DOI: http://doi.org/10.4038/tare.v25i3.5586

Tropical Agricultural Research & Extension 25 (3): 2022

RESEARCH ARTICLE

PHYSICAL BARRIERS FOR DIAMONDBACK MOTH MANAGEMENT IN CABBAGE OF UP-COUNTRY REGION IN SRI LANKA

Hettiarachchi HASN[1*] and Hemachandra KS[2]

[1]Agriculture Research Station, Seetha-Eliya, Nuwara-Eliya, Sri Lanka

[2]Faculty of Agriculture, University of Peradeniya, Peradeniya, Sri Lanka

Received: 18 April 2022, Accepted: 15 July 2022

Abstract

Central highland is one of the major Cabbage (*Brassica oleraca*) producing regions in Sri Lanka. Diamondback Moth (DBM) (*Plutella xylostella*) is one of the key pests of cabbage that causes a significant yield loss. Farmers heavily use agro-chemicals to control DBM while ignoring alternative non-chemical eco-friendly pest management strategies. Therefore, attempts were made to evaluate the combined effectiveness of three physical pest management strategies to suppress the DBM population in cabbage. Field experiments were carried out at the Agriculture Research Station, Seetha-Eliya during the 2020 and 2021 *Yala* cropping seasons. A blinking light, sprinkler irrigation and insect-proof net were selected as physical DBM control measures. The combined effects of these strategies were evaluated in comparison with recommended insecticides. The result revealed that the combined effect of blinking lights, sprinkler irrigation and insect-proof net significantly reduced DBM larval infestation and damage severity of cabbage with effective yield performance. Blinking lights and insect-proof net were found to be alternative strategies to manage DMB larval infestation. Routine application of insecticides for DBM control in cabbage could successfully be replaced with these physical barriers. It was concluded that a package for DBM management in cabbage comprising of these measures could be introduced for cabbage farmers in the up-country region in Sri Lanka.

Keywords: Cabbage, Diamondback moth, blinking light, sprinkler irrigation, insect-proof net

INTRODUCTION

Cabbage (*Brassica oleracea*) is one of the most extensively grown vegetables in the Nuwara-Eliya and Badulla districts of Sri Lanka. In 2019, nearly 4,153 ha were under cabbage and the total production was around 116,577 MT (Agstat 2020). The Diamondback Moth (DBM) (*Plutella xylostella*) has been identified as one of the key pests of Cruciferous crops and a dominant species in the Cabbage Caterpillar Complex found in the Uplands of Sri Lanka (Jesudasan and Yogarathnam 1984). Cabbage is mainly grown as a mono-crop, and the crop system becomes susceptible to DBM infestation. The cost of pesticides for controlling DBM has been estimated at around 10-14% of the total cost of cabbage production (Nishantha *et al.* 2016).

Corresponding author: shyamanadeeka@gmail.com

Cabbage farmers highly depend on insecticide spraying in cabbage pest management while giving relatively less attention to environment -friendly pest management measures. Heavy use of insecticides causes higher residue levels in vegetables thereby affecting food safety and human health. Simultaneously, the impact of insecticides on the environment such as the destruction of non-target organisms and air, soil and water pollution are significant. Moreover, continuous use of insecticides on DBMs causes resistance development which in turn weakens the effectiveness of spraying in long term (Ankersmit 1953; Odhiambo *et al.* 2010 and Walker *et al.* 2011). Therefore, it is timely and important to minimize the use of agro-chemicals in vegetables intended for better human health, food and environment safety in

Sri Lanka.

Integrated Pest Management (IPM) is a well-recognized approach to manage pest injuries effectively with minimum use of insecticides. An integrated DBM management program involves the use of all possible, compatible measures including physical, cultural and biological aimed at keeping the pest population below the Economic Threshold Level (ETL). Nonetheless, the IPM strategies need to be more convenient, cost-effective and less time-consuming at the field level thereby enabling farmers to apply them on their farm-lands. The complicatedness of IPM technology has resulted in low level of adoption in the vegetable sector and need to be developing simplified and specific IPM packages for major pest and disease (Jayasooriya and Aheeyar 2015).

However, the studies made so far on assessing the effectiveness of integrated DBM management in cabbage are inadequate. Quantifying the effectiveness is much useful for making future recommendations at the field level in large scale with maximum farmer participation.

Hence, this study was focused on assessing the combined effect of selected three (03) physical barriers that could be used at the farmer field level, as integrated DBM management practices in cabbage.

MATERIALS AND METHODS

The experiment was carried out in the research field, Agriculture Research Station (ARS), Seetha-Eliya during the two consecutive *Yala* seasons of 2020 and 2021 (Planted at February). One-month-old cabbage seedlings (variety- green cornet) were planted in the field at the spacing of 40x30 cm (96 plants/ treatment/replicate) and the crop was maintained as per the recommended agronomic practices of the Department of Agriculture (DOA), Sri Lanka. Three non-chemical DBM control measures were selected and appropriately combined to make five treatments *viz*. T1-Blinking light (BL) T2-Blinking light + Sprinkler irrigation (SI), T3-Blinking light + Sprinkler irrigation + 1 m height Insect Proof Net (IPN), T4-Insecticides only and T5- Untreated control (UTC). These treatments were arranged in a Randomized Complete Block Design (RCBD) with three replicates.

Yellow colour 1.5W, wave-length 570-590, LED blinking bulbs were established at 2m height from the ground and distance between two bulbs was 10m. Bulbs were lighted from 6 pm to 6 am every day throughout the cropping season. Sprinkler irrigation was applied for 30 minutes from 6.00 pm to 6.30 pm every day. Treatments 1, 4 and 5 were watered using the conventional method (water horse in the morning). The crop was allowed for natural pest infestations. Spinosad 25g/l SC, Emamectin benzoate 5% SG and Flubendiamide 24% WG were applied to the T4 alternatively at 10-day intervals from one to three months period and the rest of the treatments were not treated with insecticides. Double layer, 3m height black polythene barrier was established to separate treatments 4 and 5 to prevent the effect of blinking light.
DBM larval count was taken on 10 randomly selected cabbage plants per treatment per replicate at weekly intervals throughout the cropping period and the damage severity was measured by using 10 randomly selected cabbage heads at the time of harvesting. The percentage of leaf injury level was calculated based on the equation adopted by Iman *et al.,* (1990). The number of black rot infected plants/m^2 and disease severity of black rot was recorded at harvesting based on the 0-3 scale (0=no lesions, 1=1-10 lesions, 2=11-25 lesions, 3=>26 lesions) as developed by Alvarez and Cho (1978). Natural enemy counts were taken at the weekly interval by using a sweep net and each sample consisted of 20 consecutive sweeps. Natural enemy identification was done by using specimens at the Insect Museum in Horticulture Crop Research and Development Institute. Total and marketable yields were also recorded. Diamondback moth and natural enemy counts were square-root transformed before analysis. Data were analyzed by analysis of variance (ANOVA) using the SAS 9.1 statistical package.

RESULTS AND DISCUSSION

Diamondback moth infestation in cabbage

DBM infestation was observed from the fourth and third week onward during 2020 *Yala* and 2021 *Yala* seasons respectively. DBM population had developed with crop phenology and declined owing to the rainfall that prevailed during the latter part of the crop phenology in both seasons (Figure 1). However, considering the overall mean of the DBM larvae population throughout the cropping period on cabbage plants, there was a significant declined in DBM larval infestation in all treatments compared to that of untreated control where no DBM control measures were applied in both seasons.

Significant variation in the total DBM larval population was observed among treatments during 2020 *Yala* ($F_{(4,8)}$=91.75, P<0.05) and 2021 *Yala* ($F_{(4,8)}$=24.63, P<0.05) (Table 01). Cabbage plots treated with blinking light only (T1) and blinking light coupled with sprinkler irrigation (T2), showed a significant reduction (P<0.05) of DBM larval infestation compared to that of untreated control. Simultaneously, the mean number of DBM larval infestation was statistically lower (P<0.05) in the plots treated with blinking light, sprinkler irrigation and insect proof net (T3), comparison to the untreated control. Moreover, insecticide-treated plots (T4) had been effective significantly in managing the DBM larval infestation compared to that of untreated control, T1 and T2.

Blinking light showed to be one of the effective tools in controlling the DBM larval population, as it keeps the moths away from cabbage fields. Owens and Lewis (2018) reported that artificial illumination disturbed the habitat of nocturnal insects and their abundance. Further, Nishantha (2019) reported that yellow LED light (570-590 nm) is a good source to repeal the lepidopteron insects of the family Noctuidae and the emitting light disturbs the feeding, egg-laying, mating and other biological behaviours of the moth.

Although significant with untreated control, the effect of T2 and T1 were not significantly different (Table 1). However, Talekar *et al*. (1985) and John *et al*. (1995) pointed out that overhead sprinkler irrigation acted as an effective management tool to control DBM infestation as it helped to wash away eggs and DBM larvae from the leaves. Talekar and Lee (1985) and Harcort (1963) have identified rainfall as one of the unfavourable factors affecting DBM infestation in cabbage. Sprinkler irrigation disturbs the moth's flying behaviour as it creates a similar condition to the rainfall. According to the results of this study, relatively less effect of sprinkler irrigation on DBM control could be attributed to inadequate irrigating time for washing off the eggs and larvae from the cabbage plants.

As per the results, T3 was statistically significant over T1 and T2. Accordingly, the T3 (blinking light coupled with sprinkler irrigation surrounded by an insect-proof net) was found to be the most effective treatment with an average reduction of 61.12 % DBM larval infestation compared to UTC (Fig. 1, Table 1). This could be due to the fact that the insect-proof net acts as a physical barrier and disturbs the flying behaviour of DBM. According to the literature, the use of insect-proof nets has led to the success of DBM population suppression. Simon *et al*. (2014) discovered that an insect-proof net was capable of protecting the cabbage plants effectively from caterpillars and aphids' infestations. Martin *et al.* (2006) stated that the protection of vegetables with a net could prevent unsustainable insecticide application and netting provides protection from caterpillar infestation in the cabbage crop after planting out.

DBM infestation reduction was recorded in insecticide-treated plots as 60.33% and 61.92% in 2020 and 2021 *Yala* respectively. The insecticide-treated plots (T4) and BL+SI+IPN (T3) were shown significant DBM larval population reduction compared to that of untreated control from the sixth week to the twelfth week and fifth week to the seventh week during 2020 and 2021 *Yala* respectively (Fig. 1). However, there was no statistical significance between T4 and T3 with regards to the DBM larval population

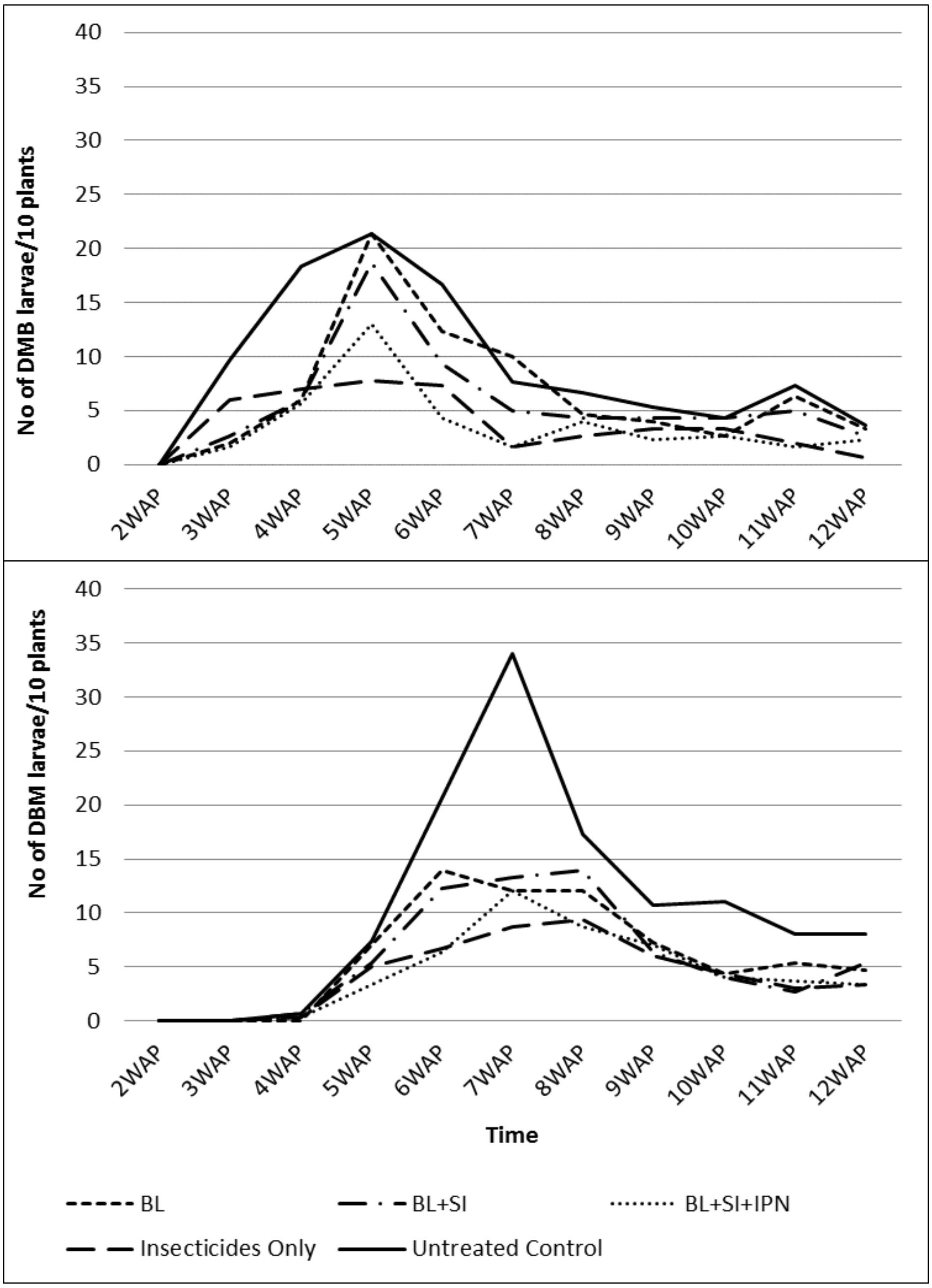

Figure1: Distribution of DBM larval population on cabbage crop cultivated under different pest management strategies at the research field, ARS, Seetha-Eliya during 2020 *Yala* and 2021 *Yala* seasons

during both cropping seasons. In addition, the interaction effect of the two seasons was also not significant ($F_{(2,4)}$=1.27, P=0.3168).

Effect of different treatments on cabbage yield and damage severity

All the treatments gave significantly ($p<0.05$) higher marketable yield compared to that of untreated control. BL+SI+ IPN treated plot (T3) recorded the highest yield (106.11t/ha) during the 2020 *Yala* season and was not significantly different from that of the plots treated with T2 (BL+SI - 94.42t/ha) and T4 (insecticides only - 93.11t/ha) (Table 2). However, the insecticide-treated plot showed a significantly higher marketable yield compared to all other non-chemical treated plots during 2021 *Yala*. A yield increment of 50.3% was observed in the T3 (treatments of

Table 1: Comparison of total DBM larval infestation and infestation reduction percentage with different management strategies

Treatments	Total DBM larval recorded throughout the cropping season		Infestation reduction % from UTC		
	2020 *Yala*	2021 *Yala*	2020 *Yala*	2021 *Yala*	Average
BL	(8.18) b 66.66	(8.55) b 72.67	43.35	32.50	37.92
BL+SI	(8.01) b 64	(7.92) b 62.33	45.60	42.11	43.85
BL+SI+IPN	(7.00) c 48.67	(6.29) c 39.33	58.63	63.47	61.05
Insecticides only	(6.84) c 46.67	(6.42) c 41	60.33	61.92	61.12
UTC	(10.86) a 117.67	(10.38) a 107.67			
CV	3.56	7.43			

Means followed by the same letter in a column are no significantly different at p=0.05. Data were square-root transformed before analysis and values in parenthesis are transformed value.

blinking light, sprinkler irrigation and insect-proof net) during the 2020 *Yala* (Table 2). The field experiment conducted by Neave and Furlong (2001) found that the exclusion of row covers effectively exclude pests with a high potential to increase the quality of the cabbage head. Similarly, Talekar *et al*. (1985) recorded a significant yield increment with the application of sprinkler irrigation. Acar and Paksay (2006) pointed out the beneficial effect of sprinkler irrigation on the yield increment of red cabbage.

Damage severity was significantly lower in all the treated plots compared to that of the untreated control (Table 3). The lowest damage severity was noted in T3 treated plots in 2020 *Yala* (23.99) whereas T4 had the lowest damage severity in 2021 *Yala* (21.67). A negative correlation was observed between the damage severity and recorded marketable yield during 2020 *Yala* (r=-0.95, p=0.009) and 2021 *Yala* (r=-0.97, p=0.005) (Fig. 2).

Effect on natural enemies

Parasitoids belong to the family Braconidae, *Cotesia* spp and family Ichneumonidae, Diadegma spp and *Diadromus* spp and predators belongs to the family Syrphidae, *Platycherirus* spp, *Ischioden scutellare* and Syrphus *adligatus* were observed in both seasons. The natural enemy populations

Table 2: Total and marketable yield obtain under different pest management conditions at the research field, ARS, Seetha-Eliya during the 2020 *Yala* and 2021 *Yala* seasons

Treatments	2020 *Yala*			2021 *Yala*		
	Total Yield	Market-able yield	Yield increment % Compared to UTC	Total Yield	Market-able yield	Yield incre-ment % Com-pared to UTC
BL	115.47 c	76.25 b	30.85	116.97 b	74.8 bc	25.70
BL+ SI	139.22 b	94.42 a	44.16	113.78 b	77.91 bc	28.67
BL+SI+IPN	156.42 a	106.11 a	50.31	118.98 b	79.95 b	30.49
Insecticides Only	143.28 ab	93.11 a	43.37	154.48 a	104.71 a	46.92
UTC	90.06 c	52.72 c	0	108.87 b	55.57 c	0
CV	90.06	10.31		14.84	15.47	

Means followed by the same letter in a column are no significantly different at p=0.05.

Table 3: Crop damage severity under different pest management conditions at the research field, ARS, Seetha-Eliya during the 2020 *Yala* and 2021 *Yala* seasons

Treatments	Damage Severity (%)	
	2020 *Yala*	2021 *Yala*
BL	31.73 b	40.06 b
BL+ SI	28.3 bc	37.53 bc
BL+SI+IPN	23.99 c	30.86 c
Insecticides Only	24.39 c	21.67 d
UTC	46.03 a	52.8 a
CV	8.76	13.28

Means followed by the same letter in a column are not significantly different at p=0.05.

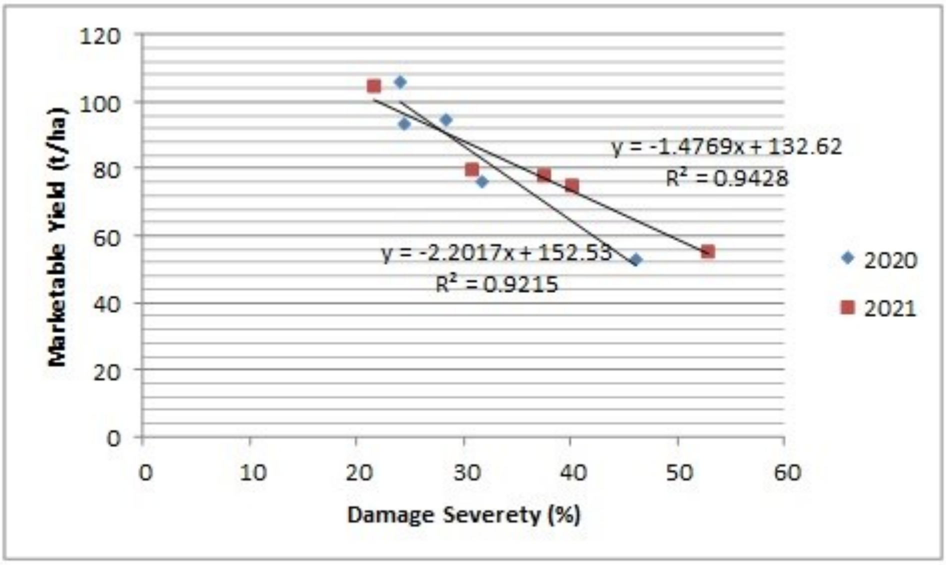

Figure 2: Correlation between marketable yield and the damage severity of cabbage in 2020 *Yala* and 2021 *Yala*.

followed similar trends to the DBM population in all treatments during 2020 *Yala*.

However, natural enemy populations became evident during the latter part of the cropping period in all treated plots in 2021. This may be the reason to observe high DBM larval infestation from the third week to the seventh week after crop establishment in 2021 (Fig. 3). Insecticides treated plots had a significantly lower ($p<0.05$) level of the total natural enemy population in 2020 *Yala*. Untreated control plots had a significantly higher level of the total natural enemy population compared to the other DMB management strategies applied plots in 2021 *Yala*. But no significant difference was observed between the insecticide-treated plots and other non-chemical-treated plots in 2021 *Yala*. Many studies conducted by researchers have discovered the intensive use of insecticides built up a negative impact on natural enemy populations (Bommarco *et al*. 2011; Patra *et al*. 2017).

Effect of different pest management strategies on the cabbage black rot disease

There was no significant difference ($p>0.05$) in black rot (*Xanthomonas campestris*) disease severity and disease incidence among treatment at harvesting during both seasons (Table 4). Bila *et al.* (2015) have reported that wet or rainy weather is one of the major factors that influence the black rot disease and cold weather conditions contribute to the decrease in the disease.

Table 4: Black rot disease severity under different pest management conditions at the research field, ARS, Seetha-Eliya during the 2020 *Yala* and 2021 *Yala* seasons

Treatments	Disease Severity		No of disease incidence plants/m^2	
	2020 *Yala*	2021 *Yala*	2020 *Yala*	2021 *Yala*
BL	**0.67 a**	**1.0 a**	**1.0 a**	**3.67 a**
BL+ SI	**0.67 a**	**1.0 a**	**1.33 a**	**4.0 a**
BL+SI+ IPN	**1.0 a**	**1.0 a**	**1.67 a**	**4.33 a**
Insecticides Only	**0.33 a**	**0.67 a**	**0.67 a**	**3.67 a**
UTC	**1.0 a**	**1.0 a**	**2.0 a**	**4.33 a**
CV	60.9	27.6	67.1	12.9

Means followed by the same letter in a column are no significantly different at p=0.05.

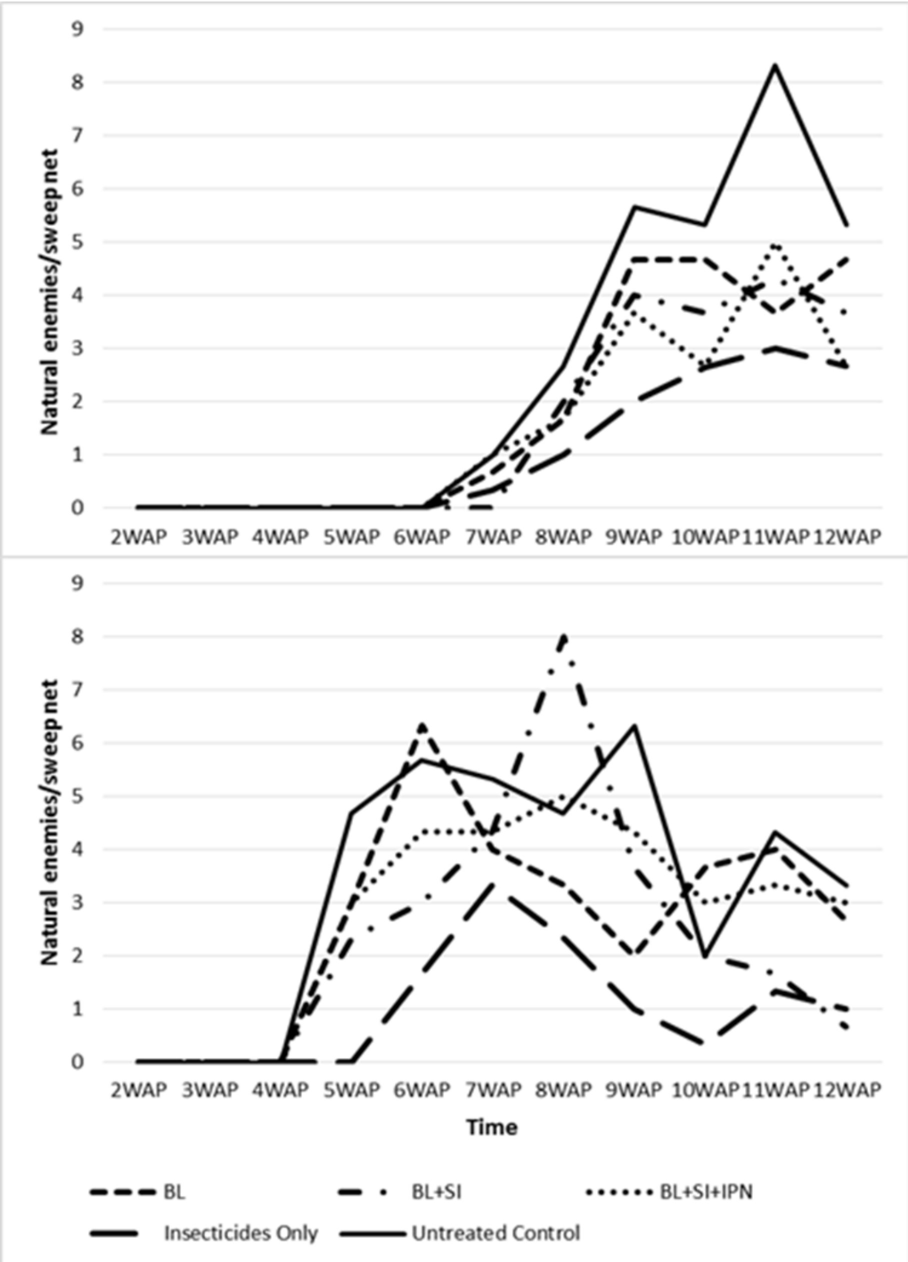

Figure 3: Development of natural enemy population under different management strategies at the research field, ARS, Seetha-Eliya during the 2020 *Yala* and 2021 *Yala* seasons

CONCLUSIONS

The synergetic effect of the blinking lights, sprinkler irrigation and insect-proof net were found to be the most effective combination in reducing DBM larval infestation with increased yield. Blinking lights and insect-proof net appears to be alternative strategies that can be applied in cabbage field for managing DBM larval population. Therefore, a DBM management package consisting of blinking lights, sprinkler irrigation and insect-proof net could be introduced for cabbage farmers in up country region in Sri Lanka with possible other benefits.

AUTHOR CONTRIBUTION

HASNH and KSH developed the concept of the study and designed the experiment. HASNH performed the experiment and analyzed the data. KSH supervised the experiment. HASNH wrote the manuscript. KSH critically revised the manuscript.

REFERENCES

Acar B and Paksoy B 2006 Effect of different irrigation methods on red cabbage (*Brassica oleraceae* L. var. *capitata* Subvar. *F. rubra*) yield and some plant characteristics. Pakistan Journal of Biological Sciences, 9:2531-2534. <https:// docsdrive.com/pdfs/ansinet/ pjbs /2006/2531-2534.pdf>

AgStat 2020 Agricultural statistics, Socio-Economic and Planning Centre, Department of Agriculture, Sri Lanka. pp 33.

Alvarez AM and Cho JJ 1978 Black Rot of Cabbage in Hawaii: Inoculum Source and Disease Incidence. Phytopathology, 68:1456-1459. <https://www.apsnet.org/publications/ phy topathology/backissues/ Documents/1978Articles/ Phyto68n10_1456.PDF>

Ankersmit GW 1953 DDT-resistance in *Plutella maculipennis* (Curt) Lepidoptera) in Java. Bulletin of Entomological Research, 44:421-425. <https://doi.org/10.1017/ S000748530002 5530>

Bila J, Mortenen NC, Wuff GE and Mandjana AM 2009 Cabbage production and black rot disease management by small holder farmers in Southern Mozambique, 9th African crop Science Conference Proceedings, Cape Town, South Africa, 28 September -2 October, 2016, pp 667-671.

Bommarco R, Miranda M, Bylund H and Bjorkman C 2011 Insecticides suppress natural enemies and increase pest damage in cabbage. Journal of Economic Entomology, 104:782-791.<https://www.researchgate.net/ publication/51473712_Insecticides_Suppress_Natural_Enemies_and_Increase_Pest_Damage_in_Cabbage>

Harcourt DG 1963 Major mortality factors in the population dynamics of the diamondback moth, *Plutella maculipennis* (Curt.) (Lepidoptera: Plutellidae). Memoirs of the Entomological Society of Canada, 32:55-56. <https://doi.org/10.4039/ entm9532055-1>

Iman M, Soekarna D, Situmorang J, Made I, Adiputra G and Manti I. 1986 Effect of Insecticides on Various Field Strains of Diamondback Moth and Its Parasitoid in Indonesia. International work shop on Diamond Back Moth Management, Tainan, Taiwan, 11-15 March, 1985, pp. 313-323.

Jayasooriya HJC and Aheeyar MMM 2015 Application of Integrated Pest Management (IPM) in Vegetable Cultivation: Past Experiences and Suggestions for Promotion. Research Report No: 175, Hector Kobbekaduwa Agrarian Research and Training Institute, Sri Lanka.

Jesudasan D and Yogaratnam V 1984 Seasonal population fluctuation of the diamondback moth, *Plutella xylostella* (L.) and its larval parasitoids in the uplands of Sri Lanka. Tropical Agriculturist 140:27-40.

John J McHugh JR and Foster RE 1995 Reduction of Diamond back moth infestation in head cabbage by overhead irrigation. Journal of

Economic Entomology, 88:162-168. < https:// doi.org/10.1093/jee/88.1.162>

Martin T Komlan FK, Houndete T, Hougard M and Chandre F 2006 Efficacy of mosquito netting for sustainable small holders' cabbage production in Africa. Journal of Economic Entomology, 99:450-455. <DOI:10.1603/0022-0493-99.2.450>

Neave SM and Furlong MJ 2011 Field Evaluation of insect exclusion netting for the management of pest on cabbage in the Solomon Islands. Proceeding of the sixth international work-shop on Management of the Diamondback Moth and Other Crucifer Insect Pests, Nakhon Pathom, Thailand, 21-25 March, 2011, pp.144-149.

Nishantha KMDWP, Sandika AL, Babu AGC, Hettiarachchi HASN, Pushpanjali K, Abeytilakeratna PD and Nugaliyadde M M 2016 Farmers' knowledge and attitudes on pesticide usage in vegetable cultivation in Sri Lanka. Tropical agricultural research and extension, 19:244-252.

Nishantha KMWDP 2019 Aloka darawak haraha paliboda mardanaya kirime kramayalk. Agri technology information, technical bulletin 29, Department of Agriculture, Sri Lanka.

Odhiambo JAO, Gbewonyo WSK, Obeng-OforI D, Wilson M D, Boakye DA and Brown C 2010 Resistance of diamondback moth to insecticides in selected cabbage farms in Southern Ghana. International Journal of Biological and Chemical Sciences, 4:1397-1409. <DOI: 10.4314/ijbcs. v4i5.65524>

Owens ACS and Lewis SM 2018 The impact of artificial light at night on nocturnal insects: A review and synthesis. Journal of Ecology and evolution. 8:11337-11358, < https:// doi.org /10.1002/ece3.4557>

Patra S, Dhote VW, Sarkar S and Samanta A 2017 Evaluation of novel insecticides against diamondback moth and natural enemies in cabbage ecosystem. Journal of Environmental Biology, 38:1383-1389. < DOI:10.22438/ jeb/38/6/MRN-439>

Simon S, Komlan FA, Adjaito L, Mensah A, Ngouajio HK and Martin T 2014 Efficacy of insect nets for cabbage production and pest management depending on the net removal frequency and microclimate. International journal of pest management, 60:208-216. < https:// doi.org/10.1080/09670874.2014.956844>

Talekar NS, Lee ST and Huang SW 1985 Intercropping and modification of irrigation method for the control of diamond back moth. International work shop on Diamond Back Moth and its management, Shanhua, Tainan, 11-15 march, 1985, pp.145-151.

Talekar, NS and Lee ST 1985 Seasonality of insect pests of Chinese cabbage and common cabbage in Taiwan. Plant Protection Bulletin, 27: 47-52.

Walker GP, MacDonald FH and Wallace AR 2011 Recent developments in management of diamondback moth in New Zealand. Proceedings of the Sixth International Workshop on Management of the Diamondback Moth and Other Crucifer Insect Pests, Nakhon Pathom, Thailand, 21-25 March, 2011, pp. 234-240.