Research Reports

Microclimate Modification Using Eco-friendly Nets for High-quality Tomato Transplant Production by Small-scale Farmers in East Africa

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SUMMARY. Unfavorable environmental conditions, pests, and viral diseases are among the major factors that contribute to poor growth and quality of tomato (*Solanum lycopersicum*) seedlings in tropical areas. Improving crop microclimate and excluding insects that transmit viruses may improve transplant quality and yield in production fields. This study was carried out in two seasons at the Horticulture Research and Teaching Field of Egerton University in Njoro, Kenya, to investigate the effects of agricultural nets herein called eco-friendly nets (EFNs) on germination and performance of tomato seedlings. Tomato seeds were either raised in the open or under a permanent fine mesh net (0.4-mm pore diameter). Eco-friendly net covers modified the microclimate resulting in significantly higher day temperatures and relative humidity, compared with the open treatment. Nets increased temperature and relative humidity by 14.8% and 10.4%, respectively. Starting seeds under a net advanced seedling emergence by 2 days and resulted in higher emergence percentage, thicker stem diameter, more leaves, and faster growth leading to early maturity of seedlings and readiness for transplanting. Netting improved root development by increasing root quantity and length. Stomatal conductance (g_s) and estimates of chlorophyll content were higher in seedlings under net covering compared with those in the noncovered control treatment. Insect pests and diseases were also reduced under net covering. The use of the net in the production of tomato transplants presented a 36.5% reduction in the cost of seeds, through improved emergence and reduced pest damage. All other factors held constant, healthy and quality transplants obtained under a net covering also translate into better field performance; hence, increasing economic returns for commercial transplants growers, as well as for tomato farmers. Results of this study suggest that EFNs can be customized not only for their effective improvement on growth and quality of tomato transplants but also for their pest and disease management in the nursery alone or as a component of integrated pest and disease management.

Tomato is a popular and versatile food crop grown and consumed all over the world and is the second most important commercial vegetable crop to potato (*Solanum tuberosum*) (Naika et al., 2005).

It is one of the most widely cultivated vegetable crops in Africa, including Kenya. It is grown for home consumption in almost every homestead across the nation serving as an important source of vitamins and a cash

crop for both small- and medium-scale commercial farmers. Apart from vitamins, tomato is also rich in lycopene, an antioxidant, which purportedly fights free radicals that interferes with normal cell growth and activity and thus reducing cancer, heart diseases, and premature aging (Nkondjock et al., 2005). The fruit also contain significant amounts of minerals and fiber. In Kenya, tomatoes always are in high demand both for fresh consumption and processing (Mungai et al., 2000).

Tomato are established by direct seeding or from transplants (Long and Cantliffe, 1975). However, reports have indicated that use of transplants is preferred because of higher plant survival, faster establishment, improved plant uniformity, earlier maturity, and reduced cost of production than direct-seeded plants (Leskovar and Cantliffe, 1994). Whether started directly or by transplants, optimum growth and quality of tomato is dependent on the environment. As a result, researchers have modified the environment to favor the growth of the plant (Caliman et al., 2010; Weerakkody, 1998). Tomato seeds are expensive and farmers in developing countries cannot afford poor germination as a result of unfavorable growing conditions [Horticultural Crop Development Authority (HCDA), 2006]. In addition, tomato seedling production in many parts of sub-Saharan Africa is faced with major challenges like unfavorable weather marked by limited or unreliable rainfall, high or low temperatures depending on the season, as well as severe pest infestation. These challenges are exacerbated by the fact that most tomato growing is by small-scale, resource-poor farmers who cannot afford expensive protected greenhouse crop production technologies. They must therefore produce their seedlings and crop in open fields subject to unfavorable growing conditions. The result of this scenario has been an increased cost of seed per unit area due to poor germination and pest damage. Insect pests like silverleaf whitefly (*Bemisia tabaci*), potato aphid (*Macrosiphum euphorbiae*), and western flower thrips (*Frankliniella occidentalis*) that transmit viral diseases are also experienced under such conditions. In a study conducted in Israel, Berlinger et al. (2002) reported effective management of tomato yellow leaf curl virus through physical exclusion of

silverleaf whiteflies using the nets. On the other hand, the use of protected seedling culture has been shown to improve crop yields. In tomato, higher yields may be achieved with protected than nonprotected seedlings (El-Aidy and Sidaros, 1996).

In an effort to enhance emergence and growth of seedlings, growers normally use mulching as a cultural practice to raise seedlings and a microclimate modification strategy. However, some mulch material, especially organic mulch which is commonly used by small-scale resource-poor farmers in sub-Saharan Africa, harbors various seedling pests and diseases, resulting in additional pesticide and fungicide costs. Many concerns have been raised on the safety of these chemicals to humans and to the environment, and on their cost (HCDA, 2006; Martin et al., 2006; Ministry of Agriculture and Rural Development, 2003). Excessive use of these chemicals also results in the development of resistance in plant pests and diseases. Thus, the need to look into effective and safer eco-friendly methods of control is increasing.

Protected culture is predominantly used in temperate regions where seasonal agro-climatic changes restrict year-round cultivation of crops under open-field conditions. Due to this advantage, Iqbal (1987) recommended its applicability in tropical environments especially for cultivating high value

crops such as tomato during the rainy season. One possibility of protected culture could be the use of EFNs. Nets have been used to protect crops from excessive solar radiation or other environmental hazards in developed countries (Majumdar, 2010). Use of EFN in protected cultivation has been tested and proven to be effective against certain pests of cabbage [*Brassica oleracea* var. *capitata* (Licciardi et al., 2007; Martin et al., 2006)], on alternaria blight (*Alternaria brassicae*), and on black rot (*Xanthomonas campestris* pv. *campestris*) of cauliflower (*B. oleracea* var. *botrytis*) seedlings (Kashyap and Dhiman, 2010). Also noted was reduction in pesticide use as a result of covering the crop with nets. In line with these observations, the current study aimed at investigating the effects of EFN on germination and performance of tomato seedlings in open fields.

Materials and methods

Experimental site

The study was conducted at the Horticulture Research and Teaching Field, Egerton University, Njoro, Kenya, in two seasons (Mar. to Apr. 2011 and Sept. to Oct. 2011). The field lies at latitude 0°23'S and longitude 35°35'E in the Lower Highland III (LH3) Agro-Ecological Zone at an altitude of ≈2238 m above sea level. Average maximum and minimum temperatures range from 19 to 22 °C and from 5 to 8 °C, respectively, with a total annual rainfall of 1200 to 1400 mm and predominantly andosols soils with a pH of 6.0 to 6.5 (Kassilly, 2002).

Planting material, experimental design, and treatments

'Rio Grande' tomato seeds (Kenya Seed Co., Kitale, Kenya) were used in the experiment. 'Rio Grande' is a cultivar with a determinate growth habit and was chosen based on the recommendation of the Kenya Agricultural Research Institute.

The experimental design was a randomized complete block with two

treatments and five replications. Treatments consisted of tomato seedlings produced either under a fine mesh net (0.4-mm pore diameter) (AgroNet; A to Z Textile Mills, Arusha, Tanzania) or in the open (control). Immediately after sowing, metal arches (U-shape) of 0.5-m height and 1-m width were placed over the plots and secured in the soil. These arches were then covered with netting, which was pegged at each corner to minimize wind interference.

Land preparation and maintenance practices

Experimental plots were manually prepared (common practice used by growers in the region) to ≈30-cm depth with final preparation using a fine tooth rake. Beds of 1 × 2 m were prepared and raised to 15-cm height. Thirteen rows, 1-m long and 15-cm apart, were prepared per bed. Tomato seeds were sown at a spacing of 1 cm within the drills. For the control treatments, dry grass was used for mulching and removed after first seedling emergence, as a standard practice used by local farmers. Thereafter, watering was done manually to field capacity whenever necessary ensuring that an equal amount was applied to each plot. Weeding and all other management practices were applied uniformly in all plots.

Data collection

MICROCLIMATE. A thermohygrometer (HM9; Shanghai Precision and Scientific Instrument Co., Shanghai, China) was mounted at the center of each bed to monitor relative humidity and air temperature. Data were collected and recorded on a daily basis in the morning (8:00 AM), at noon, and in the evening (4:00 PM) and averaged to obtain the daily average relative humidity and temperature.

LEAF g_s AND CHLOROPHYLL CONTENT. Leaf g_s (mmol·m⁻²·s⁻¹) and estimates of chlorophyll content in chlorophyll concentration index units (CCIs) were determined on the

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Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
0.4047	acre(s)	ha	2.4711
0.3048	ft	m	3.2808
2.54	inch(es)	cm	0.3937
25.4	inch(es)	mm	0.0394
(°F - 32) ÷ 1.8	°F	°C	(1.8 × °C) + 32

two lower true leaves of 20 randomly selected tomato seedlings from the central rows of each plot starting 21 d after planting (DAP) through the fifth week on a weekly basis. A steady state leaf porometer (SC-1; Decagon Devices, Pullman, WA) and chlorophyll content meter (CCM-200 plus; Opti-Sciences, Tyngsboro, MA) were used, respectively.

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

SEEDLING GROWTH. Twenty central tomato seedlings were randomly selected and tagged for data collection on the first day of seedling growth data collection. From these plants, seedling height, stem diameter, and number of leaves were determined on a weekly interval. During seedling harvesting, 10 seedlings were randomly selected, carefully uprooted, the roots were washed with clean water, the length of the main

root was measured using a ruler, and the number of lateral roots were counted.

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

SEED REQUIREMENT AND COST PER UNIT AREA. From the percentage emergence, seed requirement and cost of seed per hectare were estimated for the different treatments.

Data analysis

The Proc univariate procedure of SAS (version 9.1; SAS Institute, Cary, NC) was used to control for normality of the data before analysis. Data were then subjected to analysis of variance (ANOVA) at $P \leq 0.05$ using GLM. An initial analysis using season as a factor in the model showed no significant difference in season and

season $\times$ treatment interaction for most parameters. Based on this, data for the two seasons were pooled together and analyzed using the statistical model: $Y_{ij} = \mu + \beta_i + \alpha_j + \varepsilon_{ij}$, where Y_{ij} is the tomato seedling response, μ is the overall mean, β_i is the i th blocking effect, and α_j is the effect due to the j th net covering. Significantly different means were separated using least significant difference (LSD) at $P \leq 0.05$.

Results

MICROCLIMATE MODIFICATION. Mean daily temperature and relative humidity were significantly higher under the netting treatment compared with the control throughout the study (Fig. 1). The average daily temperature was 26.8 °C under the net and 23.3 °C in the control treatments reflecting a 15% increase under the nets. Netting also resulted in a higher relative humidity averaging 58.2% compared with 52.7% for the control. Light was not measured in the nursery but in other experiments the nets reduced light quantity ($37.3 \text{ mol} \cdot \text{d}^{-1}$)

Fig. 1. Effect of eco-friendly net on daily air temperature and relative humidity during tomato transplant production in season 1 (Mar. to Apr. 2011) and season 2 (Sept. to Oct. 2011) at Egerton University, Njoro, Kenya; $(1.8 \times ^\circ\text{C}) + 32 = ^\circ\text{F}$.

compared with the open treatment (40.1 mol·d⁻¹).

SEEDLING PHYSIOLOGY. Use of EFN significantly enhanced leaf g_s and chlorophyll content (Table 1). Leaf g_s increased significantly as seedling age increased both under the control and nets, with netting recording the highest g_s at 35 DAP (352.2 mmol·m⁻²·s⁻¹), compared with 267.9 mmol·m⁻²·s⁻¹ in the control treatment.

Leaf chlorophyll content also increased significantly as seedlings aged both under control and nets. During the final day (35 DAP), the net recorded 34.0 CCI while the control had 23.3 CCI. The CCI values are estimates of leaf chlorophyll concentration with higher values indicating higher chlorophyll content.

SEEDLING EMERGENCE AND GROWTH. Seedling emergence was enhanced by net covering (Table 2). On average, seeds sown under netting took 6 d from planting to first emergence compared with 8 d under control depicting a 25% reduction in time for seedling emergence.

Seeds sown under netting had a higher emergence percentage compared with the control throughout the evaluations. By 7 DAP, 61.9% of sown seeds had emerged in the nets compared with only 7.2% for the control. By 11 DAP, the nets had 96.2% of sown seeds emerged compared with 57.1% in the control treatment.

Seedling growth was enhanced under netting (Fig. 2). Seedling height showed a steady increase during all evaluation dates for both treatments. Seedlings under the net were significantly taller compared with the control seedlings with means of 12.0 and 4.7 cm, respectively, during the last data collection day (31 DAP).

The number of leaves differed significantly between treatments. Seedlings under netting had more leaves compared with those in the control at all dates. After 10 DAP, the number of leaves in the control treatment remained relatively constant with 2.4 leaves per seedling. However, seedlings under the nets produced more leaves at 10 and 17 DAP with 2.5 and 3.6 leaves per seedling, respectively.

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

Netting improved seedling root development. Longer roots (8.8 cm) were obtained under the net compared with 8.0-cm mean root length for the control (Table 3). More lateral roots were also observed under the net compared with the control. Mean lateral root number per seedling were 26.1 cm and 17.0 cm for the seedling under the nets and the control, respectively.

INSECT PEST POPULATION AND DISEASE INCIDENCES. Use of EFN helped manage various pest and diseases (Table 4). The number of leafminers (*Lyriomyza* sp.), cotton bollworms (*Helicoverpa armigera*), onion thrips (*Thrips tabaci*), mites (*Tetranychus* sp.), silverleaf whiteflies, and aphids (*Aphis* sp.) were significantly lower under the net covering with a mean of 0.1, 0.1, 0.2, 0.1, 0.1, and 0.2 pests per plant, respectively, over the study period compared with 0.4, 0.4, 2.9, 2.3, 1.8, and 3.6 pests per plant, respectively, under the control.

The major disease observed in the experiment was late blight (*Phytophthora infestans*). The number of seedlings with disease symptoms was significantly lower under the netting treatments with a mean of 4.3% compared with 44.5% in the control.

SEEDLING REQUIREMENT AND COST PER UNIT AREA. Based on seedling emergence percentage, there was a potential of reducing seed requirement per unit area when a net covering was used in nursery seedling production compared with when seedlings were produced in the open (Table 5). Nets had a final emergence of 96.2% while the control had only 59.6% emergence. Using the recommended spacing for 'Rio Grande' of 1 × 0.5 m, this would imply that a grower planting 1 ha of tomato would have to buy 770 more seeds (3.9%) when using the nets to raise the seedlings before transplanting while one starting the seedlings in an open nursery would have to pay for 8080 more seeds (40.4%) to

Table 1. Change in physiological characteristics of tomato seedlings as influenced by eco-friendly net covering at Egerton University, Njoro, Kenya. The values shown are averaged across two seasons, Mar. to Apr. 2011 and Sept. to Oct. 2011.

Treatment ^a	g_s (mmol·m ⁻² ·s ⁻¹)			Chlorophyll content (CCI) ^b		
	DAP (d) ^c					
	21	28	35	21	28	35
Control	178.3 b ^w	222.5 b	267.9 b	11.0 b	17.0 b	23.3 b
Net	275.2 a	322.2 a	352.2 a	18.4 a	27.0 a	34.0 a
<i>P</i> value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
LSD ^w	5.5	1.1	0.8	0.4	0.7	0.3

^aControl treatment was mulched with dry grass as a standard practice used by farmers in the region. Net treatment was covered with a fine mesh net of 0.4-mm (0.016-inch) pore diameter.

^bChlorophyll content index is an estimate of chlorophyll content.

^cDays after planting.

^wMeans followed by the same letter within a parameter and column are not significantly different according to Fisher's protected least significant difference (LSD) at $P \leq 0.05$.

Table 2. Changes in emergence of tomato seedlings as influenced by eco-friendly net covering at Egerton University, Njoro, Kenya. The values shown are averaged across two seasons, Mar. to Apr. 2011 and Sept. to Oct. 2011.

Treatment ^a	Time to first emergence (d)	Emergence (%)		
		DAP (d) ^b		
		7	9	11
Control	8 a ^x	7.2 b	55.5 b	57.1 b
Net	6 b	61.9 a	88.2 a	96.2 a
<i>P</i> value	<0.0001	<0.0002	0.0009	<0.0001
LSD ^x	0.9	11.2	10.3	3.8

^aControl treatment was mulched with dry grass as a standard practice used by farmers in the region. Net treatment was covered with a fine mesh net of 0.4-mm (0.016-inch) pore diameter.

^bDays after planting.

^xMeans followed by the same letter within a parameter and column are not significantly different according to Fisher's protected least significant difference (LSD) at $P \leq 0.05$.

Fig. 2. Effect of eco-friendly net on seedling height, number of leaves, and stem diameter evolution during tomato transplant production in season 1 (Mar. to Apr. 2011) and season 2 (Sept. to Oct. 2011) at Egerton University, Njoro, Kenya. The values shown are averaged across the two seasons. For a specific parameter, data points within the same date with the same letter are not significantly different at $P \leq 0.05$; 1 cm = 0.3937 inch, 1 mm = 0.0394 inch.

compensate the reduction in stand establishment. This represents a 36.5% reduction in seed cost under the nets compared with the control.

Discussion

Netting effectively modified the microclimate around the growing seedlings. There was an average increase in daily temperature by $\approx 3.5^\circ\text{C}$

as a result of covering the seedlings with netting. The use of netting and other types of covering has been shown to restrict air movement around the growing seedlings resulting in higher temperatures (Majumdar, 2010; Nair and Ngouajio, 2010). Similar results have been reported by Shahak et al. (2004), using nets of different colors, and Weerakkody and Peiris (1998), on

Table 3. Effects of eco-friendly net covering on root development of tomato seedlings at Egerton University, Njoro, Kenya. The values shown are averaged across two seasons, Mar. to Apr. 2011 and Sept. to Oct. 2011.

Treatment ^z	Root length (cm/plant) ^y	Roots (no./plant)
Control	8.0 b ^x	17.0 b
Net	8.8 a	26.1 a
<i>P</i> value	<0.0001	<0.0001
LSD ^x	0.1	1.5

^zControl treatment was mulched with dry grass as a standard practice used by farmers in the region. Net treatment was covered with a fine mesh net of 0.4-mm (0.016-inch) pore diameter.

^y1 cm = 0.3937 inch.

^xMeans followed by the same letter within a parameter and column are not significantly different according to Fisher's protected least significant difference (LSD) at $P \leq 0.05$.

polyethylene cover. Relative humidity also was significantly higher inside the nets compared with the control registering $\approx 10\%$ mean increase. Reduction in air movement, evapotranspiration, high temperature, and shading under netting probably caused the increase in relative humidity. These findings are in contrast with those of Parvej et al. (2010), who reported lower relative humidity under polyethylene-covered tomatoes. This is an indication that the impact of nets on microclimate may vary depending on local environmental conditions. Therefore, site-specific studies should be conducted to support recommendations on using the nets in major agro-ecological regions.

Seedlings under the nets had better physiological performance compared with those grown outside. Higher leaf g_s was recorded on seedlings inside the nets with an average increase of 42% compared with g_s of the control seedlings. Seedlings inside the nets showed higher chlorophyll content compared with the control seedlings registering a 55% increase in CCI. Tomato is a warm-season crop, thus temperature increases would favor several physiological and biochemical processes like photosynthetic enzyme activity, g_s , carbon dioxide diffusion, and photoassimilate translocation that would in turn lead to improved seedling growth. Similar observations have also been reported by Adams et al. (2001). Elevated air temperatures inside the net treatments together with improved moisture status and root development

Table 4. Effect of eco-friendly net on pest population and disease attack on tomato seedling in at Egerton University, Njoro, Kenya. The values shown are averaged across two seasons, Mar. to Apr. 2011 and Sept. to Oct. 2011.

Treatment ^z	Leafminers (no./plant)	Cotton bollworms (no./plant)	Onion thrips (no./plant)	Mites (no./plant)	Silverleaf whiteflies (no./plant)	Aphids (no./plant)	Disease (%)
Control	0.4 a ^y	0.4 a	2.9 a	2.3 a	1.8 a	3.6 a	44.5 a
Net	0.1 b	0.1 b	0.2 b	0.1 b	0.1 b	0.2 a	4.3 b
<i>P</i> value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
LSD ^y	0.1	0.1	0.3	0.2	0.1	0.1963	1.3553

^zControl treatment was mulched with dry grass as a standard practice used by farmers in the region. Net treatment was covered with a fine mesh net of 0.4-mm (0.016-inch) pore diameter.

^yMeans followed by the same letter within a parameter and column are not significantly different according to Fisher's protected least significant difference (LSD) at $P \leq 0.05$.

Table 5. Effects of eco-friendly net covering on tomato seed emergence, seed requirement, and percentage increase in seed cost at Egerton University, Njoro, Kenya. The values shown are averaged across two seasons, Mar. to Apr. 2011 and Sept. to Oct. 2011.

Treatment ^z	Emergence (%)	Seeds (no./ha) ^y	Cost increase (%) ^x
Control	59.6	28,080	40.4
Net	96.2	20,770	3.9

^zControl treatment was mulched with dry grass as a standard practice used by farmers in the region. Net treatment was covered with a fine mesh net of 0.4-mm (0.016-inch) pore diameter.

^y1 seed/ha = 0.4047 seed/acre.

^xBased on 100% emergence of tomato seedlings, which required 20,000 seeds/ha according to the spacing of 'Rio Grande' [1 × 0.5 m (3.28 × 1.64 ft)].

could have enhanced uptake of nutrients such as potassium and nitrogen, thereby favoring leaf g_s and chlorophyll content.

Higher transplant success is ideal for any grower. Tomatoes grown inside the nets emerged earlier than those under the control by 2 d. In addition, the final emergence percentage was higher under the net compared with the control. Temperature and soil moisture are among essential factors for successful emergence. The modified internal temperatures and higher soil moisture conditions observed under the nets in the current study could have favored biochemical and physiological processes necessary for germination within the seeds resulting early and higher emergence of seedlings. These findings are in line with results of a previous study on advantages of growing tomatoes under protected culture (Weerakkody and Peiris, 1998). Upon emergence, seedlings under netting showed a relatively better growth than the control seedlings. In general, seedlings in the open (control) required 7 d or more to achieve a similar height to those under the nets. Similarly, seedlings under netting obtained a given leaf number 7 d earlier than the control seedlings. Seedlings under the nets had a thicker stem diameter compared with the control by achieving

a given diameter 14 d earlier. These observations agree with the findings of Weerakkody et al. (1999), who reported enhanced growth of protected tomatoes compared with a control. Better root development (length and number of roots) was also observed under netting treatments compared with the control. These results can be attributed to the microclimate created under the net covering that could have favored better physiological development of seedlings, which is consistent with observations of Adams et al. (2001).

Use of net covering in seedling production considerably reduced populations of leafminers, cotton bollworms, onion thrips, mites, silverleaf whiteflies, and aphids. The net covering used offered a physical barrier excluding many pests, hence lowering the population on the seedlings. In addition, the white nets used could be also a visual barrier for flying pests such as leafminers, onion thrips, moths (Lepidoptera), and silverleaf whiteflies distracting their feeding and mating, hence lowering their population under the nets. In their field tests, Licciardi et al. (2007) and Martin et al. (2006) observed a delay in the infestation of cabbage by aphids under netting. The reduction of the silverleaf whitefly population in seedlings could reduce and delay the risk of begomovirus

transmission such as tomato yellow leaf curl virus to the plant (Berlinger et al., 2002). Higher relative humidity recorded under the netting could also affect the feeding habit of sucking pests, such as silverleaf whitefly and aphids, and consequently lowering their population under netting. Similar results have also been reported in previous studies (Berlinger et al., 2002). In addition, the nets effectively managed late blight incidence compared with the control. Temperature and relative humidity are necessary for the development of the crop and disease pathogens. Most fungal diseases are effective at a temperature range of 25 to 28 °C and relative humidity above 80%. Even though this temperature range was achieved under the nets, relative humidity was not high enough to favor spore germination that probably reduced disease development under the nets. These results confirm those of Kashyap and Dhiman (2010) while working with nylon nets in the management of alternaria blight and black rot in cauliflower seedlings. Although the incidence of viral diseases was not evaluated in the nursery and subsequent field evaluation, it is likely that the use of netting could provide significant benefits in management of those diseases.

Every farmer would prefer to reduce production costs while maximizing profits; the use of netting in seedling production showed a greater reduction in cost than the control. A farmer using nets for protection may save on the cost of buying seed by $\approx 36\%$ on average. This is supported by higher transplant success under the nets compared with the control requiring less seed and potentially increasing economic returns. However, a full economic analysis of the technology including net cost, net management cost, pesticides, and application costs would need to be conducted. Findings

of this study show the immense potential of using nets as an eco-friendly strategy in protecting seedlings from pests and diseases while enhancing their growth and quality as a result of the modified microclimate. In light of these findings, we recommend that the technology be tested on other crops and also with different mesh sizes and colors. It would also be extremely important to test this technology in each agro-ecological region before recommendations to growers since ambient conditions affect the changes in the microclimate that results from net use.

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