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Management of Mustard Aphid on Rapeseed in Chitwan, Nepal

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ABSTRACT

Aphids are the major insect pests reducing rapeseed production in Chitwan, Nepal. An experiment was conducted to monitor and evaluate the management practices of the aphid, *Lipaphis erysimi* (Kalt.), on rapeseed from November 2017 to February 2018. The experiment was laid out in a split-plot design with three replications. The three varieties (Pragati, Bikash, Unnati) of mustard are the main factors, and insecticidal treatments were subfactors of the experiment, which include Spinosad 45% SC at 0.44 ml/lit water, Imidacloprid 70WG at 0.14 gm/lit water, Beauveria bassiana 1.15% WP at 2g/lit water, and Untreated control. The interaction between insecticides and varieties was non-significant for all observatiowas non-significant for all observations population was observed on the Control, and the least was on Imidacloprid, while fluctuations of the aphid population were observed with Beauveria and Spinosad sprayed plots. The highest number of aphid populations was seen during the last week of December-mid January. The relative humidity was positively correlated with the number of aphids, while maximum and minimum temperatures were negatively correlated. Imidacloprid was found to be the most effective and economically viable option for aphid management, which could be a potential measure for the management of aphids in rapeseed.

INTRODUCTION

Oilseed crops have been the backbone of several agricultural economics from antiquity and play a prominent role in agricultural industries and trade throughout the world. Of the total land covered by Mustard, rapeseed occupies an area of 60 - 65%, mustard group 20 - 25% and yellow group is 10 - 15 Varieties of *Brassica napus* having less than 2% erucic acid in the oil are termed as canola. Canola seeds commonly contain 40% or more oil and produce meals with 35–40% protein (Raymer, 2002). Oilseed crops have been grown all over the world and are considered important crops due to their economical value. Oilseed crops are primarily grown for edible oil. Oil from the seeds of plants belonging to the genus Brassica, family Cruciferae, have been utilized by man for thousands of years (Prakash & Hinata, 1980), but it is only during the last 30 years that oilseed crops have become internationally important (Lamb, 1989). Rapessed crop suffer heavy loss in yield due to various biotic and abiotic factors. The native bollworm, *Helicoverpa punctigera* (Wallen); chinch bug, *Nysius vinitor* (Dallas); cabbage aphid, *Brevicoryne brassicae* (L.); mustard aphid, *Lipaphis erysimi* (Kalt.) and the green peach aphid, *Myzus persicae* (Sulzer) are irregular and unpredictable pests at the flowering and pod formation stage of rapeseed plants (Hainan, 2007). In Nepal, common insect pests infecting rapeseed crops are the Mustard sawfly, *Athalia lugens* (Proxima); Plant hopper, *Kelisia fieberi* (Muir); Mustard aphid, *Lipaphis erysimi* (kalt.) (Joshi & Manandhar, 2001). Aphids appear in large colonies on flowers, shoots, pods and stems of the brassica crops and suck the sap. Losses due to aphid depends upon their severity. *L. eyrsimi* causes 10-90% losses in yield to these crops depending upon severity of damage and crop stage (Rana, 2005). Pest incidence increases with an average temperature of 13.7 ^{0}c and RH of 65%. It decreases with temperature above 35^{0}c, RH less than 60% and ≥ 10mm/ day of rain and host crop maturity. Frequent uses of insecticides have led to the development of resistance in many species of insect pests and have negative effects on the survival and adaptation of natural enemies. Rana *et al.* (2007) reported that carbosulfan, bifenthrin and imidacloprid were effective for management of mustard aphid.

Biological control of insect pests with predators and/ or parasitoids is the most important and ecofriendly components of IPM (Naranjo, 2001; Sarfraz *et al.*, 2005; Gogi *et al.*, 2006). However, for selections and strategic application of insecticides, a comprehensive knowledge of their lethal residual effects on insect pest and associated biocontrol agents is required (Mgocheki & Addison, 2009; Mansour *et al.*, 2011). The overuse of chemicals has resulted in the pollution of environment, losses to farmers due to increase in cost of production and ecosystem instability in Chitwan district. In this study, different varieties of rapeseed were screened and entomopathogenic fungi and chemical insectides were assessed to identify the best varieties & management measure against mustard aphid.

Objective

To evaluate efficacy of potential pest management measures against mustard aphid, rapeseed production.

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LITERATURE REVIEW

Mustard Aphid, *Lipaphis erysimi* (Kalt.)

Lipaphis erysimi is a species of aphid of the family Aphididae. Its common name includes mustard aphid. It is found in most temperate and tropical areas of the world and feeds only on cruciferous plants. Park & Obrycki (2004) observed the temporal changes in aphid abundance posing a considerable challenge to ovipositing aphidophagous ladybirds, and to maximize their fitness they need to synchronize their reproduction with the early development of aphid population. Aphids secrete honeydew, which facilitates the growth of black sooty mold that makes the leaves appear dirty black. Aphid causes 35.4 to 73.3 % yield loss, 30.09 % seed weight loss and 2.75 % oil loss (Singh & Kashayp, 1998). The mustard aphid *Lipaphis erysimi* (Kalt.) is a major pest in mustard-growing regions of the world. Incidence of aphid during reproductive stage of mustard causes severe loss in yield particularly in Terai zone of West Bengal, India (Das *et al.*, 2009). The mustard aphid, *Lipaphis erysimi* (Kalt.) is a serious pest of mustard in India and other tropical regions in the world. In the inflorescence and fruiting stage of mustard plants a higher proportion of the nymphs developed into alate. Aphid population is negatively correlated with mean maximum and minimum temperatures and sunshine, positively correlated with humidity (Agrawal & Dutta, 1998).

Biology

This aphid has two modes producing young: fertilization of females by males resulting in the production of eggs (sexual reproduction), and the birthing of live female nymphs by adult females without fertilization by males (parthenogenesis).

Under Laboratory Condition

Under laboratory conditions the average preproductive period, reproductive period, post reproductive period, and total longevity of apterous aphids varied from 5.80 to 9.55, 5.85 to 14.10, 0.95 to 1.55, and 12.60 to 25.20 days, respectively. At an average low temperature differ of 7.22°C maintained in a refrigerator the aphid started reproducing 52.8 days after birth and reproduction continued for 18 days (Rout & Senapati, 1968).

Under Field Condition

The population of aphid was fluctuating throughout the season. First observation noticed in 45th days after the season and numbers of winged aphid attracted on yellow sticky trap was 0.1±0.1 aphid/plant. The population was continuing increased to 52nd days with 13.7±0.9 aphids/plant. This population was again continuing increased to 7th SW than decreased. The population was not break in the seasons. The population was positive correlate with RH but negative with rainfall (%). Pal *et al.* (2015) recorded that a population of aphid was noticed from last week of December and population was reach in second week of February. Population of winged aphid was very low at the beginning i. e. (0.2 aphid/trap) but attained its maximum density (243.4 aphids/trap) at later.

Host Plant

Phytophagous insects like aphids are pests of plants in agriculture and horticulture (Blackman & Eastop, 1984). Nutritional and biochemical changes occur in these host plants during their growth from the seedling stage to maturity (Vereijken, 1979). Aphids living on such plants, therefore, regulate their population size and structure in synchrony with changes in the quality of their hosts (Dixon, 1969).

Morphology-Eggs

Eggs are produced through fertilization. They are laid along the veins of leaves (Kawada & Murai, 1979). Eggs are white in colour. Nymphs: Nymphs are produced through parthenogenesis. There are four nymphal stages (instars). The general appearance of each stage is similar except for increase in size during subsequent instars. Adults: The aphid attacks generally during 2nd and 3rd week of December and continues till March. The total duration of adult stage is 26-37 days (Sachan & Bansal, 1975).

Damage

Losses due to cabbage aphid, *Brevicoryne brassicae* (L.) and mustard aphid, *L. eyrsimi* (Kalt.) reach to 70-80% in Pakistan to different oilseed brassicas. During the years of sporadic attack and severe infestation there may be no grain formation at all (Rustamani *et al.*, 1988; Khattak *et al.*, 2002). Late sown B. napus and B. juncea and B. carinata suffered 75.06, 77.25 and 81.86% losses from aphids in yield where insecticides were not applied at Multan (Razaq *et al.*, 2010). Nymphs and adults of mustard aphid, *Lipaphis erysimi* (Kalt.) suck the cell sap from inflorescence, terminal twig, siliqua (pod), leaves and branches which causes yield loss (Awasti, 2002).

Monitoring

The incidence and population build up of *Lipaphis erysimi* (Kalt.) on different varieties of rapeseed and mustard has been influenced by flight behavior and maturity periods (Prasad & Phadke, 1980). Several trapping techniques can be used to monitor alate aphids. These aphids have poor visual acuity, but they are known to be responsive to yellow and green light frequencies (wavelength 500-580 nm) (Liburd & Nyoike, 2008). For monitoring yellow commercial sticky traps, yellow water pan trap (Lakhanpal & Raj, 2002; Niaz a& Ayub, 2007), blue water pan trap filled with 10% detergent solutuion, can be used for monitoring migrating populations in the field with weekly monitor. Insecticidal spray should be applied in the first fortnight of January for maximum effect (Dutta, 1992). The action threshold for control of L. erysimi (Kalt.) on the oilseed rape in Heilongjiang, China, was recommended as 12 aphids/ plant (Wang *et al.*, 1997).

Pest Management-2.3.1 Cultural Management

Although these methods have significant impact in reducing the insect pests but never explored in true words and spirit. It is established fact that diversified field or crop harbored the low pest attack by hiding the target crop or by attracting the more bio control agents in the vicinity (Norris *et al*., 2002). Cultural practices play important role to minimize the aphid infestation.

Biological Control

Among several bio-agents, syrphid flies (Diptera: Syrphidae) as Syrphus confrater (Weid.), and lady bird beetle (Coccinella septempunctata) (Coleoptera: Coccinellidae) are the important entomophagous predators upon many species of aphids that were observed as efficient and mightiest predators of L. erysimi in field conditions. The bio-control agents like coccinellids and others have been reported to be effective for controlling the mustard aphid L. erysimi (Shukla *et al*., 1990). Singh (2001) emphasized the use of predators for the management of aphids. Singh (1994) reported the biology and feeding potential of ladybird beetle (*Cheilomenes sexmaculata*) on mustard aphid. There is need to evolve eco-friendly strategy using the bio-agents for the management of mustard aphid and *Cheilomenes sexmaculata* may be the potential predator. 90% of the known 4200 coccinellid species are predaceous (Iperti & Paoletti, 1999), and Indian coccinellid diversity includes 119 predaceous species (Omkar & Pervez, 2000c).

Microbial Control

Because plant pathogen populations are under constant selective pressure from changing agricultural practices, their genetic makeup changes over time to remain competitive, a variation of the "Red Queen" hypothesis (Ridley, 1995). These continual shifts in the population genetics of the pathogen require detailed molecular studies and a continuous attention to the development of new or improved measures to control harmful pathogens. Research on microbial pathogens of insects is increasing considerably in recent times to find out environmentally friendly alternatives to hazardous chemical insecticides. The most widely used bacterial pathogens include subspecies or strains of *Bacillus thuringiensis*.

Entomopathogenic Fungus

Entomopathogenic fungi are important natural regulators of insect populations and have potential as bio-pesticide agents against diverse insect pests in agriculture. Class Homoptera is important host of entomopathogenic fungi (Humber, 1989).

Beauveria Bassiana

Beauveria bassiana is a fungus that grows naturally in soil throughout the world and acts as a parasite on various arthropod species, causing white muscardine disease; it thus belongs to the entomopathogenic fungi. The genera Beauveria has pivotal place in mycoinsecticides. Beauveria (Bals.) Vuill. (Ascomycota: Hypocreales) is cosmopolitan genus. It is a significant broad spectrum entomopathogenic fungus (Mccoy *et al*., 1990; Feng *et al*., 1991; Brand *et al*., 2012); its pathogenicity was also reported against various aphid species. The B. bassiana strain PDRL1147 reported for insecticidal efficiency to mustard aphid (L. erysimi) under laboratory and screen house conditions (Ujjan & Shahzad, 2007).

Verticillium Lecanii Viegas

Entomopathogenic fungi, Verticillium lecani has been pathogenic to a wide range of insect-pests including aphids, thrips and white fly (Hall, 1982).

Botanicals-2.3.3.1 Neem Based Product

Most of the farmers are not aware with the ill effect of chemical pesticides and still using most of the systemic and organic insecticides to control this insect pest (Ali & Rizvi 2007). Neem pesticides have been reported effective in controlling mustard aphid (Singh *et al*., 1988).

Derisom

Realization of negative consequences of chemical pesticides and the growing consensuses in regard of health and environment, viable and sustainable alternatives other than chemical method of pest control is in search. In this search botanicals may be regarded potential for pest, epecailly aphid control.

Chemical-2.3.4.1 Imidacloprid

Imidacloprid is a systemic, chloro-nicotinyl insecticide with soil, seed, and foliar uses for the control of sucking insects including rice hoppers, aphids, thrips, whiteflies, termites, turf insects, soil insects and some beetles. The chemical works by interfering with the transmission of stimuli in the insect nervous system (Kidd & James, 1994). The mustard aphid, *Lipaphis erysimi* (Kalt.) (Hemiptera: Aphididae) is one of the serious pests of cruciferous crops and is distributed in many countries of the world (Setokuchi, 1983. Aphid is the most destructive of all the pests of mustard in Bangladesh (Haque & Miah, 1979) and reduces the yield of mustard considerably. In a recent study it was observed that the yield loss due to aphid infestation in mustard ranged from 87.16 to 98.16% (Anonymous, 1995) in Bangladesh. To control this pest, different kinds of insecticides are being used. In Bangladesh, insecticides generally control aphid. But the use of insecticides is hazardous as they leave many undesirable side effects such as development of resistance in pest populations, destruction of beneficial species, resurgence, out breaks of secondary pest and hazards to human and the environment (Luckmann & Metcalf, 1975; Hussain & Begum, 1984). So, it is urgently required to find the effect of insecticides on aphids and their toxicity to the predators and other beneficial insects.

Spinosad

Spinosad is an insecticide based on chemical compounds found in the bacterial species Saccharopolyspora spinosa. The genus Saccharopolyspora was discovered in 1985 and isolated from crushed sugarcane which produce yellowish-pink aerial hyphae, with bead-like chains of spores enclosed in a characteristic hairy sheath (Mertz *et al.*, 1990). Spinosad is highly active, by both contact and ingestion, in numerous insect species. It affects certain species only in the adult stage but can affect other species at more than one life stage. The species subject to very high rates of mortality as larvae, but not as adults, may gradually be controlled through sustained larval mortality. The mode of action of spinosoid insecticides is by a neural mechanism (Orr *et al.*, 2009). Spinosad also has secondary effects as a γ-amino-butyric acid (GABA) neurotransmitter agonist (Qiao *et al.*, 2007).

MATERIALS AND METHODS

The two aspects of the study were monitoring and managing Mustard aphids in rapeseed, *Lipaphis erysimi* (Kalt.), utilizing entomopathogenic fungus, microbial insecticide, and chemical insecticide. The study was carried out during the Winter Season from November 2017 to February 2018.

Monitoring

The appearance and dispersal of winged aphids, i.e., alate *Lipaphis erysimi* (Kalt.) in rapeseed crop were studied in one crop season. Three yellow sticky traps of size 60*15 cm and with sticky surface in only one side was installed at 1m height from the ground around each replication. Average number of aphids catches on yellow sticky traps were recorded in each week and traps were also changed at weekly interval. The trap was installed from 3 Decemeber 2017 to 11 February 2018.

Field Experiment

The field experiment was conducted to test the efficacy of entomopathogenic fungus, commericial insecticides and control (unsprayed) against mustard aphid in three varieties of rapeseed under field condition in Chitwan district of Nepal from November 2017 to February 2018.

Description of the Experimental Site

Location

The experiment was conducted at Agronomy Farm, AFU (Agriculture & Forestry University), Rampur, Chitwan. Geographically it is located at 27037' N latitude 840 25' E longitude and at an altitude of 256 meter above sea level. According to the geographical classification of the country, the experimental location falls in the Terai region of Central Development Region.

Agro-Meteorological Information

The climate of the site is sub-tropical (Nov 2017 to Feb 2018).

Cropping History

The Agronomy field of Agriculture and Forestry University, Rampur was the experimental field. Different entomological and pathological research were conducted during time, but the field was cultivated with rice before cropping of rapeseed.

Details of the Experiment

The experiment was carried in split plot design. Main plot factor was Variety and sub-plot factor was insecticide for the experiment. Similarly, a commercial entomopathogenic fungus (Beauveria), two chemical insecticides (Spinosad and Imidacloropid) and control (water spraying) were used as insecticidal sprays. Pragati, Bikash and Unnati are the three varieties used for the study (Table 1). The individual plot size was 2.4m×2.1m (5.04m^2) and sown with 30cm apart each row. The plant-to-plant distance was maintained at 5cm. The space between two blocks was 1m and the space between two plots was 0.5m. Each plot consisted of 8 rows of 2.1 m length, where middle 6 rows were considered for yield evaluation.

Details of Treatments

Table 1: Details of treatment

S.N.	Common name	Trade name	Dose
1	Spinosad 45% SC	Tracer	0.4 ml/ lit of water
2	Imidacloprid 70WSG	Admire	0.14gm/lit of water
3	Beauveria 1.15% WP	Racer	2gm/lit of water
4	Control (water spraying)		
5	Variety		
6	Pragati, Bikash, Unnati		

Treatment combination:

T1: Spinosad+Pragati

T2: Imidacloprid+Pragati

T3: Beauvaria bassiana+Pragati

T4: Control+Pragati

T5: Spinosad+Bikash

T6: Imidacloprid+Bikash

T7: Beauvaria bassiana+Bikash

T8: Control+Bikash

T9: Spinosad+Unnati

T10: Imidacloprid+Unnati

T11: Beauvaria bassiana+Unnati

T12: Control+Unnati

Preparation of Insecticide Sprays

In case of liquid insecticides, required quantity of insecticide was added to little quantity of water and stirred thoroughly & then remaining quantity of water was poured to get the required concentration of final spray. In case of dust insecticide, required amount was weighed & mixed with little quantity of water & remaining quantity of water added with continuously stirring. Amount of insecticide required/litre of water calculated: Insecticide per litre of water=Concentration required/ percent a.i. ×100

Method and Time of Application

Altogether three sprays wer done in all the treatments. The first spray started 40 days after sowing when population of aphids started appearing and repeated at 12 days interval. A knapsack sprayer used for spraying and cleanliness of sprayer was carried out after each spray of insecticide.

Cultural Practices

Land Preparation, Manure, and Fertilizer Application

The recommended amount of FYM (12mt/ha) was weighed/applied. The required quantity of fertilizers was applied in the individual plot after final land preparation, i.e., NPK @ 60:40:20 kg/ha, respectively as basal dose.

Seed Rate and Sowing

6 kg/ha was seed rate used for sowing. Further it was divided into 9 equal parts and each part was sown in line continuously by opening a small furrow at a depth of 2-3 cm, then covered with thin layer. Sowing-23Nov 2017.

Weeding, Thinning & Harvesting

Hand weeding and thinning were done 15 days after sowing. Final plant stands 67 plants/m^2 was maintained on 30 days after sowing. First weeding was done on 8th December 2017. The net harvesting area was 5.04m^2.

Observation and Measurement-3.2.3.1 Aphid Population

Observations of the aphids were carried from 10cm apical central shoot of inflorescence from 15 randomly selected and tagged sample plants of each plot. Both pre-treatment and post-treatment observations were taken for mustard aphid. Record of post-treatment was done after 4, 8 and 12 days of spray and pre-treatment observation was carried on 24 hours before first spray, whereas in case of second and third spray, count taken at 4, 8 and 12 days after each spray.

Statistical Analysis

The recorded data were all tabulated and systematically arranged treatment wise under three replications using Ms- Excel which were subjected to Analysis of Variance (ANOVA) and Duncan's Multiple Range Test (DMRT-0.05 level) for mean separations using Gen stat software (Gomez & Gomez, 1984).

RESULTS AND DISCUSSIONS

Aphid Monitoring

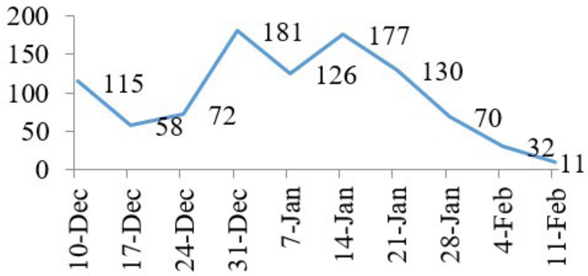

Figure 1: Monitoring of aphid during crop growing period

About 115-winged aphid were catched on yellow sticky trap on 10 December 2017 which decreased to 58 on 17th December 2017, again this number increased by 14 on 24th Decemeber, 2017. The number of aphids increased abruptly to 181 on 31st Decemeber, 2017 which flucates and become 177 on 14th January 2018. Then after its population steadly declined and reached to only 11.

Relation between Aphid Population and Climatic Parameter

Relative Humidity (RH)

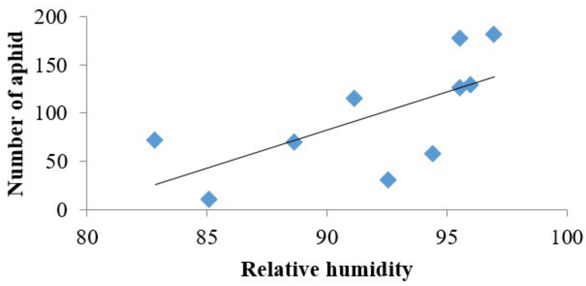

Figure 2: Number of aphid vs Relative Humidity

Number of aphids has positive relation with relative humidity. The Coefficient of determination for relative humidity and number of aphids is 44.5%. Number of aphids was found lowest (20) at 83% relative humidity.

Maximum Temperature

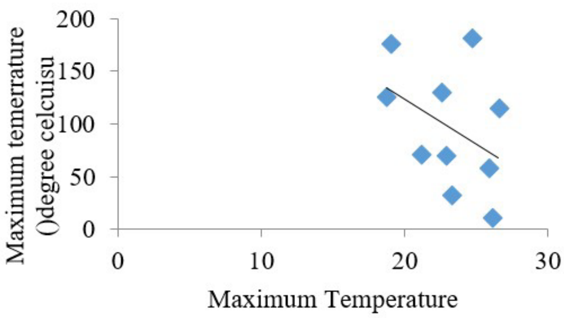

Figure 3: Number of aphid vs Maximum Temperature

Number of aphids has negative correlation with maximum temperature. The number of aphids decreases with increase on maximum temperature. The Coefficient of determination for maximum temperature and number of aphids is only 17.11% (Figure 3).

Minimum Temperature

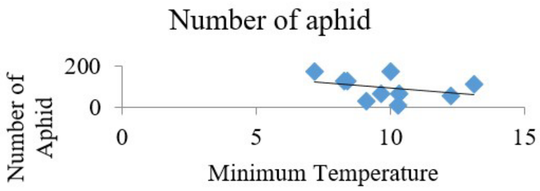

Figure 4: Number of aphid vs Minimum Temperature

Number of aphids has negative correlation with average temperature during the crop growth period. The Coeffeciant of determination of average temperature and number of aphids is only 12.01% (Figure 4).

Effect of Different Treatments on the Population of *Lipaphis erysimi* (Kalt.)-4.3.1 First Spray

The number of aphids was 1.89 at one day before spray and increased to 3.16 at twelve days after spray. Number of aphids was found non-significant between varieties at all days after spray but statistically different at one day before spray. Similarly, number of aphids was found non-significant treated by all insecticide at one day before spray and four days after spray except at eight days after spray and twelve days after spray. The interaction between variety and insecticide was also non- significant (Table 2).

At one day before spray significantly higher number of aphids was recorded in variety Pragati (4.22) followed by Bikash (4.09) and Unnati (2.81) respectively. Pragati, Bikash and Unnati were significantly different from each other. In case of insecticide treated plots highest reduction of number of aphids was provided by Spinosad (3.44) and least by Control (3.89).

After four days of spray higher number of aphids was shown by variety Pragati (1.44) and Unnati (1.21) showed the least. Similarly, comparatively Control (1.55) plot showed higher number of aphid and Imidacloprid (1.13) treated plot showed least number of aphids. After eight days of first spray higher number of aphids were noticed in variety Unnati (2.59) and least in Pragati (2.51). Insecticide Imidocloprid (1.63) gave significantly best result (i.e., highest reduction of aphid number) followed by Spinosad (2.55), Beauveria (2.88) and Control (3.24) respectively. But the least effective three treatments were statistically at par. Spinosad and Beauveria were statistically at par. Whereas, Beauveria and Control were also statistically at par with each other.

At 12 days after first spray higher number of aphids were found in variety Bikash (3.25) and least were found in Pragati (3.11). Higher number of aphids was significantly reduced by insecticide Imidocloprid (2.03) followed by Spinosad (3.21), Beauveria (3.33) and Control (4.07) respectively. Control and Imidocloprid were highly significantly different whereas Spinosad and Beauveria were statistically at par (Table 2). At one day before spray, relatively higher number of aphids were found on Bikash with Control (4.93) followed by Pragati with Beauveria (4.62) and least was found on Unnati with Control (2.00). Pragati with Beauveria (4.62) was statistically similar with Pragati with Spinosad (4.57) followed by Pragati with Imidaclroprid (4.29), Bikash with Spinosad (4.13), Bikash with Imidacloprid (3.91), Unnati with Beauveria (3.49), Unnati with Imidacloprid (3.11), Pragati with Control (3.38), Bikash with Beauveria (3.36) and Unnati with Spinosad (2.98) respectively (Table 2).

Comparatively higher number of aphids were found on Pragati with Spinosad (3.42) followed by Bikash with Control (2.99) and least were observed in Unnati with Imidacloprid (1.12) after four days of the spray. Bikash with Control (2.99) was statistically at par with Bikash with Spinosad (2.47) followed by Pragati with Beauveria (2.13), Unnati with Spinosad and Unnati with Beauveria (1.73), Pragati with Control (1.71), Unnati with Control (1.60), Bikash with Beauveria (1.49), Pragati with Imidacloprid (1.45) and Bikash with Imidacloprid (1.32) respectively (Table 2).

Relatively higher number of aphids were found on Unnati with Spinosad (12.19) spray which was followed by Pragati with Beauveria (11.00) and least was found on Bikash with Imidacloprid (2.07) after eight days of spray. Pragati with Beauveria (11.00) was statistically similar with Pragati with Spinosad (10.38) followed by Bikash with control (9.77), Bikash with Spinosad (9.47), Unnati with Beauveria (8.26), Bikash with Beauveria (6.90), Pragati with Control (6.43), Unnati with Control (4.53), Unnati with Imidacloprid (3.70) and Pragati with Imidacloprid (2.56) respectively (Table 2).

Comparatively, higher number of aphids were found on Bikash with Spinosad (4.32) followed by Pragati with Spinosad (4.04) and least was seen on Bikash with Imidacloprid (1.54) after twelve days of spray. Pragati with Spinosad (4.04) was statistically similar with Unnati with Spinosad (3.86) followed by Bikash with Control (3.59), Bikash with Beauveria (3.55), Pragati with Beauveria (3.24), Unnati with Beauveria and Unnati with Control (3.19), Pragati with Control (2.85), Pragati with Imidacloprid (2.32) and Unnati with Imidacloprid (2.23) repectively (Table 2).

Table 2: Interaction between number of aphid and treatments after first spray at different days influenced by varieties and insecticides, Rampur, Chitwan, November 2017 to February 2018

Treatment	**Number of Aphid**			
Factor A (Variety)	**1 DBS**	**4 DAS**	**8 DAS**	**12 DAS**
Pragati	4.22[a] (4.22)	2.18 (1.44)	7.05 (2.51)	10.22 (3.11)

Bikash	4.09[b] (4.09)	2.07 (1.37)	7.17 (2.55)	11.74 (3.25)
Unnati	2.81[c] (2.81)	1.55 (1.21)	7.59 (2.59)	10.31 (3.12)
SEM	0.42	0.07	0.02	0.05
LSD	0.12	NS	NS	NS
C.V.	5.5	20.8	20.3	16.9
Factor B (Insecticide)	1 DBS	4 DAS	8 DAS	12 DAS
Spinosad 45% SC @ 0.44 ml/lit. of water	3.44 (3.44)	2.01 (1.31)	6.91[b] (2.55)	10.63[b] (3.21)
Imidacloprid 70WG @ 0.14gm/lit. of water	3.77 (3.77)	1.21 (1.13)	2.77[c] (1.63)	4.44[c] (2.03)
Beauveria bassiana 1.15% WP @ 2 gm/lit of water	3.82 (3.82)	1.79 (1.30)	8.72[ab] (2.88)	11.42[b] (3.33)
Control	3.89 (3.89)	2.54 (1.55)	10.68[a] (3.24)	16.67[a] (4.07)
SEM	0.10	0.09	0.35	0.42
LSD	NS	NS	0.57	0.56
C.V	20.3	25.1	22.2	17.9
Grand mean	3.73 (1.89)	1.93 (1.35)	7.27 (2.58)	10.79 (3.16)
Interaction				
Varieties*insecticide	1DBS	4DAS	8DAS	12DAS
Pragati*Spinosad	4.57	3.42	10.38	4.035
Pragati*Imidacloprid	4.29	1.45	2.56	2.317
Pragati* Beauveria bassiana	4.62	2.13	11.00	3.240
Pragati*Control	3.38	1.71	6.43	2.850
Bikash*Spinosad	4.13	2.47	9.47	4.328
Bikash*Imidacloprid	3.91	1.32	2.07	1.542
Bikash * Beauveria bassiana	3.36	1.49	6.90	3.549
Bikash*Control	4.93	2.99	9.77	3.586
Unnati*Spinosad	2.98	1.73	12.19	3.855
Unnati*Imidacloprid	3.11	1.12	3.70	2.231
Unnati* Beauveria bassiana	3.49	1.73	8.26	3.194
Unnati*Control	2.00	1.60	4.53	3.191

DAS: Days after spraying, DBS: Days before spraying, SEM: Standard Error of Mean, NS: Non-significant, CV: Coefficient of variation; LSD: Least significant difference, value with common letters are not significantly different from each other based on DMR at 5% level of significance and the figures in parentheses are Log transformation.

Second Spray

The number of aphids was 2.47 at four days after sowing and increased to 3.25 at twelve days after sowing. Number of aphids between varieties were found non-significant for all days after spray. But for insecticide treatment were found to be significant at all days after spray. The interaction between variety and insecticide was also non- significant (Table 3). After four days of spray higher number of aphids were noticed in variety Unnati (2.69) and least in Pragati (2.31). Significantly reduction of aphid number showed that treatment of insecticide Imidocloprid gave highest result (0.97) followed by Spinosad (2.46), Beauveria (2.73) and Control (3.71) respectively. Beauveria and Spinosad were statistically at par.

At eight days after spray greater aphid number were observed in variety Bikash (3.37) and least both in varieties Pragati (3.20) and Unnati (3.00) respectively. Significantly higher aphid number were seen in Control (4.35) followed by Spinosad (3.32), Beauveria (3.28) and Imidocloprid (1.47) treated plots respectively. Beauveria and Spinosad were statistically at par, whereas Control and Imidocloprid were significantly different. Higher number of aphids were studied in case of variety Unnati (3.47) and least in Pragati (2.84) after twelve days of spray. It was also revealed that treated Control (5.15) resulted significantly higher number of aphids followed by Spinosad (3.21), Beauveria (3.11) and Imidocloprid (1.55) respectively. Furthermore, Beauveria and Spinosad were found statistically at par (Table 3).

Relatively higher number of aphids were found on Bikash with Spinosad (16.15) followed by Pragati with Spinosad (15.27) and least were observed on Bikash with Imidacloprid (0.47) after four days of spray. Pragati with Spinosad (15.27) was statistically similar with Unnati with Beauveria (11.68) followed by Unnati with Spinosad (10.55), Unnati with Control (7.22), Pragati with Beauveria (6.60), Pragati with Control (5.80), Bikash with Control (5.51), Bikash with Beauveria (5.47), Unnati with Imidacloprid (3.03) and Pragati with Imidacloprid

(0.63) respectively. Relatively higher number of aphids were found on Bikash with Spinosad (26.1) followed by Pragati with Spinosad (22.8) and least was found on Pragati with Imidacloprid (1.80) after eight days of spray. Pragati with Spinosad (22.8) was statistically similar with Pragati with Beauveria (14.20) followed by Unnati with Control (12.60), Unnati with Beauveria (11.20), Unnati with Spinosad (10.60), Bikash with Beauveria (10.40), Pragati with Control (6.70), Unnati with Imidacloprid (3.20) and Bikash with Imidacloprid (2.20) respectively.

Relatively higher number of aphids were found on Beauveria with Spinosad (5.79) followed by Unnati with Spinosad (5.18) and least was found on Pragati with Imidacloprid (1.42) after twelve days of spray. Unnati with Spinosad (5.18) was statistically similar with Pragati with Spinosad (4.48) followed by Unnati with Beauveria (3.83), Bikash with Control (3.46), Unnati with Control (3.23), Bikash with Beauveria (2.96), Pragati with Control (2.93), Pragati with Bikash (2.54) and Bikash with Imidacloprid (1.61) respectively (Table 3).

Table 3: Interaction between number of aphid and treatments after second spray at different days influenced by varieties and insecticides, Rampur, Chitwan, November 2017 to February 2018

Treatment	**Number of Aphid**		
Factor A (Spacing cm)	**4 DAS**	**8 DAS**	**12 DAS**
Pragati	6.81 (2.31)	11.39 (3.20)	10.04 (2.84)
Bikash	7.08 (2.32)	13.76 (3.37)	13.87 (3.45)
Unnati	8.12 (2.69)	9.40 (3.00)	14.81 (3.47)
SEM	0.11	0.13	0.21
LSD	NS	NS	NS
C.V.	21	16.3	20.3
Factor B (Variety)	4 DAS	8 DAS	12 DAS
Spinosad 45% SC @ 0.44 ml/lit of water	6.18^{b} (2.46)	11.92^{b} (3.32)	11.04^{b} (3.21)
Imidacloprid 70WG @ 0.14gm/lit of water	1.38^{c} (0.97)	2.39^{c} (1.47)	2.49^{c} (1.55)
Beauveria bassiana 1.15% WP @ 2 gm/lit of water	7.92^{b} (2.73)	11.91^{b} (3.28)	10.43^{b} (3.11)
Control	13.99^{a} (3.71)	19.86^{a} (4.35)	27.67^{a} (5.15)
SEM	0.57	0.51	0.74
LSD	0.54	0.91	0.97
C.V.	22.2	32.4	29.9
Grand mean	7.36 (2.47)	11.52 (3.11)	12.97 (3.25)
Interaction			
Varieties*insecticide	4DAS	8DAS	12DAS
Pragati*Spinosad	15.27	22.8	4.48
Pragati*Imidacloprid	0.63	1.8	1.42
Pragati* Beauveria bassiana	6.60	14.2	2.54
Pragati*Control	5.80	6.7	2.93
Bikash*Spinosad	16.15	26.1	5.79
Bikash*Imidacloprid	0.47	2.2	1.61
Bikash * Beauveria bassiana	5.47	10.4	2.96
Bikash*Control	5.51	16.4	3.46
Unnati*Spinosad	10.55	10.6	5.18
Unnati*Imidacloprid	3.03	3.2	1.63
Unnati* Beauveria bassiana	11.68	11.2	3.83
Unnati*Control	7.22	12.6	3.23
F-test	NS	NS	NS

DAS: Days after spraying, DBS: Days before spraying, SEM: Standard Error of Mean, NS: Non-significant, CV: Coefficient of variation; LSD: Least significant difference, value with common letters are not significantly different from each other based on DMR at 5% level of significance and the figures in parentheses are Log transformation.

Third Spray

The number of aphids after four days of third spray was 2.85 and increased to 3.17 at twelve days after third spray. Number of aphids between the varieties at all days after spray was found non-significant but found significant for insecticide treated plots at all days after spray. The interaction between variety and insecticide was also non-significant (Table 4).

The higher number of aphids was found in variety Unnati (3.37) and least found in Pragati (2.35) after four days of spray. Significantly most effective pesticide was Imidocloprid (1.49) and least was Control (4.08) with reference to reduction of aphid population. Intermediate result was shown by Beauveria (2.78) and Spinosad (3.04). Beauveria and Spinosad were statistically at par with each other. Number of aphids observed in variety Bikash was 3.53, 3.31 in Unnati and 2.45 in Pragati after eight days of spray. Significantly highest infestation of aphid was revealed in case of Control (4.30) sprayed plot followed by Spinosad (3.58), Beauveria (2.93) and Imidocloprid (1.66). Beauveria and Spinosad were statistically at par, but these treatments were significantly different with Imidocloprid.

At twelve days of spray highest infestation of aphid was recorded in variety Unnati (3.62) and least in Pragati (2.45). Significantly higher number of aphid population was recorded through Control (4.83) sprayed plots followed by Spinosad (3.27), Beauveria (2.79) and Imidocloprid (1.78) respectively. Imidocloprid and Beauveria were statistically at par whereas Beauveria and Control were statistically different (Table 4).

Relatively higher number of aphids were found on Unnati with Spinosad (23.30) followed by Bikash with Spinosad (16.40) and least was found on Pragati with Imidacloprid (0.9) after four days of spray. Bikash with Spinosad (16.40) was statistically similar with Unnati with Control (14.90) followed by Pragati with Spinosad (12.70), Unnati with Beauveria (10.4), Bikash with Control (9.10), Bikash with Beauveria (7.10), Pragati with Beauveria (7.0), Pragati with Control (5.70), Unnati with Imidacloprid (3.70) and Bikash with Imidacloprid (3.40) after four days of spray respectively (Table 4).

Relatively higher number of aphids were found on Bikash with Spinosad (4.61) followed by Unnati with Spinosad (4.48) and least was found on Pragati with Imidacloprid (1.14) after eight days of spray. Unnati with Spinosad (4.48) was statistically similar with Unnati with Control (4.22) followed by Bikash with Control (4.10), Pragati with Spinosad (3.82), Unnati with Beauveria (2.88), Pragati with Beauveria (2.70), Pragati with Control (2.41), Bikash with Imidacloprid (2.19), Unnati with Imidacloprid (1.66) and Pragati with Imidacloprid (1.24) respectively (Table 4).

Relatively higher number of aphids were found on Unnati with Spinosad (6.02) followed by Bikash with Spinosad (4.68) and least was found on Unnati with Imidacloprid (1.75) after twelve days of spray. Bikash with Spinosad (4.68) was statistically similar with Pragati with Spinosad (3.80) followed by Bikash with Control (3.71), Unnati with Control (3.51), Bikash with Beauveria (3.20), Unnati with Beauveria (3.20), Bikash with Beauveria (3.00), Pragati with Control (2.59), Bikash with Imidacloprid (2.34) and Pragati with Beauveria (2.18) respectively (Table 4).

Table 4: Interaction between number of aphid and treatments after third spray at different days influenced by varieties and insecticides, Rampur, Chitwan, November 2017 to February 2018

Treatment	**Number of Aphid**		
Factor A (Variety)	**4 DAS**	**8 DAS**	**12 DAS**
Pragati	6.57 (2.35)	8.12 (2.52)	7.88 (2.45)
Bikash	9.01 (2.82)	14.53 (3.53)	13.74 (3.43)
Unnati	13.07 (3.37)	12.97 (3.31)	16.88 (3.62)
SEM	0.21	0.31	0.36
LSD	NS	NS	NS
C.V.	24.6	42.1	42.7
Factor B (Insecticide)	4 DAS	8 DAS	12 DAS
Spinosad 45% SC @ 0.44 ml/lit of water	9.89^{b} (3.04)	14.48^{ab} (3.58)	12.91^{b} (3.27)
Imidacloprid 70 WG @ 0.14gm/lit of water	2.67^{c} (1.49)	3.60^{c} (1.66)	3.92^{c} (1.78)
Beauveria bassiana 1.15% WP @ 2 gm/lit of water	8.18^{b} (2.78)	9.83^{b} (2.93)	8.96^{bc} (2.79)
4.Control	17.47^{a} (4.08)	19.57^{a} (4.30)	25.54^{a} (4.83)
SEM	0.53	0.56	0.64
LSD	0.82	1.15	1.34
C.V.	29.1	37.2	42.6
Grand mean	9.55 (2.85)	11.87 (3.12)	12.83 (3.17)
Interaction			
Varieties*insecticide	4DAS	8DAS	12DAS

Pragati*Spinosad	12.7	3.82	3.80
Pragati*Imidacloprid	0.9	1.14	1.24
Pragati* Beauveria bassiana	7.0	2.70	2.18
Pragati*Control	5.7	2.41	2.59
Bikash*Spinosad	16.4	4.61	4.68
Bikash*Imidacloprid	3.4	2.19	2.34
Bikash * Beauveria bassiana	7.1	3.20	3.00
Bikash*Control	9.1	4.10	3.71
Unnati*Spinosad	23.3	4.48	6.02
Unnati*Imidacloprid	3.7	1.66	1.75
Unnati* Beauveria bassiana	10.4	2.88	3.20
Unnati*Control	14.9	4.22	3.51

DAS: Days after spraying, DBS: Days before spraying, SEM: Standard Error of Mean, NS: Non-significant, CV: Coefficient of variation; LSD: Least significant difference, value with common letters are not significantly different from each other based on DMR at 5% level of significance and the figures in parentheses are Log transformation.

DISCUSSIONS-5.1 Monitoring

Aphid population seems decreasing after third week of January 2018. The present findings are in conformity with the observations of Uttam *et al.*, (1993), who reported the mustard aphid population reached at peak in last week of December and third week of January. Number of aphids has positive relation with relative humidity. Several studies have shown that weather plays an important role on the aphid appearance, multiplication, and disappearance of mustard aphid (Vekaria & Patel, 2000). Number of aphids has negative correlation with temperature; however, the coefficient of determination was very small which may be due to short duration of research. Bale *et al.* (2002) concluded that increased temperature could also decrease the growth of some aphid species, depending on their thermal requirements and host specificity.

Effect of Variety and Insecticide on Aphid, *Lipaphis erysimi* **(Kalt.)**

Relatively higher number of aphids were found on Bikash with Control (4.93) and least was found on Unnati with Control (2.00). The variation in plant growth regulator on cultivars is likely to have been caused by seasonal variation in aphid pressure and plant growth factors. The cultivars identified as promising in these trials confirm the earlier findings of Manzar *et al.* (1998), Jatoi *et al.* (2002), Rana (2005). Imidocloprid with other treatment could be regarded best that has long term effect in aphid population. It has been recorded by the findings of Weiss (1983) that degree of aphid damage is correlated to time of infestation rather than the severity of infestation. According to Liu *et al.*, (2011), Ghidiu *et al.*, (2012), Ghosal *et al.*, (2013) aphids, as one of the most important targets of neonicotinoids, are effectively controlled by Imidacloprid combination with other via spraying, drip-chemigation, or root-irrigation. According to Amer *et al.*, (2009) populations of aphids did not increase after second spray due to warm weather and maturity of crop. Similarly, populations of aphid declined in Multan trials after three days of spray in plots where no insecticides were applied because aphids naturally start decreasing after mid March due to rising temperature. From the findings of Inglis *et al.*, (1993) the effect of Beauveria depends upon the genetical makeup of the strain, difference in bioassay method, aphid species to abiotic and biotic conditions like temperature (Noma & Strickler, 1999), humidity (James, 1994), Phylloplane (Shipp *et al.*, 2003) genetic variability of fungal strain, formulation, and application methods (Shah & Butt, 2005). According to Butt *et al.*, (1994), Hesketh *et al.*, (2008) and Freed *et al.*, (2012) it is estimated that the fungi causing pathogenecity in insects have been observed to cause mortality in insect pest population and therefore studied for their use as biological control agents or effectively developed for the biological control of several insect pests, which also include aphids (Shah & Pell, 2003; Ansari *et al.*, (2004) also found that mortality depended on the concentration of conidial suspension, exposure time and temperature. Beauveria shown better result after Imidacloprid which was supported by the findings of Mandal (2010). Entomopathogenic fungi that attack aphids are important agents for biocontrol and have a vital part in promoting integrated pest management (Cooke, 1977). Up till now, a variety of strains of entomopathogenic fungi such as Lecanicillium sp. (Jackson *et al.*, 1985; Jung *et al.*, 2006; Steenberg and Humber, 1999; Kim, 2004), B. bassiana (Quesada *et al.*, 2006), M. anisopliae (Shia & Feng, 2004; Wright *et al.*, 2004), Isaria (Shia & Feng, 2004), and Nomuraea rileyi (Devi *et al.*, 2003) have been used for the management of aphids. Lacey *et al.*, (1997) Askary *et al.*, (1998), Irshad (2001) and Vandenberg *et al.*, (2001) supported that efficacy of Beauveria strains are better and sustainable than Spinosad .The effect of Imidocloprid was similar with the findings of Nidhi *et al.* (2013), who found Imidocloprid as most toxic spray among all which persist for longer time in plant parts such as leaves, pods, branches, etc and damage/effect aphid population for many days of spray. Imidocloprid being sustainable persistence could also be used as seed treatment. Therefore, many studies such as from Bharadwaj (1991) and Kumar *et al*., (2000), Cheema *et al*., (2001b) and Chaudhry *et al.* (1987) agree with the above findings and detail. The study and literature clearly show that though biological methods are environmentally friendly, chemical insecticides are most effective and economically viable option for aphid management.

CONCLUSION

It was complex to record the number of mustard aphids with changing weather. Aphids' population increases tremendously during the winter season. It's good to grow mustard crops with planned technical standards. Proper preparation and application of treatment as per instruction is necessary for academic research. An experiment was conducted to monitor and evaluate the management practices of aphid, *Lipaphis erysimi* (Kalt.) on rapeseed from November 2017 to February 2018. The experiment was laid out in split plot design with three replications. The three varieties (Pragati, Bikash, Unnati) of mustard are the main factor and insecticidal treatment was a sub-factor of experiment. The highest number of aphid population was seen during the last week of December-mid January in Chitwan, Nepal. The relative humidity had a positive relationship however both maximum and minimum temperature had a negative relationship with the aphid population. The findings are in line with the various past studies. Imidacloprid was found the most effective and economically viable option for aphid management which could be a potential measure for management of aphid in rapeseed.

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