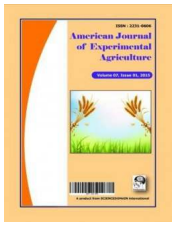

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Disease Severity on Cabbage Protected from Arthropod Pests with Insecticide Treated Agronets in Kenya

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Authors' contributions

This work was carried out in collaboration between all authors. Author JJK designed the study, wrote the protocol and wrote the first draft of the manuscript. Authors MK, LW, AT, MN and TM reviewed the experimental design and all drafts of the manuscript. Authors JJK and MK managed the analyses of the study. Author JJK identified the plants. Authors JJK, PWN and JJC performed the statistical analysis. All authors read and approved the final manuscript.

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ABSTRACT

Cabbage (*Brassica oleracea var. capitata* L.) is one of the most important vegetables in Kenya, mainly grown by smallholder farmers for food and source of income. Its production is hampered by insect pests and diseases, leading to economic yield losses. Row cover insect proof nets have been used in the past to manage insect pests of cabbage and were recently introduced to Kenya.

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This study planned to document disease incidence and severity levels on cabbage grown under insecticide impregnated Agronets as a tool to manage insect pests and microclimate. The study was conducted at KALRO-Kabete and PTC (Practical Training Centre)-Thika, Kenya both at the nursery and in the field. Treatments included 1) use of insecticide (alpha cypermethrin) impregnated Agronets with (0.9 mm mesh), 2) untreated 0.4 mm mesh Agronet, 3) grass shading as a farmer practice (at nursery) and 4) control where there was no Agronet use. The treatments had five replications in a completely randomized block design. Plots measured 2 x 6 m, with a 1 m path between consecutive plots and 2 m between consecutive blocks. Three major diseases were recorded: damping off (*Rhizoctonia solani*), downy mildew (*Peronospora parasitica*) and black rot (*Xanthomonas campestris pv. campestris*). Treatments showed significant ($P<0.05$) differences on severity of damping off, which was lowest on seedlings covered with Agronets compared with the other treatments at nursery. Comparably, the downy mildew disease severity was higher on seedlings covered with Agronets than those with no cover or shading at the nursery. The findings show that frequent disease scouting is crucial when using Agronets for cabbage pests management. This would allow farmers to take action when diseases are noticed. Further supportive studies to understand threshold limits that can trigger growers to employ disease control application may be needed.

Keywords: Cabbage seedling; downy mildew; damping off; black rot; disease incidence.

1. INTRODUCTION

Cabbage is one of the most important vegetables in Kenya and is grown by smallholder farmers as a major source of income. The crop provides proteins comprising of all essential amino acids, minerals such as calcium, iron, magnesium, sodium, potassium and antioxidant and is reported to have anti-carcinogenic properties [1]. It is also a rich source of ascorbic acids, carotene (Pro Vitamin A) and has a fiber content and calcium which may reduce the risk of colon cancer [2]. Being a major source of income for smallholder farmers, it has enabled them to support their family needs and remain financially viable, especially in the rapidly growing Kenyan peri-urban farming community. However, its production is hampered by several biotic and abiotic factors. Major constraints in Kenya, and other tropical countries, are insect pests and diseases [3]. Among cabbage diseases, the most serious are black rot caused by *Xanthomonas campenstris pv. campestris*, turnip mosaic virus and soft rot caused by several different pathogens such as *Erwinia carotova, Erwinia chrysanthemi* and *Pseudomonas flourescens* [3]. Downy mildew (*Peronospora parasitica* (Pers), is also reported as a key disease, limiting cabbage production [4]. Black rot is usually a destructive disease of a wide range of crucifer plants and cabbage is one of the main hosts. Black rot has been a major disease constraint of cabbage production in smallholder farming systems in Africa where substantial losses are experienced, especially during the warm and wet seasons [5,6,7,8]. It has been reported that under severe outbreak of this disease, the crop is subjected to attack by a variety of pathogens both at nursery as well as in the field leading to substantial reduction in yield to tune of 5 to 70% [9]. Agronets have been used extensively in various cultivations. They not only contribute to increased production but they also have a positive effect on the quality of the produce by moderating the microclimate under cover. It has also been used to enhance productivity, quality and homogeneity of plants and fruits by generating moderate greenhouse and windbreak effects. They have also been used for protection against adverse climatic action by protecting cultivations from damages due to hail, strong winds and rain [10]. In Benin, Agronets are used to protect crops against infestation by pests [11,12]. In Kenya, it has been tested and proved as an effective pest management tool against various insect pests [13,14]. It is thus prudent to understand the effects that this technology may have on diseases of cabbages, which are not targeted for control by the technology. Since the Agronets modify the microclimate, retaining higher moisture and relative humidity, and increased temperatures, there is likelihood of severe disease growth if uncontrolled. This study was carried out to document the key cabbage diseases, their incidence and severity on cabbage grown under the Agronet technology both under nursery and field conditions in Kenya.

2. MATERIALS AND METHODS

2.1 Study Site

The experiment was conducted at the KALRO-Kabete and PTC (Practical Training Centre) Thika- Kenya experiment stations, from March to September 2011. Kabete station is located Northwest of Nairobi 36º 41'E and 01º 15'S and at an altitude of 1747 m above sea level. The annual mean temperature ranges from 11ºC to 23ºC. The average rainfall received is 1000 mm per year and the soil type is Nitisol.

Practical Training Centre-Thika is located at latitude, 1º06'S and longitude, 37º 01'E. The altitude is 1520m. The mean annual rainfall at Thika is 856mm and is bimodal. Mean annual maximum and minimum temperatures are 26.1ºC and 13.6ºC respectively. The soil type is Pellic Vertisol with an average pH of 5.3 and soil depth ranged from 60 to 100 cm. The two stations were used as a repetition of the study in space.

2.2 Land Preparation and Transplanting

The land was prepared prior to sowing of the seed on 9th March 2011 at KALRO-Kabete and 15th April 2011 at PTC-Thika. Twenty nursery beds of 1 m by 2 m with an alley of 1 m maintained between plots, and a 2 m between blocks. Cabbage variety Gloria F1, a widely used variety in Kenya was sown on each plot on 21st March and 9th May, 2011, at KALRO-Kabete and PTC-Thika, respectively. One seed was placed per hole at a spacing of 15 cm between lines and 1cm between seeds within a line. Space of 20 cm was maintained from the edge of the plot to the first line. The beds were later covered with dry grass as mulch immediately after planting to prevent wind or water erosion. Nets were supported by metal rod (R6) arches measuring 0.5 m by 0.5 m by 0.5 m (two arches per plot). Nets measuring 2 m by 3 m were placed on the arches and covered on the ground with soil to prevent any opening to the crop. Watering was done manually using watering can, every day in the evening at 6.30 pm for the first two weeks, and thereafter done every three days until the seedling were ready for transplanting. A systemic fungicide, Previcur (propamocarb hydrochloride) was applied as a drench in all plots at the rate of 15 ml in 10 litres of water, for control of fungal diseases (damping off and downy mildew), which are rampant in the area. However, it was only applied after symptoms of damping off were observed on the seedlings and this was done two weeks after germination. Healthy cabbage seedlings from nursery plots protected by nets were transplanted to ploughed, fine tilled main experimental field/plots, on 30th April and 24th June 2011, at KALRO-Kabete and PTC-Thika, respectively. During transplanting, one teaspoonful (50 g) of diammonium phosphate 18:46:0 fertilizer was applied per planting hole and mixed with the soil before placement of the seedling. Watering was done to supplement rainfall.

2.3 Experimental Design

In the nursery experiment, treatments included; 1) insecticide (factory impregnated with apha cypermethrine 1%) Agronet with 0.9 mm mesh, 2) untreated 0.4 mm mesh Agronet, 3) grass shading as a farmer practice, and 4) control where there was no Agronet use. In the field, treatment included; 1) insecticide (factory impregnated with alpha cypermethrin 1%) Agronet with 0.9 mm mesh, 2) untreated with 0.9 mm mesh Agronets, and 3) control where there was no Agronet use. The treatments had five replications arranged in a completely randomized block design. Plots measuring 1 x 2 m for nursery and 2 x 6 m for field experiment, with a 1 m path between consecutive plots and 2 m between consecutive blocks were used.

2.4 Data Recording

Sampling was done from 9.00 am for 3 hours, on 20 randomly selected plants in each plot. Sampling in the nursery experiment was done within 30 days before transplanting, at weekly interval. For each selected seedling, disease incidence and severity was recorded per plant beginning first week after germination. Disease severity were scored as; 1= up to 20% leaf area affected, 2= >20 to 40% leaf area affected, 3= >40 to 60% leaf area affected, 4= > 60 to 80% leaf area affected, and 5= >80 to 100% leaf area affected.

2.5 Statistical Analysis

All the data were subjected to Analysis of variance (ANOVA) using GENSTAT Discovery 4th edition. Significance was tested at 95% confidence limit and if found significant means were separated using Students-Newman Keuls (SNK) test. The means are provided with standard error (SE). Data that were not normally

distributed were transformed using square root method $(x+0.05)^{0.5}$ before performing ANOVA.

3. RESULTS

Diseases observed in nursery included; downy mildew, damping off and black rot. Downy mildew was most severe at the nursery compared with the field. The first symptoms observed were small, light green-yellow lesions on the upper leaf surface, then later showing on the undersurface. The spots turned yellow as they enlarged. Downy mildew severity was significantly (P<0.05) higher on seedlings covered by Agronets compared with those grown under grass shade and those with no cover (control) at both Kabete and Thika. However, for damping off, there was no significant (P>0.05) difference across treatments at Kabete (Table 1) although in Thika, the severity was significantly lower (P<0.05) on those seedlings covered by Agronets compared with those shaded with grass and control. There was no significant difference between Agronets despite the difference of mesh size (0.9 mm and 0.4 mm).

Table 1. Mean disease severity on cabbage seedlings at nursery grown under different (treatments): treated net, untreated net, grass shading and control; at KALRO Kabete and KALRO Thika, March and June 2011, respectively

Treatment	Damping off		Downy mildew	
	Kabete	Thika	Kabete	Thika
Treated net	0.27	0.53a	2.07a	2.01a
Untreated net	0.33	0.53a	2.13a	2.07a
Grass shading	0.53	1.00b	0.60b	0.60b
No net	0.86	1.47b	0.73b	0.73b
P-value	0.279	0.028	0.002	0.020
SED	0.142	0.349	0.259	0.249

Mean in the same column followed by the same letter are not significantly different by Students-Newman Keuls (SNK) at P =0.05

The disease incidences on cabbage seedlings both at Kabete and Thika did not vary significantly (P<0.05) across the treatments. However, lower incidences of damping off disease were observed on plots covered by Agronets and those grown under grass shading compared with the control. Comparably higher incidences of downy mildew were observed on seedlings covered by Agronets compared with uncovered seedlings at Kabete. In Thika downy mildew did not differ significantly (P>0.05) across the treatments (Table 2).

Table 2. Mean disease incidence on cabbage seedlings at nursery grown under different (treatments): treated net, untreated net, grass shading and control; at KALRO Kabete and KALRO Thika, March and June 2011, respectively

Treatment	Damping off		Downy mildew	
	Kabete	Thika	Kabete	Thika
Treated net	4.33	4.33	56.33	25.00
Untreated net	5.00	4.53	51.33	29.33
Grass shading	0.01	7.33	32.67	24.00
No net	8.33	8.00	20.33	26.67
P-value	0.071	0.871	0.111	0.954
SED	0.629	0.822	1.401	1.599

At Kabete, severity of downy mildew was greater the 2nd week after germination, this was observed across the treatments. However, higher severity was observed in seedlings covered by Agronets compared with the uncovered seedlings and those grown under grass shading. The severity later reduced on the 3rd week after a control measure had been applied (Fig. 1).

At Kabete, damping off severity was significantly lower on seedlings covered by Agronets compared with those grown under grass shading and uncovered seedlings. The severity increased towards the end of the 1st week, and highest severity was recorded in the 2nd week. A control measure was applied and the severity reduced from the 2nd week subsequently until the crop was ready for transplanting (Fig. 2).

At Thika, damping off disease severity was significantly lower in seedlings covered by Agronets compared with uncovered seedling and those grown under grass shading. Severity was highest in the 2nd week and later decreased towards the end of the 2nd week and the 3rd week. This was due to the control measure applied (Fig. 3).

At Thika, a similar trend was observed in downy mildew severity like the one at Kabete. The severity was greater in the 2nd week of transplanting across the treatments. A control measure was applied and the severity reduced to a lower level towards the end of 2nd week until the seedlings were ready for transplanting (Fig. 4).

After planting out, downy mildew severity was significantly (P<0.05) higher on cabbages covered by Agronets compared with uncovered cabbages, this was observed in Thika. At Kabete downy mildew severity did not vary significantly (P>0.05) across the treatments, however, severity was relatively higher in cabbages covered by nets. At Thika, damping off diseases attack on cabbages were significantly lower (P<0.05) in cabbages covered by nets compared with uncovered cabbages. At Kabete, the damping off severity did not vary significantly (P>0.05) across the treatments. However, general trend showed relatively lower severity on covered cabbages compared with uncovered plants. Black rot was significantly lower (P<0.05) on covered plants compared with uncovered cabbages both at Kabete and Thika (Table 3).

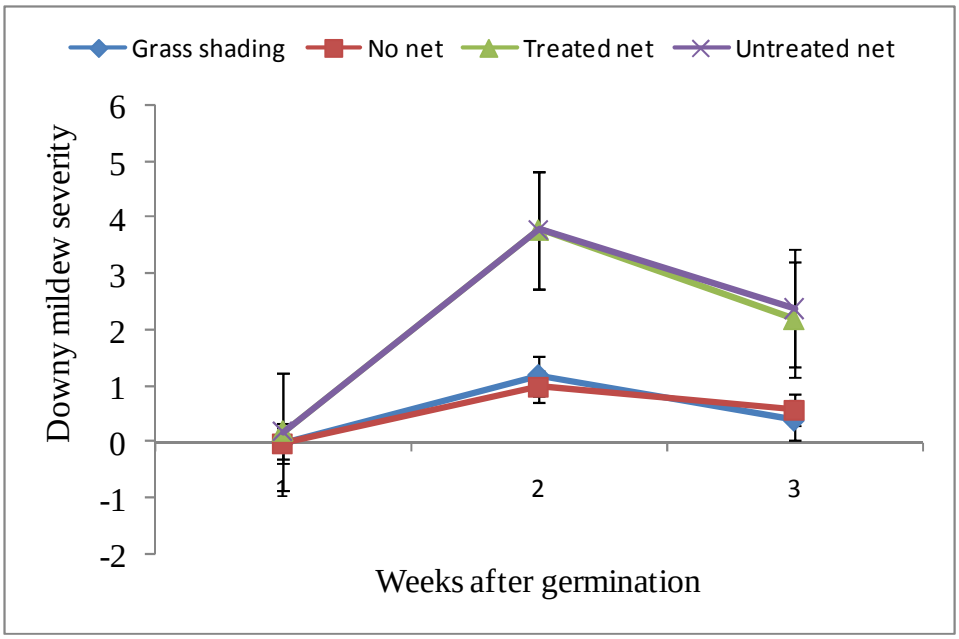

Fig. 1. Downy mildew severity on cabbage seedlings at Kabete

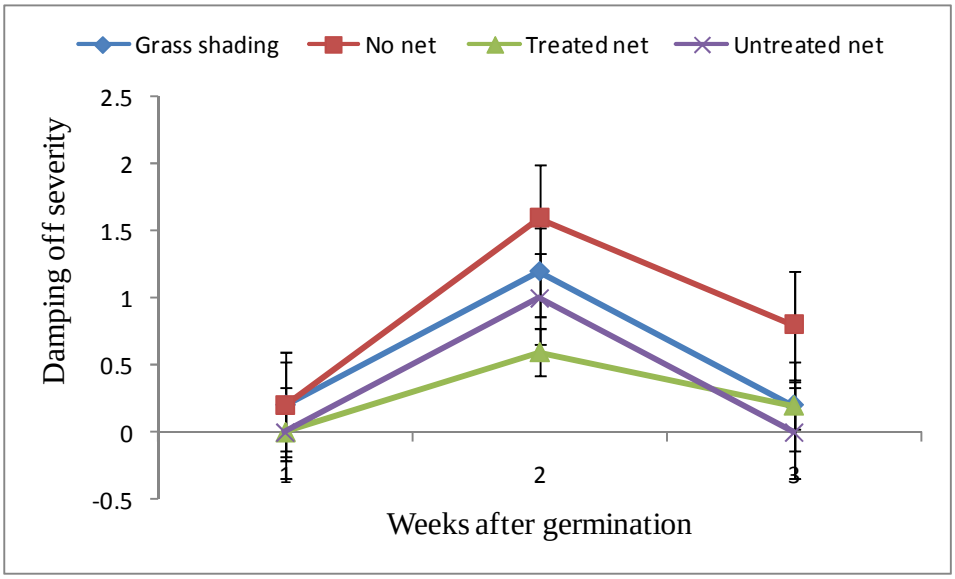

Fig. 2. Damping off severity on cabbage seedlings at Kabete

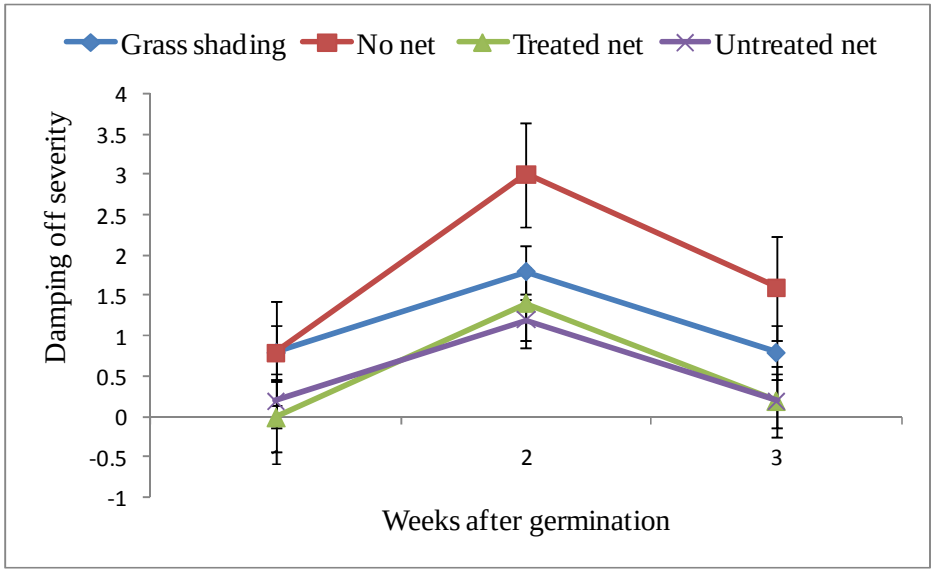

Fig. 3. Damping off severity on cabbage seedlings at Thika

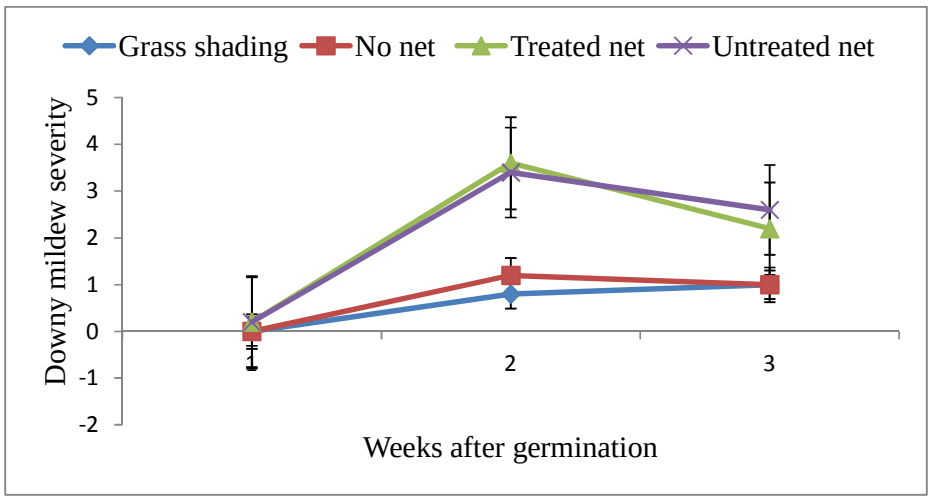

Fig. 4. Downy mildew severity on cabbage seedlings at Thika

Table 3. Mean diseases severity on field cabbage for the whole season at KALRO Kabete and Thika, April-July and July-October 2011, respectively

Treatment	Damping off		Downy mildew		Black rot	
	Kabete	Thika	Kabete	Thika	Kabete	Thika
Treated net	0.13	0.13	0.38	0.42a	0.13a	0.12a
Untreated net	0.12	0.15	0.38	0.42a	0.13a	0.17a
No net (control)	0.20	0.40	0.30	0.13b	0.55b	0.38b
P-Value	0.74	0.05	0.25	0.04	0.01	0.03
SED	0.08	0.06	0.09	0.09	0.08	0.07

Mean in the same column followed by the same letter are not significantly different by Students-Newman Keuls (SNK) at P =0.05

Damping off disease in field cabbage at Thika was observed across treatments the 1st week after transplanting (Fig. 5). Greater severity was recorded in plots with no covers. However, after application of a control measure the effect was minimized.

Black rot severity was observed across the treatments, with higher severity recorded on plots with no cover (Fig. 6). This was in comparison with those plants covered by Agronets, which were relatively lower in severity. A control measure was applied in all the treatments before the 4th week that reduced their severity, which remained low until harvesting. However, uncovered plants were later attacked from the 6th week, and severity increased progressively throughout the remaining period of the season.

Black rot symptoms were observed in the 2nd week after transplanting in Thika. Greater severity was recorded on uncovered cabbages, in the same week a control measure was applied across the treatments and the infection was minimized. However uncovered plants showed higher severity compared with covered plants from the 5th week until the crop matured (Fig. 7).

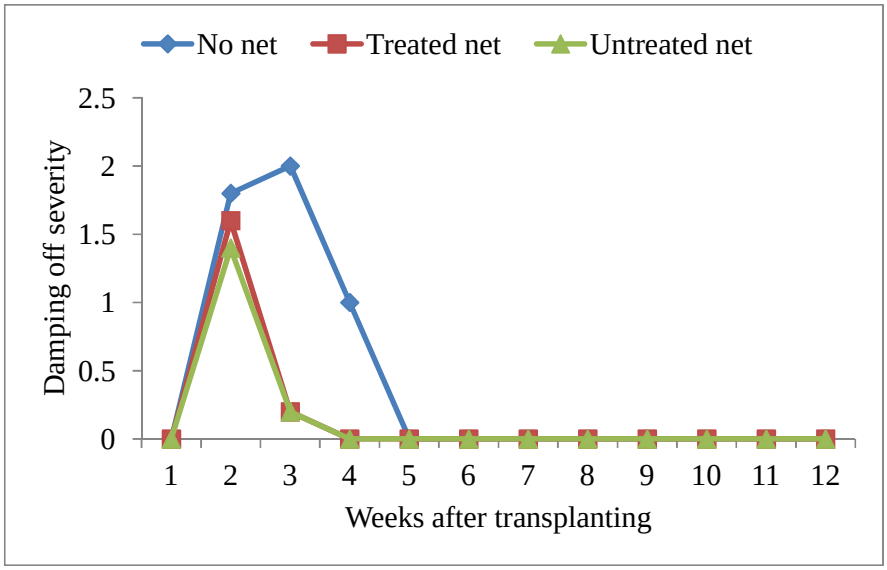

Fig. 5. Severity trend of damping off disease on cabbage at Thika

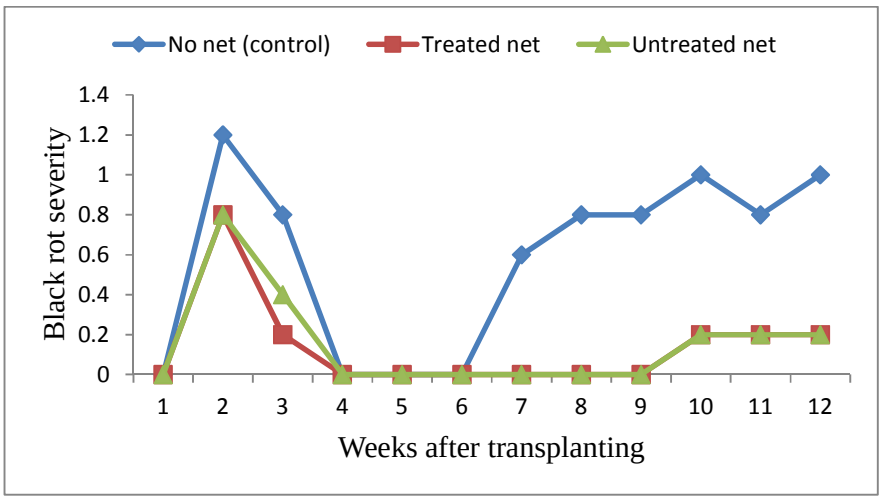

Fig. 6. Black rot disease incidences on cabbage crop in field trial at Kabete

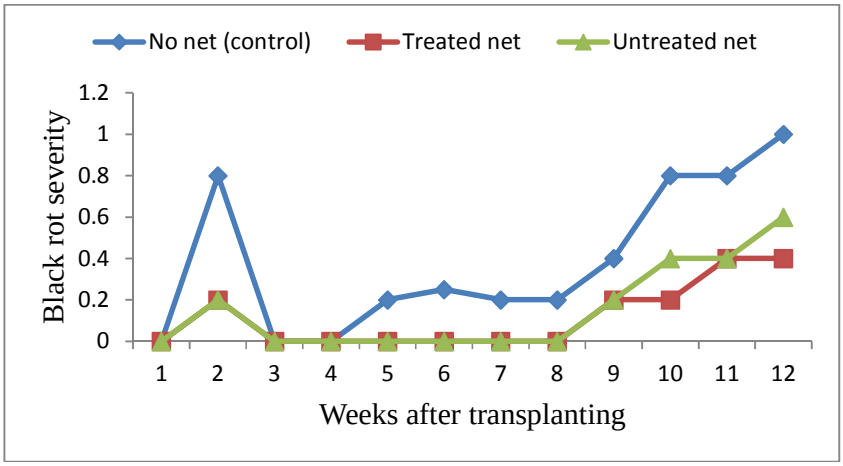

Fig. 7. Severity of black rot in field cabbage at Thika

4. DISCUSSION

Downy mildew severity was greater on seedlings covered by Agronets due to the shade effects of the net that could have increased moisture content inside the net and raised temperatures, both factors enabling disease development in a crop. This is in consistent with other findings in Kenya [13], there was 15% increase in mean daily temperature and relative humidity under the netting treatment due to reduced air movements, evapotranspiration and shading effect compared with the control. In related studies [15], some pathogens such as apple scab, late blight, and several vegetable root pathogens were reported to be more likely to infect plants with increased moisture. Other pathogens like powdery mildew species tend to thrive in conditions with lower (but not low) moisture. Moreover, higher growth rates of leaves and stems observed for plants grown under high carbon dioxide concentrations results in greater fungal spore production. The high severity was also enhanced by the delayed control measure applied on the growing seedlings; this was observed at KALRO-Kabete. This study shows that users of Agronets for cabbage production should keenly monitor for disease presence so that control options can commence before the severity is too high to cause economic damage. Damping off disease was significantly lower on seedlings covered by Agronets compared with those with no cover. This was probably due to the effect of the Agronet acting as a physical barrier during watering and ensured even distribution of water avoiding flash flooding and disease pathogen distribution from their niche of occurrence considering it being a soil borne pathogen. Therefore, covering of plants with Agronets can also provide an opportunity to include integrated disease management practices to protect cabbages both in nursery and field. In related studies by [16,17], the effects of shelterbelt (hessian cloth) on the development of bacterial canker (*Xanthomonas axonopodis pv. citrii*) and fungal scab complex (*Elsinoe fawcetti*) in citrus nursery, reportedly provided protection by acting against wind-driven rains. Moreover, it has been reported that nylon net can be a useful cultural practice for protection of cauliflower seedlings against Alternaria blight (*Alternaria brassicicola*) and black rot at least when they are still in the nursery bed [18]. Black rot is a seed-borne disease [19], though it attacks already growing crop. The spread of black rot in field cabbage was minimized by covering plants with Agronet, since there were reduced rain splashes from infected plants thus minimize spread of inoculum unlike uncovered plants. According to [20], the dispersal of black rot pathogen is due to the combined effect of flow of contaminated water droplets, rain splashes and windy conditions. If diseases are well managed, Agronet technology could provide sustainable production of cabbages and other crops with little or no pesticide application in a season. This would be encouraging considering the high amounts of pesticides consumed in protection of cabbages against arthropod pests in Kenya. For growers, even though the technology may be useful, it should be taken as component of integrated pest and disease management system where monitoring/scouting is critical. This could assist in identifying the best low cost ways of reducing infection at the onset of a disease and thus avoid calendar or frequent use of fungicides in cabbages.

5. CONCLUSION

The results from this study show that Agronets should not expected to control cabbage diseases though the problem may be minimized by use of Agronets. Thus frequent monitoring and use of monitored fungicides at onset of the diseases should form part of integrated pest and disease management on cabbages when Agronets are used. This will prevent disease development to uneconomic levels.

6. RECOMMENDATIONS

1. Field monitoring is important for early detection of disease incidence and for early application of control measures of the diseases especially when growing nursery cabbage seedlings under Agronets.
2. Tests should be done to determine action threshold limits of the diseases and mode of disease spread on Agronet protected cabbages.
3. Farmers should be encouraged to integrate the use of Agronets with application of systemic fungicide at transplanting to manage seedling diseases.

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DISCLAIMER

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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