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Effective strategies for optimizing rapeseed cultivation involve the careful selection of varieties and the appropriate use of pesticides

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ABSTRACT

This research investigates the management of rapeseed through suitable application of pesticides and variety selection. Control of aphid and variety selection of mustard have some detrimental effects on crop growth, development, and yield. Therefore, from November 2017 to February 2018, we conducted an experiment to assess the status of mustard using various varieties and pesticides. 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 and treatment were subfactors of experiment, which included Spinosad 45% suspension concentrates at 0.44 ml/liter water, Imidacloprid 70 water dispersible granule at 14 gm/ liter water, *Beauveria bassiana* 1.15% wettable powder at 2g/liter water, and untreated control. Phenological characters for plant variety were assessed to record the data regularly. Bikash had the higher plant height among other varieties. Higher leaf and branch numbers, including number of seeds per pod, were to be found the highest in the variety Pragati, but yield, biomass, and harvest index were statistically similar in all varieties. Seeds per pod, yield, biomass, and harvest index were the highest with Imidacloprid, followed by Beauveria, Spinosad, and Control. The highest number of aphid populations was seen during the last week of December-mid-January. Imidacloprid was found to be the most effective and economically viable option for rapeseed growth and production. Similar effects from cropping any varieties, Unnati, and Bikash Pragati were noticed.

Contribution/Originality: The study deals in an integrated way to investigate efficiency of insecticides in varieties. It looks unique in terms of the way aphids were managed and potentiality of inputs (insecticides and varieties) applied together to determine appropriate insecticides for better variety.

1. INTRODUCTION

Oilseed crops have been a fundamental component of agricultural economics since antiquity, and they continue to play a significant role in agricultural industries and trade worldwide. Of the total land covered by mustard, rapeseed occupies an area of 60-65%, mustard group 20-25% and yellow group is 10-15 %. The top producers were the European Union, China, Canada, India, and Japan in the world during 2017. Varieties of *Brassica napus* having less than 2% erucic acid in the oil are termed canola. Canola seeds commonly contain 40% or more oil and produce meals with 35–40% protein (Raymer, 2002). People grow oilseed crops all over the world, considering them important due to their economic value. People primarily grow oilseed crops for their edible oil. Oilseed crops are primarily grown for edible oil. Oil from the seeds of plants belonging to the genus *Brassica*, family Cruciferae, has 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).

Rapeseed crops suffer heavy losses 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, Gary, & Geoff, 2007). In Nepal, common insect pests infecting rapeseed crops are 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 aphids depend upon their severity. *L. eyrsimi* causes 10-90% losses in yield to these crops depending upon severity of damage and crop stage (Rana, 2005).

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, Shahzad, Malik, and Saleem (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 component of IPM (Gogi, Sarfraz, Dosdall, Keddie, & Ashfaq, 2006; Naranjo, 2001; Sarfraz, Keddie, & Dosdall, 2005). However, for selections and strategic application of insecticides, a comprehensive knowledge of their lethal residual effects on insect pests and associated biocontrol agents is required (Mansour, Suma, Mazzeo, Grissa Lebdi, & Russo, 2011; Mgocheki & Addison, 2009). The overuse of chemicals has resulted in the pollution of the 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 insecticides were assessed to identify the best varieties of rapeseed.

1.1. Objective

- To evaluate status of rapeseed crop under the application of various treatments (pesticides and varieties).
- To evaluate physiology of rapeseed crop under the application of various treatments (pesticides and varieties).

2. LITERATURE REVIEW

2.1. Mustard Aphid, Lipaphis Erysimi (Kalt.)

Lipaphis erysimi is a species of aphid of the family Aphididae. Its common name includes mustard aphid. Most temperate and tropical areas of the world host it, and it exclusively consumes cruciferous plants. Park and 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.

Nymphs and adults of aphid, *Lipaphis erysimi*, suck the cell sap from inflorescence, terminal twig, siliqua (pod), leaves, and branches, which causes yield loss. A severe infestation results in poor pod formation, leaves that curl and shrivel, and plants that dry out. On the other hand, 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, Wiley, Chen, Shah, & Verde, 2009).

The mustard aphid, *Lipaphis erysimi* (Kalt.), is a serious pest of mustard in India and other tropical regions in the world. The population dynamics of this species are considerably influenced by immigrant alatae, which migrate to the mustard crop from the off-season shelter.

2.2. Host Plant

According to Blackman and Eastop (1984) about 450 species of pest occur on crops, but only about 100 species pose significant economic problems. According to CABI (2005) the major hosts of aphids are *Brassica; Brassica juncea* var. *juncea (*Indian mustard*)*, *Brassica napus var. napus* (rape), *Brassica oleeacea (*cabbages, cauliflowers*)*, *Brassica oleracea var. alboglabra* (Chinese kale), *Brassica rapa* (turnip), *Raphanus sativus* (radish), *and Sinapi's alba* (white mustard).

2.3. Monitoring

Fight behavior and maturity periods influence the incidence and population buildup of *Lipaphis erysimi* (Kalt.) on different varieties of rapeseed and mustard (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 & Ayub, 2007) and the blue water pan trap filled with 10% detergent solution can be used for monitoring migrating populations in the field with a weekly monitor. Traps can be placed close to field borders to detect migrating aphids, as well as in the center of the field to monitor resident population (Liburd & Nyoike, 2008).

The EIL (Economic Injury Level) of mustard aphid, *Brassica juncea*, was evaluated in field trials in India, where values ranged between 37 and 4, and 48 and 6 aphids per 10 cm terminal shoot per plant during the 1986/87 and 1987/88 trials, respectively. A one-day increase in crop exposure to the aphids led to a significant reduction in seed yield per plant, number of siliqua per plant, and number of seeds per siliqua. The highest benefit-cost ratio was obtained at 3 weeks of exposure, when initiation of insecticide application was most economical (Dutta, 1992).

Hence, 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).

2.4. Effect of Pest, Pesticides and Varieties in Crop Physiology, Growth, and Yield

The intensity of aphid infestation and its population pressure differed with date of sowing as well as the susceptible crop growth stages (initiation of flowers, flower, and pod initiation). The crop sown on normal date (first fortnight of October) escapes the susceptible growth stage of the crop from the aphid attack and its multiplication, which is greatly affected by the conducive weather conditions in the Terai (humid moist environment) (Singh & Sachan, 1995). Such alteration in cultivation declines the peak population of the aphid above the economic threshold level, which is also influenced by the soil type, crop growth stage, and insecticides used.

The effect of sowing dates (1, 10, 20, and 30 November and 10 and 20 December) on the incidence of *Lipaphis erysimi* on mustard was investigated in the field in Dapoli, India, during 1996-97. Delay in sowing caused gradual increase in the aphid population and aphid infestation index and ultimately resulted in a reduction of yield, for which the pesticide should be applied. Applied pesticides may reflect certain changes in crop growth and yield. The peak incidence of the aphid occurred between the first fortnight of January and the second fortnight of February (Garni, Bapodra, & Rathod, 2002).

Aphids (*Lipaphis erysimi* Kaltenback) often reduce mustard's (*Brassica juncea* L.) yield in India. A study was conducted to determine if intercropping with aromatic plant species could provide an environmentally safe method for aphid control. Aphid infestation on monocrop mustard ('Rohini') was compared with intercrop treatments of artemisia (*Artemisia annua* L.), coriander (*Coriandrum sativum* L.), chamomile (*Matricaria chamomilla* L.), fennel (*Foeniculum vulgare* Mill.), and dill (*Anethum sowa* Kurz). Intercropping with fennel resulted in a significantly lower aphid infestation. These preliminary results warrant additional studies to determine control processes and if the practice is effective in commercial mustard fields (Garni et al., 2002).

2.5. Control

The continual shifts in the population genetics of the pathogen require detailed molecular studies and regular attention to the development of new or improved measures to control harmful pathogens. However, the infection of plants with certain microbes (e.g., symbiotic microorganisms) can also have beneficial effects on plant health. Continued studies are needed to understand such systems and to explore ways to expand their benefits. This is necessary as it addresses fundamental questions in biology, while it is also of practical value for the application of beneficial microbes controlling harmful pathogens to build a better environment (Watve, 1998). Highly toxic insecticides with long residual effects are believed to hamper pollination in mustard and cause seed sterility.

3. MATERIALS AND METHODS

Monitoring and management of various rapeseed mustards, utilizing entomopathogenic fungus, microbial insecticides and chemical insecticides are the two aspects of the study that were carried out during the winter season from November 2017 to February 2018.

3.1. Monitoring

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

3.2. Field Experiment

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

3.2.1. Description of the Experimental Site

3.2.1.1. Location

The experiment was conducted at Agronomy Farm, AFU (Agriculture & Forestry University), Rampur, Chitwan, which is located in the plain area of Central Development Region. Geographically, it is located at $27^0$37' N latitude, 84^0 25' E longitude, and at an altitude of 256 meters above sea level.

3.2.1.2. Agro-Meteorological Information

The climate of the experimental site is sub-tropical (November 2017 to February 2018).

3.2.1.3. Cropping History

The agronomy field of Agriculture and Forestry University, Rampur, was the experimental field. Different entomological and pathological research was conducted during time, but the field was cultivated with rice before cropping of rapeseed. Field was barren for about three months prior to rapeseed cultivation.

3.2.2. Details of the Experiment

The experiment was carried out in split-plot design. Main plot factor was variety, and the sub-plot factor was insecticide for the experiment. Similarly, a commercial entomopathogenic fungus (Beauveria), two chemical insecticides (Spinosad and Imidacloprid), and control (water spraying) were used as insecticidal sprays. Pragati, Bikash, and Unnati are the three varieties used for the study. The individual plot size was 2.4m×2.1m (5.04m^2) and sown 30cm apart in 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.

3.2.2.1. Details of Treatments

Table 1 presents combinations of different varieties and insecticides/fungicides, along with their respective doses and trade names. The replication and treatment explain volume or quantity of inputs applied to determine appropriate insecticides or fungicides for better crop variety growth and production.

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		
7	Bikash		
8	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

3.2.2.2. Preparation of Insecticide Sprays

In the case of liquid insecticides, the required quantity of insecticide was added to a little quantity of water and stirred thoroughly, and then remaining quantity of water was poured to get the required concentration of final spray. In case of dust insecticide, the required amount was weighed and mixed with a small quantity of water, and remaining quantity of water was added with continuous stirring. The amount of insecticide required per liter of water was calculated by the formula given below:

Insecticide per liter of water= Concentration required/ percent a.i. ×100

3.2.2.3. Method and Time of Application

Altogether, three sprays were done in all the treatments. The first spray started 40 days after sowing when the population of aphids started appearing and repeated at 12-day intervals. A knapsack sprayer was used for spraying, and cleanliness of the sprayer was carried out after each spray of insecticide. Maximum care was taken to cover the whole plant surface with the spray materials. Spraying was carried out at evening time.

3.2.2.4. Cultural Practices

3.2.2.4.1. Land Preparation

The field was ploughed three times to bring the soil under good tilth, and planking was done after each ploughing for leveling the land. After leveling, the clods were broken, and weeds and stubbles were removed.

3.2.2.4.2. Manure and Fertilizer Application

The recommended amount of FYM (12mt /ha) was weighed and broadcast uniformly in the experimental field after first plowing and mixed well in the soil. 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 a basal dose. Nitrogen and phosphorus were applied through DAP (Diammonium Phosphate) containing 18% N and 46% P_2O_5. The remaining dose of nitrogen was applied through urea containing 46% N and potash through Muriate of Potash (MOP) containing 60% K_2O.

3.2.2.4.3. Seed Rate and Sowing

6 kg/ha was the seed rate used for sowing. The required number of seeds for each individual plot was calculated. 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. After this, the furrow was covered with a thin layer of soil. Sowing was done on November 23rd, 2017.

3.2.2.4.4. Weeding and Thinning

Hand weeding and thinning were done 15 days after sowing. After that, two successive thinnings and hand weeding were performed at weekly intervals. Final plant stand of 67 plants/m^2 was maintained 30 days after sowing. First weeding was done on 8th December 2017.

3.2.2.4.5. Harvesting

Harvesting was done by cutting the whole plants with a sickle from the soil surface. The net harvesting area was 5.04m^2. Harvested plants were sun-dried in the field and brought to the threshing floor by making bundles of each plot separately. Threshing of the crop for each plot was done separately and carefully.

3.2.3. Observation and Measurement

3.2.3.1. Yield and Yield Attributes

3.2.3.1.1. Number of Branches

Total numbers of branches (main branches) were counted from 15 sampled plants. Effective branches were counted and converted into average number of effective branches per plant. For each replication of each treatment, we separately recorded the average number of effective branches.

3.2.3.1.2. Number of Siliquas per Plant

Total numbers of siliqua/plant were counted from 15 sampled plants of each plot. The average number of siliquas was calculated per plant and then recorded as the total number of siliquas per plant.

3.2.3.1.3. Seeds per Siliqua

Total numbers of seeds obtained from any 10 siliqua of 15 sampled plants were counted and mean taken to get seed per siliqua.

3.2.3.1.4. Test Weight

Thousand seeds were taken from the harvested seed lot randomly, and their weights were calculated separately to find out test weight and expressed in grams.

3.2.3.1.5. Seed Yield

Seed yield was taken from the net harvested area from each plot. Seeds were cleaned properly, dried at 8% moisture content, threshed, and weighed for each plot separately. Then the yield was converted into kg/ha.

3.2.3.1.6. Biomass

Biomass was taken from the whole plot. After seeds were threshed from the pod's biomass, it was weighed by a weighing machine.

3.2.4. 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).

4. RESULTS

4.1. Effect of Variety and Insecticide on Growth of Crop

4.1.1. Plant Height

The plant height was 16.93 cm at thirty days after sowing and increased to 71.49 cm at sixty days after sowing. Plant height of crop was found non-significant between varieties at 30 and 45 days after sowing but statistically different at sixty days after sowing. Similarly, plant height of crop was found non-significant due to insecticide at all days after sowing except at 45 DAS. The interaction between variety and insecticide was also non-significant (Table 2).

At thirty days after sowing, higher height was recorded in variety Unnati (17.77cm) and least was recorded from variety Bikash (16.07 cm). Similarly, in the case of insecticides, relatively highest height was found in the case of Beauveria and least was found in Control.

At forty-five days after sowing, higher height was found in case of Bikash (64.67 cm), and least was found in case of Pragati (54.00 cm). Similarly, in case of insecticides, significantly the highest height was recorded in case of Beauveria (62.92 cm), followed by Imidacloprid (60.373 cm), Spinosad (55.54 cm), and Control (52.91 cm), respectively. Plant height was found statistically at par in case of Beauveria, Spinosad, and Imidacloprid.

At sixty days after sowing, the highest plant height was found in Bikash (79.03 cm), followed by Unnati (69.26 cm) and Pragati (66.19 cm), respectively. Furthermore, plant heights of Unnati and Pragati were statistically at par. Similarly, plant height was higher with Beauveria spray (76.58 cm) and least was obtained in case of control plot (67.25) (Table 2).

Table 2. Plant height (cm) at different days after sowing influenced by varieties and insecticides, Rampur, Chitwan, November 2017 to February 2018.

Treatment	**Plant height**		
Factor A (Variety)	**30 DAS**	**45 DAS**	**6 DAS**
Pragati	16.94	54.004	66.19^{b}
Bikash	16.07	64.672	79.03^{a}
Unnati	17.77	55.004	69.260^{b}
SEM	0.491	3.35	3.873
LSD	NS	NS	7.08
C.V.	31.6	11.3	8.7
Factor B (Insecticide)	30 DAS	45 DAS	60 DAS

Treatment	Plant height		
Factor A (Variety)	**30 DAS**	**45 DAS**	**6 DAS**
Spinosad 45% SC 0.44 ml/lit of water	17.33	55.543[ab]	67.77
Imidacloprid 70WG at 0.14gm/lit of water	17.64	60.734[a]	74.371
Beauveria bassiana 1.15% WP at 2 gm/lit of water	17.91	62.92[a]	76.580
Control	14.82	52.911[b]	67.250
SEM	0.711	2.302	2.345
LSD	NS	7.43	NS
C.V.	15.3	13.9	14.8
Grand mean	16.93	58.03	71.49

Note: a, b: Means in a column having same letter(s) do not differ significantly at 5% probability by DMRT, DAS: Days after sowing, SEM: Standard error of mean, NS: Non-significant, CV: Coefficient of variation; LSD: Least significant difference, CM: Centimeter, value with common letters are not significantly different from each other based on DMR at 5% level of significance.

4.1.2. Leaf Number

At thirty days after sowing, the leaf number was 10.78, and at thirty days after sowing, it increased to 21.15. Leaf number of crop was found non-significant between varieties at all days after sowing but statistically different at sixty days after sowing. Similarly, leaf number was found non-significant due to insecticide at all days after sowing. The interaction between variety and insecticide was also non-significant (Table 3).

At thirty days after sowing, the number of leaves observed in variety Bikash was 11.15, 10.82 in variety Pragati, and 10.39 in variety Unnati. Similarly, Beauveria had more leaves (11.850) and Imidacloprid had fewer leaves (9.61). At forty-five days after sowing, the number of leaf ranges was 18.65 in variety Pragati and 15.15 in variety Unnati. Similarly, a higher number of leaves were found in Spinosad (18.284) treated plots, and the least was found in Control (15.24) treated plots.

After sixty days of sowing, a higher number of leaves was revealed in Pragati (24.78) followed by Bikash (23.22) and Unnati (15.46), respectively. The leaf numbers of Pragati and Bikash were statistically on par with each other but superior to those of Unnati. Similarly, number of leaves were found higher in case of insecticide Spinosad (23.23) and least in case of Imidacloprid (18.90) (Table 3).

Table 3. Leaf number at different days after sowing influenced by varieties and insecticides, Rampur, Chitwan, November 2017 to February 2018.

Treatment	Leaf number		
Factor A (Variety)	**30 DAS**	**45 DAS**	**60 DAS**
Pragati	10.82	18.65	24.780[a]
Bikash	11.15	17.120	23.220[a]
Unnati	10.39	15.151	15.460[b]
SEM	0.220	1.012	2.882
LSD	NS	NS	4.64
C.V.	20.6	23.4	19.4
Factor B (Insecticide)	30 DAS	45 DAS	60 DAS
Spinosad 45% SC at 0.44 ml/lit of water	11.44	18.284	23.232
Imidacloprid 70WG at 0.14gm/lit of water	9.61	16.62	20.180
Beauveria bassiana at 2 gm/lit of water	11.850	17.753	22.305
4.Control	10.234	15.24	18.90
SEM	0.520	0.674	0.99
LSD	NS	NS	NS
C.V	19.3	19.1	20.4
Grand mean	10.78	16.97	21.15

Note: a, b: Means in a column having same letter(s) do not differ significantly at 5% probability by DMRT, DAS: Days after sowing, SEM: Standard error of mean, NS: Non-significant, CV: Coefficient of variation; LSD: Least significant difference, CM: Centimeter, value with common letters are not significantly different from each other based on DMR at 5% level of significance.

4.1.3. Branch Number

The branch number was found at 2.54 at thirty days after sowing and increased to 4.01 at sixty days after sowing. Branch number was found non-significant between varieties at all days after sowing except at sixty days after sowing. Similarly, branch number was found non-significant between sprayed insecticide at all days after sowing but statistically different at thirty days after sowing. The interaction between variety and insecticide was also non-significant (Table 4). After thirty days of sowing, the number of branches recorded in Pragati, Bikash, and Unnati were 2.69, 2.53, and 2.39, respectively. A higher number of branches were observed in case of insecticide Spinosad (2.93), treated plots, followed by Beauveria (2.77), Imidacloprid (2.28) and Control (2.16) treated plots, respectively. Branch numbers of Spinosad and Beauveria are statistically at par with each other. Imidacloprid and Beauveria are also statistically at par with each other, and Imidacloprid and Control are also statistically at par with each other.

At forty-five days after sowing, the number of branches ranges from 3.97, 3.82 and 3.38 in Pragati, Bikash, and Unnati, respectively. Similarly, branch numbers observed due to Spinosad, Control, Imidacloprid, and Beauveria were 3.79, 3.76, 3.67, and 3.67, respectively.

At sixty days after sowing, a significantly higher number of branches was recorded in Pragati (4.49), followed by Bikash (4.17) and Unnati (3.36), respectively. Moreover, the number of branches in Pragati and Bikash was statistically on par with each other but superior to Unnati. Similarly, a higher number of branches was observed in insecticide Spinosad (4.31) and lowest in Control (3.89) (Table 4).

Table 4. Branch number at different days after sowing influenced by varieties and insecticides, Rampur, Chitwan, November 2017 to February 2018.

Treatment	Branch number		
Factor A (Variety)	**30 DAS**	**45 DAS**	**60 DAS**
Pragati	2.69	3.97	4.49[a]
Bikash	2.53	3.82	4.17[a]
Unnati	2.39	3.38	3.36[b]
SEM	0.09	0.18	0.334
LSD	NS	NS	0.71
C.V.	32.6	15.2	15.5
Factor B (Insecticide)	30 DAS	45 DAS	60 DAS
Spinosad 45% SC at 0.44 ml/lit of water	2.931[a]	3.79	4.31
Imidacloprid 70WG at 0.14gm/lit of water	2.28[bc]	3.671	3.94
Beauveria bassiana 1.15% WP at 2 gm/lit of water	2.775[ab]	3.671	3.90
Control	2.160[c]	3.763	3.89
SEM	0.19	0.030	0.100
LSD	0.52	NS	NS
CV	20.6	18.4	17.7
Grand mean	2.54	3.72	4.01

Note: a, b, c: Means in a column having same letter(s) do not differ significantly at 5% probability by DMRT, DAS: Days after sowing, SEM: Standard error of mean, NS: Non-significant, CV: Coefficient of variation; LSD: Least significant difference, CM: Centimeter, value with common letters are not significantly different from each other based on DMR at 5% level of significance.

4.2. Effect of Different Treatments on Yield and Yield Attributing Characters

4.2.1. Number of Seed per Pod/Siliqua

The number of seeds per pod was 11.45. The number of seeds per pod was found to be significant in case of varieties and insecticides. The interaction between variety and insecticide was non-significant (Table 5).

Significantly higher number of seeds per pod was seen in Pragati (12.54), followed by Bikash (11.89) and Unnati (9.90), respectively. The number of seeds per pod in Bikash is statistically at par with Pragati.

Similarly, a higher number of seeds per pod was seen in insecticide Imidacloprid (12.39), followed by Beauveria (11.86), Control (10.90), and Spinosad (10.55), respectively.

Furthermore, the number of seeds per pod of Spinosad is statistically at par with Beauveria and control. Similarly, the number of seeds per pod of Beauveria and Control is statistically at par. And the number of seeds per pod of Imidacloprid is statistically at par with Beauveria and Control.

4.2.2. Yield

The yield of the crop was 0.60 t/ha. Yield was found to be significant in insecticides and non-significant in varieties. The interaction between variety and insecticide was also non-significant (Table 5).

Higher yield was seen in variety Bikash (0.68 t/ha) and least was observed in Pragati (0.55 t/ha). Significantly higher yield due to insecticide was by Imidacloprid (0.93 t/ha), followed by Beauveria (0.56 t/ha), Spinosad (0.48 t/ha), and Control (0.44 t/ha), respectively. Furthermore, yields by Spinosad, Beauveria, and Control were statistically at par.

4.2.3. Biomass (t/ha)

The biomass of mustard was found to be 5.18 t/ha. Biomass was found non-significant in case of varieties and significant in case of insecticides treatment. The interaction between variety and insecticide was also non-significant (Table 5).

Higher biomass was seen in the case of variety Bikash (6.49 t/ha), and least was in Unnati (4.23 t/ha). Biomass due to insecticide was significantly higher in Imidacloprid (7.28 t/ha), followed by Beauveria (5.39 t/ha), Spinosad (4.341t/ha) and Control (3.61t/ha), respectively. Pesticides Spinosad and Control are statistically at par. Similarly, Spinosad, Beauveria and Control are statistically at par. And Imidacloprid and Beauveria, are statistically at par.

4.2.4. Harvest Index (HI)

The data revealed that the Harvest Index was highest in Pragati (0.16) treated variety and lowest in Unnati (0.15). In case of insecticide-treated plots, a significantly higher harvest index was revealed in case of imidacloprid (0.29), followed by Beauveria (0.16), Spinosad (0.11), and Control (0.09), respectively. Moreover, Spinosad, Beauveria and Control were statistically at par (Table 5).

Table 5. Yield and yield attributes influenced by varieties and insecticides, Rampur, Chitwan, November 2017 to February 2018.

Treatment	**Yield and Yield attributes**			
Factor A (Variety)	**No. of seeds per pod**	**Yield (t/ha)**	**Biomass (t/ha)**	**Harvest index**
Pragati	12.54^{a}	0.552	4.815	0.165
Bikash	11.89^{a}	0.68	6.49	0.162
Unnati	9.902^{b}	0.575	4.234	0.155
SEM	0.793	0.04	0.674	0.002
LSD	1.74	NS	NS	NS
C.V.	13.4	47.9	97.7	106.6
Factor B (Insecticide)	No. of seeds per Pod	Yield (t/ha)	Biomass (t/ha)	Harvest index
Spinosad 45% SC at 0.44 ml/lit of water	10.55^{b}	0.48^{b}	4.341^{b}	0.11^{b}
Imidacloprid 70WG at 0.14gm/lit. of water	12.393^{a}	0.93^{a}	7.281^{a}	0.29^{a}
Beauveria bassiana 1.15% WP at 2 gm/lit of water	11.860^{ab}	0.56^{b}	5.393^{ab}	0.16^{b}
Control	10.980^{ab}	0.441^{b}	3.61^{b}	0.09^{b}
SEM	0.42	0.111	0.783	0.044
LSD	1.37	0.27	2.20	0.11
C.V.	12.1	46	42.9	65.7
Grand mean	11.45	0.60	5.18	0.16

Note: a, b, c: Means in a column having same letter(s) do not differ significantly at 5% probability by DMRT, 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.

5. DISCUSSIONS

5.1. Monitoring

Peak numbers of aphids were observed during the last week of December 2017 and third week of January 2018, but fluctuated from last week of December to third week of January. Aphid population seems to be decreasing after the third week of January 2018. The present findings are in conformity with the observations of Uttam, Mohan, and Tripathi (1993) who reported the mustard aphid population reaching its peak in the last week of December and third week of January.

5.2. Effect of Variety and Insecticide on Growth of Crop

At forty-five days after sowing, we found significant differences in the plant's height among different insecticides. The highest height was recorded with spraying of Beauveria (62.92 cm), followed by Imidacloprid (60.373 cm), Spinosad (55.54 cm), and Control (52.91 cm), respectively. A similar result was supported by Ujjan (2013), according to whom *Beauveria bassiana* is more effective in killing aphid populations due to its high mycoinsecticide potential in comparison to other pesticides that directly influence the height and growth of the crop. And Beauveria strain requires half a period after sowing than Imidacloprid requires for mortality of 50% aphid population.

Variety also influenced plant height. The varietal treatment significantly influenced the plant's height after sixty days of sowing. The highest height was recorded in the case of Bikash (79.03cm), followed by Unnati (69.26 cm) and Pragati (66.19), respectively. Castro, Evangelista, Melotto, and Rodrigues (1989) found that Bikash has the highest amount of GA3 hormone compared to Unnati and Pragati, which directly influences plant growth and development.

After sixty days of sowing, a significantly higher number of leaves were observed in variety Pragati (24.78) followed by Bikash (23.22) and Unnati (15.46), respectively, which may be due to different genetic makeup of the variety. According to Kumar, Singh, and Dhingra (1997) different plants may have different plant heights due to the differences in genetic makeup of different varieties.

Significantly higher number of branches were recorded in case of pesticides Spinosad (2.93) sprayed plots, followed by Beauveria (2.77), Imidacloprid (2.28), and Control (2.16), respectively after thirty days of sowing. Efficacy of Control was seen to be inversely proportional with the days of spray, which was supported by finding of Salgado (1997) that Spinosad also has effects on GABA receptor function that may contribute further to its insect activity. This mode of action is unique, which is seen generally at recent periods of sowing. Imidacloprid and other nicotinic receptor-based insecticides act at a different site than Spinosad. No other class of products affects the insect nervous system with the same mode of action, and no cross-resistance to Spinosad has been demonstrated. This aids plants to grow rapidly and produce a higher number of branches.

Higher numbers of branches were recorded in Pragati (4.49) followed by Bikash (4.17), and Unnati (3.36), respectively. Pragati and Bikash were statistically at par. The findings of this experiment agreed with those of Cheema, Malik, Hussain, Shah, and Basra (2001) who also reported significant differences in branches per plant among different cultivars of Brassica species. A higher branch number or any other better physical growth of rapeseed plant may be due to presence of omega-2, which is present in Pragati.

5.3. Effect of Variety and Pesticide on Yield and Yield Attributes

Variety and pesticides have a significantly positive correlation with the number of seeds per pod. This yield attributing character signifies a higher number of seeds per pod in the variety Pragati (12.54), followed by Bikash (11.89) and Unnati (9.90). The variety Pragati produced a higher number of seeds and high quality of seed as compared to Bikash and Unnati, which might be due to aggressive growth characters and a better source-and-sink relationship, which ultimately results in low yield. Similar findings were reported by Bharadwaj (1991) and Kumar, Singh, and Singh (2002). Sudhir, Sairam, and Prabhu (2013) conducted a study suggesting that low seed or siliqua production could be attributed to environmental conditions, specifically heat stress.

Higher number of seeds per siliqua was revealed by applying Imidacloprid (12.39), followed by Beauveria (11.86), Control (10.90), and Spinosad (10.55), respectively, where Beauveria and Control were statistically at par with each other with respect to the number of seeds per siliqua. And Imidacloprid was statistically at par with Beauveria. The plant growth regulators like GA3 might be involved in formation of seeds in the pods, and their optimum nourishments have resulted in a smaller number of aborted seeds and thus maximized the survival of fertile seeds/pods in rapes and mustard. The efficacy of Spinosad seems lower in comparison with other treatments. This result was supported by Inanaga and Kumura (1987); Holmberg and German (1991) and Bouttier and Morgan (1992).

Higher yield of mustard was revealed in Imidacloprid (0.93 t/ha)-treated plots as compared with Beauveria (0.66 t/ha), Spinosad (0.48 t/ha), and Control (0.44 t/ha). It was sure that pesticide-treated plots produce more yield as they control aphid population over non-application of pesticides. Hossain (1993) also find similar findings. Findings of Kumar and Dikshit (2001) state that Imidacloprid provided good control of *L. erysimi* under field conditions in India, and there was no residue of this insecticide in the harvested grains. Significantly maximum yield of rapeseed obtained from application of Imidacloprid, which was supported by findings of Akhauri and Singh (2009).

Higher biomass was recorded in case of Imidacloprid (7.28 t/ha), followed by Beauveria (5.39 t/ha), Spinosad (4.34 t/ha), and Control (3.61t/ha), respectively. He, Zhao, Zheng, and Wu (2012) observed that Imidacloprid, regarded as systematic spray when applied, becomes less toxic against Coccinellid predators and checks more aphid numbers, therefore increasing yield and harvest index of the crop. Significantly higher harvest index was found in spraying Imidacloprid (0.29), followed by Beauveria (0.16), Spinosad (0.11), and Control (0.09), respectively. Study confirmed that mortality caused by Spinosad was lower at field conditions than greenhouse bioassays that directly influence harvest index, which was confirmed by the findings of Ujjan (2013).

6. CONCLUSIONS

Regarding the number of mustard aphids, it was challenging due to the unpredictable weather. Aphids' population increases tremendously during the winter season. Growing mustard crops with planned technical standards is beneficial. Proper preparation and application of treatments as per instruction is necessary for academic research. An experiment was conducted to evaluate the status of mustard through various varieties and pesticide use from November 2017 to February 2018. The experiment was laid out in split-plot design with three replications. The three varieties (Pragati, Bikash, and Unnati) of mustard are the main factor, and insecticidal treatment was a subfactor of experiment. In Chitwan, Nepal, the last week of December to mid-January witnessed the highest aphid population. The findings are in line with the various past studies. To produce appropriate quality and quantity of rapeseed application of Imidacloprid and sowing of any of three varieties, Unnati, Pragati, and Bikash could be the best options.

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