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Effect of Pest Exclusion Net (PEN) on the Sustainable Production of Late Season Broad Leaf Mustard (BLM) in Chitwan, Nepal

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Abstract: Broad leaf mustard (BLM) (*Brassica juncea* L. var. *rugosa*, Brassicaceae) is one of the most widely consumed vegetable crops in Nepal. The production of crop in open field is constrained by major pests like mustard aphid and flea beetle. This study was aimed to determine the effects of pest exclusion net (PEN) on pest-infestation and yield of BLM cultivar "Khumal Broad Leaf". The experiment was carried out in randomized complete block design (RCBD) with five treatments and four replications. The treatments included control (no mulch + no net + no pesticide spray), black plastic mulch only, reflective plastic mulch only, black plastic mulch + no net + pesticide spray, and PEN + black plastic mulch + no pesticide spray. Data were analyzed with RSTAT software package and means were separated by Duncan's multiple range test (DMRT) at 5% level of significance. The result revealed that crop under PEN had highest plant height (38.99 cm), lowest number of aphid (0-0.86 per plant), flea beetle (0-1.07 per plant) and highest total marketable yield (77.50 ton/ha) while control had lowest plant height (20.06 cm), highest number of aphid (maximum 2.49 per plant), flea beetle (maximum 2.00 per plant) and lowest total marketable yield (13.75 ton/ha). Economic analysis revealed highest benefit-cost ratio in PEN (9.90). This study indicates that the use of PEN protect BLM against aphid and flea beetle, increases yield and can be considered as a viable technology for BLM production by smallholder growers of Nepal.

Key words: Broad leaf mustard (BLM), pest exclusion net (PEN), mustard aphid, flea beetle.

1. Introduction

Broad leaf mustard (BLM) (*Brassica juncea* L. var. *rugosa*, Brassicaceae), popularly known as Rayo in Nepali, is one of the most widely consumed vegetable crops in Nepal. *Brassica* vegetables are a dietary staple in every part of the world with the possible exception of the tropics [1]. BLM has become a daily staple vegetable mainly in Asian region [2].

Regarding its area and production in the country it occupied the fifth position after cauliflower, cabbage, radish and tomato in 2015/2016 [3]. It is widely adapted and can be grown from plain areas to the high hills of Nepal [4].

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The production of *B. juncea* has been declining for the last few years in the country [5]. Infestation by insect-pests is prominent reason for the decline in the production of BLM. A dozen of insect pests have been found associated with this crop. Among these pests, mustard aphid, *Lipaphis erysimi* (Kalt) is considered one of the destructive insect pests [6]. The yield losses of 9% to 95 % were reported due to aphid, *L. erysimi* [7].

Current control strategies are heavily reliant upon insecticide sprays at the farm level [8]. More than 1,185 pesticides have been registered in Nepal [9] and more than 61% pesticides used are against insect pests and are of broad spectrum, applied without considering the consumer's health and surrounding environment [10]. Several instances of cocktail use of

pesticides are reported at the farmer's field. In terms of crops, pesticide use is most intensive in high value crops such as vegetables mustard and cotton. They sell their produce without considering the waiting period [11].

Globally agriculture consumes significant amount of pesticides—approximately 85% of the estimated 2.9 million tons used each year [12]. Awareness among urban consumers on the quality of their food and harmful effects of poisonous residues has increased greatly. Hence, the vegetable growers, especially small-holders, face the challenge of producing more, with the reduced use of chemical pesticides [13]. The current negative opinion by the general public and by scientists of the non-target toxicity of pesticides on humans [14], on beneficial arthropods [15] and on the environment [16], stresses the urgency of alternative pest management strategies. Pest exclusion net (PEN) could meet this challenge by increasing the production by reducing insect-pests incurred losses and simultaneously decreasing the dependence of small-holders to chemical insecticides. PEN provides physical exclusion for insects, thereby reducing the incidence of direct crop damage and insect-transmitted viral disease [17].

Therefore, this study was carried out to assess the efficacy of PEN in controlling the major pests of BLM and its effectiveness in sustainable production of BLM in Nepalese condition. Specifically, this study was aimed to evaluate the effectiveness of PEN in controlling aphid, *L. erysimi* and flea beetle, and compare the yield of BLM in PEN with other treatments.

2. Materials and Methods

2.1 Site Description

The study was conducted at the Horticultural Farm of Agriculture and Forestry University (AFU), Rampur, Chitwan, Nepal. Rampur is located at latitude 27°38′14.1″ N and longitude 84°21′25.2″ E with an elevation of 256 m above the sea level [18]. The field experiment was carried out from January, 2016 to March, 2016.

2.2 Experimental Designs and Treatments

The experiment was laid out in randomized complete block design (RCBD) with five treatments and four replications. The individual plot size was 1.5 m × 2 m. Each plot consisted five rows and 10 columns. Row to row and plant to plant spacing was maintained at 30 cm and 20 cm, respectively.

The treatments were control (no mulch + no net + no pesticide spray) (T_1), black plastic mulch only (T_2), reflective plastic mulch only (T_3), black plastic mulch + no net + pesticide spray (T_4) and pest exclusion net + black plastic mulch + no pesticide spray (T_5) (Fig. 1).

Two pesticide sprays were done at 12 d interval in the treatment involving pesticide spray, i.e., T_2. For aphid control, Imidachlorpid (neonicotinoid) at the rate of 2 g/15 L water was used and for flea beetle control, the mixture of Chlorpyriphos and Cipermethrin (organophosphate) at the rate of 2 mL/L water was used.

2.3 Plant Material, Planting and Harvesting

BLM variety "Khumal Chaudapaat" was used for the study. Seedlings were transplanted in the first week of January. First and second harvests were done on March 6th and March 20th, respectively.

2.4 Data Collection

Six plants from each experimental plot were randomly selected for data collection of pest count, plant development and yield. Leaves were harvested two times from the sample plants during the experiment period, first at 30 days after transplanting (DAT) and second at 45 DAT.

2.5 Data Analysis

Data from the field experiment was statistically analyzed by using RSTAT software package. Microsoft excel was used for tabulation of data and

for simple calculation. Means were separated by Duncan's multiple range test (DMRT) at 5% level of significance. The data for mustard aphid and flea beetle was statistically analyzed by using square root transformation $\sqrt{(x+0.5)}$ as suggested by Ref. [19].

3. Results and Discussion

3.1 Effect on Growth Variables

Plant height is one of the important growth parameters of any crop as it determines or modifies the yield attributing characters and finally the yield [20]. Aphid and flea beetle population had significantly negative correlation with growth variable (plant height). A highly significant result between the treatments was observed on height of the plant (Table 1). Plants inside net measured tallest (38.99 cm), followed by mulched treatments and control (20.06 cm). The possible reason for the positive effect on growth variables is due the enhancement of microclimate by nets [21].

There was highly significant difference between the treatments on breadth and number of leaves (Tables 2 and 3). Highest average breadth of leaves was observed inside net (13.16 cm) and lowest in control (7.93 cm). Likewise, highest number of leaves per plant was observed inside net (8.18) and lowest in control (6.67). This finding corresponds with the findings of Gogo *et al.* [22], who reported greater number of leaves in tomato seedlings under net than in control. This can be attributed with the enhancement of microclimate and its positive influence upon growth variables.

3.2 Effect on Aphid Population

The population of aphid remained regular with different densities on growing BLM. The first record of aphid was observed on 15 DAT. Population increased gradually and reached peak level on March 3rd, 2017. PEN was found to be best in controlling the aphid infestation with average number of aphid per plant maintained well below one during each count. Highest number of aphid per plant was found in control (no net, no mulch and no spray) with average number reaching up to 2.59 (Tables 4 and 5). Among other treatments, black plastic mulch with pesticide spray was found more effective. There was no significant difference between the treatments black plastic mulch and reflective plastic mulch.

3.3 Effect on Flea Beetle Population

Flea beetle, *Phyllotreta cruciferae*, population was low at the young phase of the crop and gradually increased at the late phase as the temperature increased. Statistical analysis revealed significant difference between the treatments on flea beetle population. Net with black plastic mulch without pesticide

Table 1 Effect of pest exclusion net (PEN) and mulching on plant height of late season broad leaf mustard (BLM) at different days in Chitwan, Nepal, 2017.

Treatments	Average plant height (cm)		
	15 DAT	22 DAT	29 DAT
Control (no mulch + no net + no pesticide spray)	12.93^{c}	16.99^{d}	20.06^{d}
Black plastic mulch only	16.33^{b}	21.32^{b}	29.73^{b}
Reflective plastic mulch only	16.15^{b}	20.65^{c}	30.59^{b}
Black plastic mulch + no net + pesticide spray	16.65^{b}	21.21^{bc}	29.87^{c}
Net + black plastic mulch + no pesticide spray	20.63^{a}	26.29^{a}	38.99^{a}
F-test	***	***	***
S.E.	0.12	0.15	0.12
LSD 0.05	0.54	0.60	0.52
CV (%)	2.12	1.84	1.14

DAT: days after transplanting; CV: coefficient of variation; LSD: least significant difference; value with the same letter in a column is not significantly different at 5% by Duncan's multiple range test (DMRT) and S.E.: standard error of the means.

Table 2 Effect of PEN and mulching on breadth of leaves of late season BLM at different days in Chitwan, Nepal, 2017.

Treatments	Average breadth of leaf (cm)		
	15 DAT	22 DAT	29 DAT
Control (no mulch + no net + no pesticide spray)	5.46[d]	7.15[c]	7.93[d]
Black plastic mulch only	6.62[c]	8.88[b]	11.28[b]
Reflective plastic mulch only	6.7[c]	9.04[b]	9.67[c]
Black plastic mulch + no net + pesticide spray	7.29[b]	9.34[b]	11.02[b]
Net + black plastic mulch + no pesticide spray	7.97[a]	10.88[a]	13.16[a]
F-test	***	***	***
S.E.	0.11	0.90	0.13
LSD 0.05	0.52	0.46	0.55
CV (%)	4.96	3.32	3.42

DAT: days after transplanting; CV: coefficient of variation; LSD: least significant difference; value with the same letter in a column is not significantly different at 5% by Duncan's multiple range test (DMRT) and S.E.: standard error of the means.

Table 3 Effect of PEN and mulching on number of leaves of late season BLM at different days in Chitwan, Nepal, 2017.

Treatments	Average number of leaves		
	15 DAT	22 DAT	29 DAT
Control (no mulch + no net + no pesticide spray)	5.04	6.21[b]	6.67[c]
Black plastic mulch only	5.01	7.13[a]	7.45[b]
Reflective plastic mulch only	5.53	7.13[a]	7.37[b]
Black plastic mulch + no net + pesticide spray	5.59	7.42[a]	8.21[a]
Net + black plastic mulch + no pesticide spray	5.02	7.16[a]	8.18[a]
F-test	Ns	***	***
S.E.	0.19	0.17	0.07
LSD 0.05	0.66	0.64	0.42
CV (%)	8.18	5.88	3.57

DAT: days after transplanting; CV: coefficient of variation; LSD: least significant difference; value with the same letter in a column is not significantly different at 5% by Duncan's multiple range test (DMRT) and S.E.: standard error of the means.

Table 4 Effect of PEN and mulching on aphid population per plant after first spray at Chitwan, Nepal, 2017.

Treatments	Aphid population per plant				
	Initial population	3 DAS	6 DAS	9 DAS	12 DAS
Control (no mulch + no net + no pesticide spray)	2.19 ± 0.14[ab]	2.03 ± 0.31[ab]	2.59 ± 0.04[a]	2.07 ± 0.24[a]	1.96 ± 0.21[a]
Black plastic mulch only	2.56 ± 0.19[a]	2.55 ± 0.18[a]	2.34 ± 0.17[a]	2.19 ± 0.08[a]	1.97 ± 0.06[a]
Reflective plastic mulch only	1.88 ± 0.15[b]	1.84 ± 0.15[b]	1.64 ± 0.09[a]	1.76 ± 0.11[a]	1.64 ± 0.08[ab]
Black plastic mulch + pesticide spray + no net	1.90 ± 0.12[b]	1.65 ± 0.09[b]	1.50 ± 0.07[b]	1.20 ± 0.10[b]	1.47 ± 0.05[b]
Net + black plastic mulch + no pesticide spray	0.78 ± 0.03[c]	0.78 ± 0.03[c]	0.79 ± 0.05[c]	0.86 ± 0.03[b]	0.73 ± 0.03[c]
F-test	***	***	***	***	***
LSD 0.05	0.40	0.58	0.30	0.43	0.34
CV (%)	13.00	21.22	10.10	17.40	14.09

DAS: days after spraying; CV: coefficient of variation; LSD: least significant difference; value with the same letter in a column is not significantly different at 5% by Duncan's multiple range test (DMRT) and figures after ± indicate standard error.

was found effective on controlling flea beetle with lowest count on each record, not exceeding on average 1.07 number per plant (Tables 6 and 7). This is followed by black plastic with pesticide spray in controlling the flea beetle infestation. Highest number of flea beetle per plant was recorded in control with maximum number recorded 2.00 (Tables 6 and 7). There was no significant difference between black plastic mulch, reflective plastic mulch and control treatments on flea beetle control.

Table 5 Effect of PEN and mulching on aphid population per plant after second spray at Chitwan, Nepal, 2017.

Treatments	Aphid population per plant			
	3 DAS	6 DAS	9 DAS	12 DAS
Control (no mulch + no net + no pesticide spray)	1.75 ± 0.05^{ab}	1.51 ± 0.04^{a}	1.55 ± 0.06^{a}	1.30 ± 0.03^{a}
Black plastic mulch only	1.80 ± 0.05^{a}	1.42 ± 0.08^{a}	1.38 ± 0.04^{a}	1.09 ± 0.04^{b}
Reflective plastic mulch only	1.63 ± 0.04^{b}	1.24 ± 0.03^{b}	1.03 ± 0.13^{a}	0.97 ± 0.09^{bc}
Black plastic mulch + pesticide spray + no net	1.11 ± 0.06^{c}	0.97 ± 0.06^{c}	0.88 ± 0.07^{bc}	0.91 ± 0.03^{b}
Net + black plastic mulch + no pesticide spray	0.84 ± 0.02^{d}	0.79 ± 0.05^{c}	0.76 ± 0.03^{c}	0.38 ± 0.02^{d}
F-test	***	***	***	***
LSD 0.05	0.140	0.18	0.22	0.17
CV (%)	6.50	9.78	12.87	10.84

DAS: days after spraying; CV: coefficient of variation; LSD: least significant difference; value with the same letter in a column is not significantly different at 5% by Duncan's multiple range test (DMRT) and figures after ± indicate standard error.

Table 6 Effect of PEN and mulching on flea beetle population per plant after first spray at Chitwan, Nepal, 2017.

Treatments	Flea beetle population per plant				
	Initial population	3 DAS	6 DAS	9 DAS	12 DAS
Control (no mulch + no net + no pesticide spray)	1.16 ± 0.09^{b}	1.20 ± 0.07^{a}	1.70 ± 0.08^{a}	1.70 ± 0.06^{a}	1.78 ± 0.06^{a}
Black plastic mulch only	0.88 ± 0.04^{b}	1.15 ± 0.00^{ab}	1.41 ± 0.05^{b}	1.71 ± 0.05^{a}	1.51 ± 0.03^{b}
Reflective plastic mulch only	0.95 ± 0.07^{ab}	1.08 ± 0.11^{ab}	1.50 ± 0.06^{ab}	1.59 ± 0.06^{ab}	1.73 ± 0.04^{ab}
Black plastic mulch + pesticide spray + no net	0.86 ± 0.03^{b}	1.07 ± 0.08^{ab}	1.13 ± 0.05^{c}	1.63 ± 0.05^{b}	1.34 ± 0.05^{c}
Net + black plastic mulch + no pesticide spray	0.93 ± 0.10^{b}	0.82 ± 0.09^{b}	0.88 ± 0.14^{d}	0.88 ± 0.14^{c}	1.07 ± 0.15^{d}
F-test	***	***	***	***	***
LSD 0.05	0.220	0.27	0.23	0.23	0.25
CV (%)	15.00	16.22	11.06	9.98	10.87

DAS: days after spraying; CV: coefficient of variation; LSD: least significant difference; value with the same letter in a column is not significantly different at 5% by Duncan's multiple range test (DMRT) and figures after ± indicate standard error.

Table 7 Effect of PEN and mulching on aphid population per plant after second spray at Chitwan, Nepal, 2017.

Treatments	Aphid population per plant			
	3 DAS	6 DAS	9 DAS	12 DAS
Control (no mulch + no net + no pesticide spray)	2.87 ± 0.04^{a}	2.53 ± 0.08^{a}	1.88 ± 0.08^{b}	2.00 ± 0.08^{a}
Black plastic mulch only	2.33 ± 0.06^{b}	2.32 ± 0.08^{a}	2.17 ± 0.10^{a}	1.75 ± 0.06^{b}
Reflective plastic mulch only	2.38 ± 0.07^{b}	2.30 ± 0.05^{b}	1.94 ± 0.07^{ab}	2.00 ± 0.08^{a}
Black plastic mulch + pesticide spray + no net	1.85 ± 0.09^{c}	1.58 ± 0.03^{c}	1.12 ± 0.11^{c}	1.55 ± 0.06^{c}
Net + black plastic mulch + no pesticide spray	0.70 ± 0.00^{d}	0.79 ± 0.02^{d}	0.76 ± 0.03^{d}	0.00 ± 0.00^{d}
F-test	***	***	***	***
LSD 0.05	0.19	0.84	0.98	0.76
CV (%)	6.22	6.10	11.28	8.13

DAS: days after spraying; CV: coefficient of variation; LSD: least significant difference; value with the same letter in a column is not significantly different at 5% by Duncan's multiple range test (DMRT) and figures after ± indicate standard error.

3.4 Effect on Yield

The analyzed data (Table 8) indicated that the marketable yield was significantly higher in the PEN (77.5 ton/ha). Among the other treatments, more marketable yield was obtained from the treatment black plastic mulch with pesticide spray (43.13 ton/ha). This was followed by the treatments black plastic mulch without pesticide spray and reflective plastic mulch. There was no significant difference between these two treatments with marketable yield of 30.42 ton/ha and 41.67 ton/ha, respectively. Lowest yield was recorded in control

treatment with total marketable yield 13.75 ton/ha (Table 8).

The better growth and higher marketable yield observed inside the PEN could be as a result of the significant reduction in mustard aphid and flea beetle. Gogo *et al*. [23] also reported reduced pest attack, and higher yield and quality tomato from plants grown under net covers compared with open field. Similarly, Nair and Ngouajio (2010) [24] reported higher marketable yields of cucumber under nets compared with control.

3.5 Benefit-Cost Ratio

PEN provided the highest benefit cost ratio (9.9) which was followed by black plastic mulch with pesticide spray (9.42), reflective plastic mulch only (9.16) and black plastic mulch only (5.10). Lowest benefit cost ratio was recorded in control (2.44) as presented in Table 9. Farm gate price in the table indicated the prevailing price at which farmer nearby the research site sold the BLM from its farm irrespective of whether it is grown inside or outside the net. But, it is likely that the BLM produced inside the net fetch higher price than the control as it is higher in quality and free from pesticides [25]. In this case, the benefit-cost ratio for PEN could be greater than the value calculated below. Moreover, Benefit cost ratio was calculated taking into account the yield achieved during single crop season, but if a year is taken into consideration then the benefit cost ratio is likely to be greater for pest exclusion net as BLM is grown in multiple seasons in a year.

Table 8 Effect of PEN and mulching on total marketable yield of BLM (late season) at Chitwan, Nepal, 2017.

Treatments	Marketable yield (ton/ha)		Total marketable yield (ton/ha)
	First harvest	Second harvest	
Control (no mulch + no net + no pesticide spray)	7.29 ± 1.10^{e}	6.46 ± 0.93^{d}	13.75 ± 1.43^{d}
Black plastic mulch only	17.50 ± 0.59^{d}	12.92 ± 0.54^{c}	30.42 ± 0.24^{c}
Reflective plastic mulch only	31.04 ± 0.71^{c}	10.63 ± 0.71^{c}	41.67 ± 0.34^{c}
Black plastic mulch + no net + pesticide spray	27.50 ± 0.34^{c}	15.63 ± 0.53^{b}	43.13 ± 0.86^{b}
Net + black plastic mulch + no pesticide spray	41.67 ± 1.67^{a}	35.83 ± 1.18^{a}	77.50 ± 1.32^{a}
F-test	***	***	***
S.E.	3.51	2.30	4.40
LSD 0.05	2.89	2.34	3.24
CV (%)	7.50	9.32	5.09

CV: coefficient of variation; LSD: least significant difference; value with the same letter in a column is not significantly different at 5% by Duncan's multiple range test (DMRT) and S.E.: standard error of the means.

Table 9 Economics of different treatments for the production of late season BLM at Chitwan, Nepal, 2017.

Treatments	Cost of nursery raising ($/ha)	General cost of cultivation ($/ha)	Variable cost of cultivation ($/ha)	Total cost of cultivation ($/ha)	Total yield (ton/ha)	Farm gate price ($/kg)	Gross income ($/ha)	Net profit ($/ha)	B:C ratio
Control (no mulch + no net + no pesticide spray)	756.19	823.45	2,113.84	2,113.84	13.75	0.53	7,287.5	5,173.66	2.44
Black plastic mulch only	756.19	823.45	2,641.59	2,641.59	30.42	0.53	16,122.6	13,481.01	5.10
Reflective plastic mulch only	756.19	823.45	2,172.05	2,172.05	41.67	0.53	22,085.1	19,913.05	9.16
Black plastic mulch + no net + pesticide spray	756.19	823.45	2,192.6	2,192.6	43.13	0.53	22,858.9	20,666.3	9.42
Net + black plastic mulch + no pesticide spray	756.19	823.45	3,773.13	3,773.13	77.50	0.53	41,150.44	37,377.31	9.9

$/ha indicates US dollar per hectare.

Fig. 1 Broad leaf mustard (BLM) production in different treatments (a) control; (b) black plastic mulch only; (c) reflective plastic mulch only; (d) pest exclusion net.

4. Conclusions

The results of this research demonstrated PEN as a viable technology for improving BLM yield through reduction in major pest population. PEN offer multiple benefits in BLM production. It reduces the number of chemical spray applications and increases the production in quantity and quality. The use of white net is recommended for BLM production in regions with similar climate to those of the site of current study. However, further research on different colored net, vegetable crops and climatic regions is suggested to assess the applicability and flexibility of this technology at global level. In light of above findings, it is recommended that the technology be studied on quantification of reduced amount of insecticides and their residues in a crop cycle.

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