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Efficacy testing of 'soft' pesticides for the management of cabbage butterfly (*Pieris brassicae nepalensis Doubleday*) in Salyan, Nepal

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Abstract
Hit-or-miss use of chemical pesticides, and benightedness on the long-term impacts of hard pesticides on plants, soil, human health, and environments in conjunction with the resurgence of cabbage butterfly are the major impediments to the production of cabbage across the globe. This study, thus, was executed to disinter the effective soft pesticides which can keep the *Pieris brassicae nepalensis* well below the economic injury level, minimize their resurgence or even eradicate them so as to surge the production and productivity of cabbage in Salyan district, Nepal from April to July 2022. The experiment was set down in one factorial randomized complete block design with soft pesticides: Neemix @5 ml/l, Cow urine solution @ 1:10, Botanical extract fermented with cow urine (BEFCU)@1:5, Emamectin benzoate @2 gm/l, Spinosad @0.3 ml/l, Cypermethrin@2 ml/l, and Control, were used as treatments and each treatment were replicated thrice. Mean larval population, percentage of infested leaves, average hole per infested leaves, head diameter, height, and yield of cabbage were the parameters that were documented during the entire experimental period. Spraying of soft pesticides unraveled significant sway in larval mortality as well as diminution in the damage. Zenithal reduction in the cabbage butterfly population was recorded on the application of Spinosad (80%) followed by Cypermethrin (71.29%), Emamectin benzoate (71.25%), and Neemix (67.22%). Similarly, the nadir percentage of damage on leaves was documented on the application of Spinosad and Cypermethrin followed by Emamection benzoate. Maximum head diameter (16.10 cm) and yield (23.44 Mt/ha) were obtained when cabbage was sprayed with Spinosad followed by Cypermethrin whereas minimum head diameter (13.37 cm) and yield (13.76 Mt/ha) was recorded with the control. Spinosad and Cypermethrin, thus, are superior soft pesticides for the management of cabbage butterfly relative to other treatments in Salyan district. Farmers, therefore, are suggested to exploit Spinosad and Cypermethrin for the control and management of cabbage butterfly in an attempt to boost the production and productivity of cabbage.

Keywords: Bio-pesticides, *Pieris brassicae nepalensis*, cabbage, Spinosad, cypermethrin

Introduction

Cabbage (*Brassica oleracea var. capitata* L.), one of the important winter leafy vegetables worldwide having large production and export potential (Talekar, 2000) [28], is believed to have originated from Western Europe and the Mediterranean region (Khan *et al*., 2017) [14]. The leading producer of cabbage on a global scale is China accounting for 47.77% of total cabbage production, followed by India accounting for 13.01% of total cabbage production (FAOSTAT, 2021) [7]. Cabbage, in terms of area and production, is an important cole crop of Nepal after cauliflower which is grown year-round at higher elevations whereas in tropical regions, it can be successfully grown in winter with an average annual production of 494,053 Mt and productivity of 16.67 Mt/ha (MoALD, 2021) [18]. Given that the fertility and water regime of soil is good, cabbage can be grown anywhere (Adhikari *et al*., 2004) [1] which usually requires a long and cool growing season for their commercial production (Cutcliffe & Munro, 1976) [5]. It can't tolerate acidic soil and the optimum pH for the crop is 6.0-6.5. Salyan district, having diverse climatic conditions ranging from tropical to temperate, offers year-round cultivation of off–season vegetables like tomato, cabbage, cauliflower, capsicum, etc. Among them, cabbage is cultivated on 183 ha of land with a production of 2838 Mt and productivity of 15.49 Mt/ha (MoALD, 2021) [18].

Various insect pests such as cabbage butterfly (*Pieris brassicae nepalensis*), diamondback moth (*Plutella xyllostella*), aphids (*Brevicoryne brassicae*), cutworm (*Agrotis ipsilon)*, tobacco caterpillar (*Spodoptera litura*), semi looper (*Thysanoplusia orichalcea*), and others have been known to attack this crop. Among them, the cabbage butterfly (*Pieris brassicae nepalensis*) is a deleterious pest in late-season cultivars of cabbage and cauliflower in Nepal, engendering average annual output losses upto 80-100% (Joshi, 1994) [13]. The cabbage butterfly, belonging to the Pieridae family, is the most destructive pest causing damage at all growth stages: seedlings, vegetative, and flowering stages (Khalid, 2006) [15] leading to over 40% yield loss annually (Ali & Rizvi, 2007) [3]. In Nepal, it passes winter in the plains and migrates to hilly regions during summer (Gupta, 2002) [2]. High temperatures and more sunshine hours, accompanied by low relative humidity and rainfall, favor population build-ups (Sood & Bhalla, 1996) [27]. The life cycle of *Pieris brassicae* varies according to different environmental conditions which usually takes 15-22 days to complete its life cycle during March-April and 30-40 days during November-February. The young larvae are pale yellow which later becomes greenish yellow consisting of a black head, dorsum marked with black spots, and body decorated with short hairs while adults: the butterflies are pale white, with a black patch on the apical angle of each forewing and a black spot on the coastal margin of each hind wing. Males are smaller than females having two black spots on the underside of each forewing.

Early instars larvae/caterpillars (damage-causing stage) feed gregariously and indiscriminately on foliage, scraping the leaf lamina and then biting making round holes that ultimately skeletonize leaving intact the main veins (Younas *et al*., 2004; Khalid, 2006) [37, 15]. Leaves may be riddled thereby making them unfit for consumption which sometimes bores into the head causing significant damage to the crop which in extreme cases, usually during March-April, results in crop collapse (USDA, 1984) [34].

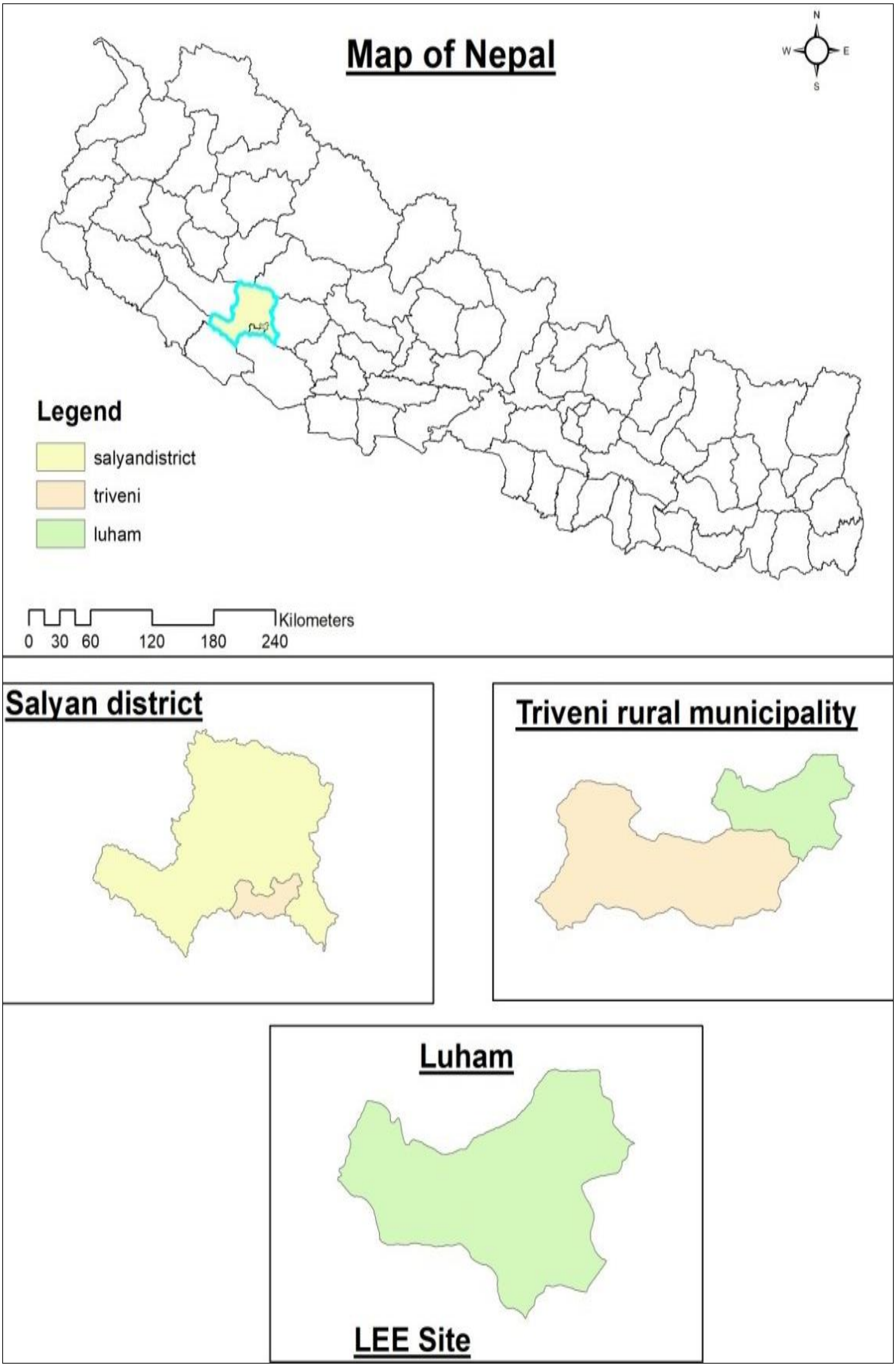
Pieris brassicae has already been introduced in Nepal and is spreading throughout the country and it is now seen in Salyan district. The complete eradication of this pest is impossible; however, many control measures are being discovered to control this pest. Chemical pesticides, bio-pesticides, physical methods, cultural methods, and local methods have been adopted by commercial vegetable growers to combat insect pests. As a sole means of plant protection, 80% of the farmers are using chemical pesticides while the remaining 20% use them in conjunction with other protective measures (Rijal *et al*., 2006) [22]. Nepalese farmers, having a paucity of knowledge or even nescient, normally regard pesticides as a weapon of pest management (Yassin *et al*., 2002) [35]. Insecticide resistance in insects has evolved as a result of the rampant and indiscriminate application of chemical pesticides (Lim, 1990) [17]. The use of organic fertilizer is minimal, whereas chemical fertilizer use is in superfluous amounts, resulting in pest outbreaks as well as resurgence. Apart from the cost, the use of toxic chemical pesticides can engender detrimental effects on human health since cruciferous plants are eaten raw or in semi-cooked conditions. Zenithal use of pesticides was observed in vegetables among cereals, vegetables, cash crops, and fruits: 160 kg ai/ha (PPD, 2015) [21]. The use of pesticides in Nepal has been waxing rapidly at @10-20% per year with an eye to boost up the crops yield (Adhikari, 2018) [2]. In Terai, mid-hills, and mountains, the consumption of pesticides for vegetable cultivation is 25%, 9%, and 7% respectively (Nepali *et al*., 2018) [20]. The current application, arbitrary use of pesticides, has numerous negative consequences for humans and the environment (Thapa, 2003) [32]. Chemical pesticides have been found to have long-term impacts on soil, the environment, human health, groundwater contamination, pesticide resistance, pest resurgence, and other ecological effects (Thapa & GC, 2000) [31]. Therefore, as an alternative to it, plant and animal extracts such as neem leaf extract, cow urine, garlic extract, BECFU, and other soft pesticides can be used for the management of cabbage butterfly (Giri *et al*., 2006) [10]. Soft pesticides are benign and environmentally friendly for stepping down and controlling key insect pests which are commonly known as biopesticides. Bio-pesticides, made from natural products of living organisms such as bacteria, viruses, and fungi in conjunction with plants, are exploited to manage pest populations (Thakore, 2017). Use of such bio-pesticides either kills or repels insects thereby protecting the crops from such pests. Neem trees (*Azadirachta indica)* and garlic (*Allium sativum*), for instance, produce oil that alters the hormones of bugs making them unable to fly, breed, or eat. Tite-pati (*Artemisia vulgarius*) and Timur (*Zanthoxylum armatum*) are extensively utilized for grain storage (Giri *et al*., 2006) [10].

Farmers are in desperate need of precise and reliable information regarding the efficacy of different soft pesticides to minimize infestation by cabbage butterfly. This research will galvanize or enable farmers to switch and demonstrate propensity from chemical management practices to eco-friendly practices though owing slow but long-lasting effect on the quality, production, and productivity of cabbage through the application of effective soft pesticides for controlling *the P.brassicae nepalensis*. With due regard to all IPM-related technologies, the study regarding the pertinent eco-friendly management practices of *P. brassicae nepalensis* is an utmost necessity and hence this study emphasized evaluating the efficacy of market-accessible soft pesticides against cabbage butterfly control with an attempt to disinter the most effective bio-pesticides.

Materials and Methods

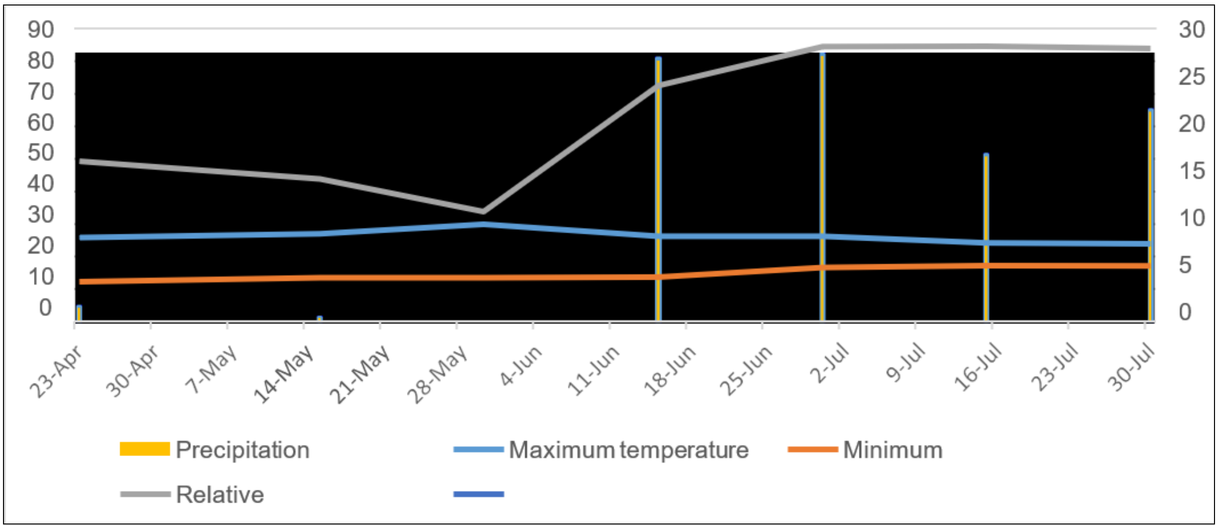
Experimental site

The field trial was performed in Triveni rural municipality-06, Luham, Salyan (Figure 1) located within the line of latitude of 28.30ºN and longitude of 82.23ºE at an altitude of 1009 m above the main sea level. The soil of the study area had a pH of 6.1, organic matter (5.4%), Nitrogen (0.27%), Phosphorous (99 kg/ha), Potassium (168 kg/ha), and Boron (0.591 ppm). The experiment was executed from April to July 2022 during which the average temperature, relative humidity, and precipitation are presented in Figure 2.



Source: (ArcGIS)

Fig 1: Location of the site of study



Source: (NASA-Power, 2022).

Fig 2: Meteorological conditions during the experimental period

Experimental Methods

Entire experimental setup constituted seven treatments *viz*: Neemix, Cow urine solution, Botanical extract fermented with cow urine solution (BEFCU), Spinosad 45% SC, Emamectin benzoate 5% SC, Cypermethrin 10% EC, and control, where each treatment was replicated thrice. Details of each treatment are mentioned in Table 1.

Table 1: Details of each treatment to evaluate their efficacy on management of cabbage butterfly

Treatment Number	Treatments	Trade name	Recommendation dose	Group of insecticide
T1	Neem based pesticide	Neemix	5ml/l	Botanicals
T2	Cow urine solution	-	1:10	Animal origin
T3	BEFCU	-	1:5	Botanicals
T4	Spinosad	Tracer	0.3ml/l	Spinosyns
T5	Cypermethrin	Superkiller-10	2ml/l	Synthetic pyrethroid
T6	Emamectin benzoate	Kingstar	2gm/l	Avermectin
T7	Control			

Design of study

The trial was laid out by utilizing the “T-621” hybrid variety of cabbage in a randomized complete block design having three replications of each treatment. There were altogether 21 plots where plot size was maintained at $4m^2$ (2m×2m) with a total of 25 plants per plot in 5 rows and 5 columns. Row-to-row spacing as well as plant-to-plant spacing was kept at a distance of 40cm while the distance between the replication and treatment was maintained at 1m and 50cm respectively with a field margin of 50cm each on all sides.

Experimental materials, preparation, and their application

All the insecticides were applied on their respective plots with a knapsack sprayer. The first application was made 15 days after transplanting of cabbage and repeated at 15 days intervals where the field efficacy of selected soft pesticides *viz*. Neemix, Cow urine solution, Botanical extract fermented with cow urine solution (BEFCU), Spinosad 45% SC, Emamectin benzoate 5% SC, and Cypermethrin 10% EC were compared with untreated control respectively. All the respective spray fluids were sprayed thoroughly to cover each plant in every treatment.

BEFCU was prepared from locally accessible materials *viz*: 3kg botanical plants (Asuro, Titepati, Lantana), 25 liters cow urine, 50gm chilly, 25gm cardamom, 10gm garlic, 25gm onion, 250gm turmeric powder, and 25 liters water. It was fermented for 4 weeks which was then thoroughly mixed with water in a ratio of 1:5 and the entire mixture of 555 ml/liter was sprayed.

Nursery bed preparation and seed sowing

For nursery bed preparation, the experimental plot was thoroughly ploughed, and well-decomposed FYM was incorporated into the soil. The hybrid variety of cabbage: T-621 was used for the study. The nursery bed was kept 3m in length and 1m in width where seeds were sown in March 2022, under protected conditions, at a depth of about 2cm in lines 5cm apart. Regular watering was carried out as per the requirement. After complete germination of the seed and seedling growth, they were transplanted to the main field.

Field preparation and agronomic practices

The field was thoroughly ploughed twice with a mini tiller followed by leveling. Well-decomposed FYM was incorporated into the soil @20ton/ha. Pits with dimensions of 20cm in width and 15cm in depth were made for transplantation of cabbage seedlings wherein the chemical fertilizers *viz*: Urea (46:0:0), DAP (18:46:0) and MOP (0:0:60) were used @120:90:40 kg NPK/ha were mixed well in the soil. Seedlings that were 28 days old with 3-4 true leaves were transplanted. Half of the recommended dose of Nitrogen was applied as basal dose while the remaining half dose was given in two equal split doses as a top dressing by ring method at 30 DAT and 45 DAT respectively. To overcome the deficiency of boron, 15 kg/ha was applied (MOALD, 2021) [18].

Observations and data collection

Pre-counting was made prior to each spray while post-treatment counting was executed at 3 and 7 days after each treatment application. The number of Cabbage butterfly larvae was determined from 5 randomly selected plants of each plot through visual counting by opening the leaves from the head of the cabbage usually in the morning. The percentage of infested leaves and the number of holes per leaf were documented at the 7th day of spraying whereas the head height, diameter, and yield were recorded at the time of harvesting. Diminution in the pest population through the use of different treatments over control was calculated by exploiting the modified Abbott's formula used by Fleming and Ratnakaran (1985) [8].

$$\text{Population Reduction over Control (PROC) \%} = \left[1 - \left(\frac{Ca}{Cb} \times \frac{Tb}{Ta}\right)\right] \times 100$$

Where,

Ta: Post-treatment population in treatment Tb: Pre-treatment population in treatment Cb: Pre-treatment population in control Ca: Post-treatment population in control

Statistical analysis

Microsoft Excel and GenStat version 14.2 were used to carry out statistical analysis of amassed data. One-way ANOVA was used to test the impact of different soft pesticides over control on larval population, number of infested leaves and holes per leaf, head height, diameter, and yield of cabbage. With an eye to disinter the significant divergence among the different parameters that were considered, one-way ANOVA with Duncan's Multiple Range Test (DMRT) was executed. Data were also transformed by using square root transformation [SQR (x+0.5)] as and when required (Gomez & Gomez, 1984) [11].

Results

Effect of Treatments on the average larval population of cabbage butterfly

The first spray of insecticides

Application of soft pesticides after 15 days of transplanting unleashed a substantial difference in abating the larval population count of *P. brassicae nepalensis* clearly visible from Table 2. The nadir larval population (0.26) was documented from the application of Spinosad subsequently followed by Cypermethrin (0.33) whereas the apical larval count was documented with control (1.06). Likewise, at 7 days after the first spray, the lowest larval population was recorded from spraying of Spinosad and Cypermethrin each displaying the figure of 0.2 subsequently followed by Emamectin benzoate (0.26). Larval population, however, was documented as the highest with control exhibiting the figure of 0.86.

Similarly, Spinosad was unveiled to be pre-eminently superior pesticide in subsiding the larval population displaying a reduction of 74% and 71.67% at 3 and 7 days after application respectively which is subsequently followed by Cypermethrin (60% and 71.29%) while cow urine was disinterred to the least effective pesticide exhibiting the reduction of 35.33% and 28.67% at 3 and 7 days after application respectively.

Table 2: Effect of different treatments against cabbage butterfly after 1st spray

Treatments	Pre-treatment	3DAS	PROC (%)	7 DAS	PROC (%)
Neemix @5ml/l	0.86	0.40^{b}	57.67	0.26^{b}	67.22
Cowurine@1:10	0.86	0.66^{c}	35.33	0.53^{c}	28.67
BEFCU@1:5	0.66	0.53^{bc}	51.11	0.33^{bc}	61.67
Emamectin benzoate@2gm/l	1.13	0.40^{b}	60.00	0.26^{b}	71.25
Spinosad@0.3ml/l	0.86	0.26^{a}	74.00	0.20^{a}	71.67
Cypermethrin@2ml/l	1.13	0.33^{ab}	60.00	0.20^{a}	71.29
Control	1.0	1.06^{d}		0.86^{d}	
F-test	Ns	***		***	
P-value		<0.001		<0.001	
SEm(+-)		0.015		0.018	
LSD(0.05)		0.42		0.51	

Note: Means with the same letter in the column are not significantly different at p = 0.05 by DMRT. *Significant at 5% (*p*< 0.05), ** Significant at 1% (*p*< 0.01), *** Significant at 0.1% (*p*<0.001), and NS: not significantly different at 5% (*P*>0.05). SEM = Standard error of mean, LSD = Least significant difference, CV = Coefficient of variance, DAS = Day after spraying and figure in the parenthesis indicate [SQR(x+0.5)] transformation value

3 days after the first spray, the highest population reduction of cabbage butterfly was recorded with Spinosad (74.00%) and Cypermethrin (60.00%) as well as Emamectin benzoate (60.00%) followed by Neemix (57.67%) and BEFCU (51.11%) while the lowest reduction percentage was found with cow urine solution (35.33%). Similarly, Spinosad was found continuously superior at reducing the larval population at 7 days after the first spray with a 71.67% reduction rate which was followed by Cypermethrin and Emamectin benzoate with a reduction rate of 71.29% and 71.25% respectively. Likewise, the population reduction of larvae with Cow urine (28.67%) was found to be the least among all treatments at 7 days after the first spray.

The second spray of insecticides

During the second spray, different insecticides were found significantly efficacious in forestalling the increase in the larval population of cabbage butterfly as evinced from Table 3. Spinosad was disinterred to be extremely effective in stepping down the larval population exhibiting the lowest population of 0.13 at three days after 2nd spray whereas the highest larval population was documented with control (1.13). Likewise, at 7 days after the second spray, the nadir larval count was recorded with Spinosad (0.13) which is statistically compatible with the application of Cypermethrin (0.13) whereas the zenithal larval population was noted with control (1.06).

In addition to this, Spinosad was disinterred to be the pre-eminently superior pesticide in waning the larval population displaying a reduction of 71.91% and 74% at 3 and 7 days after application respectively followed by Cypermethrin (64.75% and 60%) whereas cow urine was disinterred to the least effective pesticide exhibiting the reduction of 30.41% and 35.33% at 3 and 7 days after application respectively.

Table 3: Effect of different treatments against cabbage butterfly after 2ndspray in Salyan, Nepal 2022

Treatments	Pre-treatment	3DAS	PROC (%)	7DAS	PROC (%)
Neemix @5 ml/l	0.66	0.26bc	61.98	0.26b	57.67
Cowurine@1:10	0.66	0.40c	30.41	0.40c	35.33
BEFCU@1:5	0.46	0.33bc	45.27	0.33bc	51.11
Emamectin benzoate@2 gm/l	0.86	0.25b	63.54	0.26b	60.00
Spinosad@0.3 ml/l	0.73	0.13a	71.91	0.13a	74.00
Cypermethrin@2 ml/l	0.66	0.20a	64.75	0.13a	60.00
Control	1.43	1.13d		1.06d	
F-test	Ns	***		***	
P-value		<0.001		<0.001	
SEm(+-)		0.07		0.02	
LSD (0.05)		0.18		0.20	

Note: Means with the same letter in the column are not significantly different at p = 0.05 by DMRT. *Significant at 5% ($p< 0.05$), ** Significant at 1% ($p< 0.01$), *** Significant at 0.1% ($p<0.001$), and NS: not significantly different at 5% ($P>0.05$). SEM = Standard error of mean, LSD = Least significant difference, CV = Coefficient of variance, DAS = Day after spraying and figure in the parenthesis indicate [SQR(x+0.5)] transformation value

The third spray of insecticide

The application of insecticides produced a significant difference in controlling the larval population of cabbage butterfly as evidenced by Table 4. 3 days after the third spray, the lowest larval population was documented with Spinosad (0.13) followed by Cypermethrin and Emamectin benzoate each displaying the value of 0.2 whereas the highest larval population was noted with control (1.2). Similarly, the lowest larval population of 0.13 was noted with the application of Spinosad at 7 days after the third spray which is statistically at par with Cypermethrin (0.13) while the highest larval population was noted with control (1.26).

In addition to this, Spinosad was unraveled to be pre-eminently superior pesticide in dwindling the larval population displaying a reduction of 80% followed by Cypermethrin (76.67% and 70%) at 3 and 7 days after application respectively whereas cow urine was disinterred to the least efficacious pesticide exhibiting the reduction of 26.67% and 30% at 3 and 7 days after application respectively.

Table 4: Effect of different treatments against cabbage butterfly after 3rd spray in Salyan, Nepal 2022

Treatments	Pre- treatment	3DAS	PROC (%)	7DAS	PROC (%)
Neemix@5ml/l	1.13	0.33b	43.33	0.20b	56.67
Cowurine@1:10	0.86	0.53c	26.67	0.46c	30.00
BEFCU@1:5	0.86	0.33b	35.55	0.20b	40.00
Emamectin benzoate@2gm/l	1.13	0.20ab	60.00	0.20b	62.22
Spinosad@0.3ml/l	0.86	0.13a	80.00	0.13a	80.00
Cypermethrin@2ml/l	0.66	0.20ab	76.67	0.13a	70.00
Control	1.0	1.20d		1.26d	
F-test	**	***		***	
P –value	<0.01	<0.001		<0.001	
SEm(+-)	0.081	0.013		0.026	
LSD(0.05)	0.29	0.10		0.24	

Note: Means with the same letter in the column are not significantly different at p = 0.05 by DMRT. *Significant at 5% ($p< 0.05$), ** Significant at 1% ($p< 0.01$), *** Significant at 0.1% ($P<0.001$), and NS: not significantly different at 5% ($p>0.05$). SEM = Standard error of mean, LSD = Least significant difference, CV = Coefficient of variance, DAS = Day after spraying and figure in the parenthesis indicate [SQR(x+0.5)] transformation value

Effects of different treatments on the percentage of infested leaves at all sprays Significant difference was observed in the proportion of infested leaves at each spray of insecticides which is pellucid from Table 5. From the scrutinization of the table, it is evident that cabbage plants that were sprayed with Spinosad displayed the minimum percentage of infested leaves (13.48%) seven days after the third spray which is statistically compatible with the application of Cypermethrin exhibiting 13.83% of infested leaves. Quite the contrary, the maximum proportion of infested leaves (45.71%) were documented from those cabbage plants which were not applied with insecticides followed by the application of cow urine solution displaying the maximum percentage of infested leaves (36.33%).

Table 5: Effects of different treatments on the percentage of infested leaves at all sprays in Salyan, Nepal 2022

Treatments	First spray		Second spray		Third spray 3DAS 7DAS	
	3 DAS	7 DAS	3 DAS	7 DAS		
Neemix@5ml/l	27.26^{bc}	29.68^{bc}	28.72^{b}	32.84^{b}	28.11^{b}	24.43^{b}
Cow urine@1:10	29.98^{c}	33.99^{c}	33.89^{b}	35.79^{b}	36.33^{c}	34.56^{c}
BEFCU@1:5	29.79bc	33.41c	31.94b	34.73b	30.26bc	25.79bc
Emamectin benzoate@2gm/l	21.14ab	25.23ab	27.21b	29.95b	19.58ab	17.22ab
Spinosad@0.3ml/l	17.77a	18.35a	18.73a	17.41a	15.08a	13.48a
Cypermethrin@2ml/l	19.19a	20.22a	19.76a	18.93a	16.58a	13.83a
Control	34.36c	37.71c	41.65c	45.71c	37.94c	37.88d
F-test	***	***	***	***	***	***
LSD (0.05)	6.962	7.810	7.403	6.855	7.135	6.533
SEm(+-)	2.260	2.535	2.403	2.225	2.322	2.038
P-value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Means with same letter in column are not significantly different at p = 0.05 by DMRT. *Significant at 5% ($p< 0.05$), ** Significant at 1% (P< 0.01), *** Significant at 0.1% (P<0.001), and NS: not significantly different at 5% (P >0.05). SEM = Standard error of mean, LSD = Least significant difference, CV = Coefficient of variance, DAS = Day after spraying and figure in the parenthesis indicate [SQR(x+0.5)] transformation value

Effects of different treatments on the average number of holes per infested leaves at all sprays

Although there was a substantial reduction in the larval population through the application of soft pesticides, there was no considerable difference in the number of holes on leaves on any day even after all sprays which is evinced from Table 6.

Table 6: Effects of different treatments on the average number of holes per infested leaf at all sprays in Salyan, Nepal 2022

Treatments	First spray		Second spray		Third spray	
	3 DAS	7 DAS	3 DAS	7 DAS	3 DAS	7 DAS
Neemix@5ml/l	3.56	2.70	1.89	1.53	1.40	1.30
Cowurine@1:10	4.19	3.43	1.97	1.49	1.57	1.14
BEFCU@1:5	3.84	2.97	1.84	1.423	1.54	1.38
Emamectin benzoate@2gm/l	3.86	3.12	1.68	1.553	1.36	1.08
Spinosad@0.3ml/l	3.71	2.86	2.03	1.37	1.50	0.74
Cypermethrin@2ml/l	3.60	3.24	2.01	1.72	1.22	0.74
Control	3.66	2.83	2.12	1.59	1.22	1.64
Grand mean	3.77	3.04	1.93	1.52	1.46	1.14
F-test	Ns	Ns	Ns	Ns	Ns	Ns

Means with the same letter in the column are not significantly different at p = 0.05 by DMRT. *Significant at 5% ($p< 0.05$),** Significant at 1% ($p< 0.01$), *** Significant at 0.1% ($p<0.001$), and NS: not significantly different at 5% ($p>0.05$). SEM = Standard error of mean, LSD = Least significant difference, CV = Coefficient of variance, DAS = Day after spraying and figure in the parenthesis indicate [SQR(x+0.5)] transformation value

Effects of different treatments on cabbage yield, head diameter, and height

From the perusal of Table 7, it is unraveled that there was a significant impact of soft pesticides on the yield, head diameter in conjunction with height. Maximum head yield (23.44 Mt/ha) was obtained through the application of Spinosad whereas minimum yield (13.76 Mt/ha) was recorded from the control. Similarly, cabbage plants in Spinosad-treated plots gave a maximum head diameter of 16.10 cm whereas the minimum head diameter (13.37 cm) was recorded from plots where no treatments were applied. In addition to this, the maximum head height (13.97 cm) was documented from the plots where they were sprayed with BEFCU which is statistically analogous (13.54 cm) with the application of Spinosad; however, head height was the lowest (11.02 cm) in those cabbage plants where no any pesticides were applied.

Table 7: Effects of different treatments on cabbage yield, head diameter, and height

Treatments	Yield (mt/ha)	Head diameter (cm)	Head height (cm)
Neemix @5ml/liter	18.19c	14.77bc	12.30b
Cow urine @1:10	16.33d	14.06c	12.06c
BEFCU @1:5	17.04d	14.17c	13.97a
Emamectin benzoate@ 2 gm/l	19.29c	14.47c	13.30ab
Spinosad@0.3ml/l	23.44a	16.10a	13.54a
Cypermethrin@2ml/l	22.02b	15.06ab	13.46ab
Control	13.76e	13.37d	11.02d
Grandmean	17.46	14.58	12.82
F-test	**	**	*
P-value	<0.01	<0.01	<0.05
SEm (±)	1.057	0.230	0.027

LSD (0.05)	3.25	0.71	0.08
CV (%)	12.10%	3.16%	1.49%

Means with the same letter in the column are not significantly different at p = 0.05 by DMRT. *Significant at 5% (p< 0.05),** Significant at 1% (p< 0.01), *** Significant at 0.1% (p<0.001), and NS: not significantly different at 5% (p>0.05). SEM = Standard error of mean, LSD = Least significant difference, CV = Coefficient of variance, DAS = Day after spraying and figure in the parenthesis indicate [SQR(x+0.5)] transformation value

Discussions

Sway of soft pesticides on the mean larval population of cabbage butterfly

Soft pesticides were found to be substantial, efficacious, and consistent in waning the cabbage butterfly population thereby precluding their resurgence to reach the economic injury level. Spinosad proved to be superior relative to others as a result of the zenithal stepping-down of the larval population of *P. brassicae nepalensis* over control all the time. We obtained maximum PROC (80%) on 3rd and 7th days after the third spray of Spinosad which is in conformity with the findings of Muthukumar *et al*. (2007) [19] who recorded the highest PROC of 78.7% against cabbage butterfly (Figure 3).

Cypermethrin was disinterred as another promising bio-pesticides in our study which exhibited a 76.67% of dwindling of *P. brassicae nepalensis* after 3 days of third spray which is compatible with the inference drawn by Legwaila *et al*. (2014) [16], Khan & Kumar (2017) [14], Dhawan *et al*. (2010) [6] and Tomlin (1994) [33].

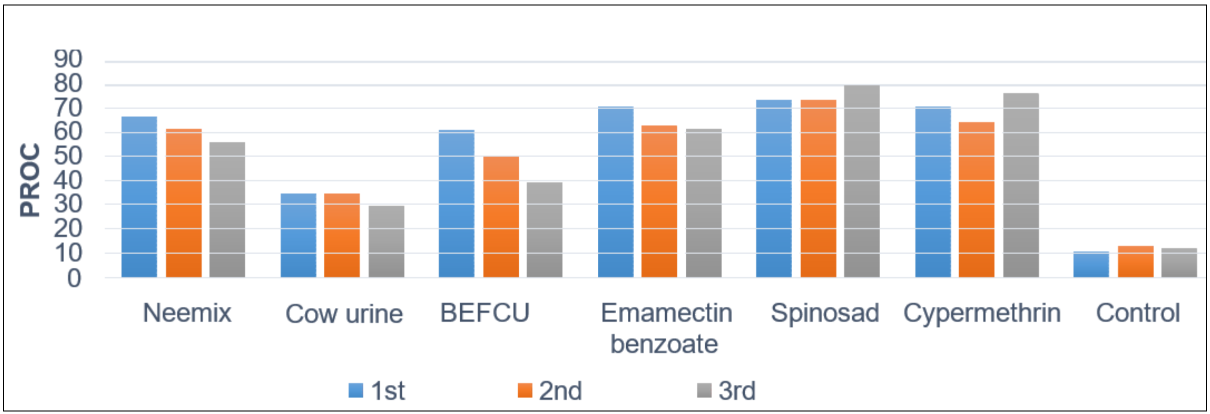


Fig 3: Impact of spraying of different insecticides on PROC (%) of cabbage butterfly population

Emamectin benzoate was found nearly as efficacious as Cypermethrin in dwindling larval population of cabbage butterfly exhibiting a reduction of 71.25% after 7 days of the first spray. This contention is in harmony with the assertion of Singh, Rai and Singh (2010) [26] and Youha & Hongemi (2009) [36] who reported a step-down of 80-90% over the control on lepidopteran pests. Neemix gave poor performance compared to other insecticides giving a maximum PROC of 56.67% (seven days after the third spray) which is in line with the contention of Temurade, Deshmukh, and Nemade (1992) [29]. Sharma and Gupta (2009) [24], however, reported neem-based pesticides to be effective rendering up to 88% of reduction over control against *P. brassicae* which contradicts our assertion.

Impacts of soft pesticides on the percentage of infested leaves

Application of Spinosad divulged least percentage of leaves (13.48%) infested by *P. brassicae* seven days after the third spray relative to others whereas the highest percentage of damaged leaves were recorded with control at 3rd and 7th days after all spraying followed by cow urine solution displaying the minimum percentage of infested leaves (29.98%) three days after the first spray. These findings are in accordance with the inferences drawn by Bajracharya *et al*., (2016) [4] who reported that Cypermethrin and Spinosad were effective for waning the leaves damage and achieving higher larval population control in the field condition.

Influence of soft pesticides on the average number of holes on the leaf

Despite the reduction in the larval population by the use of soft pesticides, there is a non-significant difference in the number of holes per leaf. This might be due to the infestation of the field by *P. brassicae* even before the application of pesticides. Sallam, Soliman and Khodary (2015) [23] results accorded strong ground to warrant our findings who reported that the post-infestation application of chemical insecticides doesn't have a significant effect on mining percent reduction.

Effects of soft pesticides on head yield, diameter, and height

Maximum head yield of 23.44 Mt/ha was obtained with the application of Spinosad whereas the lowest was recorded from the control (13.76 Mt/ha) followed by cow urine solution and BEFCU. Similar results were also documented by Gautam (2022) [9]. Cabbage in Spinosad treated plots gave a maximum head diameter of 16.10 cm which was followed by the application of Cypermethrin and Emamectin benzoate. In addition to this, a maximum head height of 13.97 cm was obtained from the use of BEFCU, however, the lowest height was obtained from the plants that were applied with cow urine solution. These inferences are corroborative with the assertion drawn up by Singh and Bhandari (2015) [25] who reported that Spinosad is one of the effective pesticid es to control cabbage butterfly thereby resulting in higher crop yield.

Conclusion

Deep insights on the efficacy of soft pesticides for the management of cabbage butterfly (*Pieris brassicacae nepalensis*) galvanize the farmers to forestall the rampant application of chemical pesticides which have untoward consequences on plants, soil, human health in conjunction with the environment. From the experiment, it was unveiled that a maximum reduction in cabbage butterfly population and head yield was found through the application of Spinosad followed by Cypermethrin and Emamection benzoate. Neemix and BEFCU were disinterred as considerable soft pesticides in abating the pest population via frequent application. All in all, Spinosad and Cypermethrin were found to be cost-effective pesticides in securing the superior yield by thwarting the cabbage butterfly population to reach economic injury level thereby subsiding the damage to the leaves and plant as a whole.

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Conflict of interest statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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