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Efficiency of different insecticides against major insect pest of summer squash (*Cucurbita pepo*) in Mandhana-Kanpur, UP, India

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Abstract
The major insect pests of summer squash are Red pumpkin beetle, fruit fly, flea beetle, whitefly, squash bug, melon aphid, etc. which effect in huge loss to farmers and thus discouraging the farmers for cultivation of crop. Hence, a field trial were conducted to find out the efficacy of various insecticides against the major insect pests of summer squash from December 2020 to May 2021, in Kanpur, Mandhana, U.P. The experiment was laid in single factor Randomized Complete Block Design (RCBD) with 4 replications. "Anna 303" variety of summer squash was used under study. Two different botanical insecticides i.e. azadirachtin (nimbicidine) 500ppm @ 5 ml/L, jholmol @ 1:5 concentration and two chemical insecticides i.e. imidachloropid 17.8 SL @1.5ml/l and spinosad 45SC @1ml/L was used as treatments of experiment. Normal water spray was used as control. The results revealed that, among all the insecticides evaluated at all the four spray. Imidachloropid and spinosad recorded the minimum number of red pumpkin beetle (RPB), other insects, minimum leaf infestation percentage and leaf damage severity percentage per plant followed by azadirachtin and Jholmol respectively. The experiment also revealed that the efficacy of insecticide reduced with increasing time intervals of spraying i.e. all the insecticides showed greater reduction of RPB and other insects (45-90%) after 1 and 3 days of all the spray and decreased after that at all four sprays. Imidachloropid and spinosad gives comparatively lower fruit infestation by fruit fly i.e. 23.85% and 28.90% respectively than other insecticides. The population of beneficial insects (lady bird beetle, honeybee, wasps etc) were found to be minimum undertreatment of imidachloropid while spinosad, azadirachtin and jholmol (botanical pesticide) seems to be comparatively safer for those kind of beneficial insects. Both imidachloropid and spinosad treated plot was statistically ($p<0.05$) similar for yields (53.11 MT/ha and 51.41t ha^{-1} respectively); for fruit length (37.62 cm and 37.12cm respectively) and fruit diameter (26.78 and 26.51 respectively). The benefit cost ratio was highest for plot treated with imidachloropid (4) followed by spinosad, azadirachtin, jholmol and control. Thus, imidachloropid and spinosad was most effective and economic for the control of major insect pests and were economical whereas azadirachtin and jholmol was safer for beneficial insects.

Keywords major insect pest, summer squash, *Cucurbita pepo*

1. Introduction
Summer squash (*Cucurbita pepo* L.), also called zucchini, which is one of the most important summer vegetable of Cucurbitaceae family. Zucchini plants are typically bushy. Some varieties have a creeping habit. The leaves are large. The stems and the leaves have small prickly trichomes. It have large unisexual flowers which have yellow-orange petals. Some varieties are dark green cylindrical, but some are round or intermediate shapes. The fruit type is berry known as a pepo which is usually harvested before become hard (Encyclopædia, 2018) [10]. In some place of world, tender fruits are commonly eaten raw or with salt in salad, also used for pickle making. There is also a saying that, it acts as detoxifying agent found to prevent hair loss, control diabetes and many more. It is important nutritionally also.

Summer squash is susceptible to the number of insects, pests and diseases that affect reduction in production and also in quality of crop. Among the several pests like red pumpkin beetle, epilachna beetle, squash bug, etc., melon fruit fly is as serious pest of cultivation (Shorab, CS, & Wajid, 2018) [35]. Red pumpkin beetle being polyphagous in nature, both larval and adult stages are harmful to crop and cause major damage in seedlings and young, tender leaves and flowers; (Doharey K, 1983). It is an active, brilliant orange-red colored insect whose adult feed voraciously in leaf making irregular holes and also larvae damage by various ways by boring into the roots along with the underground stem part also by feeding on the leaves and fruits line in contact with the soil (Srivastava & Butani, 1998) [36]. According to Shivanlingaswamy, Kumar, Satpathy, Bhardwaj, & Rai, 2008, the maximum population of red pumpkin beetle was active in the month of May. The losses due to the infestation by this pest are quite evident which may reach up to 35-75% (Alam, 1969).

According to result obtained from the field experiments on assessment of losses caused by cucurbit fruit fly in different cucurbits, % yield losses in pumpkin, bitter gourd, bottle gourd, cucumber, and sponge gourd was found to be 28.7 - 59.2, 24.7 - 40.0, 27.3 - 49.3, 19.4 - 22.1, and 0 - 26.2% respectively(Pradhan, 1976) [28]. Depending on the susceptibility of crop and the season the extent of losses caused by fruit fly varies from 30 to 100% (Dhillon, Singh, Naresh, & Sharma, 2005) [8]. Fruit fly adults often lay their eggs 2 to 4 mm deep in the young, green soft skinned fruit tissues, which hatches into maggots which further feed inside the fruit resulting in a sunken, discolored patches, distortions and open cracks(Dhillon, Singh, Naresh, & Sharma, 2005) [8]. These sunken patches serve as entry points for fungi and bacteria, causing fruit rot. At times, the eggs are also laid in the corolla of the flower, and the maggots feed on the flowers. Thus, Fruit flies undergo three stages of development before emerging as adults: egg, larva and pupa. At room temperature, fruit flies can develop into adults within one to two weeks. The egg and larval stages span approximately eight days, while the purple stage lasts six days. The adult fruit fly lives for several weeks.

Many chemicals as well as biological insecticides having high efficacy on the prevention as well as the control of insects, pests and diseases are available in agro-vets, markets. Also, now a days integrated pest management techniques like use of resistant varieties, sex pheromones (leucin lure, cue lure, Spodo lure), cultural methods (sanitation, proper tillage), physical and mechanical barriers (bagging of fruits), bio-pesticides (spinosad, neemax) and bio-control agents (NPV, Trichogramma spp., *Bacillus thuringiensis*), botanical (cow urine, jholmol) and chemical (cypermethrin, chlorantraniliprole) means of management are gaining popularity among the farmers. The as usual method for controlling those harmful insect pests could be application of insecticides. But the main problem is improper information use of synthetic pesticide i.e. indiscriminate application of the doses of synthetic pesticides due to which several problems has been seen like development of insect resistance to insecticides, induction of resurgence to major sent pests, outbreak of secondary pests and undesirable effect on non-target organisms as well as serious environment pollutions is occurred. It is very necessary to determine the damages and to find out the accurate/proper dose of the insecticide in order to control those pests properly in the field.

In India, Diseases, insects, weeds and others pests causes the substantial loss in the yield and quality of summer squash. Improper farming practices like in proper spacing between the crops, lack of proper knowledge and technical person, ineffective management of pests diseases causes the low productivity of summer squash.

India is known to be the hub of the vegetable production. The major problem seen in the vegetable production is of market and the second one is of insects, pests and diseases. Red pumpkin beetle and fruit fly in summer squash is considered to be the major and problematic pest of the summer squash causing the subsequent loss in the yield as well as on the quantity and quality of the crops. About 50 per cent of cucurbits are partially or completely damaged by those problematic insect pests (Gupta & Verma, 1992) [12]. Due to the huge loss in the quality as well as quantity of the fruits because of those insect pests, farmers are discouraged in cultivation of summer squash. However, many farmers are currently using harmful, hazardous chemicals in the higher rate for faster result for the management of fruit fly without knowing about pesticide residue, and pest resistance, resurgence of pest, destruction of beneficial insects and environmental pollution, detrimental effects on the fertility of soil and human health and other content too. (Abang, Kouame, Abang, Hanna, & Fotso Kuate, 2013) [1].

Farmers using pesticides in high amount in wrong way i.e. they did not know about safety measures and the waiting period for the pesticides that results in the health problems in human as well as animals, birds and other useful insects of our environment. The hazardous chemicals used in harmful way are not good for sustainable vegetables production thus substitution of chemical pesticide should done. Also, the old and traditional insecticides have become ineffective for the management of major insect pests of cucurbits even if they are used at higher doses. Hence, it is very necessary to conduct site based researches and site specific recommendations regarding the proper use of various insecticides and for identifying most effective novel insecticides in the management of insect pests of vegetables.

2. Materials and Methods

2.1 Experimental site

The experimental site was horticultural field of Rama University, Mandhana, Kanpur, Uttar Pradesh, India. Geographically it is located between26.35°N 80.09°E Coordinates: 26.35°N 80.09°E. The altitude of the site ranges from130.00m/426.51ftabove sea level.

2.2 Weather condition

The research site lies in the tropical zone of India. It is characterized by three distinct seasons namely, rainy monsoon (June – October), cool winter (November – February), and hot summer (March – May). Research was conducted during the month of December to May. The weather pattern during the research period is shown in the figure below. Great variations was observed on the weather paramters. The maximum and minimum temperatures was observed in the range of 16-30^{0}C and 5-18^{0}C respectively. Relative humidity was recorded in the range of 40-70%. Precipitation was recorded in the range of 0-9 mm/day. Higher rainfall was found in the later period of crop development (fruiting and harvesting).

2.3 Sample and Sampling Techniques

At first, the preliminary survey for major problem related to vegetable cultivation was carried out in the areas of vegetable block. According to the problem identified field research for the fruit fly management in summer squash was conducted in the field of farmer. The samples were collected from the replications made on the plots of summer squash field. Five sample plants was taken from each of the plots removing the border plants.

2.4 Experimental design

Design: Randomized Complete Block Design
No. of Treatments: 5
No. of Replication: 4
Individual plot size: 4 × 4m
Row-Row spacing: 80cm
Plant-Plant spacing: 80cm
Thus, the experiment was conducted in Randomized

Complete Block Design (RCBD) with 5 treatments and each treatment was replicated 4 times. Each plot contained 5 rows and each row accommodated 5 plants. Five plants were taken randomly as sample plant from middle 8 plants.

2.6 Treatment details
For the research, 5 treatments were selected with four insecticides including one untreated control.
T_1- Spinosad 45SC @ 1ml/l
T_2- Azadiractin (Nimbecidine) 300ppm @5ml/l
T_3- Botanical pesticide 'Jholmal'-(Jholmol: water at 1:5 ratio)
T_4- Imidachloropid @1.5 ml/lit
T_5- Control (normal water spray)

Jholmol is a botanical pesticide prepared by using Local biological products i.e. the leaf extract of half kg leaves of each: neem, ashuro, tulsi, tomato, titepati, bojho, sayapatri, godawari, and khirro will be chopped and mixwith cow urine, fresh cow dung and spices (100g of each fresh garlic, chilli, and zinger. @ 1:5 concentration) and kept on air tight plastic drum over 60 days.

2.7 Field operation
2.7.1 Seedlings preparation
Summer squash of variety Anna 303 was used for the trial. One seed per poly bag was sown in poly-bags of size 4*5 inch under protected conditions. Regular watering was carried out as required before and after germination. After complete germination of the seed, seedlings @ 4-5 leaf stage were transplanted.

2.7.2 Transplanting
The field was ploughed twice followed by planking to attain good tilth. Pit was dug to accommodate the seedlings with soil intact and the seedlings was transplanted with spacing of 80 cm * 80 cm P-P * R-R.

2.7.3 Intercultural operations
Irrigation, weeding, manuring and fertilizers are the main intercultural operations performed in the field. Irrigation was done through surface irrigation system as per plant requirement. Recommended dose of FYM (30 ton/ha) and N: P: K @ 140:80:40 kg/ha was used. Recommended full dose of FYM, phosphorous as DAP, potassium as MOP and recommended half dose of nitrogen through urea were applied as basal dose. Remaining half dose of nitrogen was supplied at two split doses at 30 DAT and 45 DAT respectively. Also, different insects, pests and diseases have been seen in the field at different stages of the growth of the crop and for those appropriate management and control techniques were applied.

2.7.4 Harvesting
Harvesting was done manually with hands using secateurs. Fruits was harvested when still green, immature and tender stage.

2.8 Method of recording of observations
For recording the observation related to the morphology and insect infestation from the field, five sample plants were selected from each plot and were tagged with the rope for the indication and the data were collected from the plant
For the comparison of the effectiveness of the treatment on the Red pumpkin beetle, fruit fly and other insects of summer squash, data on the following parameters were recorded on the field.

a) No. of insect per plant (red pumpkin beetle and other)
The number of Red Pumpkin Beetle per plant was manually counted (one day)24 hr. before spray and after (one day)24hr of spray, i.e. after third, sixth and tenth day of spray.

b) Leaf infestation percentage
The total leaves and number of infested leaves were recorded from the sample plant before spray and on 6th and 10th day of spray. Based on this, percentage of leaf infestation was recorded.

c) Damage severity percentage in the infested leaf
On those damaged or infested leaves recorded, based on the infested area on the individual infested leaf percentage of damage were assigned on the infested leaves and were recorded.

e) Number of other insects per plant
The number of other insects as flea beetle, squash bug, white fly etc found per sample plant was manually counted 24 hr. before spray and after 24 hr. of spray, third, sixth and ten day of spray. Also number of beneficial insects like lady bird beetle, bees, wasp were also recorded.

f) Percentage fruit damage/infested
The number of fruit damaged by fruit fly was also recorded at each harvest and the percent fruit infestation was computed on the basis of number of infested fruits out of total number of fruits observed.

$$\text{Percentage Fruit damage} = \frac{\text{Number of infested fruits}}{\text{Total number of harvested fruits}} \times 100$$

Also, following yield attributing characters were recorded from the sample plants at each harvest

g) Average Fruit length
Length of the fruit of sample plant will be measured with the help of measuring tape or scale and average of the length of fruits were taken.

h) Average fruit diameter
Diameter of the fruit of sample plant was measured with the help of Vernier caliper and average fruit diameter was calculated.

i) Fruit Yield
The fruit yield was recorded treatment wise. Fruits harvested from the selected plants was taken and weighed, and expressed in terms of Mt ha^{-1}.

2.9 Data analysis
All the recorded data was arranged systematically treatment wise under four replications on the basis of various observed parameters by Ms Excel Studiosoftware was used to analyze the data. Duncan's Multiple Range Test (DMRT) was employed to find out the significant differences between the mean values at 5% level of significance. The significance was determined using format of ANOVA table.

3. Results and Discussion

3.1Number of Red pumpkin beetle per plant

The number of red pumpkin beetle (RPB) per plant a day before spray and after spray at different dates is as shown in the table no 1. The average no. of red pumpkin beetle per plant was found to be 3.4 before the first spray and the no. of RPB per plant was not significantly different among the treatments. The average no. of RPB per plant at 1 DAS, 3 DAS, 6 DAS and 10 DAS were 1.03, 1.59, 2.72 and 3.08 respectively (Table no 1). The percentage reduction of RPB over control for all the treatments at different dates of spray is also shown in the table no 1.

At 1 DAS and 3 DAS of first spray, the no. of RPB was significantly minimum in imidachloropid treated plots and was statistically similar with spin sad treated plots. However, the no. of RPB was found to be maximum for jholmol and azadirachtin treated plots which were also statistically similar.

The no. of RPBAt 6 DAS, in imidachloropid and spinosad was significantly lower than other insecticides and was statistically similar. Whereas the no. of RPB per plant was observed significantly higher for jholmol followed by Azadirachtin. Likewise, At 10 DAS, the no. of RPB was significantly higher and statistically similar in jholmol and Azadirachtin followed by spinosad and imidachloropid. The highest population of RPB per plant was found in the control.

The population of RPB were reduced by 96.71 percent at 1 DAS for imidachloropid treated plots over control followed by spinosad (95.45%), azadirachtin (81.36%) and jholmol (80.62%) respectively. At all the dates of observation the percentage reduction of RPB over control was found to be highest in imidachloropid treated plots followed by spinosad, azadirachtin, and jholmol respectively and was also found that maximum reduction of RPB by the treatments over control was recorded at 1 DAS followed by percentage reduction recorded at 3, 6 and 10 DAS respectively. Like Highest reduction of RPB were observed at 1 DAS by imidachloropid treated plots at 1 DAS which were observed consequently decreased as 84.38%, 46.14%, 44.28% at 3 DAS, 6 DAS, and 10 DAS respectively. At 10 DAS, PROC for jholmol treated plots was found to be zero.

Table 1: Effect of insecticides on no. of Red pumpkin beetle per plant of Summer squash before and after First spray.

Treatment Insecticide	No of Red Pumpkin Beetle per plant (before spray and reduction after spray)								
	BS	**1 DAS**	**PROC**	**3 DAS**	**PROC**	**6 DAS**	**PROC**	**10 DAS**	**PROC**
Imidachloropid	3.50	0.16	96.71	0.56	84.38	1.91	46.14	1.96	44.28
Spinosad	3.30	0.14	95.45	0.61	81.81	1.99	40	2.51	24.24
Azadirachtin	2.95	0.54	81.35	1.04	64.44	2.72	7.45	2.84	3.39
Botanical pesticide(Jholmol)	3.25	0.6	80.62	1.36	58.46	3.01	7.69	3.24	0
Control	3.50	3.60		3.91		3.91		4.81	
F-test	Ns	***		***		***		***	
LSD(0.05)	0.41	0.24		0.42		0.23		0.75	
SEm(±)	0.13	0.08		0.14		0.07		0.24	
CV%	7.96	15.58		18.29		5.41		15.81	
Grand Mean	3.4	1.03		1.59		2.72		3.08	

SEm: Standard error of means. LSD: Least significant difference. CV: Coefficient of variation. Means followed by the same letter in a column are not significantly different by DMRT at 5% level of significance. Ns= Non-significant, *=significant at 5% probability level, **= significant at 1% probability, ***=significant at 0.1% probability BS= before spray DAS= Days before spray PROC= Percentage reduction over control

3.2 Number of other insects per plant

Table 2: Effect of insecticides on no. of other insects per plant of Summer squash before and after spray.

Treatment Insecticide	No of other insects per plant (1st spray)								
	BS	**1 DAS**	**PROC**	**3 DAS**	**PROC**	**6 DAS**	**PROC**	**10 DAS**	**PROC**
Imidachloropid	2.35	0.14	94.63	0.54	78.61	0.71	70.24	0.84	63.88
Spinosad	2.55	0.41	84.38	0.79	69.44	0.92	63.83	1.36	47.09
Azadirachtin	2.55	1.01	60.88	1.46	43.22	1.69	34.22	1.94	28.83
Botanical pesticide(Jholmol)	2.50	1.28	48.8	1.74	30	1.86	27	2.31	
Control	2.85	3.61		3.31		3.66		3.81	
F-test	NS	***		***		***		***	
LSD(0.05)	0.71	0.28		0.55		0.26		0.43	
SEm(±)	0.23	0.09		0.18		0.08		0.14	
CV%	17.93	14.36		22.98		9.44		13.65	
Grand Mean	2.56	1.28		1.57		1.76		2.05	

SEm: Standard error of means. LSD: Least significant difference. CV: Coefficient of variation. Means followed by the same letter in a column are not significantly different by DMRT at 5% level of significance. Ns= Non-significant, *=significant at 5% probability level, **= significant at 1% probability, ***=significant at 0.1% probability BS= before spray DAS= Days before spray PROC= Percentage reduction over control

Note: The data of BS is the data recorded at 10 DAS of the 3rd spray

3.3 Number of Beneficial insects per plant

The number of other insects per plant a day before 1st spray and after 1st spray at different dates is as shown in the above table. The percentage reduction of the insects other than RPB over control for all the treatments at different dates of 1st spray is also shown in the table no 2. The average no. of insects other than RPB per plant was found to be 2.56 before the first spray and the no. of other insects per plant was not significantly different among the treatments. At all the dates after the first spray, the no. of other insects was found to be significantly affected by the application of different insecticides (table no 2)

At all the observations, the minimum population of other insects per plant was recorded in imidachloropid treated plots followed by spinosad, azadirachtin and jholmol respectively. While at 1, 3 and 6 DAS, the no. of other insects per plant in imidachloropid treated plot was found to be statistically similar with spinosad treated plots. Likewise, population of other insects per plant in azadirachtin and jholmol treated plots were found to be statistically similar at all the observations. However, at 10 DAS imidachloropid treated plots showed significantly reduction in the population of other insects. The highest population of other insects per plant was found in the control plots in which no chemical was sprayed.

Thus, at all the observations, Imidachloropid treated plots recorded maximum reduction of other insects over control (94.63% at 1 DAS, 78.61% at 3 DAS, 70.24at 6 DAS and 63.88% at 10 DAS) followed by spinosad (84.38% at 1 DAS, 69.44% at 3 DAS, 63.83% at 6 DAS and 47.09% at 10 DAS), azadirachtin (60.88% at 1 DAS, 43.22% at 3 DAS, 34.22% at 6 DAS and 23.83% at 10 DAS) and jholmol (48.81% at 1 DAS, 30.2% at 3 DAS, 27% at 6 DAS and 9% at 10 DAS) respectively. It was found that at 1 DAS, there was maximum reduction of other insects over control in all the treatments which were gradually decreased and showed minimum reduction at 10 DAS.

The effect of different insecticides in no. of beneficial insects per plant a day before 1st spray and after 1st spray at different dates is as shown in the above table. The average no. of beneficial insects per plant was found to be 1.54 before the first spray and the no. of beneficial insects per plant was not significantly different among the treatments. Highly significant effect of treatments in no. of beneficial insects per plant was observed at 1 and 3 DAS of 1st spray. Maximum population of natural enemy was recorded in jholmol treated plots which was significantly at par. with control plots followed by azadirachtin, spinosad and imidachloropid respectively. Azadirachtin and spinosad treated plots were found to be statistically similar. At both observations imidachloropid treated plots showed significant reduction in the no. of beneficial insects per plant (table no 3)

No significant effect of insecticides in no. of beneficial insects was observed at 6 and 10 DAS of first spray.

Table 3: Effect of insecticides on no. of beneficial insects per plant of Summer squash before and after spray.

Treatment	No of beneficial insects per plant (1st spray)				
Insecticide	**Before spray**	**1 DAS**	**3 DAS**	**6 DAS**	**10 DAS**
Imidachloropid	1.75	0.21	0.80	1.05	1.35
Spinosad	1.60	1.16	1.21	1.75	1.75
Azadirachtin	1.60	1.21	1.46	1.65	1.65
Botanical pesticide(Jholmol)	1.45	1.70	1.91	2.25	2.25
Control	1.30	1.70	1.86	1.75	1.75
F-test	NS	***	***	NS	NS
LSD(0.05)	0.70	0.49	0.26	0.21	0.66
SEm(±)	0.23	0.16	0.08	0.21	0.21
CV%	29.68	25.65	11.47	8.67	24.42
Grand Mean	1.54	1.21	1.45	1.56	1.75

SEm: Standard error of means. LSD: Least significant difference. CV: Coefficient of variation. Means followed by the same letter in a column are not significantly different by DMRT at 5% level of significance. NS= Non-significant, *=significant at 5% probability level, **= significant at 1% probability, ***=significant at 0.1% probability DAS=Days after spray

3.4 Leaf infestation percentage and Leaf damage severity percentage per plant

The effect of different insecticides in leaf infestation percentage at different spray is as shown in the table no 4. The average leaf infestation percentage of plant a day before 1st spray was found to be 40.20 and the leaf infestation percentage recorded was not significantly different among the treatments.

At 1st spray, the minimum leaf infestation percentage was recorded in imidachloropid treated plots (32.85% in 6 DAS and 28.81% in 10 DAS) which was statistically similar in spinosad treated plots (33.85% in 6 DAS and 29.84% in 10DAS) followed by azadirachtin (42.01% in 6 DAS and 39.55% in 10 DAS), botanical pesticide (43.28% in 6 DAS and 40.28% in 10 DAS) and control plots (50.85% in 6 DAS and 52.24% in 10 DAS) respectively. Azadirachtin and jholmol were found to be statistically similar.

Similar results were observed in other 2nd, 3rd and 4th spray which showed highly significant result where imidachloropid recorded significantly lower percentage of leaf infestation which was statistically similar with spinosad followed by azadirachtin and botanical pesticide respectively. Highest percentage of leaf infestation was found in control plots in which no chemicals was sprayed.

Table 4: Effect of insecticides on Leaf infestation percentage per plant of Summer squash at different dates of spray.

	Leaf infestation percentage per plant								
Treatment	**First spray**			**Second spray**		**Third spray**		**Fourth spray**	
Insecticide	**1 DBS**	**6 DAS**	**10 DAS**	**6 DAS**	**10 DAS**	**6 DAS**	**10 DAS**	**6 DAS**	**10 DAS**
Imidachloropid	38.57	32.85	28.31	28.81	30.16	27.91	24.93	28.72	24.87
Spinosad	40.52	33.85	29.84	29.59	32.26	29.11	27.76	31.98	27.58
Azadirachtin	44.19	42.01	39.55	39.09	38.16	36.70	37.99	38.38	36.38
Botanical pesticide(Jholmol)	38.73	43.28	40.28	39.85	39.45	35.50	37.18	42.08	39.55
Control	39.00	50.85	52.34	52.27	51.68	49.71	51.78	52.95	57.57
F-test	NS	***	***	***	***	***	***	***	***
LSD(0.05)	5.35	1.54	2.98	3.49	2.80	4.87	4.64	4.63	3.86
SEm(±)	1.74	0.55	0.97	1.13	0.91	1.58	1.51	1.51	1.24
CV%	8.64	2.40	5.09	5.10	4.75	8.83	8.38	7.75	6.73
Grand Mean	40.20	40.3	37.92	37.82	38.34	35.80	35.93	38.82	37.19

SEm: Standard error of means. LSD: Least significant difference. CV: Coefficient of variation. Means followed by the same letter in a column are not significantly different by DMRT at 5% level of significance. NS= Non-significant, *=significant at 5% probability level, **= significant at 1% probability, ***=significant at 0.1% probability DBS= Day before spray DAS= Days before spray

3.5 Average length of fruit
Length of the fruits harvested from all the plots were found to be significantly affected by application of the treatments (table 5). Maximum length of the fruit was observed in the imidachloropid treated plots (38.63cm) which was statistically similar with spinosad (38.12cm) followed by azadirachtin (35.47cm) and botanical pesticide (36.33cm) respectively. Azadirachtin and jholmol were also found to be statistically similar.

Table 5: Effect of insecticides on average length of fruit of Summer squash.

Treatment Insecticides	Average length of the fruit
Imidachloropid	38.63
Spinosad	38.12
Azadirachtin	35.47
Botanical pesticide(Jholmol)	36.33
Control	32.45
F-test	***
LSD(0.05)	0.93
SEm(±)	0.30
CV%	1.71
Grand Mean	35.20

SEm: Standard error of means. LSD: Least significant difference. CV: Coefficient of variation. Means followed by the same letter in a column are not significantly different by DMRT at 5% level of significance. Ns= Non-significant, *=significant at 5% probability level, **= significant at 1% probability, ***=significant at 0.1% probability

3.6 Average diameter of fruit
The effect of insecticides on the diameter of the fruit was found to be significant among the treatments. The average diameter of the fruits was observed to be 25.96 cm.

The fruits of imidachloropid treated plots were observed to have maximum diameter i.e. 26.88cm followed by the fruits of spinosad (26.81cm), azadirachtin (24.24cm) and jholmol (24.27cm) respectively. Azadirachtin and jholmol treated plots showed statistically similar result. The minimum diameter of the fruit was recorded in control plot in which no chemical was sprayed.

Table 6: Effect of insecticides on average diameter of fruit of Summer squash.

Treatment Insecticides	Average diameter of the fruit
Imidachloropid	26.88
Spinosad	26.81
Azadirachtin	24.34
Botanical pesticide(Jholmol)	24.27
Control	24.12
F-test	**
LSD(0.05)	0.074
SEm(±)	0.30
CV%	0.60
Grand Mean	25.96

SEm: Standard error of means. LSD: Least significant difference. CV: Coefficient of variation. Means followed by the same letter in a column are not significantly different by DMRT at 5% level of significance. Ns= Non-significant, *=significant at 5% probability level, **= significant at 1% probability, ***=significant at 0.1% probability

3.7 Fruit infestation percentage per plant
Table no 7 signifies that the fruit infestation by fruit fly is highly influenced by the application of different insecticides. At 1st harvest (30 DAT), the imidachloropid treated plots recorded the significantly lower percentage of fruit infestation (23.74%) followed by spinosad (28.51%), azadirachtin (37.70%) and jholmol (41.26%) and control plot (64.19%) respectively.

At 2nd harvest (35 DAT), minimum fruit infestation percentage was found in imidachloropid treated plots (19.01%) which was statistically similar with spinosad treated plots followed by azadirachtin (38.15%) and botanical pesticide (35.43%) respectively. Azadirachtin and jholmol were also found to be statistically similar. Control plots recorded maximum fruit infestation percentage (71.23%) in which no chemicals were sprayed.

Similar results were observed at 3rd and 4th harvest. Also at 5th harvest, imidachloropid treated plots was found to have significantly lower fruit infestation percentage (15.74%) followed by spinosad (16.56%), azadirachtin (31.34%) and botanical pesticide (33.34%) and control plot (71.08%) respectively. Imidachloropid and spinosad were found to be statistically similar.

Table 7: Effect of insecticides on Fruit infestation percentage per plant percentage per plant of Summer squash at different dates of spray.

Treatment	Fruit infestation percentage per plant				
Insecticide	30DAT	35 DAT	40 DAT	45 DAT	50 DAT
Imidachloropid	23.74	19.01	15.67	18.19	15.73
Spinosad	28.51	20.51	17.00	17.67	16.58
Azadirachtin	37.70	38.15	35.05	32.55	31.34
Botanical pesticide (Jholmol)	41.26	35.43	35.20	33.70	33.32
Control	64.19	71.23	72.87	62.32	71.08
F-test	***	***	***	***	***
LSD(0.05)	3.26	3.73	5.71	4.53	1.71
SEm(±)	1.07	1.22	1.85	1.47	0.55
CV%	5.43	6.57	10.54	8.94	3.30
Grand Mean	39.08	36.82	35.15	32.88	33.61

SEm: Standard error of means. LSD: Least significant difference. CV: Coefficient of variation. Means followed by the same letter in a column are not significantly different by DMRT at 5% level of significance. Ns= Non-significant, *=significant at 5% probability level, **= significant at 1% probability, ***=significant at 0.1% probability Days after transplanting

3.8 Average yield in tons/ha of summer squash
Effect of insecticides on yield of the fruits was found highly significant among the treatments (table 8). The maximum yield of fruit was recorded in imidachloropid treated plots i.e. 52.11tons/ha followed by spinosad (50.41tons/ha), azadirachtin (43.75tons/ha), and botanical pesticide (38.74 tons/ha) respectively. The yield of fruits of imidachloropid treated plot was found to be statistically at par with spinosad treated plot. The minimum yield of the fruit was recorded in control plots (29.81 tons/ha) at which no chemical was sprayed.

Table 8: Effect of insecticides on Yield (tons/ha) of Summer squash

Treatment Insecticides	Yield(tons/ha)
Imidachloropid	52.12
Spinosad	50.41
Azadirachtin	43.75
Botanical pesticide(Jholmol)	38.74
Control	29.81
F-test	***
LSD(0.05)	2.43
SEm(±)	0.79
CV%	3.69
Grand mean	43.78

SEm: Standard error of means. LSD: Least significant difference. CV: Coefficient of variation. Means followed by the same letter in a column are not significantly different by DMRT at 5% level of significance. Ns = Non-significant, *=significant at 5% probability level, **= significant at 1% probability, ***=significant at 0.1% probability

4. Conclusion

The study on efficiency of different insecticides against major insect pests of summer squash in open field condition brought some information.

Imidachloropid and spinosad were found to be most effective insecticides against the red pumpkin beetle and other insects as they showed significant reduction in their population. Likewise, in terms of Leaf infestation %, leaf damage severity % as well as fruit infestation %, Imidachloropid and spinosad were proved to be most effective as they showed superior result. Botanical pesticides, Azadirachtin and Jholmol were also effective against the pests of summer squash as they showed superior result compared to control and thus can be recommended as the alternative insecticides against the major insect pests of summer squash. Greater yield and yield attributes (length and breadth of fruit) were observed in all insecticidal treatments but superior imidachloropid and spinosad treated plots.

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