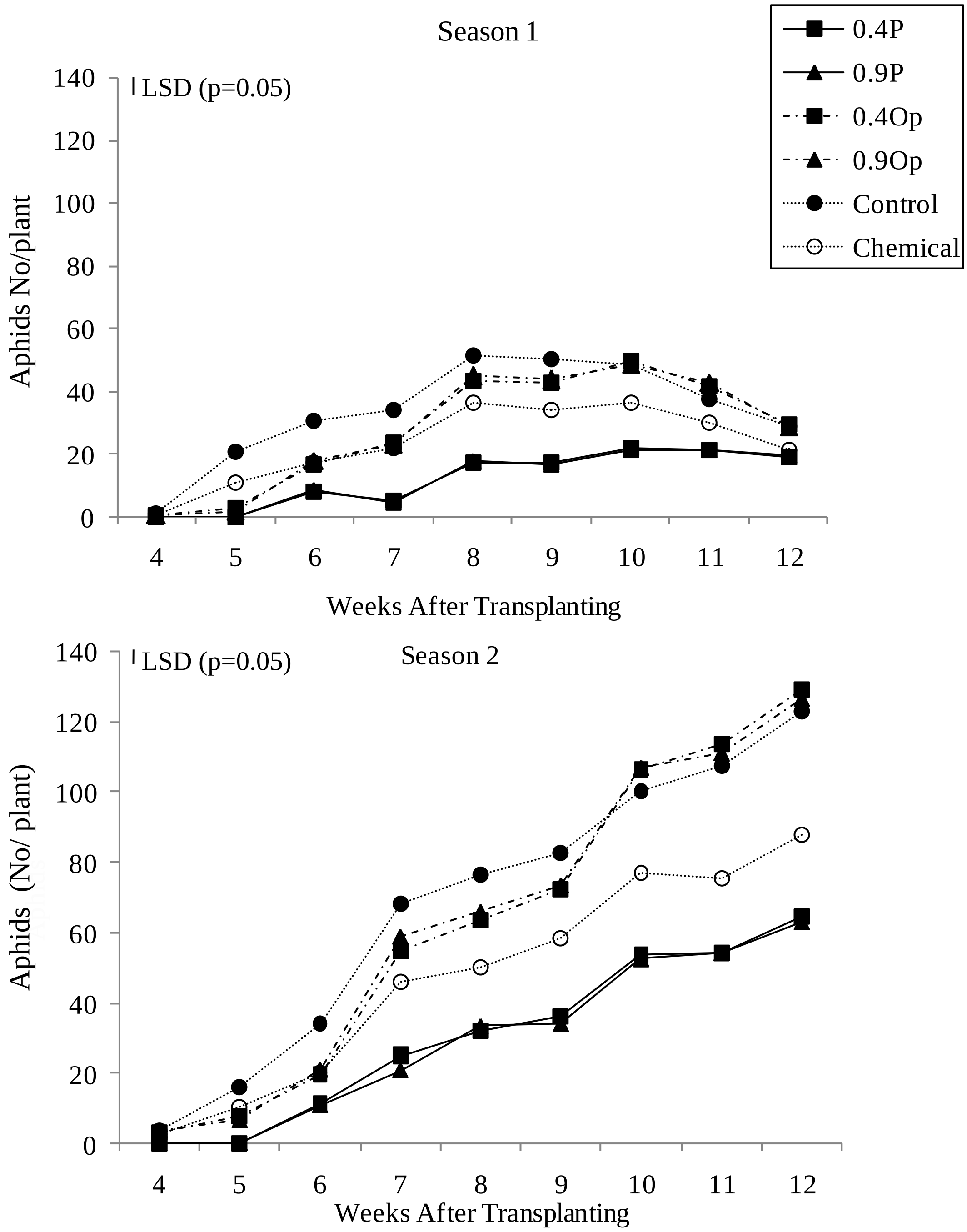


Fig. 13: Changes in aphid population on cabbage plants as influenced by agronet covers during season 1(May-Aug, 2011) and season 2(Oct-Jan, 2012) field experiment. Control had no agronet cover; chemical had no agronet cover but the crop was sprayed with insecticide; Op is where the agronet was opened three times a week; P is where agronet was maintained permanently covered except during maintenance and data collection periods while 0.4 and 0.9 were the different agronet mesh sizes(mm) used. Aphids data was subjected to square root transformation before ANOVA and mean separation.

Table 13: Effects of net mesh size and management on aphid population (no/plant) on cabbage during season 1(May- Aug, 2012) and season 2(Oct-Jan, 2012) field experiment

	Weeks after transplanting						
	4		8		12		
	Mesh size		Mesh size		Mesh size		**Management Means**
Management*	0.4mm	0.9mm	0.4mm	0.9mm	0.4mm	0.9mm	
			Season 1				
Opened	0.7op**	0.6op	43.6j	44.8ij	28.9k	29.4k	**24.7f**
Permanent	0.1p	0.03p	17.0n	17.8mn	19.0lmn	19.4lmn	**12.3g**
Mesh size Means	**0.4c**	**0.4c**	**30.3a**	**31.3a**	**24.1b**	**24.2b**	
			Season 2				
Opened	3.0o	3.9o	63.3kl	66.0kl	128.7ij	126.1i	**65.2f**
Permanent	0.4o	0.1o	33.6mn	32.2mn	63.0kl	64.0kl	**32.3g**
Mesh size Means	**1.8c**	**2.0c**	**48.4b**	**49.0b**	**95.8a**	**95.5a**	

***In opened management the net cover was opened thrice weekly while in permanent management the net cover was used permanently.

**Means followed by the same letter within a letter series and within a season are not significantly different according to the Tukey's HSD test ($p \leq 0.05$). Aphids' data was subjected to square root transformation before ANOVA and mean separation but means presented are original values.

Similarly, within a given net management regime, aphid populations were maintained low with the use of finer mesh (0.4mm) agronet than when the larger mesh (0.9mm) agronet was used. In all sampling dates, the least aphid numbers on cabbage plants were therefore obtained under the 0.4mm agronet used permanently while the most aphid numbers were recorded in the 0.9mm agronet opened thrice a week.

4.2.4.2 Cabbage Looper

Cabbage looper infested the cabbage crop at different stages of the crop growth. The first infestation was noted at 7 WAT and 4 WAT in season one and two, respectively and persisted till harvest. However, regardless of the time of infestation, protecting the cabbage crop with agronets significantly influenced the cabbage looper (*Tricopulsia ni*) population. (Fig.14). Throughout the study, cabbage looper populations were significantly reduced when cabbage plants were permanently covered with either the 0.4mm or the 0.9mm agronet ; with lower populations recorded under the 0.4mm than 0.9mm agronet in both seasons. On the other hand, cabbage looper populations tended to be highest in the 0.4mm agronets opened thrice a week in most sampling dates of both seasons. More cabbage loopers were also recorded on the insecticide sprayed cabbage than on cabbage grown under the 0.4mm or 0.9mm agronet maintained permanently throughout the study. In all sampling dates, cabbage looper population for this treatments were, however, lower than those on unsprayed cabbage. In both seasons, cabbage looper populations increased in the second week after infestation but declined at crop maturity.

The main effect of mesh size and net management on cabbage looper population was also found to be significant. More cabbage loopers were recorded when the agronets were opened thrice a week compared to when the nets were maintained permanently covered in both seasons. Cabbage looper population was also higher under the 0.4mm agronet covers than under the 0.9mm covers although the differences in the two treatments were significant in all sampling dates of season two only. Generally, within a given mesh size, cabbage lopper populations were lowered by maintaining the agronets permanently covered than when the covers were managed by opening thrice a week. Similarly, within a given net management regime, lower looper populations were recorded with the use of larger mesh (0.9mm) agronet than when the finer mesh (0.4mm) agronet was used. In all sampling dates, the least cabbage looper numbers on cabbage plants were therefore obtained under the 0.9mm agronet used permanently while the most looper numbers were recorded in the 0.4mm agronet opened thrice a week (Table 14).

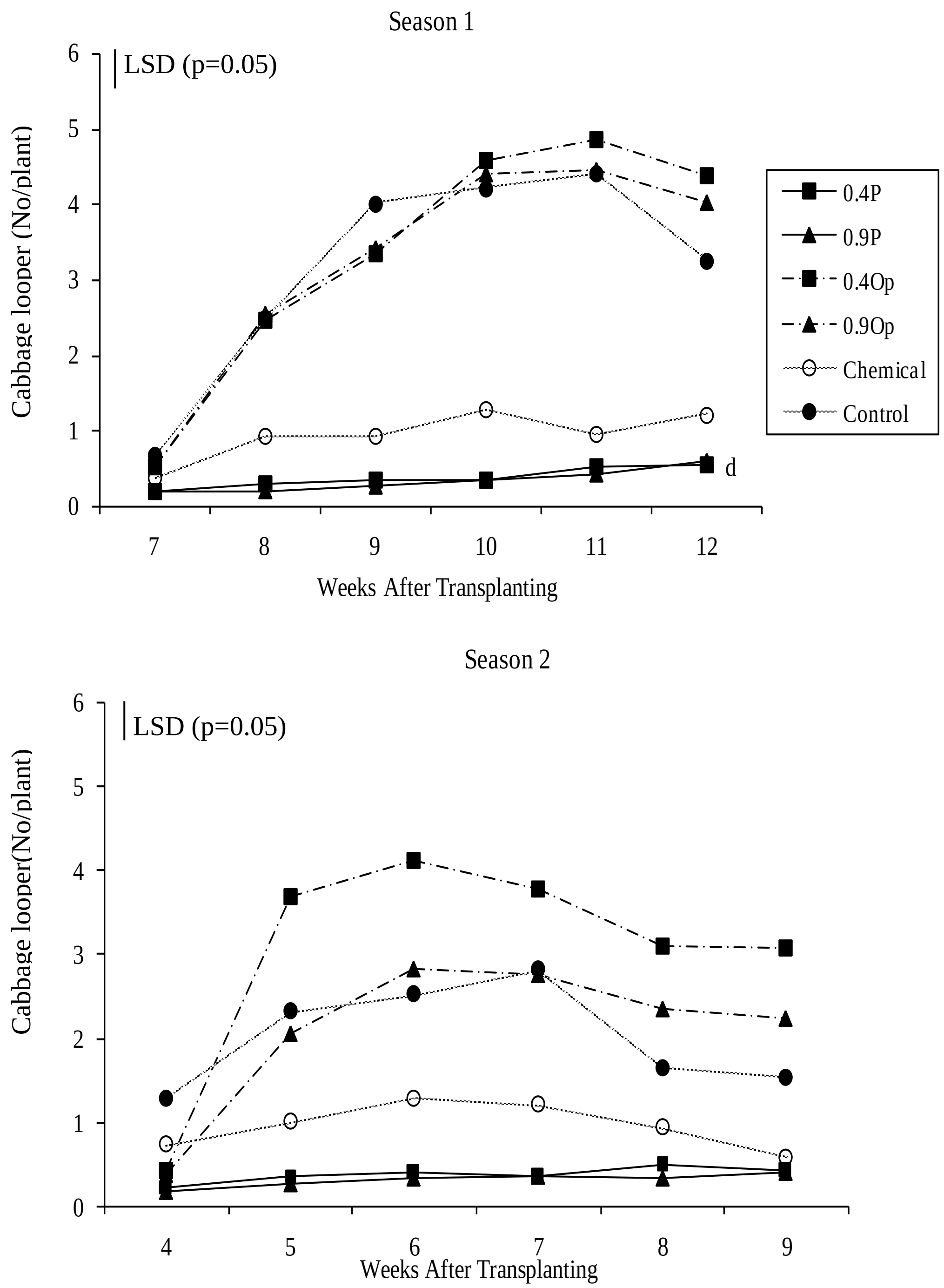


Fig. 14: Changes in cabbage lopper population on cabbage plants as influenced by agronet during the season 1(May-Aug, 2011) and season 2 (Oct-Jan, 2012) field experiment. Control had no agronet cover; chemical had no agronet cover but the crop was sprayed with insecticide; Op is where the agronet was opened three times a week; P is where agronet was maintained permanently covered except during maintenance and data collection periods while 0.4 and 0.9 were the different agronet mesh sizes(mm) used. Cabbage looper data was subjected to square root transformation before ANOVA and mean separation.

Table 14: Effects of net mesh size and management on cabbage looper population (no/plant) during season 1(May-Aug, 2011) and season 2(Oct-Jan, 2012) field experiment.

	Week after transplanting												
	7 ***		8		9		10		11		12		
	Mesh size		Mesh size		Mesh size		Mesh size		Mesh size		Mesh size		
Management*	0.4mm	0.9mm	0.4mm	0.9mm	0.4mm	0.9mm	0.4mm	0.9mm	0.4mm	0.9mm	0.4mm	0.9mm	**Management Means**
							Season 1						
Opened	0.5r**	0.5r	2.4r	2.6pq	3.3op	3.4no	4.6lm	4.3lm	4.8l	4.5lm	4.4lm	4.1mn	**3.2h**
Permanent	0.2r	0.2r	0.3r	0.2r	0.4r	0.2r	0.4r	0.3r	0.5r	0.4r	0.6r	0.6r	**0.4i**
Mesh size Means	**0.4e**	**0.4e**	**1.4d**	**1.4d**	**1.8bc**	**1.8bc**	**2.5a**	**2.4a**	**2.7a**	**2.4a**	**2.5a**	**2.3ab**	
							Season 2						
	Week after transplanting												
	4		5		6		7		8		9		
Opened	0.4s	0.4s	3.7no	2.0r	4.1n	2.8pq	3.8no	2.4pqr	3.1op	2.4pqr	3.1op	2.2qr	**2.5j**
Permanent	0.2s	0.2s	0.4s	0.3s	0.4s	0.3s	0.4s	0.3s	0.5s	0.3s	0.4s	0.4s	**0.3k**
Mesh size Means	**0.3g**	**0.3g**	**2.0ab**	**1.2f**	**2.3a**	**1.6cde**	**2.1ab**	**1.5de**	**1.8ab**	**1.3de**	**1.7bcd**	**1.3ef**	

*****In opened management the net cover was opened thrice weekly while in permanent management the net cover was used permanently.

** Means followed by the same letter within a series and within a season are not significantly different according to the Tukey's HSD test ($p \leq 0.05$)

***Week at which cabbage looper infested the cabbage crop during the field experiment. Cabbage looper data was subjected to square root transformation before ANOVA and mean separation but means presented are original values.

4.2.4.3 Diamond Backmoth

The use of agronet covers over cabbage crops lowered the population of diamond backmoth (*Plutella xylostella*) on the crop (Fig. 15). Throughout the study, diamond backmoth population on cabbage plants was significantly reduced when cabbage plants were permanently covered with either the 0.4mm or the 0.9mm agronet with lower populations recorded under the 0.4mm than 0.9mm agronet especially in season two. On the other hand, diamond backmoth populations were highest in the unprotected unsprayed treatment, 0.4mm and 0.9mm agronets opened thrice a week in most sampling dates in season one and in the unprotected unsprayed treatment in season 2. More diamond backmoth were also recorded on the insecticide sprayed cabbage than on cabbage grown under the 0.4mm or 0.9mm agronet maintained permanently throughout the study. In all sampling dates, diamond backmoth population for this treatment was however lower than that of unsprayed cabbage. In season one, while diamond backmoth numbers increased only at 9WAT and persistently declined soon after, this pest increased significantly throughout the study in season two and attaining its peak at maturity.

The main effect of mesh size and net management on diamond backmoth population was also found to be significant. More diamond backmoths were recorded when the agronets were opened thrice a week compared to when the nets were maintained permanently covered in both seasons. In season one, mesh size did not significantly influence the diamond backmoth population on the cabbage plants. However, higher diamond backmoth population was recorded under the 0.9mm agronet covers than under the 0.4mm covers in all sampling dates of season two. Generally, within a given mesh size, the diamond backmoth populations were lowered by maintaining the agronets permanently covered than when the covers were managed by opening them thrice a week. Within a given net management regime, mesh size did not have much effect on the diamond backmoth population on cabbage plants. In season two, however, lower diamond backmoth populations were recorded with the use of finer mesh (0.4mm) agronet than when the larger mesh (0.9mm) agronet was used for any given net management regime (Table. 15).

4.2.4.4 Mites

In season one, mites appeared at 6 WAT and persisted for up to four weeks when the rains began, while in season two they appeared when the dry period commenced i.e. at 9 WAT and persisted to the end of the growing season. In both seasons, the use of agronet covers reduced mite (*Tetranycus sp*) population on cabbage crops when compared to production of the crop in the unprotected field (Fig.16).

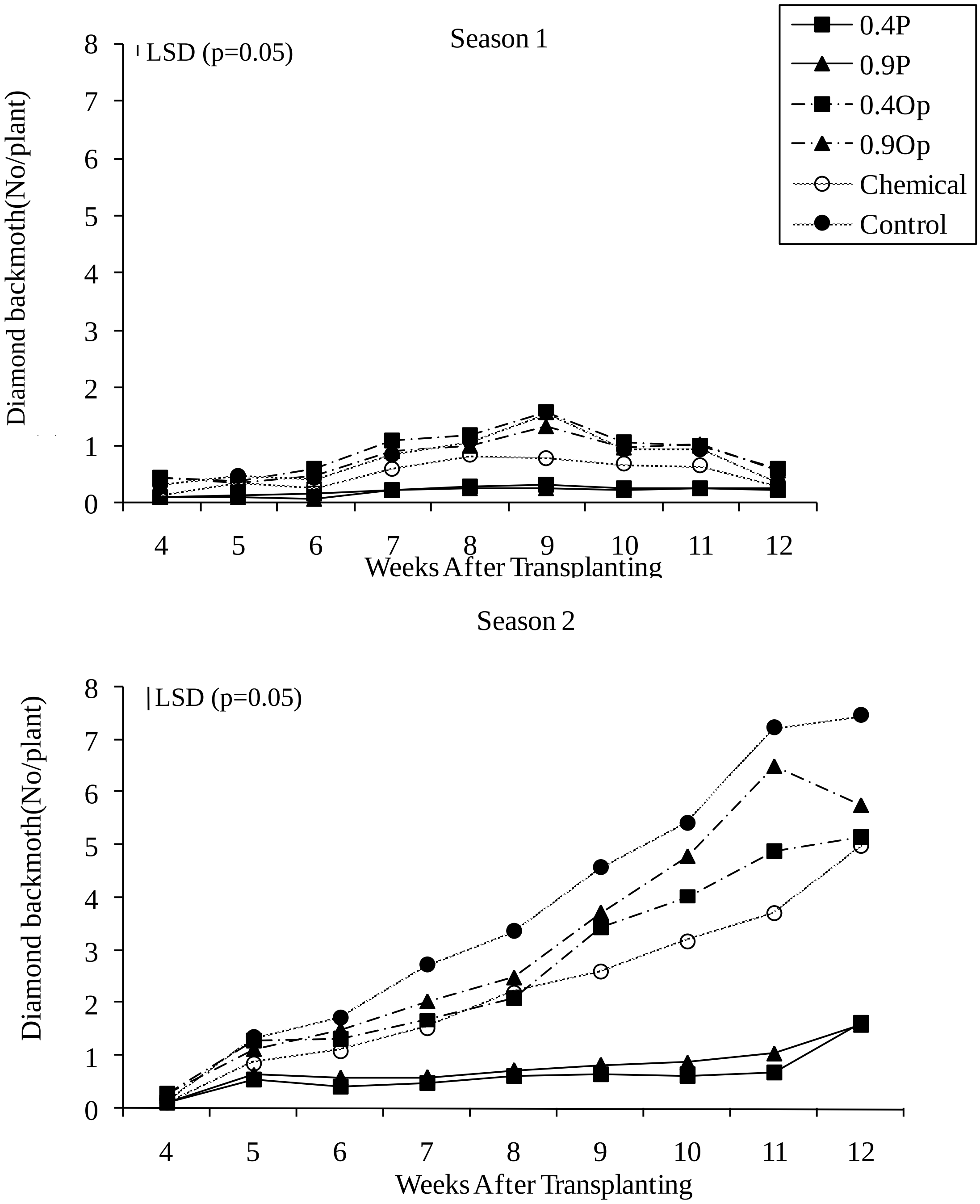


Fig. 15. Changes in diamondback moth population on cabbage plants as influenced by agronet covers during season 1(May-Aug, 2011) and season 2 (Oct-Jan, 2012) field experiment. Control had no agronet cover; chemical had no agronet cover but the crop was sprayed with insecticide; Op is where the agronet was opened three times a week; P is where agronet was maintained permanently covered except during maintenance and data collection periods while 0.4 and 0.9 were the different agronet mesh sizes(mm) used. Diamond backmoth data was subjected to square root transformation before ANOVA and mean separation

Table 15: Effects of net mesh size and management on diamond backmoth population (no/plant) on cabbage during season 1(May-Aug, 2011) and season 2(Oct-Jan, 2012) field experiment.

	Week after transplanting						
	4		8		12		
	Mesh size		Mesh size		Mesh size		**Management**
Management*	0.4mm	0.9mm	0.4mm	0.9mm	0.4mm	0.9mm	**Means**
			Season 1				
Opened	0.5pqr**	0.5pqr	1.2lmn	1.0mn	0.6op	0.6op	**0.7h**
Permanent	0.1qr	0.1qr	0.3pqr	0.3pqr	0.2pqr	0.2pqr	**0.2i**
Mesh size Means	**0.3e**	**0.3e**	**0.7ab**	**0.6bc**	**0.4cd**	**0.4cd**	
			Season 2				
Opened	0.2rs	0.2rs	2.2lm	2.4l	5.3jk	5.7j	**2.7f**
Permanent	0.1t	0.1t	0.4hi	0.8pq	1.5no	1.6n	**0.75g**
Mesh size Means	**0.2c**	**0.2c**	**1.4b**	**1.6b**	**3.4a**	**3.7a**	

*****In opened management the net cover was opened thrice weekly while in permanent management the net cover was used permanently.

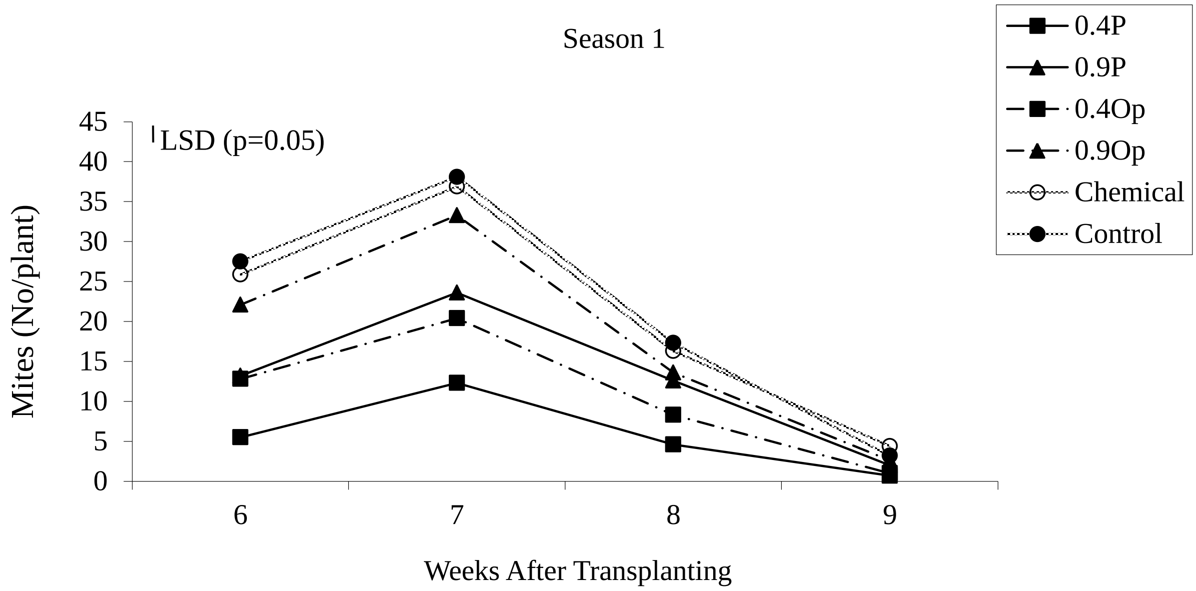
Means followed by the same letter within a letter series and within a season are not significantly different according to the Tukey's HSD test ($p \leq 0.05$). Diamond backmoth data was subjected to square root transformation before ANOVA and mean separation but means presented are original values.**

Significantly lower mite numbers were observed on cabbage plants grown under the 0.4mm agronet maintained permanently covered. The highest mite numbers were observed under the unsprayed control plots in most sampling dates. In both seasons, mite populations were similar for the insecticide spray and the control treatment. Mite populations were also generally higher on cabbage sprayed with insecticides than on plants grown under the 0.9mm net either maintained permanently covered or managed by opening thrice a week. Mite populations also remained lower under the 0.4mm agronet cover opened thrice a week than under the permanent cover of 0.9mm agronet in most sampling dates. In season one, the mite population in most treatments was highest at 7 WAT and declined till harvest. In the second season however, mite population increased significantly in all treatments, a trend that persisted to crop maturity.

Mite population on cabbage plants was also influenced by the main effects of mesh size and management (Table. 16). More mites were found on cabbage plants grown under the larger mesh size of 0.9mm than under the finer mesh size of 0.4mm. Higher mite populations were also recorded when the nets were managed by opening thrice a week than when they were maintained permanently covered. Generally, within a given mesh size, maintaining the agronets permanently covered resulted in a greater reduction on the mite population on cabbage plants than when the covers were managed by opening them thrice a week. Similarly, within a given net management regime, mite populations were maintained low with the use of finer mesh (0.4mm) agronet than when the larger mesh (0.9mm) agronet was used. In all sampling dates, the least mite numbers on cabbage plants were therefore obtained under the 0.4mm agronet used permanently while the highest mite numbers were recorded in the 0.9mm agronet opened thrice a week.

4.2.4.5 Leaf miners

Cabbage plants grown under agronet covers registered lower cabbage leaf miner (*Lyriozyma brassicae*) numbers compared to those grown in the open in both seasons (Fig. 17). At all sampling dates, the lowest leafminer populations were recorded on cabbage plants grown under the 0.4mm net or 0.9mm agronet maintained permanently covered in both seasons. The highest leaf miner numbers were recorded under the unsprayed control treatment at most sampling dates, although the leaf miner numbers for this treatment were not any different from those recorded under the 0.9mm and 0.4mm agronets opened thrice a week. Spraying cabbage plants with insecticides on the other hand resulted in lower leaf miner populations than the unsprayed control and the 0.4mm and 0.9mm agronets opened thrice a week.



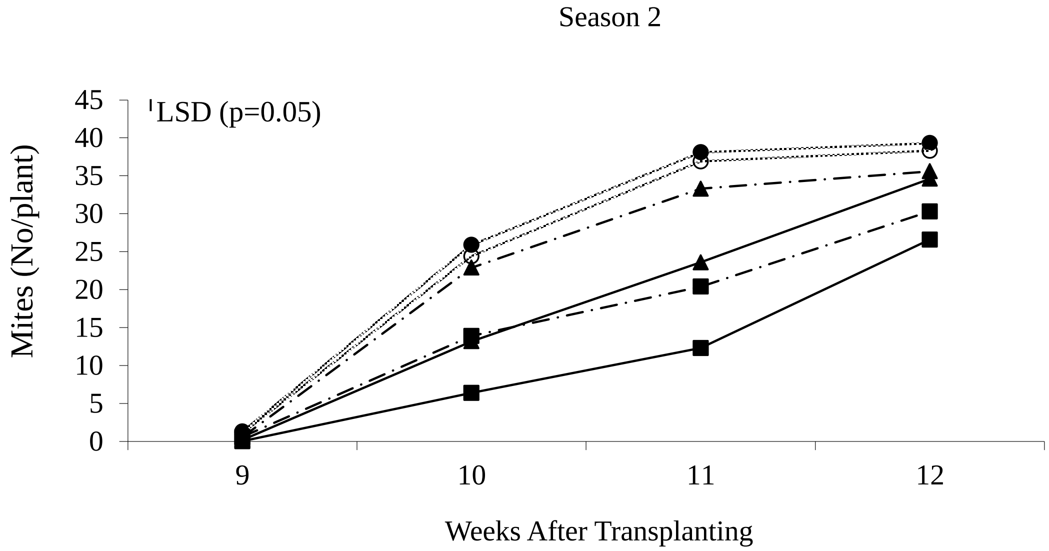


Fig. 16. Changes in mite population on cabbage plants as influenced by agronet covers during season 1(May- Aug, 2011) and season 2 (Oct-Jan, 2012) the field experiment. Control had no agronet cover; chemical had no agronet cover but the crop was sprayed with insecticide; Op is where the agronet was opened three times a week; P is where agronet was maintained permanently covered except during maintenance and data collection periods while 0.4 and 0.9 were the different agronet mesh sizes(mm) used. Data for mites was subjected to square root transformation before ANOVA and mean separation.

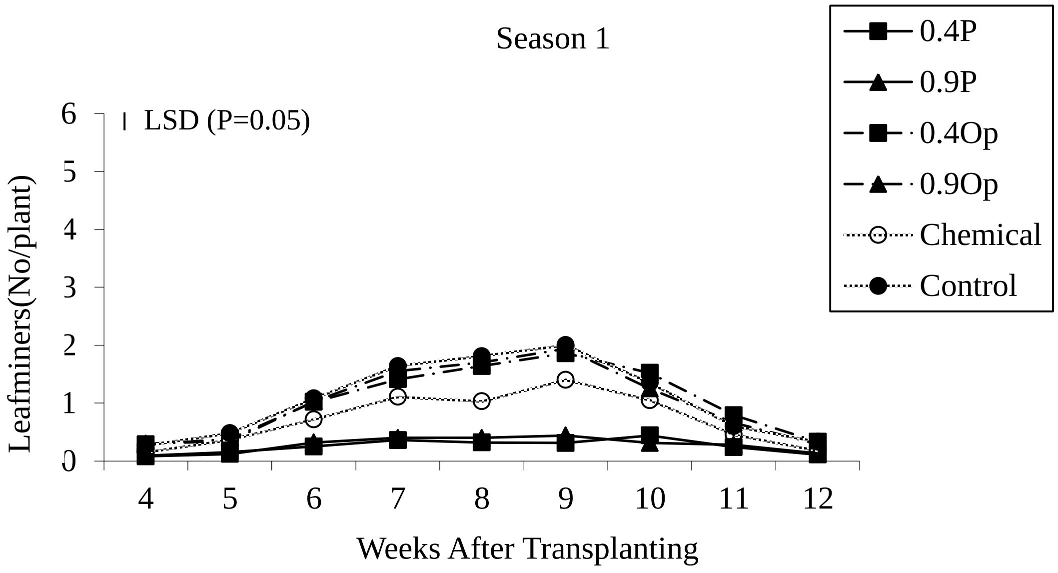
Table 16: Effects of net mesh size and management on mite populations (no/plant) on cabbage during season 1(May-Aug, 2011) and season 2 (Oct-Jan, 2012) field experiment

Management*	Mesh size 0.4mm	Mesh size 0.9mm	Mesh size 0.4mm	Mesh size 0.9mm	Mesh size 0.4mm	Mesh size 0.9mm	Mesh size 0.4mm	Mesh size 0.9mm	**Management Means**
Season 1									
	Week after transplanting								
	6		7		8		9		
Opened	12.8q	22.1op	20.4p	33.3n	8.3r	13.6q	1.0u	2.6tu	**14.3j**
Permanent	5.5s	13.3q	12.3q	23.6o	4.6st	12.6n	0.7u	2.0u	**9.3k**
Mesh size Means	**9.1e**	**17.7b**	**16.3c**	**28.4a**	**6.5f**	**13.1d**	**0.9g**	**2.3f**	
Season 2									
	Week after transplanting								
	9		10		11		12		
Opened	0.6t	0.6t	13.9r	22.9pq	20.4q	33.3mn	30.3n	35.6m	**19.7i**
Permanent	0.1t	0.2t	6.4s	13.3r	12.3r	23.6op	26.6o	34.6m	**14.6j**
Mesh size Means	**0.3f**	**0.4e**	**10.2d**	**18.1c**	**16.3c**	**28.4b**	**28.5b**	**35.1a**	

*In opened management the net cover was opened thrice weekly while in permanent management the net cover was used permanently.

**Means followed by the same letter within the same letter series and within a season are not significantly different according to the Tukey's HSD test (p≤0.05). Data for mites was subjected to square root transformation before ANOVA and mean separation but means presented are original values.

***Week at which mites infested the cabbage plants.



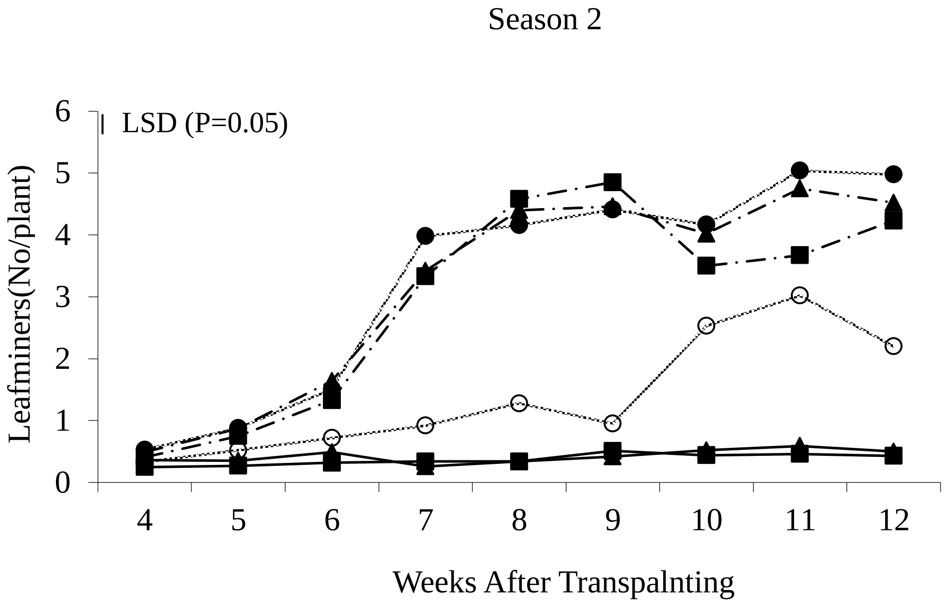


Fig. 17. Changes in leaf miner population on cabbage plants as influenced by agronet covers during season 1(May-Aug, 2011) and season 2(Oct-Jan, 2012) field experiment Control had no agronet cover; chemical had no agronet cover but the crop was sprayed with insecticide; Op is where the agronet was opened three times a week; P is where agronet was maintained permanently covered except during maintenance and data collection periods while 0.4 and 0.9 were the different agronet mesh sizes (mm) used. Leafminers data was subjected to square root transformation before ANOVA and mean separation.

Leaf miner populations were, however, higher under this treatment than under the 0.4mm or 0.9mm agronets maintained permanently covered in most sampling dates. The population of leaf miners escalated at 8 and 9 WAT in season one and from 7 WAT throughout to maturity in season two under both the control and the treatments which were managed by opening.

The main effect of mesh size and net management on leafminer population was also found to be significant. More leaf miners were recorded when the agronets were opened thrice a week compared to when the nets were maintained permanently covered in both seasons. Except for some few sampling dates in season two, mesh size did not influence leaf miner populations in most sampling dates of the study. Within a given mesh size, leaf miner populations were significantly lowered by maintaining the agronets permanently covered compared to when the covers were opened thrice a week. (Table17).

4.2.4.6 Diseases Incidences

The use of agronet covers generally had no significant effect on cabbage disease incidences in both seasons except in the last week of season one (Fig.18). Similarly, the net management regime did not significantly influence the disease incidences on cabbage. The effect of mesh size on cabbage disease incidences was, on the other hand significant only in season two of the study when the use of the finer 0.4mm mesh resulted in more diseased cabbages than with the use of the larger 0.9mm mesh whether maintained permanently covered or managed by opening it thrice a week (Table.18). Among the diseases observed was black rot of cabbage, powdery mildew and Alternaria leaf spot.

4.2.5 Effects of Agronets on Cabbage Yield Components, Yield and Quality

This section presents results on cabbage (i) yield components which included cabbage head weight and polar and equatorial diameter, (ii) yields in terms of total dry weight, total fresh weight and marketable head numbers and weight and (iii) head quality measured in terms of per cent moisture content, total soluble solids and head firmness

4.2.5.1 Yield Components

(a) Cabbage Head Diameter

The use of agronet covers in the production of cabbage significantly influenced the cabbage head polar diameter but did not affect the equatorial diameter in both seasons of the study (Table 19). Cabbage heads produced under all the agronet treatments had a longer polar diameter compared to that of uncovered cabbage. Among the four different net treatments, cabbages grown under the 0.4mm agronet cover maintained permanently covered had the highest polar diameter although the differences in polar diameter of cabbage from the different net treatments was not significant in both seasons of the study.

Table 17: Effects of net mesh size and management on leaf miner populations (no/plant) on cabbage during season 1(May-Aug, 2011) and season 2 (Oct-Jan, 2012) field experiment.

	Weeks after transplanting						
	4		8		12		
	Mesh size		Mesh size		Mesh size		**Management Means**
Management*	0.4mm	0.9mm	0.4mm	0.9mm	0.4mm	0.9mm	
			Season 1				
Opened	0.3k**	0.3k	1.6j	1.7j	0.3k	0.3k	**0.8f**
Permanent	0.1k	0.1k	0.3k	0.4k	0.1k	0.1k	**0.2g**
Mesh size Means	**0.2c**	**0.2c**	**0.9b**	**1.1a**	**0.2c**	**0.2c**	
			Season 2				
Opened	0.4p	0.5p	4.6ij	4.3kl	4.3kl	4.5jk	**3.2e**
Permanent	0.2p	0.4p	0.3p	0.4p	0.4p	0.5op	**0.4f**
Mesh size Means	**0.3b**	**0.4b**	**2.5a**	**2.4a**	**2.3a**	**2.5a**	

*****In opened management the net cover was opened thrice weekly while in permanent management the net cover was used permanently.

Means followed by the same letter within a letter series and within a season are not significantly different according to the Tukey's HSD test ($p \leq 0.05$). Leafminer data was subjected to square root transformation before ANOVA and mean separation but means presented are original values.**

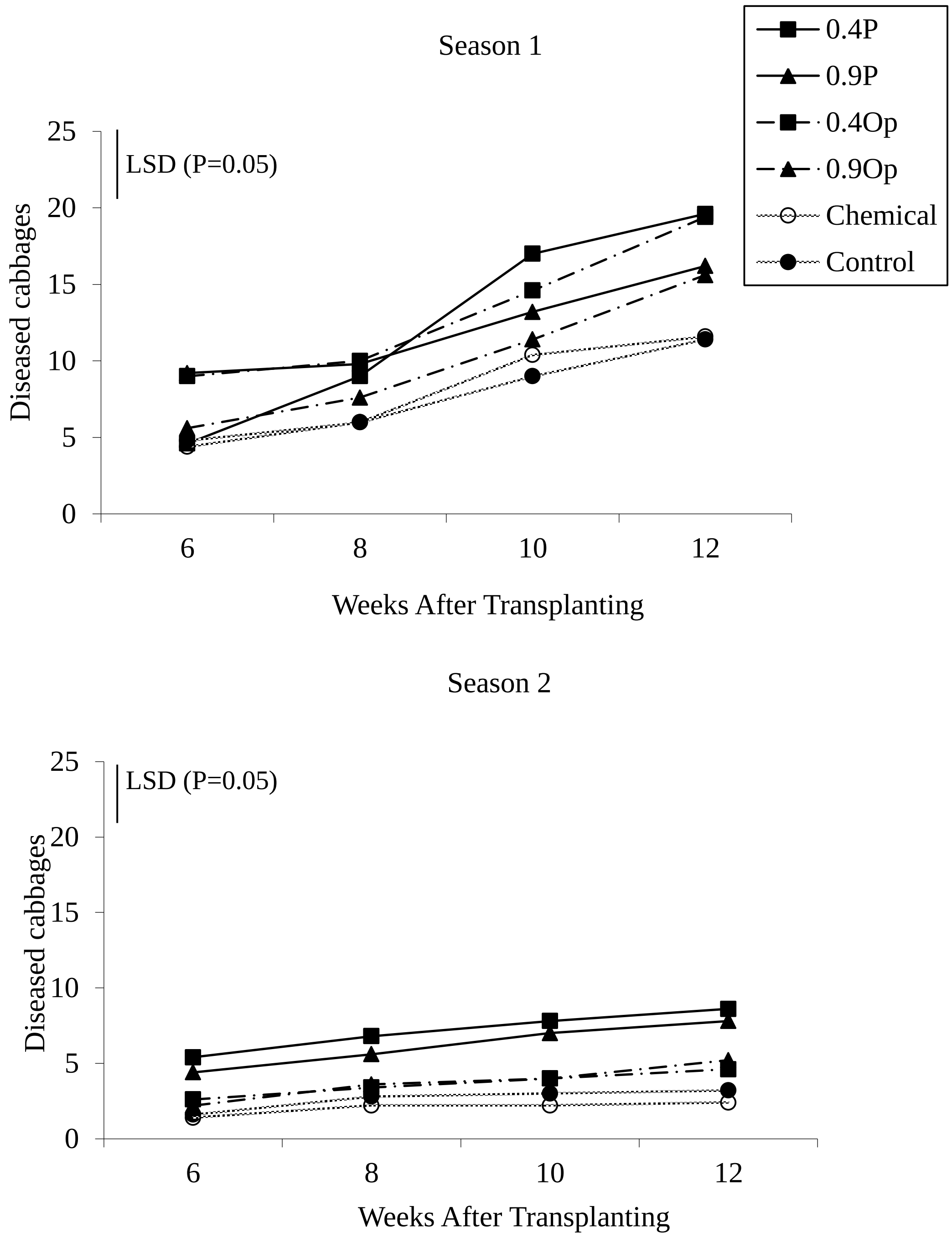


Fig. 18: Disease profile on cabbage plants as influenced by agronet covers during Season 1(May-Aug, 2011) and season 2(Oct-Jan, 2012) field experiment. Control had no agronet cover; chemical had no agronet cover but the crop was sprayed with insecticide; Op is where the agronet was opened three times a week; P is where agronet was maintained permanently covered except during maintenance and data collection periods while 0.4 and 0.9 were the different agronet mesh sizes (mm) used Data for diseases was subjected to square root transformation before ANOVA and mean separation.

Table 18: Effects of net mesh size and management on cabbage disease incidences (no of plants/plot) during season 1(May-Aug, 2011) and season 2(Oct-Jan, 2012) field experiment.

	Weeks after transplanting						
	6		10		12		
	Mesh size		Mesh size		Mesh size		**Management**
Management*	0.4mm	0.9mm	0.4mm	0.9mm	0.4mm	0.9mm	**Means**
			Season 1				
Opened	9.0no**	5.6op	10.0mn	7.6nop	14.6kl	11.4lmn	**9.7h**
Permanent	4.6p	9.2mno	9.0no	9.8mn	17.0k	13.2klm	**10.4g**
Mesh size Means	**6.8d**	**7.4cd**	**9.5c**	**8.7cd**	**15.8a**	**12.3b**	
			Season 2				
Opened	4.4no	2.6o	5.6lmn	3.4no	7.0lm	4.0no	**4.5hi**
Permanent	5.4mn	2.2o	6.8lm	3.6no	7.8l	4.ono	**4.9h**
Mesh size Means	**4.9c**	**2.4e**	**6.2b**	**3.5 cd**	**7.4a**	**7.4a**	

*In opened management the net cover was opened thrice weekly while in permanent management the net cover was used permanently.

**Means followed by the same letter within a letter series and within season are not significantly different according to the Tukey's HSD test ($p \leq 0.05$). Data for diseases was subjected to square root transformation before ANOVA and mean separation but means presented are original values.

Table 19: Effect of agronets on cabbage head diameter (cm) and unit head weight (kg) during season 1(May-Aug, 2011) and season 2(Oct-Jan 2012) field experiment

	Polar diameter (cm)	Equatorial diameter (cm)	Head weight (kg)
	Season 1		
Control	17.69c**	20.84***	2.2cde
Chemical	17.70c	20.66	2.2cde
0.9mm opened	21.61ab	18.32	3.3a
0.9mm permanent	21.54ab	18.77	3.5a
0.4mm opened	21.74ab	18.50	2.5bc
0.4mm permanent	21.75a	17.95	2.1cde
	Season 2		
Control	15.14d	19.44	1.8e
Chemical	15.16d	19.58	2.0de
0.9mm opened	19.69c	17.37	3.0a
0.9mm permanent	20.19c	18.13	3.1a
0.4mm opened	20.47bc	17.23	2.4bcd
0.4mm permanent	20.87abc	16.17	2.2cde

*Control treatment had no agronet cover or chemical sprayed, chemical had no agronet cover but was sprayed with pesticides, opened is where the agronet was opened three times a week, permanent is where agronet was maintained permanently covered except during maintenance and data collection periods while 0.4 and 0.9mm were the different agronet mesh sizes used.

** Means not followed by a letter are not significantly different according to the F-Test ($p \leq 0.05$).

*** Values followed by the same letter within a column and within a season are not significantly different according to the Tukey's HSD test ($p \leq 0.05$).

Although no significant differences were detected in the equatorial diameter of cabbage from the different treatments, a trend could be established within the two seasons marked by higher equatorial diameter of heads of cabbages grown in the open compared to those grown under agronets. The 0.4mm permanent agronet treatment that yielded the highest polar diameter had heads with the smallest equatorial diameter.

(b) Cabbage Unit Head Weight

The use of agronets generally resulted in heavier cabbage heads than when the plants were grown in the open (Table 19). In both seasons, cabbage grown under the larger mesh of 0.9mm maintained permanently covered yielded heads with the highest unit head weight. The unit head weight for cabbage from this treatment were, however, not significantly different from that of the 0.9mm mesh managed by opening it thrice a week in both seasons. Cabbage unit head weight was generally lower in the uncovered plots with the least unit head weight obtained under the control treatment in season 2. Among the 0.4mm agronet covers, plants tended to yield a higher unit head weight under the opened treatment than under the permanently covered treatment.

4.2.5.2 Yields

(a) Total Weight

Cabbage total fresh yield was significantly influenced by growing the crop under agronet covers (Table 20). In general, higher yields were realised in season one than in season two. Within a given season, the highest yields were obtained with the use of the 0.9mm agronet maintained permanently covered followed by the same mesh size maintained by opening thrice a week. The lowest yields were obtained from the unsprayed control in both seasons. Among the agronet treatments, the lowest total yields were obtained under the 0.4mm agronet maintained permanently covered in both seasons

(b) Number of Marketable Cabbage Heads

The effect of agronets on the number of marketable cabbage heads followed a trend similar to that of total fresh weight. Within a given season, more marketable cabbage heads were obtained with the use of the 0.9mm agronet maintained permanently covered in both seasons (Table 20). More marketable heads were obtained from the 0.9mm agronet opened thrice a week than from the 0.4mm agronet maintained permanently covered in season one.

Table 20: Effects of agronets on cabbage yields during season 1(May-Aug, 2011) and season 2 (Oct-Jan, 2012) field experiment.

Treatment*	Total weight (Mt/ha)	Marketable heads (no./ha)	Marketable weight (Mt/ha)	Plant dry weight (gm/plant)
		Season 1		
Control	121.8125cd**	40666.7fg	89.04441f	0.58b
Chemical	126.2500cd	46916.7cdef	100.5304e	0.57b
0.9mm opened	187.8125ab	52500abc	171.000ab	0.88a
0.9mm permanent	197.1250a	57500a	190.910a	0.87a
0.4mm opened	136.4375c	45625cdef	115.509d	0.66b
0.4mm permanent	119.750cde	48125cde	102.5025e	0.65b
		Season 2		
Control	81.1875f	38125g	67.697.25g	0.53b
Chemical	95.000ef	41875efg	84.090f	0.57b
0.9mm opened	165.9375b	49375bcd	144.508.8c	0.99a
0.9mm permanent	169.000b	55565ab	169.910.6b	0.94a
0.4mm opened	102.062.5def	45000defg	106.270de	0.68b
0.4mm permanent	91.625.0f	50000bcd	109.280de	0.61b

*Control treatment had no agronet cover or chemical sprayed, chemical had no agronet cover but was sprayed with pesticides, opened is where the agronet was opened three times a week, permanent is where agronet was maintained permanently covered except during maintenance and data collection periods while 0.4 and 0.9mm were the different agronet mesh sizes used.

**Values followed by the same letter within a column are not significantly different according to the Tukey's HSD test ($p \leq 0.05$).

In both seasons, the lowest marketable head numbers were obtained under the unsprayed control. The insecticide sprayed cabbage crop yielded more marketable heads than the 0.4mm agronet opened thrice a week in season one. However, in season two, the number of marketable cabbage heads was lower for this treatment compared to all agronet treatments. More marketable heads were obtained from cabbage plants grown under the larger mesh of 0.9mm agronet than when grown under the finer mesh size of 0.4mm in both seasons. More marketable heads were also obtained when the agronets were maintained permanently covered than when they were managed by opening them thrice a week.

(c) Marketable Fresh Weight

Cabbage marketable fresh yield was significantly influenced by growing the crop under agronet covers (Table 20). In both seasons, cabbage grown under the larger mesh of 0.9mm maintained permanently covered yielded the highest marketable cabbage fresh weight. Marketable weight for this treatment was, however, not significantly different from that of the 0.9mm mesh managed by opening it thrice a week in both seasons. Marketable fresh weight was generally lower in the uncovered plots with the least marketable weight obtained under the control treatment in both seasons. Among the 0.4mm agronet covers, higher marketable fresh weights were also obtained when the cover was maintained permanently covered than when it was opened thrice a week.

(d)Total Dry Weight

Growing cabbage under agronets affected the crops' total dry weight (Table 20). Cabbage grown under the 0.9mm agronets whether maintained permanently covered or managed by opening thrice a week yielded higher dry weight than the uncovered cabbage in both seasons. The lowest dry weight was obtained in cabbage grown under the open field sprayed with insecticide or unsprayed. The use of 0.4mm agronet permanent or opened thrice a week yielded cabbage with higher dry weight than the uncovered cabbage but significantly lower than that of cabbage grown under the 0.9mm agronets in both seasons.

4.2.5.3 Cabbage Quality

(a) Percent Moisture Content

Growing of cabbage under 0.9mm or 0.4mm netting resulted in cabbage with higher water content than growing cabbage in uncovered plots regardless of whether the nets were maintained permanently covered or managed by opening them thrice a week (Table 21). Among the agronet covered treatments, there was no significant difference in the water content of cabbage in both seasons. Similarly, there was no significant difference in water content registered among the uncovered treatments in both seasons.

Table 21: Effect of agronets on cabbage quality during season 1(May-Aug, 2011) and season 2 (Oct-Jan, 2012) field experiment.

Treatment*	Water content (%)	Total soluble solutes (% brix)	Firmness (kg force)
Season 1			
Control	89.3e**	5.6bc	4.1de
Chemical	89.1e	5.5cd	4.1cde
0.9mm opened	92.5abc	4.0ef	5.1ab
0.9mm permanent	92.7ab	4.1e	5.5a
0.4mm opened	93.2ab	3.5ef	4.8bc
0.4mm permanent	93.6a	3.5ef	4.6bcd
Season 2			
Control	81.6f	6.2ab	3.7e
Chemical	81.7f	6.2a	3.8e
0.9mm opened	90.1de	5.1cd	4.6bc
0.9mm permanent	90.5de	4.9d	5.0ab
0.4mm opened	90.8cde	4.0ef	4.0de
0.4mm permanent	91.3bcd	3.7ef	4.0de

*Control treatment had no agronet cover or chemical sprayed, chemical had no agronet cover but was sprayed with pesticides, opened is where the agronet was opened three times a week, permanent is where agronet was maintained permanently covered except during maintenance and data collection periods while 0.4 and 0.9mm were the different agronet mesh sizes used.

**Values followed by the same letter within a within a column are not significantly different according to the Tukey's HSD test ($p \leq 0.05$).

(c)Total Soluble Solids

The use of agronet covers in cabbage production significantly lowered the TSS of cabbage heads compared to open field production (Table 21). In both seasons, TSS was highest in uncovered cabbage whether sprayed or unsprayed with insecticide. Total soluble solutes were lowest in the 0.4mm agronets treatments in both seasons. The 0.9mm agronet whether maintained permanently covered or opened thrice a week also yielded cabbage heads with lower TSS than the uncovered cabbage but higher than for the cabbages grown under the 0.4mm agronets in both seasons .

(d)Cabbage Head Firmness

Agronet covers enhanced the firmness of cabbage heads (Table 21). In both seasons, cabbages grown under the 0.9mm agronets permanently covered yielded the most firm heads followed by those grown under the 0.9mm agronet opened thrice a week. The least firm cabbage heads were obtained under open field production sprayed or unsprayed with insecticide. The use of 0.4mm treatments yielded cabbage heads that were firmer than those under open field production but less firm than those of cabbage grown under the 0.9mm agronets in both seasons.

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4.3 Relationships between Microclimate and other Selected Response Variables.

The Relationship between microclimate variables and other selected response variables was studied using linear regression analysis with the best fit relationships based on the R^2 value and the root mean square value.

4.3.1 Relationships between Relative Humidity and Other Selected Response Variables

(a) Leaf number

A linear positive relationship between relative humidity and cabbage leaf number was observed with an increase in relative humidity resulting in an increase in cabbage leaf numbers. The regression model fitted was highly significant ($P<0.0001$) with R^2 value of 0.94. According to the model fitted, relative humidity could explain up to 94% of the variation in cabbage leaf numbers. Increase in relative humidity corresponded with increase in cabbage leaf number (Fig. 19A).

(b) Mites

The regression model fitted for mites and relative humidity was also highly significant ($P<0.0001$) with an R^2 value of 0.87 (Fig. 19.B). Mite numbers were found to have a negative relationship with relative humidity implying that mite population decreased with increase in relative humidity of the surrounding environment.

(c) Aphids

Similar to mites, aphid populations were found to have a negative relationship with relative humidity (Fig. 19C). The regression model was highly significant at ($P<0.0001$) with an R2 value of 0.62. These results show as the relative humidity of the surrounding environment increases, aphid population on the cabbage crop decreased.

4.3.2 Relationships between Air Temperature and Other Response Variables

(a) Stem height

The relationship between stem height and air temperature is shown in Fig 22(A) strong positive relationship ($P<0.0001$) existed between cabbage stem height and temperature. The R^2 value for the fitted model was 0.81 implying that temperature explains 81% of variations in stem height

(b) Total Soluble Solutes

Based on the results presented on Fig.20(B) higher total soluble solutes content was observed at lower air temperatures hence a negative relationship between total soluble solutes and air temperature. Temperature as a variable could explain 69% of the variation in total soluble solutes of cabbage heads. The fitted model was highly significant ($P<0.0001$).

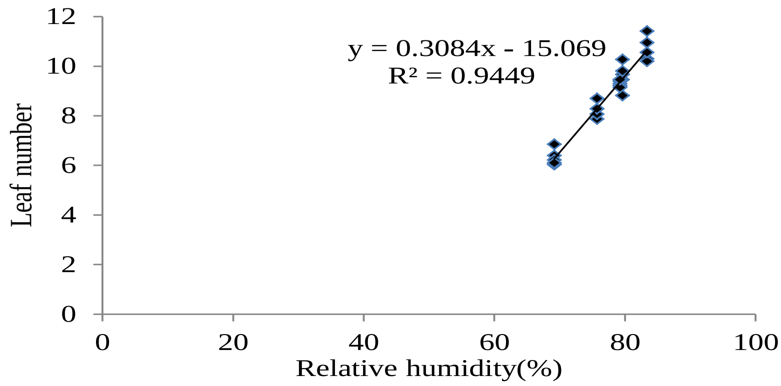

Fig. 19 (A) :Relationship between relative humidity and cabbage leaf number during season 1(May-Aug, 2011) and season 2 (Oct-Jan, 2012) field experiment

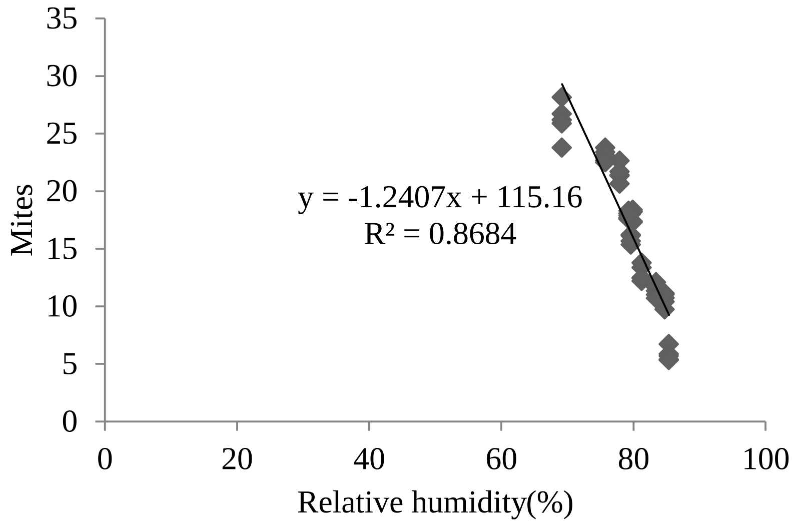

Fig.19 (B): Relationship between relative humidity and mites during season 1(May-Aug, 2011) and season 2 (Oct-Jan, 2012) field experiment

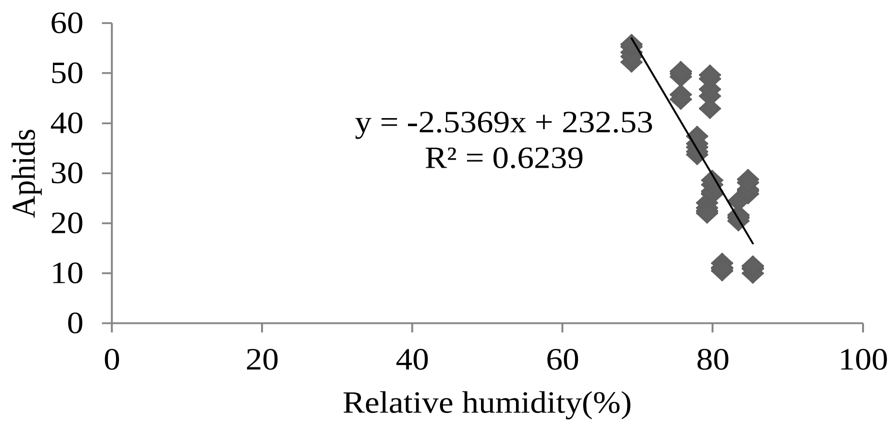

Fig. 19(C): Relationship between relative humidity and aphids during season 1(May-Aug, 2011) and season 2 (Oct-Jan, 2012) field experiment

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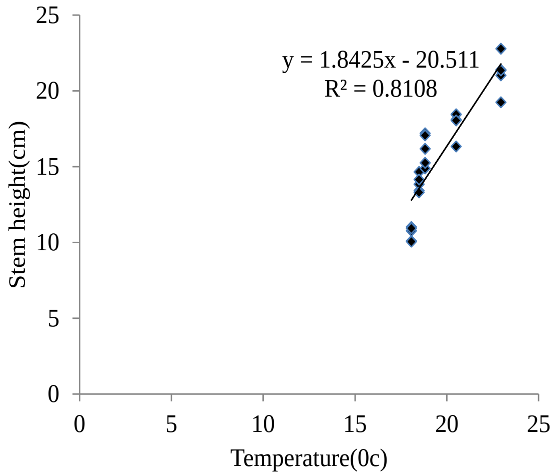

Fig. 20(A): Relationship between temperature and stem height during season 1(May-Aug, 2011) and season 2 (Oct-Jan, 2012) field experiment

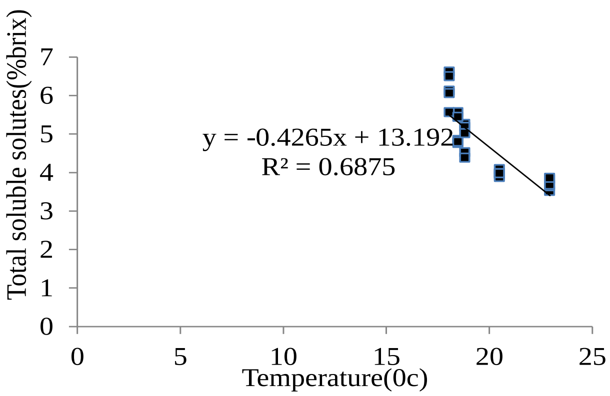

Fig. 20(B): Relationship between temperature and total soluble solutes during season 1(May-Aug, 2011) and season 2 (Oct-Jan, 2012) field experiment

(c) Diseased Cabbage Plants

A strong positive relationship was established between temperature and cabbage disease incidences (Fig. 20C). As temperature increased, the number of diseased cabbage plants also increased. The R^2 value for the regression model fitted was 0.78 and the model was highly significant ($P < 0.0001$).

4.3.4 Best Fit Relationships between Volumetric Water Content and Response Variables

(a) Cabbage Looper

A negative linear relationship between cabbage looper and volumetric water content resulted in both seasons (Fig. 21A**)** as such; an increase in volumetric water content led to a decrease in cabbage looper numbers. The fitted regression model was significant ($P<0.0001$) and with an R^2 value of 0.62.

(b) Cabbage Head Weight

The relationship between cabbage head weight and volumetric water content was also found to be significant ($P < 0.0001$; R^2 value of 0.58) and portrayed a positive relation between the two variables. This implies that an increase in volumetric water content prompted an increase in cabbage head weight (Fig. 21B)

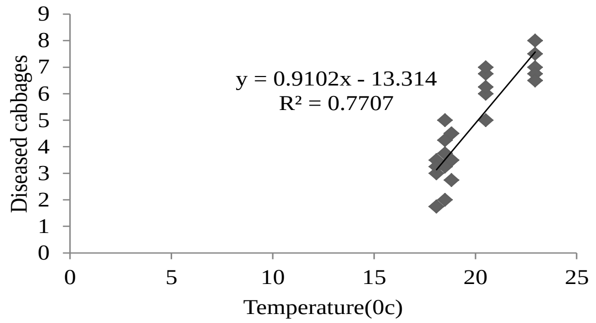

Fig.20(C) : Relationship between temperature and number of diseased cabbages during season 1(May-Aug, 2011) and season 2 (Oct-Jan, 2012) field experiment

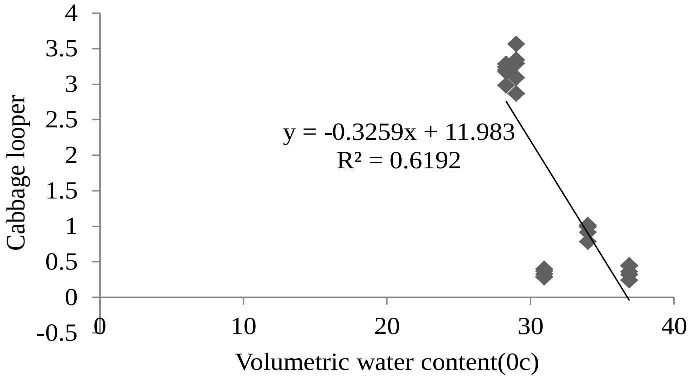

Fig.21(A): Relationship between volumetric water content and cabbage looper during season 1(May-Aug, 2011) and season 2 (Oct-Jan, 2012) field experiment

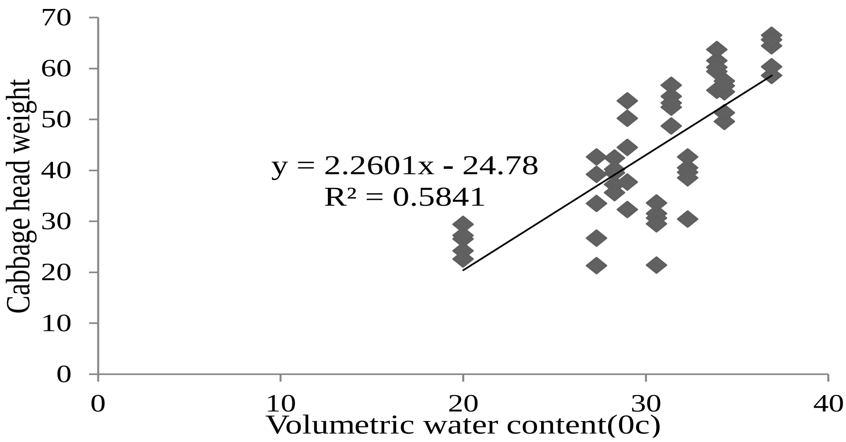

Fig.21(B): Relationship between volumetric water content and cabbage head weight during season 1(May-Aug, 2011) and season 2 (Oct-Jan, 2012) field experiment

CHAPTER FIVE

5.0 DISCUSSION

In this chapter, the results presented in chapter four have been discussed. Results of nursery and field experiments have been considered together in the discussion following the same order of presentation as in the results chapter.

5.1 Effects of Agronets on Seedling and Crop Microclimate

Results on microclimate revealed a modification in all variables under study following the use of agronet covers. Air temperature, relative humidity and volumetric water content remained higher in agronet covered than in uncovered treatments throughout the current study. On the other hand, photosynthetic active radiation and diurnal temperature range were reduced by the use of net covers. With all measured microclimate variables, the extent of modification was also influenced by the size of the mesh used and whether the covers were maintained permanently covered or managed by opening them thrice a week. Microclimate modification was generally higher under the finer agronet mesh size of 0.4mm than under the larger mesh size of 0.9mm. Higher microclimate modification was also obtained by maintaining the agronets permanently covered than when they were opened thrice a week.

The existence of a screen has been shown to alter the exchange of radiation, momentum and mass between the crop and the atmosphere hence modifying the crop microclimate (Llyod et al., 2004). Screens reduce the mixing of outside and inside air hence effectively reducing loss of heat to the surrounding atmosphere which leads to a temperature build up (Tanny et al., 2003). The finer mesh (0.4mm) used in the current study possibly provided more resistance to air movement than the larger mesh (0.9mm) leading to the higher temperatures observed under the finer agronet than under the larger mesh size net. Findings of this study support those of Perez et al (2006) on leather leaf fern, Tanny et al.(2003) on tomatoes and Stamps (1994) on cut foliage where netting screen increased temperature by between 2.3^{o}C and 5^{o}C.. From the results section of the current study, mean temperatures were slightly lower under netting in season two than in season one while day temperatures were generally higher in season 2 than in season 1. The use of nets in warmer conditions has been shown to reduce maximum temperatures under the nets, which has been attributed to the interception of radiation (‘shade effect’) and air circulation (“greenhouse effect’’) which tend to be greater than the gain of temperature caused by the use of nets (Iglesias and Alegre, 2006).

Relative humidity tended to be higher under agronets than in the uncovered plots in the current study. Relative humidity is often higher under netting than outside as a result of water vapour being transpired by the crop and reduced mixing of drier air outside with that of the netted area , even when temperatures under the netting are higher than the outside (Elad et al., 2007). Reduction in radiation resulting from netting also contributes to increased relative humidity with finer mesh providing a higher shade factor than larger mesh sizes (Stamps, 1994). Besides reducing radiation, nettings also reduce wind speeds which in turn minimize mixing of inside air with outside dry air hence maintaining a higher relative humidity (Tanny et al., (2003). These arguments lend support to the observations made in the current study where relative humidity was higher in agronet covered plots than in the uncovered plots. Among the agronet covered plots, relative humidity was also higher under the finer mesh (0.4mm) than under the larger mesh (0.9mm) possibly due to greater resistance of air movement. These findings are also is in line with results by Crete et al. (2001), which reported a 2-6% increase in relative humidity associated with the use of nets.

Volumetric water content is a measure of the amount of water in the soil medium. In the current study, volumetric water content was higher under the agronet covers than in the uncovered plots. The existence of shade netting may have reduced soil evaporation rate under netted areas due to restricted air movement, resulting in higher soil water retention. One of the potential benefits of net covers above crops is creation of a shading effect which coupled with high atmospheric water content slows the rate of evaporation and as such higher water content is maintained in the soil medium. Another possible explanation to the higher soil moisture level under covers is the reduction of transpiration thereby minimising water uptake by plants leading to better moisture retention in the soil. This attribute of net covers presents a potential for lowering cabbage crop irrigation requirement. Similar to the findings of this study, Akpo et al. (2005) observed increased volumetric water content in soils under shade than in the open.

The photosynthetic active radiation (PAR) reaching the cabbage crop was in this study reduced under netting treatments with the highest reduction observed under the fine mesh (0.4mm) than under the larger mesh (0.9mm). These observations indicate the possibility of finer mesh size nets filtering more light hence resulting in lowered PAR. These findings agree with those of a study by Retamales et.al. (2006) where white nets reduced PAR by 28% when used in high bush berry production. Similar findings were also obtained by Solomakhin and Blanke (2009) where overall, incident solar radiation (as PAR) was reduced by 12% with the use of white (crystal, translucent) hail nets relative to the control outside.

5.2 Effects of Agronets on the Physiology of Cabbage

Growing cabbage crop under net cover enhanced leaf stomatal conductance when compared to growing the crop in the open field. These findings are consistent with those of Smith et.al. (2007) who reported increased stomatal conductance in blushed apple cultivars under netting. As discussed in the preceding section of this chapter, at all ages of the crop, agronet covered treatments registered higher relative humidity values than the uncovered plants. Plants are generally known to react to low relative humidity by closing their stomata with a consequent reduction in CO_2 uptake and water loss. Stomatal response to atmospheric humidity is further intensified by the effect of high wind speed which reduces the leaf water potential by depleting the moist boundary layer close to the leaf surface (Bunce, 1999). The low stomatal conductance observed in cabbage plants produced in the open field could have therefore been a reaction of the plants to the low relative humidity and higher wind levels that they were exposed to throughout the growing seasons.

Microclimate data from the current study also revealed reduced soil moisture content levels in the open treatments compared to the agronet covered treatments. Soil moisture reduction leads to declines in gaseous exchange and leaf water potential (Borchert 1994; Breshears et al. 2005; Saha et al. 2005; Gitlin et al. 2006; Otieno et al. 2006). Although use of agronet covers generally increased stomatal conductance in the current study, using the 0.9mm agronet covers resulted in higher stomatal conductance than the 0.4mm netting. Stomatal conductance is known to be affected by factors such as carbon dioxide (CO_2) concentration, light, humidity and temperature. The differences in stomata conductance following the use of the different agronet mesh sizes and/or net management regimes could be attributable to the differences in these factors. Elevated levels of CO_2 could have resulted due to resistance of air movement with the finer mesh imposing greater resistance. This coupled with low light, high relative humidity and temperature have been found to affect stomatal conductance. A study by Bunce (1999) revealed that stomatal conductance decreases more rapidly in elevated levels of CO_2, low light, high relative humidity and high temperature.

Higher values of chlorophyll content estimates were also observed under agronet covers than under open field produced cabbage at all growth stages of the crop. As discussed earlier in this chapter, agronet covered treatments had decreased levels of irradiance; with the decrease being higher under the finer mesh (0.4mm) agronet covers as well as in treatments where the nets were maintained permanently covered than under the larger mesh of 0.9mm or when the nets were managed by opening them thrice a week. Leaves of shaded plants are thinner and contain larger pigment-rich chloroplasts. Low irradiance causes chloroplasts to be oriented along the upper and lower cell walls in order to maximize light absorption as opposed to when plants grow under high irradiance when the chloroplasts orient themselves mainly along the vertical cell walls parallel to incident irradiance (Brugnoli and Bjorkman, 1992; Park et al, 1996). The higher chlorophyll estimates recorded for the agronets covered treatments in the current study could therefore have resulted from the alignment of the chloroplasts along the upper and lower cell walls as a coping mechanism for the plant following the reduced irradiance levels received under these treatments.

Cabbage crops covered with agronets also had high tissue water content compared to the control plants in this study. High leaf water content is vital in maintaining maximum amount of chlorophyll in the plant. Water is very important in the synthesis of chlorophyll. High and stable water supply increases the amount of chlorophyll while erratic and low water supply decreases chlorophyll content (Bohrani and Habili, 1992). In the current study , leaf chlorophyll content also tended to be lower under the finer mesh which was characterized by high air temperature and soil moisture. Majid et al. (2011) observed that very high soil water levels cause a decrease in the chlorophyll content of leaves. Gazula et al. (2011) also detected a decrease in chlorophyll content of lettuce at temperatures above 21^{o}C. In the current study temperatures beyond 20^{o}C were recorded under the 0.4mm agronet treatments. Such high temperatures could possibly have contributed to the lower leaf chlorophyll contents recorded for cabbage plants grown under these treatments compared to those of plants grown under the 0.9mm agronets. Lobos et al. (2009) also reported increased leaf chlorophyll content in *Vaccinium corymbosum* as shading intensity under net treatment increased.

5.3 Effects of Agronets on Cabbage Plant Growth

Starting cabbage seeds under net covering proved a beneficial technology in cabbage transplant production. When compared with convectional farmer practice, netting resulted in early emergence as well as high germination percentages. Cabbage seeds are small and consequently have fewer reserves to sustain a developing seedling before forming a photosynthetic surface. Any condition that make it difficult for the cotyledons of developing seedlings to reach the surface quickly, such as low moisture and temperature are therefore likely to have an adverse effect on the subsequent emergence and development of a seedling

(Bewley and Black,1994). The chemical and metabolic processes which enable downward elongation of the radicle and upward elongation of the hypocotyl (embryonic leaf) are faster in warmer conditions triggering faster germination and emergence as temperatures rise within the optimal range of any given seed. Adequate moisture on the other hand is necessary for activation of important enzymes involved in germination which break down stored reserves in the cotyledons to provide energy for utilization by the growing points (Raven et. al, 2005). In the current study, temperatures and moisture conditions remained higher under net covering compared to the control throughout the study period. The significant differences in days to first germination and per cent emergence between seedlings started under net covering and control seedlings in the current study attest to the importance of the microclimate of a seed in the seedling germination process with sub-optimal conditions affecting seedling emergence and better microclimate conditions favouring early germination and seedling emergence. Similar to the findings of this study, Song et al. (2011) observed better germination of chieh-qua seeds under shade net covering compared to unprotected seedlings.

Upon seedling emergence, better seedling and subsequent plant growth was also observed in agronet covered treatments than in the uncovered treatments. Adequate moisture besides enhancing nutrient uptake and activating enzymatic activity is important in cell division and expansion, phenomena that bring about growth. Differences in moisture content between net covered and control treatments could possibly account for the differences in seedling and the subsequent plant growth between the plants under net covers and those grown in the open field. This saw plants grown under net covers in the current study ending up with more leaves and higher stem height and collar diameter compared to the control plants. Enhanced plant growth under netting treatments in the current study could be attributed to modified microclimate under the net covers. Similarly, Medany et al. (2009) observed increase in growth characteristics of sweet pepper grown under black net screen house which they attributed to better microclimate under the screens in terms of reduction in temperature, relative humidity, wind speed and light intensity.

In the present study, the highest stem height was obtained under the 0.4mm net; the treatment that also recorded the lowest PAR. According to Ratamales et al. (2008), net treatments which reduce PAR affect vegetative growth the most with increasing internode, leaf and shoot lengths, and leaf widths compared to the no-net control. According to Kasperbbauer (1987), the vegetative growth of plants maintained under low light intensity is optimised in order to increase light interception and to facilitate photosynthetic processes.

Cermeno et al. (2001) reported increased stem length in chrysanthemums under a moderate reduction in radiation. On the other hand, high temperature and low light intensity have also been shown to cause plant stems to grow spindly with reduced stem diameter (Brosnan et al., 2012). The lower light intensities received by cabbage plants especially under the 0.4mm agronet cover coupled with the higher temperatures under the 0.4mm netting in the current study could have contributed to the reduced stem thickness recorded for cabbage under this treatment. Fajinmi and Fajinmi (2010) similarly observed increased plant height in okra plants grown under netting compared to control plants.

5.4 Effects of Agronets on Insect Pests and Disease Incidences

Net covering has not only been used to offer a physical barrier to exclude pests, but also to attract various insects because of their bright colour, hence distracting their feeding and mating habit leading to lower pest population in the covered crop (Martin et al., 2006; Khorsheduzzaman et al, 2010; Licciardi et al., 2007). Results of the current study revealed a reduction in insect pest incidences when cabbage was grown under agronet covers than when grown in the open field, which could be attributed to the physical and visual barrier to some insect pests created by the net covers.

Temperature, relative humidity and the general moisture content of the immediate environment of the crop has also been shown to influence the population of certain pests like aphids, whiteflies and mites on growing plants. According to Gutierrez (2001) cabbage aphids become numerous during prolonged warm and dry periods. Mites have also been shown to be more problematic under hot dry conditions than under moist and humid conditions. The lower aphid and mite numbers recorded under the permanently covered agronet treatments in the current study could also be attributed to the high moisture conditions under these treatments. In the current study managing net covers by opening them thrice a week also prompted an increase in all pests under study. This could have been as a result of pests finding their way into the covers when opened coupled with modified conditions within the net covers which could have favoured rapid feeding, multiplication and development of some of the insects.

According to Skipp and Christensen (1982), slowed emergence together with low moisture may also increase the exposure of a developing seedling to a range of diseases which could be injurious to plants; a scenario that could have rendered control seedlings in the current study more vulnerable to disease attack. The damp conditions at the seedling bases created by the grass mulch used as part of the control treatment may also have contributed to the higher disease incidences recorded for this treatment during the seedling production experiment.

5.5 Effects of Agronets on Yield Components, Yields and Quality of Cabbage

Cabbage is a cool season crop and as such does not perform well under high temperatures. The optimum temperature range for cabbage production is 15 to 20°C. High temperatures above 20°C delay maturity, increase vegetative growth (number of leaves) and lead to formation of loose heads. In the current study, temperature within the vicinity of the crop was affected by both the mesh size of the agronet used as well as by the management of the cover i.e, maintaining covers permanently covered or opened thrice a week. Temperatures remained generally above 20°C under the fine mesh (0.4mm) agronet covers than under the larger mesh cover (0.9mm) under which temperatures mostly remained at below 20°C. The temperatures below 20°C recorded under 0.9mm netting could therefore have favoured optimal growth and heading of cabbage, subsequently resulting in the higher head yields and better quality. Although low temperatures were exhibited by the uncovered treatments, the absence of a netting cover meant that other environmental factors remained unstable resulting in low physiological performance of the crops as evidenced by the low leaf chlorophyll contents, stomatal conductance and general plant growth in these treatments.

Stomatal conductance decreases in response to low moisture as a result of which the supply of CO_2 to chloroplasts reduces (Taub, 2010). Low physiological performance results in low photosynthetic turnover which in turn reduces growth and subsequently yield. On the other hand, microclimate modification under nets resulted in high stomatal conductance and chlorophyll content which could consequently have led to high photosynthetic turnover resulting in the higher yields obtained especially under the 0.9mm net.

In the current study, high tissue water content was noted for cabbage heads grown under agronet covers than for the cabbage heads grown in the open field which could have been a result of high water uptake against reduced transpiration experienced by the net covered cabbage. Cabbage heads grown under agronets were also low in total soluble solutes than those grown in the open field. This study’s findings reveal that temperatures remained lower in the unprotected treatment than in the net covered treatments throughout the study. Generally low temperatures have been shown to reduce respiration rate and carbohydrate consumption, thus favouring accumulation of soluble solids and vice versa. McArtney and Ferree (1999) indicated that total soluble solids content (TSS) decrease with increase in temperature, which could explain the differences in TSS among the net covered and unprotected cabbage in the current study

Findings from the current study revealed that heads harvested from 0.9mm mesh size agronet were firmer than those from the 0.4mm agronet. Although both treatments had higher levels of tissue water content, temperatures were higher under the 0.4mm agronet than the 0.9mm agronet. High leaf water potential is a prerequisite for both leaf elongation and expansion and thus for head formation of cabbage. Leaf thickness has also been hypothesized to be closely related to water potential. According to Gardner and Ehling (1995), high temperature lowers the leaf water potential of cabbage thereby reducing leaf thickness which, in turn makes heading more difficult. This result in loose heads and subsequently lowered yields and quality observed for cabbage under high temperatures. The general increase in yield and quality of produce under netting observed in the current study is consistent with findings in pepper where Elad et al. (2007) reported increased yields of two *Capsicum annum* cultivars when grown under shade nets compared to the no-net control.

CHAPTER SIX
6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Based on the results and the observations of this study, the following conclusions can be drawn:

1. The use of agronets in cabbage transplant production enhances cabbage seedling performance by increasing seedling growth and reducing pest infestation.
2. Agronets modify the microclimate both in cabbage seedling production in the nursery and crop production in the field.
3. Agronets provide a physical barrier resulting in reduced insect pest populations around a cabbage crop.
4. Agronets enhance the growth, yield and quality of cabbage.
5. Agronet mesh size and net management affected the microclimate, insect pest population and as well as growth, yield and quality of cabbage.
6. Microclimate conditions created by agronets influence pest populations, growth and yield of cabbage.

6.2 Recommendations

From the above conclusions and other observations during the study, the following recommendations can be made:

1. The 0.4mm mesh size agronet can be effectively used to enhance cabbage seedling production.
2. The 0.9mm mesh size agronet is the most ideal mesh size for use in cabbage crop production.
3. Net management by maintaining permanent cover is the more ideal for cabbage production at all growth stages of the crop.
4. Effective use of the tested agronets against insect pests requires frequent pest monitoring since netting cover provides microclimatic and crop factors which favour rapid insect pest multiplication and crop destruction.
5. Integrated mite control measures would be imperative where the 0.9mm agronet is to be used in cabbage growing since mite numbers remained relatively high under this net cover despite the fact that it gave the highest yields and quality.

6.3 Future Studies

1. Additional studies using net mesh size slightly larger or smaller than 0.9mm are needed in order to identify the best mess size for cabbage production.
2. Studies on the effects of agronets on cabbage water requirement and water use efficiency may be beneficial in order to maximize on the yields per unit amount of water used.
3. Additional research is needed to demonstrate and elucidate the effects of netting height on cabbage performance.
4. There is also need for economic analysis of the nets against the conventional cabbage production system, which would play a key role in adaption of the technology.

REFERENCES

Akpo, L. E.,V.A Goudiaby, M. Grouzis, H. N.Le Houerou. 2005. Tree shade effects on soils and environmental factors in a savannah of Senegal. *PI. Ecol*.131:241-248.

Abdel-Mawgoud, A.M.R., S. O. El-abd, S. M. Singer, A. F. Abou-Hadid and T. C. Hsiao. 1996. Effect of shade on the growth and yield of tomato plants. *Acta Hort* 434: 313-319.

Antignus, Y. and D Ben-Yakir,. 2004. Ultraviolet-absorbing barriers, an efficient integrated pest management tool to protect greenhouses from insects and virus diseases. In: A.R. Horowitz, and I. Ishaaya (Eds.). *Insect Pest Management - Field and Protected Crops*. Springer Publishers, Berlin, Germany. 335 pp.

AVRDC. 2007. *AVRDC Report 2004*. Publication Number 07-691. AVRDC –The World Vegetable Center Shanhua, Taiwan. 158 pp.

Bewley.J.D. and .M Black. 1994. *Seeds.* Physiology of Development and Germination. 2nd Edition. Plenum Press, N.Y. pp445.

Blanco, F.F. and M.V. Folegatti. 2003. A new method for estimating the leaf area index of cucumber and tomato plants. *Horticultura Brasileira* 21(4):666-669.

Bohrani M, Habili .N. 1992. Physiology of plants and their cells.Translation. Chamran University publication.

Borchert R. 1994. Water status and development of tropical trees during seasonal drought. *Trees* 8: 115–125.

Breshears DD, N.S. Cobb, P.M. Rich, K.P. Price, C.D. Allen, R.G Balice. 2005 Regional vegetation die-off in response to global-change-type drought. *Proc Natl Acad Sci* 102:15144–15148

Brethour, C. and A. Weersink. 2001. An economic evaluation of the environmental benefits from pesticide reduction. *Agricultural Economics* 25:219-226.

Brosnan J,Brandon H., Samples T.,Sorochan J.,Thorns A.2012.Drought and heat taking toll on Tennessee turf grass.

Brugnoli E, O. Björkman. 1992. Chloroplast movements in leaves: influence on chlorophyll fluorescence and measurements of light-induced absorbance changes related to ΔpH and zeaxanthin formation. *Photosynth Res* 32**:** 23–35

Bukovinszky, T. R.P.J. Potting, Y. Clough, J.C. Lenteren and L.E.M. van Vet. 2005. The role of pre- and post-alighting detection mechanisms in the responses to patch size by specialist herbivores. *Oikos* 109:435-446.

Bunce, J. A. 1999. Leaf and root control of stomatal closure during drying in soybean. *Physiol.plant* 106:190-195.

Cermeno, P., J.A. Sotomayor, Z. Serrano and A.I. Escobar, 2001. The effects of solar radiation on Dendranthema. *Acta Hort.*, 559: 339–344

Cooper, J.F.C. 1999. Pest management in horticultural crops; Integrating sustainable pesticide.Use into biocontrol-based peri-urban production systems in Kenya. Final Technical Report, R6616.1996-2002. Natural Resources Institute, Chathan, UK. 25 pp.

De Lannoy, G. 2001. *Leafy Vegetables,* p. 403-511. In: Crop Production in Tropical Africa Raemaekers, R.H. (Ed). Directorate general for International Co-operation (DGCIC), Brussels, Belgium.

David T S, Ferreira M I, Cohen S, Pereira J S and David J S. 2004 Constraints on transpiration from an evergreen oak tree in southern Portugal. Agric. *Meteorol*. 122, 193–205.

Elad, Y., Y Messika, ., M. Brand, D.R. David, A. Sztejnberg, 2007. Effect of colored shade nets on pepper powdery mildew (*Leveillula taurica*) *Phytoparasitica 35*:285–299.

Fahey, J.W., A.T. Zalcmann and P. Talalay. 2001. The chemical diversity and distribution of glucosinolates and isothiocyanates among plants. *Phytochemistry* 56:5-51.

Fajinmi1, A. A. and O. B. Fajinmi. 2010. Incidence of Okra Mosaic Virus at Different Growth Stages of Okra Plants ([*Abelmoschus Esculentus* (L.) *Moench*) Under Tropical Condition. *Journal of General and Molecular Virology*. 2 (1): 028-031

Food and Agricultural Organization of the United Nations (FAO). Statistical Database-Agriculture. http://faostat.fao.org/faostat/collections?subset=agriculture. 24th August, 2012.

FAOSTAT. 2009, Cabbage. *Food and Agricultural Organization Statistics Quarterly Bulletin of Statistics* 46: 160-165.

Garnaud, J.P. 1988. *Protected cultivation —yesterday, today and tomorrow,* p. 182. Conferences on ‘Plastics in the Nineties’ held from 9th to 13th December at British Agricultural and Horticultural Plastics Association, UK.

Gazula A., D. Mathew, J. Streater R. Miller .2005. Temperature and cultivar effects on anthocyanin and chlorophyll b concentrations in three related Lollo rosso lettuce cultivars. *HortSci* 40(6)1731-1733.

Gelernter, W.D. and C.J. Lomer. 2000. *Success in Biological Control of Above-ground Insects by Pathogens*, p. 297-322. In: Gurr, G. and S. Wratten (Eds) Biological Control: Measures of Success. Dordrecht, Kluwer Academic Publisher, Germany.

Gitlin AR, C.M Sthultz, M.A Bowker, S.A Stumpf, C.A Paxton, K. Kennedy 2006 Mortality gradients within and among dominant plant populations as barometers of ecosystem change during extreme drought events. *Conserv Biol* 20:1477–1486

Gutierrez, A.P. 2000. Crop ecosystem response to climate change: pest and population dynamics. *Climate Change and Global Crop Productivity*. Eds K. R. Reddy & H.F Hodges,pp.353-374.CAB International, New York.

HCDA. 2007. *Fruits and Vegetables*. Agricultural Information Centre, Nairobi, Kenya.150 pp.

Hajek, A. 2004. *Natural Enemies*: An Introduction to Biological Control. Cambridge, Cambridge University Press, 394 pp.

Harmanto, T.H.J. 2006. Evaluation of net greenhouses for tomato production in the tropics. Hannover University, PhD Dissertation. http://deposit.ddb.de/cgi. 10th August, 2012.

Harpaz, I. 1982. *Nonpesticidal control of vector-borne viruses. Pathogens, Vectors, and Plant Dishases.* Academic Press. USA. 21 pp.

Hubpages, 2010. www.hubpagesexplained.com. 20th August, 2011.

Herbal remedies,www.herbalremediesinfo.com/best-herbal-remedies.html. 27th April, 2012.

Iglesias, I., and S. Alegre. 2006. The effect of anti-hail nets on fruit production, radiation, temperature, quality and profitability of ‘Mondial Gala’ apples. *Journal of Applied Horticulture* 8:91-100.

ISTA. 1985. International Seed Testing Association: International Rules for Seed Testing. *Seed Sci. Technol.* 13:307–513.

Jaetzold, R. and H. Schmidt. 1983. *Farm Management Handbook of Kenya*. Vol. II Natural Conditions and Farm Management Information. Part B. Central Kenya (Rift Valley and Central Province). Ministry of Agriculture, Nairobi, Kenya. 413 pp.

Kasperbauer, M.J. 1987.Far-red light reflection from green leaves and effects on phytochrome-mediated assimilate partitioning under field conditions. *Plant Physiology*, v.8, p.350-354, Khorsheduzzaman, A.K.M., Z. Nessa and A. Rahman. 2010. Evaluation of Mosquito Net Barrier on Cucurbit Seedling with Other Chemical, Mechanical and Botanical Approaches for Suppression of Red Pumkin Beetle Damage in Cucurbit Bangladesh J. *Agril. Res*. 35(3): 395-401.

Kibata, G.N. 1996. The *diamondback moth*: a problem pest of the brassica crops in Kenya. The management of diamondback moth and other crucifier pests, p. 24-35. Proceedings of the third International Workshop held from 29th October to November 1996 Kuala Lumpur, Malaysia.

Kinyanjui, H. C. 1979. *Detailed soil survey of Tatton Farm*, Egerton College, Njoro. Ministry of Agriculture-National Agricultural Laboratories. Nairobi, Kenya. 50 pp.

Licciardi S., F. Assogba-Komlan, I. Sidick, F. Chandre, J.M. Hougard, 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* 27:3-4, 152

Linda-Marie, R., P. Anderson, U. Nilsson and B. Rämert. 2009. *Open Field Vegetable Production*. Department of Plant Protection Biology. Swedish University of Agricultural Sciences, Sweden. 48 pp.

Liu, B. and D. Yu. 1996. Research on control of *plutella xylostella* L.with the nutrient biocide ‘thuricide’. J. Fujian Acad. *Agric Sci*.11:46-49.

Lloyd, A.E. A.P. Hamacek, R.J. George and G. Waite. 2004. Evaluation of Exclusion Netting for Insect Pest Control and Fruit Quality Enhancement in Tree Crops. *International Journal of Tropical Insect Science* 27:3-4.

Lobos et al. 2008. Physiological Response of Vaccinium corybosum ‘Elliot’ to Shading Nets in Michigan”, Proceedings of 9th International Vaccinium Conference.

Lubulwa, G. and S. McMeniman. 1997. *An economic evaluation of realised and potential impacts of 15 of ACIAR’s biological control projects (1983-1996).* Working Paper Series IAP-WP 26. Canberra, ACIAR. 42 pp.

Margni, M., D. Rossier, P. Crettaz and O. Jolliet. 2002. Life cycle impact assessment of pesticides on human health and ecosystem. *Agriculture, Ecosystem and Environment* 93(1): 379-392.

Majumdar, A. 2010. *Results from the 2009 Insect Monitoring Pilot Project in Alabama. American Vegetable Grower* R. Gordon (Ed.). Miester Media, MI. USA. 342 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.

Medany, M.A., M.K. Hassanein and A.A. Farag, 2009. Effect of black and white nets as alternative covers to sweet pepper production under greenhouses in Egypt. *Acta Hort.*, 807: 121–126

McArtney SJ, D.C. Ferree. 1999. Shading effects on dry matter partitioning, remobilization of stored reeserves and arly season vegetative development of grapevines in the year after treatment. *J Am Soc Hort Sci* 124(6):591–597

Neave, S.M., G. Kelly and M.J. Furlong. 2011. *Field evaluation of insect exclusion netting for the management of pests on cabbage (Brassica oleracea var. capitata) in the Solomon Islands*. AVRDC – The World Vegetable Center, Taiwan. 101 pp.

Nissim-Levi, A., L. Farkash, D. Hamburger, R. Ovadia, I. Forrer, S. Kagan and Oren-Shamir M. 2008. Light-scattering shade net increases branching and flowering in ornamental pot plants. *J. Hort. Sci. Biotech*. 83:9-14.

Ninsin, K.D., J.C. Mo and T. Miyata. 2000. Decreased susceptibilities of four field populations of the diamondback moth, *Plutella xylostella* L. (Lepidoptera: Plutellidae) to acetamiprid. *Appl. Ent. Zoo*. 35:591-595.

Oren-Shamir, M., Y. Shahak, I. Dori, E. Matan, , E. Shlomo, R. Ovadia, E.E. Gussakovsky, A. Nissim-Levi, K. Ratner, Y. Giller, Z. Gal and R. Ganelevin. 2003. Lisianthus: aumento di altezza di piante coltivate in estate sotto reti colorate. *Flortecnica* 6: 84-86.

Otieno, O., L. Asaba, J.F. and H.M. Kindness. 2000. *Factors affecting uptake and adoption of outputs of crop protection research in peri-urban vegetable systems in Kenya*, p. 27-34. In: Sustaining change: proceedings of a workshop on the factors affecting uptake and adoption of Crop Protection Programme (CPP) research outputs held from 10th to 11th May. Department for International Development (DFID), Nairobi, Kenya.

Palada, M.C. and D.L. Wu. 2009. Grafting sweet peppers for production in the hot-wet season. International Cooperator’s Guide, AVRDC. Taiwan. 400 pp.

Palada, M.C. and M. Ali. 2007. Evaluation of technologies for improving year-round production of safe vegetables in peri- urban agriculture of Southeast Asia. *Acta Horticulturae* 762: 271-281.

Park Y-I, W.S, Chow, J.M. Anderson. 1996. Chloroplast movement in the shade plant *Tradescantia albiflora* helps protect photosystem II against light stress. *Plant Physiol 111***:** 867–87

Pérez, M., B.M. Plaza, S. Jiménez, M.T Lao, J. Barbero, J.L. Bosch. 2006. The radiation spectrum through ornamental net houses and its impact on the climate generated. *Acta Hort.* 719:631–636

Prado, J.C. and M. Raga-as. 2008. Growth and yield of broccoli (*Brassica oleracea* Linn.) as influenced by different layers of shading nets. *Philippine Journal of Crop Science* 14:20-25.

Radul G. 2008. Peri-urban and urban livestock keeping in East Africa. *Journal of animal production* 2:213-219.

Rajapakse, N.C. and Y. Shahak. 2007. *Light quality manipulation by horticulture industry,* p 290-312. In: G. Whitelam and K. Halliday (Eds.). Light and Plant Development, Blackwell Publishing, UK.

Retamales, J.B., J.M. Montecino, G.A. Lobos, L.A. Rojas. 2006. Colored shading nets increase yields and profitability of highbush blueberries. *Acta Hort.* 770:193–197

Raven P. H. Ray F. Evert ,S. E. Eichorm. 2005. Biology of Plants, 7th Edition. W.H. Freeman and Company Publishers. New York: pp. 504-508.

Saha S, H. Bassirirad, J. Gladwin. 2005. Phenology and water relations of tree sprouts and seedlings in a tropical deciduous forest of South India. *Trees (Berl)* 19:322–325

Sengonca, C. B. Liu, Y.J. Zhu. 2010. Efficiency of the mixed biocide GCSC-BtA against vegetable pests of different arthropod orders in the South-eastern China. *Journal of Pest Science* **74:**33-36.

Shahak, Y. 2008. Photoselective netting for improved performance of horticultural crops. A review of ornamental and vegetable studies carried in Israel. *Acta Hort*. 4:451-467.

Shahak, Y., K. Ratner, N. Zur, Y. Offir, E. Matan, H. Yehezkel, Y. Messika, I. Posalski and D. Ben-Yakir. 2008. Photoselective netting: an emerging approach in protected agriculture. *Acta Horticulturae* 807:79-84.

Skipp, R.A. and M.J. Christensen. 1982. Invasion of white clover roots by fungi and other soil microorganisms. *New Zealand Journal of Agricultural Research.* 25: 97-101

Smit, A. 2007. Apple tree and fruit responses to shade netting. MSc Dissertation. University of Stellenbosch, South Africa.

Solomakhin, A. and M. Blanke. 2009. The microclimate under coloured hailnets affects leaf and fruit temperature, leaf anatomy, vegetative and reproductive growth as well as fruit colouration in apple. *Annuals of Applied Biology*,156:121-136

Song .S.W., L.Y. Yi .., H.C Liu ., G.W Sun . 2011. Effect of Color Shading - Nets on the Growth and Physiological Characteristics of Chieh-Qua Seedling. *Advanced materials research*: 366:197-201

Srinivasan, R. 2011. *Vegetable Production under Protective Structures Technical Innovation brief*. Robinson, D.W. Baron's Brae, Baily, Developments in Plastic Structures and Materials for Horticultural Crops. County Dublin, Ireland.

Stamps, R.H. 1994. Evapotranspiration and nitrogen leaching during leatherleaf fern production in shadehouses .SJRWMD Spec. Publ. SJ94-SP10. St. Johns River Water Management District, Palatka, F)

Talekar, N.S., F.C. Su and M.Y. Lin. 2003. *How to produce safer leafy vegetables in nethouses and net tunnels.* Asian Vegetable Research and Development Center, Shanhua, Tainan, Taiwan. 18 pp.

Tanny, J., S. Cohen, A. Grava, A. Naor, V. Lukyanov. 2003. The effect of shading screens on microclimate of apple orchards. *Chilean Journal* 4: 347-359.

Tanny, J., C. Shabtai and T. Meir. 2003. *Screenhouse Microclimate and Ventilation*: an Experimental Study, Institute of Soil, Water and Environmental Sciences, Agricultural Research Organization,UK. 129 pp.

Taub, D. 2010. Effects of Rising Atmospheric Concentrations of Carbon Dioxide on Plants. *Nature Education Knowledge* 1(8):21

Teitel, M., O. Liron, Y. Haim and I. Seginer. 2008. Flow through inclined and concertina-shape screens. *Acta Hort.* 801: 99-106.

Varela, A. M., A. Seif and B. Löhr. 2003. *A Guide to IPM in Brassicas Production in Eastern and Southern Africa,* Nairobi: International Centre of Insect Physiology and Ecology (ICIPE) Science Press, Nairobi, Kenya. 95 pp.

Vernon, R.S. 2003.The effect of exclusion fences on the colonization of rutabagas by cabbage flies (Diptera: Anthomyiidae). *Canadian Entomologist* 130: 153-162

Wambani H., E. Nyambati, M. Kamidi and J. Mulati. 2007. *Participatory evaluation of cabbage varieties as a source of food and income for smallholder farmers in north western Kenya*, p. 355-357. African Crop Science Conference Proceedings held from 9th to 15th August, Nairobi, Kenya.

Waterer, D. T. Sanderr, J. Spencer and D. Bantle. 2002. *Vegetable Cultivar and Cultural Trials.* University of Saskatchewan , Saskatoon, Saskatchewan, Canada. 758 pp.