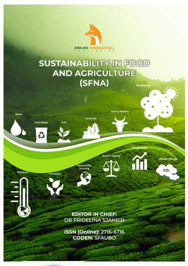
ZIBELINE INTERNATIONAL PUBLISHING

ISSN : 2716-6716 (Online)
CODEN: SFAUBO

Sustainability in Food and Agriculture (SFNA)

DOI: http://doi.org/10.26480/sfna.02.2020.80.87



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RESEARCH ARTICLE

EFFICACY AND PROFITABILITY OF USING DIFFERENT IPM (INTEGRATED PEST MANAGEMENT) MEASURES FOR THE CONTROL OF CAULIFLOWER APHIDS (*Brevicoryne brassicae* Linn.) IN DIFFERENT GENOTYPES OF CAULIFLOWER IN CHITWAN DISTRICT, NEPAL

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ARTICLE DETAILS

Article History:

Received 24 April 2020
Accepted 25 May 2020
Available online 02 June 2020

ABSTRACT

Cauliflower is a vegetable with huge nutritive benefits and economic importance. However, it is vulnerable to economic damage by many insects and cauliflower aphids (Brevicoryne brassicae) are considered one of them. The irrational use of chemical pesticides for control of pests has become a threat to human health as well as the ecosystem. An alternative method is hence, felt necessary. In this context, a two factorial experiment was laid out in RCBD design to determine the efficacy of various pesticides against cauliflower aphids in different varieties of cauliflower. Three bio-pesticides viz Jholmol, Beauveria(2ml/L), and Neemix(2ml/L) along with a synthetic pesticide Acetamiprid (1g/L) and control (water) were sprayed on varieties: Kathmandu Local, Snow Grace and Snow Mystique. The results revealed that acetamiprid treated plots showed highest reduction of aphids after 4 and 8 days of first and second spray and 4,8 and 12 days of third spray. Significant results were seen among varieties for number of aphids after 12 days of second and third spray as significantly lower number of aphids were seen in Snow Mystique compared to Kathmandu Local and Snow Grace. Acetamiprid was statistically superior over other treatments for reduction of aphids in Snow Grace, Kathmandu Local and Snow Grace, Snow Mystique after 4 and 8 days of third spray respectively. Snow Grace was statistically superior over other varieties for yield, harvest index and curd height. Hence, this study elucidates that Acetamiprid could be suggested for optimum control of aphids. Jholmol, Beauveria and Neemix also showed promising bio-efficacy against aphids. Beauveria and Jholmol could be suggested as cost-efficient pesticides against cauliflower aphids.

KEYWORDS

Jholmol, Beauveria, Neemix, IPM, B: C ratio, aphids.

1. INTRODUCTION

Cauliflower (*Brassica oleracea* var. *botrytis*) is a member of the family Cruciferae and is one of the popularly cultivated vegetables. It falls among top preferred vegetables due to its nutritional importance and is hence, grown extensively in Nepal. It is consumed as vegetable in forms of curries, soups and pickles. It is a rich source of minerals viz iron, magnesium, phosphorus, potassium and sodium accompanied by its richness in vitamin A and B1 (Savita et al., 2014). Besides, cauliflower contains relatively lower amount of fat compared to a higher amount of fiber, Vitamin B9, L-Ascorbic acid including water, thus possessing an opulent nutritional density (Eimon et al., 2019).

About 9.71 % of Agri-GDP in Nepal is contributed by vegetables and cruciferous vegetables are one of the top contributors. Cauliflower is grown in an area of around 35,974 ha with productivity of 14.8 mt/ha (MOALMC, 2018). The production of cauliflower in China is 20 mt/ha and 19.76 mt/ha in India, which is far greater than that of Nepal (FAO, 2018). The main reasons for low production and productivity of cauliflower, limiting the profitable cultivation quality and marketable yield, is high cost of pesticides and attack by various insect pests and diseases (Imran, 2018). The insect pests viz aphid (*Brevicoryne brassicae* Linn.), diamondback moth, tobacco caterpillar, etc. are of more significance in cauliflower because they affect its yield and quality (Yadav and Malik, 2014). Aphids suck sap from the leaves throughout the season and when large colonies develop, the leaves become bleached and distorted making

Quick Response Code	Access this article online	
	Website: www.sfna.org.my	**DOI:** 10.26480/sfna.02.2020.80.87

Cite the Article: Kafil Ahamad, Rabin Thapa, Rajendra Regmi , Resham Bahadur Thapa, Bhola Gautam (2020). Efficacy And Profitability Of Using Different Ipm (Integrated Pest Management) Measures For The Control Of Cauliflower Aphids (*Brevicoryne Brassicae* Linn.) In Different Genotypes Of Cauliflower In Chitwan District, Nepal. *Sustainability in Food and Agriculture, 1(2): 80-87.*

them unable to develop a marketable head. They play a prominent role in reducing the yield ranging from 50-80% (Yonus et al., 2004). They not only bring damage by their sucking nature but further aggravate the problem via transfer of viral pathogens. They are a vector of at least 20 viral pathogens that can cause diseases in crucifers. The aphid's mode of pathogen transmission is non-persistent (Kessing and Mau, 2013).

Various IPM methods can be used for control of aphids. They can be cultural, mechanical, biological, chemical, etc. Cultural method like choice of cultivar could reduce aphid populations and their damage but farmers generally use chemical pesticides for the control of insect pests because chemicals have an immediate knock-down effect and are easily available in the local market (Kessing and Mau, 2013). The use of synthetic pesticides is one of the primary methods for aphid control but their irrational use has caused adverse effects on the ecosystem and non-target organisms due to poor knowledge regarding antibiosis resistance via overuse (Jahan et al., 2016). Among chemical pesticides, Neonicotinoids are of potential use for control of aphids. The commonly used neonicotinoids include imidacloprid, acetamiprid, and thiamethoxam (Ghanim and Ishaaya, 2010).

Biopesticides and botanicals have a diverse range of biological actions viz repellent effect, sterility, poor fitness, stunted growth and oviposition, feeding dissuasion which has characterized their pesticidal nature making them a natural and rather an usual method of controlling aphids; while synthetic insecticides might bring an adverse impact on birds, beneficial insects and mammals (Solangi, et al., 2016). The use of bio-pesticides like *Beauveria* (entomopathogenic fungi) is gaining popularity as an alternative pest control agent. Unlike bacterial and viral pathogens, *Beauveria* infect the insect upon contact and need not to be consumed by their host for infection. It produces millions of new infective spores that are released to the environment which further reduce the pest population (Groden, 2012; Kim, Jeong et al., 2013).

Integration of botanicals in agricultural production systems have been found to bring benefits to the farmers viz food safety, reduced pest levels, improved quality of produce; which fetches higher prices and guaranteed market access. They are effective against insecticide-resistant pests, nontoxic to mammals and birds, and do not affect beneficial insects (Nefzi, et al., 2016). The use of botanicals like Jholmol and extracts of Neem *(Azadirachta indica*) is also considered eco-friendly as the application of this slurry product has been found effective for control of pests affecting the vegetables accompanied by supply of required nutrients to the plants in sufficient amount (ICIMOD, 2016).

Consequently, with increasing concern towards the human health and ecosystem, use of plant extracts over synthetic pesticides has increased. The fact that pesticide residues have been reported in food products, especially vegetables, has encouraged the use of plant-based pesticides (Geraldin et al., 2019). Taking into consideration, the economic and nutritive aspects of cauliflower and the potential threat of chemical pesticides on human health and environment, the objective of this study is to view the alternative methods of management of aphids in cauliflower which will minimize the use of chemical pesticides. The current experiment aims to determine the most effective, economic and safe plant protection measure along with assessment of the variety showing less infestation of aphid at farm conditions.

2. Methods and Methodology

2.1 Location of experimental site

The experiment was carried out during winter season of 2018, at Mangalpur, located in Bharatpur Metropolitan city, Chitwan (27.67°North; 84.35°East and 270m above sea level) in a farmer's field. The experimental area is situated in humid sub-tropical zone, characterized by four distinct seasons viz monsoon, winter, spring and summer season (Basnet et al., 2018).

2.2 Details of the experiment

The experimental field was laid out in a 2-factorial randomized complete block design (RCBD) with three replications. Three Cauliflower varieties (Kathmandu Local, Snow Grace and Snow Mystique) were taken as first factor and five level of plant protection measures viz Jholmol, *Beauveria bassiana*, a chemical pesticide (Acetamiprid), Neemix (Neem formulation) and control (water spray) were taken as second factor, making a total of 15 treatments (Table 1). Each of the treatments were replicated thrice with randomization in each block. Individual plot size was 3 m*2.25 m (6.75 m^2) with a row to row spacing of 60 cm and plant to plant spacing of 45 cm. Each individual plot had 5 rows and there were 5 plants in each row making a total of 25 plants per plot. The total number of seedlings required per plot and whole experiment were 25 and 1125 respectively.

Table 1: Treatment Details

Treatments	Variety x Pesticide Used
V1T1	Kathmandu Local+ Jholmol
V1T2	Kathmandu Local + *Beauveria bassiana*
V1T3	Kathmandu Local + Acetamiprid
V1T4	Kathmandu Local + Azadirachtin
V1T5	Kathmandu Local + Control
V2T1	Snow Grace + Jholmol
V2T2	Snow Grace + *Beauveria bassiana*
V2T3	Snow Grace + Acetamiprid
V2T4	Snow Grace + Azadirachtin
V2T5	Snow Grace + Control
V3T1	Snow Mystique+ Jholmol
V3T2	Snow Mystique + *Beauveria bassiana*
V3T3	Snow Mystique + Acetamiprid
V3T4	Snow Mystique + Azadirachtin
V3T5	Snow Mystique + Control

2.3 Field preparation and cultural operations

The experimental field was thoroughly ploughed to facilitate better growth of cauliflower. At first, a seed bed was prepared with a mixture of fine sand and farmyard manure (FYM) and then irrigated with water by rose can. Seeds were sown on the seed bed on September 9, 2018 which were later transplanted to experimental field on 13th of November. Fertilizers viz FYM@ 1500 kg/ha, NPK @ 200:120:100 kg/ha and Borax @1 kg per ropani (0.05 ha) were applied to the main field. Further irrigation, weeding and other intercultural operations were done when necessary.

2.4 Preparation of treatments for spray

The preparation and spraying of various pesticides used are mentioned below:

2.4.1 Jholmol

Jholmol was prepared few months before its application i.e. on 31st of October, making a combination of various components (Table 2). The preparation and use of Jholmol was done as per the directions in a report (ICIMOD, 2016). In a drum of 50-liter capacity, about 25 liters of cow urine and 25 liters of water were kept. The leaves and stems of the locally available plants with bitter, sour and pungent taste (Table 3) were filled in the drum. After about 25 days the solution gave a stronger odor of rotten leaves and then the solution was filtered, using a cotton cloth. For its use as pesticide, 3-6 liters of water was added, depending on the age of plants i.e. for younger plants (less than 3-week-old) a solution diluted with 6 liters of water was used and gradually the amount of water was lowered to 3 plants as plants got older. The solution was then sprayed on the plants making sure the leaves were well covered with it.

Table 2: Major components of Jholmol

Components	Amount
Ash	1kg
EM (Effective Mycorrhiza)	100 ml
Jaggery	100g
Cow Urine	25 liters
Plant materials (Table 3)	10 kg

Table 3: Locally available plants and their parts used.

English Name	Local Name	Botanical Name	Parts used
Calotropis	Aank	*Calotropis spp.*	Leaves and flowers
Papaya	Mewa	*Carica papaya*	Leaves
Mugwort	Titepati	*Artemesia vulgaris*	Leaves
Ginger	Adhuwa	*Zingiber officinale*	Rhizome
Sweet flag	Bojho	*Acorus calamus*	Rhizome and leaves
Turmeric	Besar	*Curcuma longa*	Rhizome
Chinaberry	Bakaino	*Melia azadirach*	Leaves
Chilli	Khursani	*Capsicum frutescens*	Fruits
Marigold	Sayapatri	*Tagetes patula*	Leaves and flowers
Night Jasmine	Parijaat	*Nyctanthes arbor-tristis*	leaves
Neem	Neem	*Azadirachta indica*	Leaves
Siam Weed	Banmara	*Lantana camara*	Leaves and stem
Onion	Pyaj	*Alium cepa*	Rhizome
Garlic	Lasun	*Alium sativa*	Cloves

2.4.2 Acetamiprid

The amount of insecticide required per liter of water was calculated using the formula:

Insecticides per liter = (Concentration required / Percent a.i.) * 100

After assessment of the required amount of acetamiprid, the amount was weighed and mixed with little quantity of water followed by addition of remaining quantity of water with continuous stirring. Commercial acetamiprid had concentration of 20% SP (Water Soluble Powder) and was used at rate of 1g/L of water.

2.4.3 Bio-pesticide (Beauveria bassiana)

The bio-pesticide, *Beauveria bassiana* had concentration of 1 x 10^9 CFU (colony forming units) and was used at the rate of 2ml/L of water.

2.4.4 Neemix

Commercially available Neemix with concentration of 300ppm was used at rate of 2ml/L of water.

2.4.5 Control

The untreated plots were sprayed with water.

2.5 Method and time of application

After the preparation of spray materials, separate hand sprayer was used for spray of each of the treatments. Before spray, volume of spray needed to cover the plants in the plot were assessed. The volume of spray was made 1 liter for each treatment in the first spray as the plant foliages were small, while in the second and third spray, the volume of spray solution was increased to 2 liters. After each spray, all the foliages were made sure to be well covered with the spray solution. With the appearance of aphid larva and adults in the field, the first spray was made on 26th of December i.e. 43 days after transplanting. The second and third spray were made on 7th and 20th of January respectively. After every spray, the hand sprayer was cleaned properly. Generally, spraying was done in the evening time i.e. after sunset.

2.6 Evaluation of efficacy of treatments

In each plot, 10 plants were randomly selected, leaving border plants, and were marked with a red thread for identification as a sample plant which were used for observation purpose. The following parameters were evaluated in the sample plants from each plot:

2.6.1 Aphid population

2.6.1.1 Aphid mortality

The pre-treatment and post-treatment observations were recorded from the sample plants. The pre-treatment observation was made 24 hours before spray and post-treatment observation were made on 4, 8 and 12th days of spray. The aphid population were counted from the inner, middle and upper leaves of tagged plants. The counts recorded at 12 days after each spray were taken as the pre-treatment population for succeeding spray i.e. 12th day recording of the first spray was the pre-treatment observation for second spray and so on.

2.6.1.2 Data calculation

Percentage population reduction over control (PROC) was calculated by using the modified Abbots formula given by (Flemming & Retnakaran, 1985) as follows:

$$\text{PROC}(\%) = 1 - \frac{\text{Ta x Cb}}{\text{Tb x Ca}} \text{ x } 100$$

Where,

PROC = Percent population reduction over control
Ta = Number of aphids in treatments after spray
Tb = Number of aphids in treatments before spray
Ca = Number of aphids in control after spray
Cb = Number of aphids in control before spray

2.6.2 Yield, HI and yield attributes

2.6.2.1 Yield

The weight of curd along with stem, stem leaves and root were taken as biological yield whereas the edible part i.e. curd was weighed separately for determining the economic yield. Each of the yield were taken separately for all plants of each plot and ultimately the yield was ultimately assessed as mt/ha.

2.6.2.2 Harvest Index (HI)

The harvest index of each plot was assessed from the sample plants after taking the economic yield and biological yield separately. The following formula was then used to assess HI:

HI=Economic Yield/Biological Yield

Where, HI = Harvest Index

2.6.2.3 Curd diameter (cm)

The diameter of the curd was recorded from sample plants at the time of harvesting with the help of a meter scale.

2.6.2.4 Curd height(cm)

The height of the curd was recorded from sample plants at the time of harvesting with the help of a meter scale.

2.7 Profitability of using different IPM measures

The yield(kg) of cauliflower with respect to different pesticides and control were converted into mt/ha terms. Total profit (NRs) per hectare was calculated by multiplying the yield (mt/ha) with market value of the product. The variable costs viz human labor, bullock labor, tractor use, pump set use, sprayer use, seeds, manure and fertilizers (Urea, DAP and MOP), plant protection measures (Jholmol or *Beauveria* or acetamiprid or Neemix), management cost, and land lease were added to get the cost incurred and calculated in terms of cost incurred per hectare(NRs/ha). Net profit (NRs/ha) was calculated as:

Net Profit = Total profit – Cost incurred

The profitability of cauliflower production using different IPM measures were hence assessed as:

BC ratio = Net Profit / Cost incurred

2.8 Statistical Analysis

The data collected was entered in MS-Excel and then analyzed using R-Studio Version 3.6.2. ANOVA followed by mean comparison using Duncan's Multiple Range Test (DMRT) was done. CV (Coefficient of Variation) and S.E.M. (Standard Error of Mean) of the parameters were also assessed. In order to acknowledge the basic assumptions of the data to be analyzed, data was first tested for the normal distribution using the Shapiro-Wilkins normality test.

3. Results and Discussion

3.1 Results

3.1.1 Aphid mortality after 1st Spray

Before first spray, there was no significant result for the number of aphids among different treatments, but after first spray, the number of aphids was found to be statistically significant at 4 and 8 DAS (days after spray) while non-significant results were seen for number of aphids among the varieties (Table 3) and interaction of pesticides and varieties (Table 4). After 4 and 8 days of first spray, acetamiprid treated plots had significantly lower number of aphids. Acetamiprid treated plots showed highest reduction of aphids (84%,74% and 37% respectively) while *Beauveria* showed 55%, 45% and 27% reduction after 4,8 and 12 days of spray respectively. Jholmol showed 58%, 43% and 30% reduction and Neemix showed 51%, 40% and 37% reduction of aphids over control after 4,8 and 12 days of their first spray.

Table 3: Effect of different IPM control measures and varieties on aphid population after 4,8 and 12 days of first spray

Treatments Insecticides	Pre-treatment population (per plant)	Aphid Population (per plant)		
		4 DAS	8 DAS	12 DAS
Jholmol	12.67	5.56c (58)	9.11b (43)	20.00b (30)
Beauveria	12.67	6.00bc (55)	8.89b (45)	20.67b (27)
Acetamiprid	14.22	2.44d (84)	4.67c (74)	20.00b (37)
Neemix	14.22	7.33b (51)	10.89b (40)	20.00b (37)
Control	12. 11	12.67 (-)	15.33a (-)	27.11a (-)
SEM (±)	0.98	3.737	3.855	3.58
LSD (=0.05)	NS	1.54***	2.258***	2.97***
Varieties				
Kathmandu Local	13.47	7.20	10.00	21.13
Snow Grace	12.60	6.73	10.20	21.80
Snow Mystique	13.47	6.47	9.133	20.27
SEM (±)	0.500	0.371	0.57	0.77
LSD (=0.05)	NS	NS	NS	NS

Table 4: Interaction effect of different IPM control measures and varieties on aphid population after 4,8 and 12 days of first spray

Varieties x Insecticides	Pre-treatment population (per plant)	Aphid Population (per plant)		
		4 DAS	8 DAS	12 DAS
Kathmandu Local x Jholmol	16.00a	5.33 (71)	8.67(62)	20.00(49)
Kathmandu Local x *Beauveria*	11.67a	7.00 (47)	9.33 (45)	20.33(29)
Kathmandu Local x Acetamiprid	12.33a	3.00 (79)	4.33 (76)	18.00(41)
Kathmandu Local x Neemix	15.67ab	7.33 (59)	10.67(53)	18.67(52)
Kathmandu Local x Control	11.67ab	13.3 (-)	17.00 (-)	28.67 (-)
Snow Grace x Jholmol	10.67ab	5.33 (52)	10.0 (33)	19.67(28)
Snow Grace x *Beauveria*	13.00ab	5.67 (58)	10.33(44)	23.00(31)
Snow Grace x Acetamiprid	16.00ab	2.00 (88)	4.67 (79)	17.33(57)
Snow Grace x Neemix	12.67ab	8.33 (36)	11.00(38)	21.67(33)
Snow Grace x Control	10.67ab	11.00 (-)	15.00 (-)	27.33(-)
Snow Mystique x Jholmol	11.33b	6.00 (46)	8.67 (24)	20.33(8)
Snow Mystique x *Beauveria*	13.33b	5.33 (59)	7.00 (47)	18.67(23)
Snow Mystique x Acetamiprid	14.33b	2.33 (83)	5.00 (65)	17.33(33)
Snow Mystique x Neemix	14.33b	6.33 (55)	11.00(23)	19.67(24)
Snow Mystique x Control	14.00b	13.67 (-)	14.00 (-)	25.33(-)
SEM (±)	1.833	3.547	3.6875	3.528
LSD (=0.05)	3.36*	NS	NS	NS
CV (%)	15.25	13.49	13.91	14.60

*, ** and *** represent significant at 5%,1% and 0.1% level of significance respectively. **NS** = non-significant. Treatment means followed by common letter(s) within column are not significantly different among each other based on DMRT at 0.05 level of significance. Figures in parentheses are percent reduction over control.

3.1.2 Aphid mortality after 2nd Spray

After second spray, the number of aphids was found to be statistically significant at 4, 8 and 12 days of spray (Table 5). The varieties were statistically significant for number of aphids after 12 days of second spray while non-significant results were seen among the interaction of pesticides and varieties (Table 6). After 4 and 8 days of second spray, acetamiprid showed highest reduction of aphids (63%, 40% and 24% reduction respectively) and significantly lower number of aphids at 4 and 8 days of spray while *Beauveria* treated plot showed significantly low number of aphids after 12 days of spray.

Beauveria showed 42%, 29% and 5% reduction, Jholmol showed 39%, 26% and 15% reduction and Neemix showed 16%, 23% and 15% reduction of aphids over control after 4, 8 and 12 days of second spray respectively. Unlike the first spray, Snow Mystique was statistically superior over other two varieties with lowest number of aphids after 12 days of second spray.

Table 5: Effect of different IPM control measures and varieties on aphid population after 4,8 and 12 days of second spray

Treatments Insecticides	Pre-treatment population (per plant)	Aphid Population (per plant)		
		4 DAS	8 DAS	12 DAS
Jholmol	20.00b	7.00c (39)	14.55b (26)	29.78bc (15)
Beauveria	20.67b	6.89c (42)	14.56b (29)	27.44c (5)
Acetamiprid	20.00b	4.30d (63)	11.89c (40)	32.11ab (24)
Neemix	20.00b	9.67b (16)	15.22b (23)	29.67bc (15)
Control	27.11a	15.59a (-)	26.78a (-)	35.11a (-)
SEM (±)	3.58	4.298	4.844	2.910
LSD (=0.05)	2.97***	1.99***	2.56***	3.54**
Varieties				
Kathmandu Local	21.13	9.60	17.07	31.13a
Snow Grace	21.80	8.42	17.07	33.13a
Snow Mystique	20.27	8.04	15.13	28.20b
SEM (±)	0.77	0.81	1.11	2.48
LSD (=0.05)	NS	NS	NS	2.746**

Table 6: Interaction effect of different IPM control measures and varieties on aphid population after 4,8 and 12 days of second spray

Varieties x Insecticides	Pre-treatment population (per plant)	Aphid Population (per plant)		
		4DAS	8DAS	12DAS
Kathmandu Local x Jholmol	20.00	8.67 (28)	15.33 (13)	27.33 (11)
Kathmandu Local x *Beauveria*	20.33	8.00 (35)	16.00 (11)	29.00 (17)
Kathmandu Local x Acetamiprid	18.00	5.00 (54)	11.67 (48)	32.33 (47)
Kathmandu Local x Neemix	18.67	9.00 (20)	15.00 (27)	32.00 (40)
Kathmandu Local x Control	28.67	17.33 (-)	25.33 (-)	35.00 (-)
Snow Grace x Jholmol	19.67	5.67 (41)	16.67 (21)	35.33 (40)
Snow Grace x *Beauveria*	23.00	6.00 (47)	14.67 (26)	25.67 (13)
Snow Grace x Acetamiprid	17.33	3.90 (54)	10.33 (31)	33.33 (50)
Snow Grace x Neemix				
Snow Grace x Control	21.67	9.33 (11)	17.00 (10)	32.33 (17)
Snow Mystique x Jholmol	27.33	13.33 (-)	23.67 (-)	35.00 (-)
Snow Mystique x	20.33	6.67 (48)	11.67 (41)	18.67 (34)
Beauveria	18.67	6.67 (44)	14.67 (21)	19.67 (24)
Snow Mystique x Acetamiprid	17.33	3.00 (73)	9.67 (44)	14.67 (39)
Snow Mystique x Neemix	19.67	9.67 (23)	13.67 (29)	24.67 (11)
Snow Mystique x Control	25.33	16.10 (-)	25.00 (-)	35.33 (-)
SEM (±)	3.528	4.14	4.729	3.883
LSD (=0.05)	NS	NS	NS	NS
CV (%)	14.60	13.76	16.17	11.91

*, ** and *** represent significant at 5%,1% and 0.1% level of significance respectively. **NS** = non-significant. Treatment means followed by common letter(s) within column are not significantly different among each other based on DMRT at 0.05 level of significance. Figures in parentheses are percent reduction over control.

3.1.3 Aphid mortality after 3rd Spray

After third spray, the number of aphids was found to be statistically significant at 4, 8 and 12 days of spray of the treatments. The varieties were also found to show significant results for number of aphids after 12 days of spray (Table 7) accompanied by interaction of pesticides and varieties, which were also statistically significant after 4 and 8 days of spray (Table 8). After 4,8 and 12 days of third spray, acetamiprid was found to be significantly superior over other treatments with lowest number of aphids. Acetamiprid treated plots showed 68%, 60% and 41% reduction of aphids over control after 4,8 and 12 days of third spray respectively. Jholmol, *Beauveria* and Neemix were statistically at par for number of aphids after all three days of spray. Jholmol showed 49, 27 and 7 percent reduction of aphids over control, *Beauveria* showed 42, 21 and 10 percent reduction of aphids over control and Neemix treated plot showed 47,26 and 8 percent reduction of aphids over control after 4,8 and 12 days of the spray respectively.

Similar to the second spray, after 12 days of third spray, Snow Mystique had lowest number of aphids and was statistically superior over other two varieties. All the varieties showed non-significant results for the number of aphids after 4 and 8 days of third spray. In case of interaction of varieties and pesticides used, Acetamiprid showed significant results over other treatments with lower number of aphids (after 4 days of spray) in Kathmandu Local and Snow Grace; showing 76% reduction of aphids over control in each of the varieties. Acetamiprid also showed statistically lower number of aphids over other treatments in interaction with Snow Grace and Snow Mystique varieties, showing 67 and 53 reduction of aphids over control respectively (after 8 days of spray). In contrary, there was no significant result of interaction between the varieties and pesticides used after 12 days of spray.

Table 7: Effect of different IPM control measures and varieties on aphid population after 4,8 and 12 days of third spray

Treatments Insecticides	Pre-treatment population (per plant)	Aphid Population (per plant)		
		4 DAS	8 DAS	12 DAS
Jholmol	29.78bc	14.22b (49)	23.00b (27)	45.56b (7)
Beauveria	27.44c	14.89b (42)	22.78b (21)	48.67b (10)
Acetamiprid	32.11ab	9.44c (68)	13.44c (60)	31.00c (41)
Neemix	29.67bc	14.56b (47)	23.11b (26)	45.00b (8)
Control	35.11a	32.67a (-)	37.11a (-)	58.11a (-)
SEM (±)	2.910	8.95	8.46	9.74
LSD (=0.05)	3.54**	2.738***	4.29***	7.48***
Varieties				
Kathmandu Local	31.13a	17.73	24.87	50.27a
Snow Grace	33.13a	17.80	25.00	48.80a
Snow Mystique	28.20b	15.93	21.80	37.93b
SEM (±)	2.48**	1.059	1.81	6.73
LSD (=0.05)	2.746**	NS	NS	5.79***

Table 8: Interaction effect of different IPM control measures and varieties on aphid population after 4,8 and 12 days of third spray

Varieties x Insecticides	Pre-treatment	Aphid Population (per plant)		
		4 DAS	8 DAS	12 DAS
Kathmandu Local x Jholmol	27.33	13.33cd (54)	25.33cd (16)	47.67(9)
Kathmandu Local x *Beauveria*	29.00	15.67cd (48)	22.67d (29)	55.33(5)
Kathmandu Local x Acetamiprid	32.33	8.00e (76)	13.67ef (62)	30.33(51)
Kathmandu Local x Neemix	32.00	15.00cd (55)	24cd (32)	51.00(17)
Kathmandu Local x Control	35.00	36.67a (-)	38.67ab (-)	67.00(-)
Snow Grace x Jholmol	35.33	18.33c (46)	20def (52)	49.00(20)
Snow Grace x *Beauveria*	29.67	14.33cd (50)	23.33cd (33)	49.33(5)
Snow Grace x Acetamiprid	33.33	7.67e (76)	12.67f (67)	41.67(28)
Snow Grace x Neemix	32.33	15.00cd (52)	23.67cd (37)	52.00(7)
Snow Grace x Control	35.00	33.67a (-)	41.33a (-)	56.00(-)
Snow Mystique x Jholmol	26.67	11.00de (47)	20def (15)	32.00(17)
Snow Mystique x *Beauveria*	23.67	14.67cd (21)	23.33cd (11)	29.33(15)
Snow Mystique x Acetamiprid	30.67	12.67de (47)	12.67f (53)	25.00(44)
Snow Mystique x Neemix	24.67	13.67cd (29)	21.67de (10)	32.00(10)
Snow Mystique x Control	35.33	27.67b (-)	31.33bc (-)	51.33 (-)
SEM (±)	3.883	8.65	8.16	11.17
LSD (=0.05)	NS	4.74**	7.43**	NS
CV (%)	11.91	16.52	18.60	16.07

*, ** and *** represent significant at 5%,1% and 0.1% level of significance respectively. **NS** = non-significant. Treatment means followed by common letter(s) within column are not significantly different among each other based on DMRT at 0.05 level of significance. Figures in parentheses are percent reduction over control.

3.1.4 Yield, HI and yield attributes

The varieties showed statistically significant results for yield, harvest index (HI) and height of curd, while non-significant results were seen for

Cite the Article: Kafil Ahamad, Rabin Thapa, Rajendra Regmi , Resham Bahadur Thapa, Bhola Gautam (2020). Efficacy And Profitability Of Using Different Ipm (Integrated Pest Management) Measures For The Control Of Cauliflower Aphids (*Brevicoryne Brassicae* Linn.) In Different Genotypes Of Cauliflower In Chitwan District, Nepal. *Sustainability in Food and Agriculture, 1(2): 80-87.*

curd diameter. The pesticides used showed significant results for yield only (Table 9). The interaction of pesticides and varieties showed non-significant results for any of the parameters (Table 10). Highest yield (41.91 mt/ha) was reported in the plots treated with acetamiprid and it was statistically superior over Jholmol, *Beauveria* and Neemix for yield. The variety Snow Grace was found to be statistically superior over Kathmandu Local and Snow Mystique for both yield and harvest index. None of the factors were statistically significant for diameter of curd. In contrary, curd height of Snow Grace and Kathmandu Local were statistically similar with each other and both were statistically superior over Snow Mystique.

Table 9: Effect of different IPM control measures and varieties on yield, HI and yield attributing characters

Treatments	Yield, HI and yield attributes			
Insecticides	**Yield (mt/ha)**	**Harvest Index (HI)**	**Curd Diameter(cm)**	**Curd Height(cm)**
Jholmol	36.44b	0.560	16.475	11.092
Beauveria	35.97b	0.549	16.378	11.047
Acetamiprid	41.91a	0.570	16.907	10.762
Neemix	35.76b	0.538	15.837	10.826
Control	27.82c	0.530	16.808	11.236
SEM (±)	5.02	0.014	0.588	0.277
LSD (=0.05)	4.33***	NS	NS	NS
Varieties				
Kathmandu Local	31.46b	0.501b	16.593	11.211a
Snow Grace	41.44a	0.617a	17.184	11.262a
Snow Mystique	33.84b	0.530b	15.668	10.505b
SEM (±)	5.21	0.011	0.455	0.215
LSD (=0.05)	3.35***	0.0319***	NS	0.622*

Table 10: Effect of interaction among different IPM control measures and varieties on yield, HI and yield attributes.

Varieties x Insecticides	Yield (mt/ha)	HI	Curd Diameter(cm)	Curd Height(cm)
Kathmandu Local x Jholmol	31.29	0.497	16.530	11.225
Kathmandu Local x *Beauveria*	28.46	0.502	15.816	11.319
Kathmandu Local x Acetamiprid	38.51	0.466	17.660	10.788
Kathmandu Local x Neemix	32.44	0.520	15.063	10.911
Kathmandu Local x Control	26.59	0.521	17.896	11.812
Snow Grace x Jholmol	42.80	0.624	16.543	11.503
Snow Grace x *Beauveria*	41.72	0.587	17.223	10.377
Snow Grace x Acetamiprid	46.22	0.619	16.900	11.333
Snow Grace x Neemix	42.57	0.613	17.590	11.596
Snow Grace x Control	33.88	0.643	17.663	11.503
Snow Mystique x Jholmol	35.23	0.559	16.353	10.550
Snow Mystique x *Beauveria*	37.72	0.558	16.096	11.444
Snow Mystique x Acetamiprid	40.98	0.505	16.163	10.166
Snow Mystique x Neemix	32.27	0.481	14.860	9.973
Snow Mystique x Control	22.99	0.546	14.866	10.392
SEM (±)	6.688	0.025	1.018	0.480
LSD (=0.05)	NS	NS	NS	NS
CV (%)	12.61	7.77	10.70	7.56

*, ** and *** represent significant at 5%,1% and 0.1% level of significance respectively. **NS** = non-significant. Treatment means followed by common letter(s) within column are not significantly different among each other based on DMRT at 0.05 level of significance.

3.1.5 Profitability of cauliflower production using different IPM measures

The Benefit: Cost (BC) ratio of using different IPM measures have been shown below (Table 11). The higher net profit was observed when acetamiprid was used, which is due to the highest yield (41.91 mt/ha). Highest BC ratio (1.67) was observed when Jholmol and *Beauveria* were used followed by acetamiprid with BC ratio of 1.65. However, Neemix showed a lower B: C ratio of 1.47 which was better than control (1.07)

Table 11: BC ratio of cauliflower production using different IPM measures (per hectare)

Treatments	Costs (NRs/ha)	Yield (mt/ha)	Total return (NRs/ha)	Net Profit (NRs/ha)	B:C ratio
Jholmol	136,151	36.44b	364,400	228,249	1.67
Beauveria	134,951	35.97b	359,700	224,749	1.67
Acetamiprid	158,651	41.91a	419,100	260,449	1.64
Neemix	144,651	35.76b	357,600	212,949	1.47
Control	134,151	27.82c	278,200	144,049	1.07

Note: ha = hectare, mt= Metric tonnes, NRs= Nepalese Rupee, B:C= Benefit: Cost ratio

3.2 Discussion

3.2.1 Efficacy of the treatments

Acetamiprid was found highly efficacious against aphid and found to suppress 85.11% aphids which was 84% after 4 days of first spray in our current finding (Ghosh, 2017). Also, a reduction of 80% cauliflower aphids after 168 hours of spray in case of first spray and second spray with a neonicotinoid pesticide, imidacloprid, was reported which is similar with our results (Akbar et al., 2014). Similarly, reported the highest reduction of jassids (84-92%) after all three sprays using a neonicotinoid followed by other botanicals similar with our experiment (Thapa et al., 2019). The highest reduction of aphids by acetamiprid may be due to water solubility accompanied by its translaminar action and better translocation. Acetamiprid interacts with nicotinic acetylcholine receptors at the central and peripheral nervous system, resulting in excitation and paralysis, followed by death of aphids (Ghanim and Ishaaya, 2010).

A group researchers reported a reduction of 55% aphid population after 168 hours of first spray of Azadirachtin and was found similar with our results after second spray (Akbar et al., 2014; Ghosh, 2017; Thapa et al., 2019). A reduction of 33 to 48% in the pest population was also reported when Neemix was used. Neem derived pesticides have Azadirachtin as their prime compound which have been found to stop the formation and ultimately the release of ecdysone at the physiological level, which causes partial molting in insects during their juvenile phase. In female aphids, similar metabolic action causes infertility which in fact decreases the population of aphids (Thapa, et al., 2019). The action of Neemix and Jholmol (botanicals i.e. plant extracts) is due to presence of certain compounds and secondary metabolites that are toxic to insects through contact, respiratory or stomach poison (Kareru et al., 2013).

Lopez, Zhu-Salzman, Ek-Ramos, and Sword, reported a mortality of 60% from treatment of *Beauveria* after 7 days of spray which is similar with our result after first spray (Lopez et al., 2014). Juliya also reported mortality of aphids varying from 47% to 100% using *Beauveria bassiana* at similar concentration (Juliya, 2019). A field trial against *M. persicae* on canola gave up to 86% mortality in plots treated with *B. bassiana* and it was suggested that the aphid-derived isolates were promising for aphid control (Miranpuri and Khachatourians, 1993). The reduction of aphids by *Beauveria* may be due to enhanced response by plants that confers resistance against plant pathogens (Lopez et al., 2014). The fluctuating response of the bio-pesticide may be due to influence of various factors like temperature, humidity, etc. (Kim et al., 2013).

A study reported the reduction in number of aphids in plot treated with cow urine and mixture of plant extracts which is similar with our experiment where Jholmol has been efficient for reduction of aphids (Patel et al., 2019). The action of bio-constituents is exerted on insect development and survival; cow urine can therefore be considered as a potential biopesticide while the other plant extracts, due to their phytochemicals are able to reduce the aphid population (Gahukar, 2013).

3.2.2 Effect on yield and its attributes

Poudel, Rahaman, and Shah reported the best performance of Snow Grace under varietal trial where both the yield and curd height were recorded the highest which is similar with our experiment (Poudel et al., 2017). Similarly, the highest curd weight and yield were recorded in case of Snow Grace variety which was significantly superior over Kathmandu Local (Paudel et al., 2019). The highest yield and harvest index (HI) in case of chemical treated plots have been reported which is similar with our experiment (Basnet et al., 2018). The highest yield of chemical treated plot maybe due to greater reduction of aphids while the variety selected showed varied yield as yield is a government by genotype and environment.

3.2.3 Economic efficiency of treatments

Basnet, Thapa, Regmi, and Shrestha reported higher BC ratio when *Beauveria* was used against chemical pesticides which is similar with our results, where BC ratio of *Beauveria* treatment was higher than acetamiprid (Basnet et al., 2018). Similarly, Sharma and Tayde, reported a lower B: C ratio of Neemix than synthetic pesticides (Sharma and Tayde, 2017). Similarly reported higher BC ratio when botanicals were used against major sucking pest in vegetables over chemical pesticides (Thapa et al., 2019). However, our result was in contrary with them, as the profitability of using Neemix was lower than using chemical pesticide. The B: C ratio of using acetamiprid may be lower than Jholmol and *Beauveria* due to higher cost of chemical pesticides.

4. Conclusion

The study aimed to assess the efficacy of different bio-pesticides and chemical pesticide against cauliflower aphids and the current findings show that acetamiprid is an effective synthetic pesticide for control of aphids (showing upto 84% reduction of aphids) while Jholmol, Neemix and *Beauveria* have also shown promising results for control of aphids, upto 58% reduction of aphids in some cases. Thus, it can be suggested to cauliflower growing farmers of Chitwan to use Jholmol and *Beauveria* if they are looking for a cost-effective control of aphids while for the optimum control of aphids and a better yield, Acetamiprid can be suggested. Considering the variety of cauliflower, for a higher yield, better harvest index and higher curd height, Snow Grace variety can be suggested. Further investigation on using the combination of synthetic and bio-pesticides in appropriate dose and at appropriate growth period is necessary to enhance the efficacy of pesticides.

Acknowledgement

The authors are grateful towards CARD Nepal for funding the experiment. We would also like to acknowledge all the helping hands and farmers of Mangalpur, Chitwan.

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