Research Paper

Evaluation of Polypropylene Spun-bond Nets for Viral Disease Management in Bitter Gourd (*Mormodica charantia* L.)

J.P. Marasinghe[1*], R.J.K.N.P. Samarasinghe[1], M.G.D.M. Dayawansha[1], G.G.C.N. Silva[2], K.G.S. Senevirathne[1], S.S. Weligamage[1], T.J.D. Saman[3]

[1] *Horticultural Crops Research & Development Institute, Gannoruwa, Sri Lanka*

[2] *Division of Agri-business Unit, Department of Agriculture, Peradeniya, Sri Lanka*

[3] *Best Seeds Company (Pvt) Ltd, Sri Lanka*

[*] *Corresponding author: jeevanimarasinghe@gmail.com*

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Abstract

Bitter gourd (*Momordica charantia* L.) is one of the highly susceptible cucurbits to viral diseases which transmits mainly via insect vectors. The success of existing pest control techniques is limited. Thus, investigating new pest control tactics are important to protect highly valued bitter gourd crop. In the present study, the impact of three practices viz. individual plant netting, seed treatment and plant nursery protection on viral disease incidence and yield was studied. The studies were conducted for 3 consecutive seasons from 2018 *Yala*. Eight treatment combinations were practiced. Seeds were treated with thiamethoxam 70% WS at the rate of 10 g kg^{-1} of seeds. Seedlings were kept in an insect proof net house for two weeks before transplanting in the field. Spun bonded net was used to cover individual plants for 4 weeks. Treatments were placed in a split plot design. Individual and combined effects were statistically analyzed using ANOVA in SAS software. A highly significant effectson virus control (P<0.0001) and yield increase (P<0.001) were detected with netting individual plants and nursery protection gave a significantly high yield (P<0.03). Impact of seed treatment was negative on both virus control and yield. A higher profit margin was estimated with net cover practice over the control without net covers using a partial cost estimation. The individual plant netting practice is a significantly effective new technique for controlling viral diseases and enhancing yield while protecting the environment. It is mostly suitable for organic cultivations, quality seed production and IPM programs.

Keywords: **Bitter gourd, Individual plant netting system, Spun-bond nets, Viral disease management**

Introduction

Bitter gourd (*Momordica charantia* L.) is an important vegetable in Sri Lankan diet and has an export potential too. Bitter gourd grows in a wide range of environments from sea level to a higher elevation and in both *Yala* and *Maha* seasons as well. However, there are certain districts i.e., Anuradhapura and Hambantota identified to favour bitter gourd cultivation.The average yield of the crop has been estimated to be 15 t ha^{-1} (DOA, 2019). In a cost calculation made by the Department of Agriculture (DOA) in 2018 it was estimated that nearly 20% of the total expenditure is attributed to pest and disease control measures in bitter gourd (DOA, 2019). There are many pests and diseases in bitter gourd which cause a significant yield loss. Mainly the sucking insect pests like whiteflies and aphids play a major role in spreading virus diseases in cucurbits, including bitter gourd. Viruses can cause up to 100% yield loss by destroying the whole crop (Brown and Bird, 1992; Dragich *et al*., 2014). Several vector borne viruses have been reported in bitter gourd in Sri Lanka (Bandaranayake *et al*., 2014; Abeykoon *et al*., 2018). A recent study carried out in the Horticultural Crops Research and Development Institute in Gannoruwa has exhibited that all the tested local and imported bitter gourd varieties *Pali*, *Thinnaweli White*, *Matale Green*, *Neerogi*, *Shakthi*, *Krishna* and *Maya* were vulnerable to viral diseases in different extents (DOA, 2017). Though chemical pest control is widely practiced especially in commercial cultivations, there are inefficiencies including resistance build up in vectors (Marasinghe *et al*., 2017) and adverse effects on the environment. Thus, effective vector control strategies to minimize the spread of viral disease that enhance yield and reduce cost of production is scarce for bittergourd currently. Netting is a good alternative to avoid plants from insect transmitted viral diseases.

The present study explores the efficacy and adoptability of spun-bond net material to cover individual plants as a new technology for managing vector borne viral diseases in bitter gourd.

Materials and Methods

The study was carried out in 2018 *Yala* and 2018 -19 *Maha* at the research field of the Horticultural Crops Research & Development Institute, Gannoruwa and 2019 *Yala* in a farmer field in Gannoruwa. The hybrid bitter gourd variety '*Maya*' was used. The trial was laid in a split plot design with three replicates. The plants covered with net bags and without net bags were considered as main plots which separated by a 3 m height insect proof net and left a 2 m border to each side in order to minimize insect interference in between the treatments. Two other practices described below (seed treatment and nursery protection) were randomized in plots with and without net covers and considered as sub plots. Two weeks old plants were transplanted in 18 m2 plots keeping 1.5 m × 1.5 m spacing in between plants and within the rows.

Two plants were maintained in a planting hole and considered as one for the ease of analysis. Accordingly, twelve number of plants were maintained per sub-plot. Fertilization was carried out according to the recommendation of Department of Agriculture (DOA) with the application of basal dressing two days before planting followed by the first application after 4 weeks of planting. Organic fertilizers were also added to planting holes as per the DOA recommendations. Proper irrigation was maintained using sprinklers. The effectiveness ofthe following three practices on managing viral diseases in bitter gourd was tested.

Net bagging

In one set of plots the individual plants were covered with white colour polypropylene spun-bond netting material imported by Hayleys Agriculture Holdings Ltd. Pieces of nets of 2 m ×0.8 m size were used (Figure 1). Two and a half meter Gliricidia poles were stuck to the ground at the four corners around the plant maintaining a 40 cm distance in between each to support the net bag. The bottom of the net bag was covered with soil to prevent entrance of insects and the upper side was knotted above the poles. A coir rope pegged closer to the plant was held upward inside the net bag and tied to the upper part of a pole to support the growth of the vine. The net was established just after transplanting and maintained for 4 weeks and then removed. The other set of plants were grown without covering.

Figure 1. Individual plants covered with spun-bond net

Seed treatment

For the treated set,the seeds were soaked in anaqueous mixture of thiamethoxam 70% WSat the rate of 10 g kg^{-1} of seeds and kept one day and drained and left for germination. Untreated seeds were soaked in water and kept for germination.

Nursery protection

One set of nursery pots were kept in an insect proof net housewhile the other set was kept outside. Both sets were irrigated properly and taken care until transplanting after two weeks from germination. The treatments combinations are given in Table 1.

In the third season (2019 *Yala*) experiment was conducted in a farmer field based on the treatment effects on % virus incidence and or yield observed in the first two seasons. Accordingly, the field was separated to two sections with an insect proof net and seeded with variety ‘Maya’ at the rate of 2 germinated seeds per planting hole. At the time of seedlings popping out at one section of the field each seedlings was covered separately with the net. The nets were removed after 4 weeks and the vine was trained to the trellis which was supported by the wooden poles stuck in between rows. The seedlings of the other section were grown without a net.

Other management practices were carried out within net bag protected and unprotected plants depending on the requirement as in Table 2.

The number of plants with virus diseases in each plot was counted at weekly intervals for three months. In the net covered plots the counts were taken after removal of net cover at the fourth week of transplanting. In research field studies, the average yield was estimated from only six picks of fruits at weekly intervals due to clearance of the field. However, in farmer field study, a total yield was obtained from first to last pick at minimum of 2 day intervals for 2.5 months.

The log transformed virus counts and yield data of each treatment were analysed using ANOVA by SAS software to find the effect of three practices (*i.e*. net bagging, seed treatment and nursery protection). The means were separated by Duncan grouping to find the significantly effective application of each practiceon yield and virus count.

Table1.Treatments of the study used for controlling virus transmission in bitter gourd

Treatment number	Treatment
T_{111}	With net bag + Treated seeds + Protected nursery
T_{211}	Without net bag + Treated seeds + Protected nursery
T_{112}	With net bag + Treated seeds + Unprotected nursery
T_{212}	Without net bag + Treated seeds + Unprotected nursery
T_{121}	With net bag + Untreated seeds + Protected nursery
T_{221}	Without net bag + Untreated seeds + Protected nursery
T_{122}	With net bag + Untreated seeds + Unprotected nursery
T_{222}	Without net bag + Untreated seeds + Unprotected nursery

Table 2. Other management practices carried out within net bag protected and unprotected treatments in the studies during 2018 *Yala*, 2018 -19 *Maha* and 2019 *Yala*

Management practice	Plants without net covers	Plants covered with net
Insecticide usage	Four to five sprays from 10 days after transplanting to prevent gall fly attack and virus transmission	One spray after removal of net
Fungicide usage	Three to four sprays as per requirement to prevent fungal diseases	None or one spray
Water shoot removal	At weekly intervals.	Once only after removal of net.
Trellising and training	Vines were trained from the beginning.	Vines were trained after removal of net.
Weeding	Regular weeding	Weeding 2-3 days before net removal

A partial cost calculation was carried out with additional management practices pertaining to net covering and similarly for without net cover practices. Accordingly, the expenditure and revenues were estimated per season. The profit (profit = revenue– expenditure for additional management practices) and the profit margin (PM) [profit margin =(profit/revenue) × 100] were compared.

Results and Discussion

The cumulative virus incidence during the study periodin each treatment in 2018 *Yala* and 2018-19 *Maha* are presented in Figure 2. Similarly, the average percent viral disease incidence after three months of planting and average yield of 6 picks of fruits in each treatment in 2018 *Yala* and 2018 -19 *Maha* are presented in Figure 3 and Table 4. The combined effect of each practice in each treatment is reflected in the virus incidence and yield.

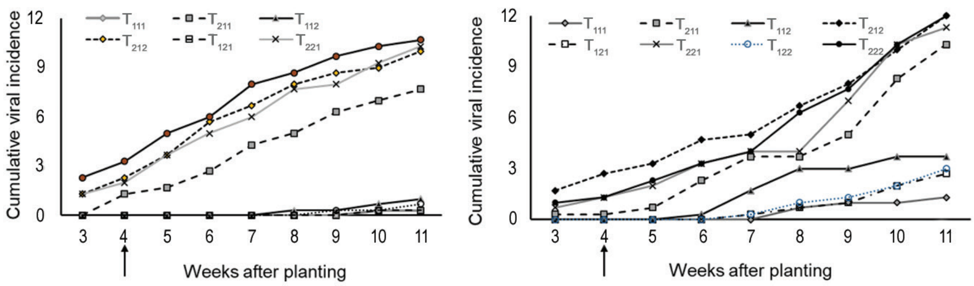

Figure 2. Cumulative viral disease incidence in different treatments during 2018 *Yala* (left) and 2018 -19 *Maha* (right)

Note: Treatment names are explained in Table 1

Effect of practices

On viral disease incidence and yield: The significance of the effect of each practice on viral disease incidence and yield of 2018 *Yala* and 2018 -19 *Maha* are presented in Table 3. Accordingly, a highly significant effect of net bagging was observed (P<0.001). There was a significant reduction of viral disease incidence and yield increment in net covered treatments over the uncovered treatments in both seasons (P< 0.05; Table 3). A significantly higher yield was recorded in untreated seeds than treated seeds during 2018 - 2019 *Maha*. Effect of nursery protection was significant on yield in both seasons with significant increase in protected nurseries. There were no significant interactions among the considered practices (P>0.05).

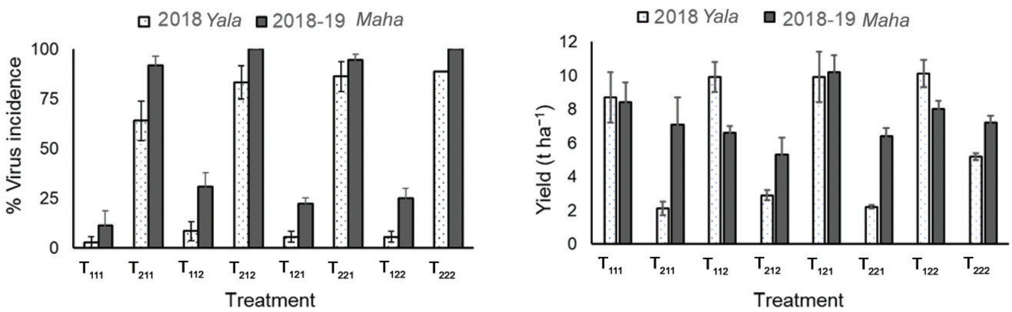

Figure 3. Percentage viral disease incidence after three months of planting (left) and average yield of six picks of fruits in each treatment (right)in 2018 *Yala* and 2018 -19 *Maha.*

Note: Treatment names are explained in Table 1

Table 3. The probability of the significance of effect of tested practices on viral disease incidences and yield in 2018 *Yala* and 2018-19 *Maha*

Practice	Significance of the effect			
	Viral disease incidence		Yield	
	2018 *Yala*	2018-19 *Maha*	2018 *Yala*	2018-19 *Maha*
Net bagging	<0.0001	<0.0001	<0.0001	0.001
Seed treatment	0.5	0.4	0.1	0.02
Nursery protection	0.4	0.1	0.03	0.01
CV%	30.3	20.7	20.1	13.1

CV- Coefficient of variation

Table 4.Treatment effects on viral disease incidence and yield in 2018 *Yala* and 2018-19 *Maha*

Practice	Treatment	Mean virus counts*		Mean Yield (t ha^{-1})	
		2018 *Yala*	2018-19 *Maha*	2018 *Yala*	2018-19 *Maha*
Net bagging	With net bagging	0.2^{B}	0.5^{B}	9.7^{A}	8.3^{A}
	Without bagging	1.0^{A}	1.1^{A}	3.1^{B}	6.5^{B}
Seed treatment	Treated seeds	0.6^{A}	0.8^{A}	5.9^{A}	6.8^{B}
	Untreated seeds	0.6^{A}	0.8^{A}	6.9^{A}	7.9^{A}
Nursery protection	Protected nursery	0.6^{A}	0.8^{A}	7.1^{A}	8.1^{A}
	Unprotected nursery	0.6^{A}	0.8^{A}	5.7^{B}	6.7^{B}

Log transformed data:For the two treatments of each practice the means denoted by different letters are significantly different (P< 0.05) and the letters denoted for two observation (viz. virus count and yield) are not inter-related.

Results in both seasons revealed that net bagging had a significant positive impact on increasing yield and a positive trend in reducing viral disease incidences while nursery protection had a significant impact on increasing yield only. It was also observed that seed treatment had a negative impact on yield at 2018–19 *Maha* season which is controversial with current practices in the DOA. Since the second season results were also lower in the treated seed plots though not significant, future studies are required to find the effects of seed treatment with insecticides on bittergourd with regard to the dose and duration of the treatment on seed germination and pest control. The effect of viral incidence was contrast to the effect on yield. There are limited publications on the impact of seed treatment with neonicotinoids such as thiamethoxam on cucurbit seeds and even difficult to find on bitter gourd. Publications can be found on the impact of seed treatment with different chemicals reporting reduced germination of sorghum, reduced plant vigor in corn (Bittencourt *et al*., 2000) and corn and rice (Stevens *et al*., 2008; Dan *et al*., 2013) due to the use of high doses, phyto-toxicity produced by the chemical, temperature, and duration of treatment. One of the observations made in the study was comparatively slow germination rate after seed treatment.

Considering the significant effects displayed by individual plant netting practice and nursery protection on virus control and/or yield, these two practices were validated ina farmer field study in 2019 *Yala*. The percentage viral disease incidence and yield parameters are presented in Figure 4. The results indicated that in net covered plants, the percentage viral disease incidence was considerably lower and the yield was considerably higher compared to the unprotected plants.

The measurable significant effect of netting technique was the reduction of viral disease incidence and subsequent increase in yield. Seedlings are the most susceptible for virus infection.

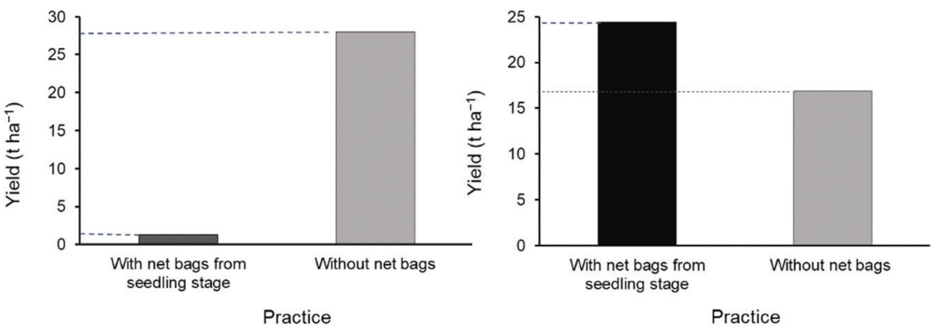

Figure 4. Percentage of viral disease incidence after three months of planting and total yield from first to last pick at 2-3 day intervals for 2.5 months of the farmer field study- 2019 *Yala*

It was observed that after removal of net, the viral disease incidence in the plants were comparatively low and also has taken a longer period to show the symptoms if infected (Figure 2). For certain viruses in cucurbits the young stage is more susceptible since they are preferred by the vectors (Dragich *et al*., 2014) and cucumber mosaic virus infection at young stage would express severe symptoms in the plant and reduce the quality of the pod (Ziiter and Murphy, 2009).

The net cover also reduces virus spread among plants from sap transmission by vectors or mechanical means to a great extent.Net cover has reduced the pesticide requirement for virus vector control and provided an alternative control measure for other pests and diseases *i.e*.,gall fly, aulacophora beetle, downey mildew, while minimizing residues on the crop and environment.The micro climate develop inside the net has supported the main vine to grow well and produced less number of water shoots in contrast to the open plants those required regular removal of water shoots. Also, it was noted that with the net cover practice, regular weeding was not necessary. Weeding was required only towards the removal of net, for preventing viral infections. Further, there was no need to replace virus infected seedlings once covered with the net whereas the seed and seedling requirement for the open plant replacement was comparatively higher. Overall, the net cover protection is expected to offer quality produce while minimizing harm to the environment. A limiting factor with large scale netting is the requirement of high capital investment for the material. However, the cost can be minimized by reusing the netting material and wooden poles for 2-3 seasons.

A partial cost estimation is presented in Table 5. The costs were calculated for 200 m^2 study area. According to the cost comparisons of yield and additional/ compensational practices offered for net Protection of plants using spun-bond nets as a crop cover for individual plants is a new technique to Sri Lanka. Spun-bond nets are used in many applications i.e., weed control, wind protection, thermal protection, reducing sun radiation, preventing soil damage, and preventing insect and other pests (Marasovic and Kopitar, 2019). Spun bonded net is a non woven agro-textile and used to cover crops in different ways as row covers, directly on the plant, and covering of fruits.

In addition to the specific uses of the net, these applications have increased the percentage germination of radish seeds (Rekika *et al*., 2008), gave high yield in potatoes, sweet pepper, zucchini, garlic, lettuce, tomato, maize and cucumber (Cerne, 1994; Rekika *et al*., 2009; Michalik, 2010; Govedarica-Lučić and Milić, 2011; Eugeniusz *et al*., 2011; Govedarica-Lučić and Milic, 2011; Rosa, 2013; Kalisz *et al*., 2014; Rębarz *et al*., 2015; Adamczewska-Sowińska and Turczuk, 2016) and increased plant growth (Rumpel, 1994). The use of spun-bond has a long history and reported to replace insecticide applications in many crops including cucurbits (Vaissiere and Froissart, 1996; Ajmeri and Ajmeri, 2018). Present study also revealed a significant positive impact on controlling viral diseases and subsequent yield increase in bitter gourd. The advantages of the individual net cover practice are ideal for organic agriculture, quality seed production and can be used as a good agricultural practice in IPM programs too.

Table 5. The partial cost estimation of the crop with and without the net cover for 200 m^2 area

Activity	Net covered crop			Crop without net covers		
	Expenditure (average of the costs for additional activities per season (Rs. per 200 m^2)					
	Labour*	Material	Total	Labour*	Material	Total
Pesticide application	1,500.00	100.00	1,600.00	4,500.00	1,500.00	6,000.00
Weeding till net removal	1,500.00	N/A	1,500.00	6,000.00	N/A	6,000.00
Netting & planting	3,000.00	5,625.00 2,880.00 (net and sticks)#	11,505.00	N/A	N/A	N/A
Net removal+ water shoot removal + training	3,000.00	N/A	3,000.00	N/A	N/A	N/A
Water shoot removal + trellising + training	N/A	N/A	N/A	3000.00	N/A	3000.00
Harvesting (extra harvest)	1,500.00	N/A	1,500.00	N/A	N/A	N/A
Total expenditure	10,500.00	8,605.00	19,105.00	13,500.00	1,500.00	15,000.00
Yield × unit	Revenue (Rs. per 200 m^2)					
price$	56,600.00 (566 kg +× Rs.100)	N/A	56,600.00	36,000.00 (360 kg^ × Rs. 100)	N/A	36,000.00
Profit#	Profit = Revenue- Expenditure (Rs. per 200 m^2)					
	N/A	N/A	37,495.00	N/A	N/A	21,000.00
Profit margin (PM)	Profit margin (PM) = (revenue – expenditure)/ revenue (Excluding the expenditure for seeds, fertilizer, irrigation, other labour, etc.					
	66 %			58 %		

[*]Unit price for labour- Rs. 1500.00 (man-day); [$]Price per kg was considered as Rs.100.00; # seasonal cost is given; +total yield of the farmer field study obtained for 'net bagging + untreated seeds + protected nursery'; ^average yield of the three seasons for 'without net bagging + untreated seeds + unprotected nursery'; N/A- Not applicable.

Conclusion

Use of a spun-bond net for covering young individual bitter gourd plants and, seedling protection gave a highly significant effect on reducing viral disease incidences and increased the yield. Although, a high cost is calculated for netting practice, the significant yield increase has compensated the loss, accounting for a higher profit margin compared to the practice without net covers. The use of net cover is an environment friendly technique which reduces the pesticide usage and gives a number of other advantages. Therefore, it is highly compatible for organic farming, quality seed production from healthy plants and IPM programmes. As a potential technology for viral disease management in vegetables including bitter gourd, further advancements of the technique *i.e.*, use pattern, different crops, pests and diseases, and different agro climatic regions arerequired.

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