Original Research Article

Correlation between the Seasonal Incidence of Aphids and Coccinellids on the Indian Mustard in Different Varieties and Sowing Dates

Abstract

Ecological engineering plays an important role in Integrated Pest Management. Considering this, a field experiment was conducted at the Students' Instructional Farm (SIF), Chandra Sekhar Azad University of Agriculture and Technology, Kanpur during the rabi season of 2020-21. The severity of the mustard aphid, *Lipaphis erysimi* (Kalt.) in mustard (*Brussica juncea* L.) crop and its period of occurrence were not uniform in two successive crop seasons. The highest aphid intensities of 120.8 aphids per plant, 138.0 aphids per plant, 148.7 aphids per plant, and 176.1 aphids per plant were recorded on mustard varieties Varuna, Varuna, Azad Mahak, and Ashirwad, respectively, during mid-February (6th MSW) when the mustard was planted on 13th November, 23rd November, 25th November, and 10th December 2020. A negative correlation was established between the average temperature (r = -0.3599) and the actual intensity of aphids, as well as the weekly increase of aphids (r = -0.5838). On the other hand, average relative humidity had a positive influence on aphid incidence. The potentiality of predatory beetles (coccinellids) in the mustard ecosystem was found to be weather-dependent. The weather factors favourable for aphid multiplication did not support the enhancement of the population of predatory ladybird beetles.

Keywords: Coccinellids, Ecological, *Lipaphis erysimi*, Temperature, Varuna

Introduction:

Indian mustard (*Brassica juncea*) is an economically significant oilseed crop cultivated extensively across various regions of the Indian subcontinent. Aphids (Hemiptera: Aphididae) are notorious pests known for infesting mustard crops, causing damage by sucking sap and transmitting plant viruses. These infestations can lead to reduced yields and adversely impact the quality of mustard oil. In terms of economic importance, the mustard aphid (*Lipaphis erysimi*) is regarded as a national pest. Mustard aphid (*Lipaphis erysimi* Kalt.) is of prime significance, which tolls up to 91.30 per cent seed yield. This pest alone can devastate the entire mustard crop. Both nymph and adult cause damage by sucking the cell sap from leaves, petioles, tender stems, inflorescence and pods. Due to continuous desapping by a large aphid population, yellowing,

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curling and subsequent drying of leaves take place, which ultimately leads to the formation of weak pods and undersized grains. The aphids also secrete the honeydew which provides a suitable medium for the development of sooty mould which ultimately hampers the process of photosynthesis. On the basis of economic importance, the mustard aphid is considered to be a key pest. The losses in yield caused by mustard aphid ranged from 9% to 95% (Singh *et al.* 1980), 35.4% to 72.3% (Bakhetia *et al.*, 1986), 24.0% to 96% (Phadke, 1985), up to 96% (Verma, 2000) and 35.4% to 91.3% (Patel *et al.*, 2004) at different places of India such as Haryana, Delhi, Kanpur and Gujarat, respectively. Such losses may go up to 100% in certain mustard-growing regions (Singh and Sachan, 1999). The bio-control agents like Coccinellids, chrysopids and syrphids have been reported to be effective in controlling the aphid, *Lipaphis erysimi* (Kalt.) The balance between aphid infestation and the presence of coccinellids can significantly affect crop health and productivity. This research endeavours to investigate the seasonal dynamics of aphids and coccinellids on Indian mustard, considering the influence of various mustard varieties and sowing dates. Varieties of mustard may exhibit varying resistance or susceptibility to aphids, impacting pest population dynamics. Additionally, sowing dates can influence the timing and severity of aphid infestations and the presence of coccinellids. Understanding the correlation between aphids and coccinellids in relation to mustard varieties and sowing dates is vital for developing effective integrated pest management (IPM) strategies. These strategies should aim to optimize pest control while minimizing the use of chemical interventions, thus promoting sustainable and environmentally friendly agricultural practices. The findings of this study will provide valuable insights into the ecology of aphids and coccinellids in Indian mustard cultivation, offering a foundation for enhanced pest management practices and improved crop yields.

Materials and methods:

An experiment was conducted during 2020-21 at Students' Instructional Farm (SIF), Chandra Shekhar Azad University of Agriculture and Technology, Kanpur. Geographically, Kanpur is situated at 25.26° and 26.58° North Latitude and 80.34° East longitude at an elevation of 125.9 meters above mean sea level. Three varieties of Indian mustard namely Varuna, Azad Mahak and Ashirwad were obtained from the Principal Scientist (Oilseeds) Section of Economic Botanist (Oilseeds) of the university. The varieties namely Varuna, Azad Mahak and Ashirwad were sown in 5×3 plot size in five replications. Variety Varuna was sown on 13th November and

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23rd November 2020, while varieties Azad Mahak and Ashirwad were planted on 25th November and 10th December 2020, respectively. The crop was sown at a row distance of 30 cm and plant spacing of 10 cm was maintained by thinning of the crop. The observations were recorded at weekly intervals on ten tagged plants for seasonal incidence of aphids, while it was recorded at fortnightly intervals in from each replication/genotypes on 10 cm top shoot length evaluation of different genotypes against aphid following them methodology of Bakhetia *et al.* (1989). Weekly observations on aphid incidence as well as predatory coccinellids (Species-wise population of adult coccinellids and total grubs)were observed for seasonal incidence, whereas the crop growth parameters were recorded at the physiological maturity of the crop.

Result and Discussion:

1.1:Seasonal incidence of mustard aphid (*Lipaphis erysimi*) in relation to varieties and sowing dates

Seasonal incidence of mustard aphid and its predatory coccinellid beetles was observed on Indian mustard sown on 13th November (cv. Varuna), 23rd November (cv. Varuna), 25th November (cv. Azad Mahak) and 10th December. (cv. Ashirwad). The data were recorded on 10 tagged plants/replications from the appearance of aphids. The results on the intensity of pest and predator are presented here:

(i) Aphid intensity:

The appearance of mustard aphid *(Lipaphis erysimi*) on different varieties of Indian mustard (*Brassica juncea*) varied according to their sowing dates. The first appearance of the pest was noticed to be 5.7, 11.0, 10.4 and 13.2 aphid /plant on crop sown on 13th November (cv.Varuna), 23rd November(cv.Varuna), 25th November (Azad Mahak) and 10th December (Ashirwad), respectively (Table-1 and Fig.-1).The first appearance of this pest was observed in the 1st, 2nd and 3rd meteorological standard weeks on the varieties sown on different sowing dates. The intensity of aphids on all the varieties irrespective of sowing dates was found to increase up to the 6th standard week, which was recorded to be 140.8,138.0,148.7 and 176.1 aphids/plant on variety Varuna sown on 13th November Varuna sown 23rd November Azad Mahak sown on 25th November and Ashirwad sown on 10th December, respectively. During this week, the highest plant infestation 93.2 to 100% due to this pest was also recorded on all the varieties.

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Table 1: Seasonal incidence of aphids in relation to cultural practices during

Aphid incidence								
	V1D1		**V_1D_2**		**V_2D_3**		**V_3D_4**	
MSW	Int.	Int.	Int.	Inf.	Int.	Inf.	Int.	Inf.
52	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0 (0.0)	0.0 (0.0)
1	5.7 (5.7)	10.6 (10.6)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
2	25 (19.3)	13.3 (2.7)	11.0 (11.0)	16.6 (16.6)	10.4 (10.4)	23.0 (23.0)	0.0 (0.0)	0.0 (0.0)
3	44.8 (19.8)	26.0 (12.7)	59.0 (48.0)	53.3 (36.7)	61.5 (51.1)	45.6 (22.6)	13.2 (13.2)	20 (20.0)
4	74.5 (29.7)	33.3 (7.3)	81.0 (22.0)	64.0 (10.7)	68.2 (6.7)	83.3 (37.7)	66.0 (52.8)	33.3 (13.3)
5	99.6 (25.1)	53.3 (20.0)	130.4 (49.4)	100.0 (36.0)	135.5 (67.3)	100.0 (16.7)	170.3 (104.3)	86.7 (53.4)
6	120.8 (21.2)	100 (46.7)	138.0 (7.6)	100.0 (0.0)	148.7 (13.2)	96.6 (-3.4)	176.1 (5.8)	93.3 (6.6)
7	105.0 (-15.8)	86.6 (-13.4)	120.0. (-18.0)	74.2 (-25.8)	140.0 (-8.7)	86.6 (-10.0)	164.0 (-12.1)	100.0 (6.7)
8	39.0 (-66)	73.3 (-13.3)	110.0 (-10.0)	68.8 (-5.4)	58.5 (-81.5)	79.3 (-7.3)	144.5 (-18.5)	100 (0.0)
9	17.5 (-21.5)	46.6 (-26.7)	22.8 (-87.5)	40.2 (-28.6)	47.0 (-11.5)	52.2 (-27.1)	98.5 (-46.0)	84.6 (-15.4)
10	0.0 (-17.5)	0.0 (-46.6)	8.4 (-14.4)	0.0 (-40.2)	11.0 (-36.0)	46.6 (-5.6)	17.5 (-81.0)	70.5 (-14.1)
11	0.0 (0.0)	0.0 (0.0)	0.0 (-8.4)	0.0 (0.0)	4.5 (-6.5)	20.0 (-20.6)	6.5 (-11)	30 (-40.5)
12	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
GEP	**44.4**	**37.0**	**57.0**	**43.0**	**60.4**	**52.7**	**67.7**	**56.2**

NB: Inte.- Aphid intensity (No/plant), Inf.- Infested plants (%)

Figures in parentheses are intrinsic weekly increases.

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Maximum intrinsic multiplication of this pest was calculated as being 25.1,49.4,67.3 and 104.3 aphids/plant in the 5th standard week on 13th November, 23rd November, 25th November and 10th December sown crop irrespective of varieties, respectively.

The infestation on plants was also found maximum during the same week on all sowing dates. This trend of aphid incidence proved that the best suitable period for maximum multiplication of this pest was during the 2nd standard week (2nd week of January) to the 6th standard week (2nd week of February) for all the varieties of different sowing dates. After 6th standard week (mid-February), the pest was found in a declining trend, which vanished completely in the 10th,11th, and 12th MSW on 13th November, 23rd November, 25th November and 10th December sown crop on the test varieties, respectively.

The general equilibrium position (GEP) of aphids was calculated being 44.4,57.0, 60.4 and 67.7 aphids/plant on 13th November sown Varuna, 23rd November sown Varuna, 25th November sown Azad Mahak and 10th December sown Ashirwad varieties, respectively. This trend of GEP exhibited that early sowing of Indian mustard was found suitable with the lowest aphid intensity against the late sown crop having a maximum intensity of this pest. As far as the susceptibility rank of these three varieties under test is concerned, cv. Varuna received lower rank intensity (44.4 and 57.0 aphids/plant) against Azad mahak (60.4 aphids/plant) and Ashirwad (67.7 aphids/plant), which may be due to the variation in sowing time of these cultivars.

This economic threshold level of aphids in mustard was reported to be 16 to 22aphid/plant with a mean of 19 aphid/plant under Kanpur conditions (Singh *et al*., 2000 and Kumar *et al*., 2000), while 15 aphids/plant as ETL in central Uttar Pradesh was determined by Singh and Malik (1998). On the basis of these researches, the average economic threshold level (ETL) of 19 aphids/plants was considered for Kanpur conditions in central Uttar Pradesh. The threshold level of this pest crossed in the 2nd MSW on 13th November sown crop, in the 3rd MSW on the 23rd and 25th November sown crop and the 4th MSW on 10th December planted mustard on different varieties, respectively. Seasonal incidence of aphids on different varieties and sowing dates, the general equilibrium position (GEP) and the economic threshold of aphids determined by earlier workers for the Kanpur region have been illustrated in Fig.-1 to understand the status of this pest. The general equilibrium position of 44.4, 57.0, 60.4 and 67.7 aphids/plant was higher than the economic threshold level of 19 aphids/plant on the mustard varieties sown on 13th November, 23rd November, 25th November and 10th December, respectively, which justifies the

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status of aphid in the mustard ecosystem as a key pest. The thresholdlevel crossed the weekly incidence level in the 2nd MSW on the 13th November sown crop, in the 3rd MSW on the 23rd and 25th November sown crop and in the 4th MSW on the 10th December sown mustard crop, which qualifies for the application of synthetic insecticide at ET level. In a nutshell, the crop must be kept under regular monitoring during 2nd week of January in relation to the ecological consideration of the specific area. The crop will be required for insecticide application as and when the pest intensity crosses the threshold value to minimize the yield losses. This is the most important and applicable rule of integrated pest management (IPM) for a sustainable, economical and eco-friendly aspect of pest management strategy.

Substantial knowledge is required of the population dynamics of the pest in order to determine the density of pest infestation imbibed under the concept of economic injury level (EIL) and the knowledge of the value of EIL is an important input which monitors the quantum of pest damage resulting in crop loss. The quantum of damage is determined by finding out the values of the economic injury level and Economic threshold level. The economic threshold level helps to reduce crop loss and ensure less pesticide application, which results in increased profit as a sequel. The economic injury level of any pest depends on the susceptibility level of the crop variety, population dynamics of the pest in relation to ecological conditions of the region, treatment cost for damage and price of the produce. These variables change from season to season, place to place and agro-techniques adopted for crop cultivation.

Ecological consideration in crop protection technology leads to sound and economic pest management systems, particularly in a climate-changing scenario. The ETL of aphids reached different meteorological standard weeks in present studies. Pest management requires a sound knowledge of insect pest biology in relation to environmental parameters and the application of pesticides before touching the ET level of the pest in present studies. The ET level of aphids (16 to 22 aphids/plant) was quite lower than the GEP of aphids (44.4 to 67.7 aphids/plant) on different sowing dates irrespective of varieties. The phenomenon of aphid appearance on Indian mustard qualifies it as a key pest of this crop, which requires an ecologically sound and economically viable pest management strategy.

The incidence of aphids in mustard sown at different dates received the full support of **Bhadauria *et al.*(1992**), who reported less infestation of aphids with the highest seed yield from the 15th October sown crop**. Dinda *et al*. (2016**) reported the severity of aphid *(Lipaphis erysimi)*

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infestation on different varieties of rapeseed and mustard sown at different dates under medium land situations of Gangetic flood plains. The aphid appeared on the field on the 1st week of January. Their population increased progressively in the successive days and finally, they disappeared from the field by the second fortnight of February. It was found that the rapeseed varieties (B-9 and NC-1) were more affected by the aphid than the mustard varieties (JD-6, NPJ-112, SEJ-2 and NRCHB-101). The variety B-9 was the most susceptible and the variety NRCHB-101 was least susceptible to the aphid attack. It was also found that the severity of aphid infestation was more on the crop sown later than those sown earlier, which in turn resulted in the reduced yield of the delayed sown crop. Similarly, **Patel and Singh (2018)** reported that early-sown crops had significantly lower numbers of aphids as compared to late-sown crops. The views of Das *et al.* (2018) regarded the minimum intensity of aphids recorded on early sown crops are in accordance to the present results, who reported the lowest intensity of 69 aphid/plant observed on 18th November planted mustard. The essence of the impact of sowing dates on the incidence of aphids in mustard can be drawn that the crop sown at the recommended time received a lower incidence of the pest and produced higher yields irrespective of varieties. Contrary to this, late-sown mustard harboured higher intensity of the pest with lower production. The crop should be sprayed with synthetic insecticides as and when the pest reaches an economic threshold level to attain maximum seed production.

(ii) Population of coccinellids:

The population of coccinellids and grubs stage were noticed as per the prescribed method and thus, the data obtained have been presented in Table 2 & 3 and Fig. 2-5. The data portrayed in Table 2 revealed that *Coccinella septempunctata, C. transversalis and C. repanda* constituted the main predatory species recorded in the mustard ecosystem. Population of *Coccinella septempunctata*, *C. transversalis,* and *C. repanda* ranged between 0.20 to 4.23 adults/plant, 0.06 to 2.26 adults/plant and 0.06 to 1.73 adults/plant on variety Varuna sown on 13th November, respectively. The population of these predatory beetles varied between 0.26 to 4.13, 0.23 to 2.96, and 0.10 to 2.23 adults /plant on 2ndsowing (23rd November) of variety Varuna, respectively. Variety Azad mahak sown on 25th Nov. harboured 0.7-7.0, 0.53-4.16 and 0.36-3.50 adults/plant of *C. septumpunctata*, *C. transversalis* and *C. repanda,* respectively, while the population of these beetles varied between 1.30 to 6.83, 0.96 to 5.16 and 0.73 to 4.33 adults/plant on cultivar Ashirwad sown on 10th December 2020.

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Average population of adult beetles of *C. septempunctata*, *C. transversalis* and *C. repanda* during the season was found to be 1.29 beetle/plant,0.88 beetle /plant and 0.71 beetle/plant recorded in first date of sowing(13th November);1.61, 0.94 and 0.88 beetle/plant in 2nd sowing (23rd November); 2.65,1.65 and 1.22 beetle/plant on crop sown on 25thNovemberand 3.28,2.4 and 1.82 beetle/plant noticed on the crop sown on 10th December, respectively. The population of different species of beetle revealed that *C. septempunctata* was recorded in higher numbers (1.29-3.28 beetle/plant) followed by *C. transversalis* (0.88-2.04 beetle/plant) and *C. repanda* (0.71-1.82 beetle/plant). The population of these predatory beetles was found to increase trend with the delay in sowing of the crop. It was also observed that the enhancement in their population was not very prominent during January (1-4 MSW), but increased at a faster rate from the 1st week of February (5th Meterological Standard Weeks) onwards.

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Table 2: Population of different species of coccinellids on the Indian mustard

Population of **C**occinellids beetle (No./plant)												
MSW	**V_1D**			**V_1D_2**			**V_2D_3**			**V_3D_4**		
	C. sep.	***C. trans***	***C. rep.***	***C. sep.***	***C. trans.***	***C. rep.***	***C. sep.***	***C. trans.***	***C. rep.***	***C. sep.***	***C. trans.***	***C. rep.***
52	0	0	0	0	0	0	0	0	0	0	0	0
1	0.20	0.06	0.06	0	0	0	0	0	0	0	0	0
2	0.50	0.26	0.23	0.26	0.23	0.10	0.70	0.53	0.36	0	0	0
3	0.67	0.26	0.26	0.67	0.43	0.36	1.26	0.90	0.46	1.30	0.96	0.73
4	0.80	0.40	0.33	1.10	0.86	0.53	2.50	1.56	1.20	2.00	1.40	1.00
5	1.83	0.56	0.43	1.43	1.23	0.90	3.10	1.86	1.46	2.93	2.06	1.60
6	2.50	0.67	0.50	2.30	1.43	1.13	3.70	2.10	1.67	4.00	2.90	2.13
7	3.00	1.63	1.33	2.93	1.56	1.73	4.60	2.67	2.36	4.80	3.56	3.26
8	3.60	1.90	1.50	3.43	1.73	1.93	5.50	3.83	3.16	6.60	4.13	3.67
9	4.23	2.36	1.73	4.13	2.96	2.23	7.00	4.16	3.50	6.83	5.16	4.33
10	1.16	0.73	0.76	1.56	0.90	0.80	2.67	1.56	1.26	5.00	2.93	2.26
11	0	0	0	0	0	0	0.83	0.40	0.30	3.16	1.43	1.06
12	0	0	0	0	0	0	0	0	0	0	0	0
GEP	**1.29**	**0.88**	**0.71**	**1.61**	**0.94**	**0.88**	**2.65**	**1.63**	**1.22**	**3.28**	**2.04**	**1.82**

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Table 3:Population of Coccinellids beetle (No./plant) in the Indian mustard ecosystem

MSW	V_1D_1		V_1D_2		V_2D_3		V_3D_4	
	Adult	**Grub**	**Adult**	**Grub**	**Adult**	**Grub**	**Adult**	**Grub**
52	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
01	0.33	0.06	0.0	0.0	0.0	0.0	0.0	0.0
02	1.00	0.40	0.60	0.13	1.60	0.40	0.0	0.0
03	1.20	0.90	1.46	0.43	2.63	1.06	3.00	1.50
04	1.50	1.06	2.75	1.20	5.26	1.83	4.40	2.26
05	2.80	1.40	3.56	1.83	6.43	3.73	6.60	3.93
06	3.60	2.26	4.86	2.26	7.46	4.83	9.00	6.50
07	5.90	3.83	6.23	3.63	9.63	6.33	11.63	7.00
08	7.00	4.60	7.10	4.26	12.50	7.66	13.86	7.80
09	8.30	5.40	8.66	5.60	14.6	8.00	16.33	8.00
10	2.60	1.30	3.26	1.26	5.50	3.50	10.20	5.83
11	0.0	0.0	0.0	0.0	1.53	0.46	5.60	3.16
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GEP	**2.85**	**1.92**	**3.20**	**1.87**	**5.59**	**3.11**	**7.32**	**4.18**

Data portrayed in Table 3 on the population of adults and grubs of predatory beetles exhibited that the total population of adults ranged between 0.33-8.30, 1.60-14.60 and 3.00-16.33 adults/plant on mustard crop sown on 13th November, 23rd November, 25th November and 10th December, respectively. Similarly, the intensity of grubs of different coccinellids varied from 0.06 to 5.40, 0.13 to 5.60, 0.40 to 8.00 and 1.50 to 8.00/plant recorded on the crop planted on respective dates. It is crystal clear from this data that the population of adults were always higher in comparison to immature stages. The overall mean population of adults and grubs stages of ladybird beetle were found to be 2.85 and 1.92/plant, 3.20 and 1.87/plant, 5.59 and 3.11/plant and 7.32 and 4.18/plant for the respective stages on 13th November, 23rd November, 25th November and 10th December sown crop, respectively.

The population of coccinellid beetles with specific species and immature stages can be drawn that their population increased slowly up to the first week of February, which grew at a faster rate thereafter. The population of these beetles was found to increase in each delayed sowing on mustard crop irrespective of varieties depending upon their prey. The population of coccinellids being 3.60 adults + 2.26 grubs/plant, 4.86 adults + 2.26 grubs/plant, 7.46 adults + 4.43 grubs/plant and 9.00 adults + 6.50 grubs/plant were observed up to mid-February, which increased thereafter with the maximum intensity of 8.30 adult + 5.40 grubs/plant, 8.66 adults +

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5.60 grubs/plant, 14.6 adults + 8.00 grubs/plant and 16.33 adults + 8.00 grubs/plant in 9th MSW (first week of March), respectively

The population of different coccinellids increased slowly upto mid of February, which enhanced very fast after this period. The increasing population of aphids and coccinellids showed a positive trend during the season. Views of Sarvar (2009) expressing a lack of synchronization between populations of mustard aphid and its predators on canola rape, support these findings. Kumar *et al*. (2012), reported significantly higher larval and adult populations of coccinellids on the crop sown at the end of November in comparison to other sowing dates. Kumar *et al*. 2020 reported the highest population of *Coccinella septempunctata*. During the first week of March, they also reported that this ladybird beetle increased gradually up to February and at a faster rate during March. Koirala (2020) reported as a matter of fact that aphids thrive at a temperature below 20℃, while coccinellids thrive above 20℃, eventually leading to phonological asynchrony in their peak periods of activity.

2.1:Effect of weather parameters on the multiplication of aphid and coccinellids in Indian mustard

(I)Effect on aphid incidence

Data on actual intensity and weekly intrinsic increase of aphid and predatory coccinellid beetles were correlated with the prevailing weather parameters during the season and regression equations were also computed between these parameters. Thus, the results obtained are depicted in Table 1.

The simple correlation coefficient (r) between the actual intensity of aphid and its weekly intrinsic increase showed a negative correlation with temperature, while a positive correlation was found with relative humidity. The sunshine hour has a positive impact on the actual intensity but showed a negative effect on its weekly intrinsic increase. Wind speed and evaporation rate had a negative relationship with aphid multiplication, but a positive and negative effect on the weekly rise of aphid, respectively. The impact of weather factors was the same in all four dates of sowing. The impact of average temperature showed that a number of 19.4, 19.81, 19.73 and 20.45 aphids were found to increase with every 1°C decrease in average temperature in 1st, 2nd, 3rd, 4th, and dates of sowings, respectively. A unit increase in average relative humidity was found to be responsible for the enhancement of 63.10, 63.7, 64.7 and 67.08 aphids/plant in respective dates of sowing. Similar effects of temperature and relative humidity were analyzed

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for weekly intrinsic increase of the aphid for all the dates of sowing. Every unit increase or decrease in sunshine hour, wind velocity and evaporation rate could exhibit the enhancement and reduction of merely 2 to 4 aphids for all the sowing dates. Conclusively, it can be summarized based on ongoing results that the first week of February (5^{th} MSW) was found most conducive for the best multiplication of aphids (*Lipaphiserysimi*) with a maximum intrinsic increase of 25.1, 49.4, 67.7 and 104.3 aphid /plant during this week on 13^{th} November, 23^{rd} November, 25^{th} November and 10^{th} December sown varieties of Indian mustard, respectively. However, the highest intensity of this pest being 120.8, 138.0, 148.7 and 176.1 aphid/plant were counted during mid-February (6^{th} MSW) on respective sowing dates. Weather conditions responsible for the best multiplication of this aphid ranged between 12.45-19.0°C , 62.0 to 81.0%, 1.4 to 5.4 hr/day and 1.2-1.9 mm/day as average temperature, average relative humidity, sunshine and evaporation rate during the suitable period up to mid February, respectively. However, the pest showed a declining trend after mid-February, when the average temperature, average relative humidity, sunshine, wind speed and evaporation rate ranged between 18.70-24.40°C (max. 27.3-32.5^{o}c and min. 10.10-16.70^{o}c), 67-93% (morning 67-93% and evening 30-42%), >5 hr/day, >3 km/hr and >2 mm/day, respectively.

Regarding the sowing time of crops concerning aphid incidence, early sowing was found to be better in comparison to late sowing crop, as the GEP of aphids was found to increase with the advancement in sowing date. The reproductive phase of early or timely sown crops before 15^{th} November is mismatched with the period of aphid appearance, while late sown crops after 15^{th} November coincide with the appearance of aphid resulting in a higher incidence of aphid with lower production. This pest was found a declining trend after mid-February due to the advancement in crop physiology along with the rise in average temperature (>19 °C), reduction in average relative humidity (<65%), enhancement in the sunshine (>5hrs.), higher wind speed (4 km/hrs.) and higher evaporation rate (>2mm/day). This phenomenon proved that the pest required succulent crops with less than 19 °C average temperature, >65% average relative humidity, sunshine hours <5 hr/day, wind speed <4 km/hr and evaporation rate <2 mm/day.

The impact of temperature on aphid multiplication in mustard has been reported by several workers **Ansari *et al*. (2007)** observed that peak aphid population was found at a maximum, minimum, and average temperature of 23.37°C, 6.87°C and 15.76°C, respectively, and mean relative humidity of 54.75% on 10^{th} February at 90 days after sowing. Maximum and

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average temperature showed a positively non-significant effect, while minimum temperature showed a negatively non-significant effect on the population of aphids. **Singh and Lal (2012)** stated that mustard aphid incidence showed a non-significant positive correlation with maximum temperature humidity, rainfall, sunshine, and a non-significant negative correlation with minimum temperature. **Shruthi *et al*. (2018)** stated a positive effect between temperature and coccinellid population, whereas a negative correlation was observed with relative humidity. **Sreedhar *et al*. (2021).** reported that aphid was positively correlated with maximum and minimum temperature negatively correlated with maximum relative humidity and positively correlated with minimum relative humidity and with rainfall.

(II) Relationship of coccinellids with prey and abiotic factors

Simple correlation coefficient (r) and regression equation were developed between aphid intensity and population of coccinellids while the impact of weather parameters on coccinellids was analyzed for all the planting dates of Indian mustard (Table-4)

A positive correlation was found between the intensity of coccinellids and aphids, which was found to be 0.3076, 0.5008, 0.4432 and 0.6192 in the case of the crop sown on 13th November, 23rd November, 25th November. and 10th December, respectively. Regression equation developed between aphid (x) and coccinellid beetles (y) revealed that a unit increase in aphid intensity was found responsible for the enhancement of 0.918 beetles/plant in first sowing, 1.892 beetles/plant in second sowing, 3.843 beetles/plant in third sowing date and 3.883 beetles/plant in fourth date of sowing of Indian mustard. The increasing trend of coccinellids beetles in every late sown condition of the crop might be due to the ascending population of aphids in the sowing dates, which can be well understood from the seasonal incidence of aphids in different sowing dates (c.f. Table 4).

The first appearance of aphids varied in different sowing dates, which touched a maximum intensity of 120.8, 130.0, 148.7 and 176.1aphid/plant in 6th MSW on the crop planted on 13th November, 23rd November, 25th November and 10th December, respectively. The incidence of this pest increased at a faster multiplication rate during mid-January to mid-February. During this period, the coccinellids (adults and grubs) could not increase with the pace of aphid multiplication, as the adult beetles varied between 1.0-3.6, 0.6-4.86, 1.6-7.46 and 0.0-9.0 adults/plant. Similarly, the population of grubs was found to be 0.4-2.26, 0.13-2.26, 0.4-4.83 and 0.4-6.50 grubs/plant during the same time frame. However, the highest population of aphids

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was recorded during mid-February (6^{th} MSW), which favoured the enhancement in the population of predatory beetles. After mid-February, the aphid population was observed a a declining trend due to the advancement in crop stage towards maturity coupled with unfavourable weather parameters and the availability of predatory beetles.

Weather parameters played an important role in the host-pest relationship. The crop remained in the succulent stage upto mid February along with a low population of coccinellid beetles and favourable weather parameters. These conditions were found congenial for the best multiplication of aphids. Average temperature ranges between 12.25 –18.70 °C (maximum temperature 17.0-24.5°C and minimum temperature 6.0-10.6°C), average relative humidity between 62-81% (maximum relative humidity 87-94% and minimum relative humidity 37-68%), sunshine hours being 1.4-6.4 hours/day, wind speed between 2.30-4.81 km/hour and evaporation in the range of 1.2-1.9 mm/day were recorded as favourable weather conditions in boosting up the aphid incidence up to mid-February in mustard. Under these weather conditions, the aphid multiplied at a faster rate and its predatory coccinellids beetle could not achieve the proportionate multiplication, as the highest intensity of aphid being 120.8, 130.0, 148.7 and 176.1 aphid /plant was observed during mid-February (6^{th} MSW) along with the population of coccinellids being 3.60 adults +2.26 grubs/plant, 4.86 adults+2.26 grubs/plant, 7.46adults+4.83grubs/plant and 9.0 adult+6.50 grubs/plant on different varieties planted on 13^{th} November, 23^{th} November, 25^{th} November and 10^{th} December, respectively.

However, the weather conditions changed after mid-February, onwards which was not conducive for the incidence of this pest, but the coccinellids were found in an increasing manner up to 1^{st} week of March. The highest population of 8.30 adults+5.4 grubs/plant8.66 adults+5.60 grubs/plant, 14.60 adults+8.00 grubs/plant and 16.33 adults + 8.00 grubs/plant were recorded on mustard crop sown on respective dates, while the aphid intensity was observed in a declining trend. The average temperature is between 18.70- 24.40°C (maximum 27.3-32.5°C and minimum 10.10-16.70°C) and the average relative humidity ranging 48.5-69.0% (maximum 67-93% and minimum 30-42%) favoured the biology of coccinellids from mid-February to mid-March, which declines thereafter due to the maturity of crop along with non-availability of their host (aphid). Sunshine hours>5 hr/day, wind speed >3 km/hr and evaporation rate >2.0 mm/day were also in favour of the coccinellids population in mustard. It revealed that average temperature <19°C and average relative humidity >70% proved to be congenial weather for a

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rapid multiplication of aphids but unsuitable for coccinellids beetles, while average temperature >19°C coupled with <70% average relative humidity along with >5 hr/day sunshine and >3 km/hr wind speed were found able to suppress the aphid and to enhance the population of predatory beetles.

The impact of weather factors on the population built-up of coccinellids was very much pronounced, as the predatory beetles grew up slowly upto mid-February and increased at a faster rate thereafter. Average temperature, average relative humidity, sunshine, wind speed, and evaporation rate ranging between 12.25-18.70°C, 62-81%, 1.4-6.4 hr/day, 2.3-4.87 km/hr and 1.2-1.9 mm/day did not favour the multiplication of coccinellids at a faster rate, while these weather factors favoured the most for aphid multiplication. A slight change in environmental parameters took place after mid-February, which provided a rise in temperature with dryness, longer sunshine days, high wind velocity and higher evaporation rate. Average temperature, average relative humidity, sunshine wind speed and evaporation rate were recorded to be 18.70-24.40°C, 48.5-69.0%, >5 hrs/day, >3 km/hours, >2 mm/day after mid-February, which suited best for increasing the population of predatory beetles, but found unfavourable for aphid multiplication. Weather parameters specifically average temperature below 19°C, average R.H. >65%, shorter sunshine <5 hrs/day, wind speed >3.0 km/hr and evaporation rate <2.0 mm/day were found congenial for aphid incidence, but slightly suitable for predatory beetles upto mid-February. Plenty of food (aphids) pushed to faster increase in predator population, which resulted in a faster reduction in aphid population coupled with crop hardness and changed weather factors after mid-February. Specifically, it can be inferred that average temperature <19°C and average relative humidity >65% upto mid Februaryfavoured the aphid multiplication but did not suit the predatory beetles, while average temperature >19°C and average relative humidity< 65% did not favour aphid multiplication but found congenial for coccinellids. Thus, the weather factors suitable for aphid multiplication were not favourable to coccinellid beetles in present studies. Thus, the weather factors played a significant role in boosting the aphid intensity upto mid of February and a significant reduction in its population after this period, while it had vice versa impact on predatory coccinellids.

The work of Lal *et al.* (2014) finds similarity with the present studies, who reported that the population of *Coccinella septempunctata* was recorded positively significant correlation with temperature and sunshine hours and a negative correlation with relative humidity and rainfall.

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Kalasariya *et al.* (2017)observed a highly significant positive correlation (r = 0.908) between predators and aphids. **Dwivedi *et al.* (2018)**. noticed that the appearance of *Coccinella* species positively correlated with temperature. The appearance of predatory beetles during the first week of January reported by **Mishra and Kunwat (2018)** gets full support. Pradhan *et al.* (2020). reported a positive impact of temperature on the coccinellids population, while relative humidity showed a negative impact.

Table 4:Impact of weather parameters on aphid multiplication on different sowing dates in Indian mustard during 2020-2021

Parameters		**Aphid intensity (No. /plant)**			
		Actual intensity		**Weekly Intrinsic increase**	
		Regression equation	**Simple Correl.(r)**	**Regression equation**	**Simple Correl.(r)**
First sowing date					
Temp.	Max.	y=26.574-0.032x	-0.2827	y=26.407-0.060x	-0.2673
	Min.	y=11.255-0.032x	-0.4241	y=10.720-0.035x	-0.2276
	Ave.	y=18.914-0.032x	-0.3599	y=17.491-0.085x	-0.5838*
R.H.	Max.	y=83.069+0.079x	0.4203	y=85.237+0.074x	0.1776
	Min.	y=43.491+0.045x	0.1652	y=44.687+0.086x	0.1831
	Ave.	y=63.268+0.101x	0.4308	y=65.794+0.148x	0.3546
Sunshine		y=04.309+0.004x	0.0898	y=04.724-0.012x	-0.1142
Wind speed		y=04.014-0.006x	-0.2508	y=03.785+0.014x	0.2337
Evaporation		y=02.075-0.004x	-0.2596	y=02.020-0.006x	-0.2051
Second sowing date					
Tem.	Max	y=26.790-0.021x	-0.2259	y=25.696-0.076x	-0.4710
	Min.	y=12.138-0.031x	-0.5332	y=10.258-0.029x	-0.2675
	Ave.	y=19.467-0.026x	-0.3683	y=17.885-0.061x	-0.5674
R.H.	Max.	y=83.460+0.046x	0.2967	y=85.938+0.016x	0.5875*
	Min.	y=47.104+0.017x	0.0782	y=45.557+0.171x	0.4612
	Ave.	y=63.760+0.069x	0.3973	y=67.635+0.158x	0.5281
Sunshine		y=04.187+0.009x	0.1711	y=04.6153-0.032x	-0.4754
Wind speed		y=04.197-0.006x	-0.2223	y=03.825+0.007x	0.2323
Evaporation		y=02.090-0.003x	-0.2634	y=01.946-0.007x	-0.3472
Third sowing date					
Temp.	Max.	y=26.557-0.017x	-0.2259	y=25.530-0.073x	-0.4284
	Min.	y=12.007-0.029x	-0.5332	y=10.196-0.035x	-0.3311
	Ave.	y=19.281-0.023x	-0.3267	y=17.862-0.053x	-0.5314
R.H.	Max.	y=83.658+0.043x	0.3397	y=86.321+0.105x	0.3973
	Min.	y=47.486-0.024x	-0.0647	y=45.947+0.129x	0.3666
	Ave.	y=64.735+0.053x	0.3267	y=67.984+0.159x	0.5325
Sunshine		y=03.826+0.011x	0.2085	y= 04.546-0.025x	-0.4214

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Wind speed		y=4.1724-0.006x	-0.2126	y= 03.806+0.002x	0.0075
Evaporation		y=02.071-0.002x	-0.2445	y= 01.931-0.009x	-0.4773
Fourth sowing date					
Tem.	Max	y=27.166-0.008x	-0.1154	y=25.549-0.071x	-0.5724
	Min.	y=13.472-0.030x	-0.6247*	y=10.210-0.042x	-0.4893
	Ave.	y=18.220-0.004x	-0.0913	y=17.879-0.056x	-0.6832*
R.H.	Max.	y=86.900-0.007x	0.1837	y=86.329+0.092x	0.4496
	Min.	y=51.498-0.070x	-0.2001	y=45.930+0.102x	0.3526
	Ave.	y=67.093+0.012x	0.1804	y=67.918+0.186x	0.8024**
Sunshine		y=03.214+0.017x	0.3870	y=04.549-0.019x	-0.3954
Wind speed		y=03.944-0.001x	-0.3074	y=03.807-0.009x	-0.0550
Evaporation		y=01.926-0.008x	-0.2551	y=01.933-0.009x	-0.5447

NB: Significant at 5% and 1% level of significance, respectively

Table 5: Relationship of coccinellids with prey and abiotic factors in different sowing dates of mustard during 2020-21

Parameters		Adult coccinellids		Grub	
		Regression equation	S.Correl.(r)	Regression equation	S.Correl.(r)
First sowing date					
Aphid		y=00.899+0.019x	0.3076	y=1.207+0.019x	0.3026
Temp.	Max.	y= 22.798+0.824x	0.2590	y=23.072+1.175x	0.2471
	Min.	y=09.375+0.160x	0.0227	y=9.458+0.212x	0.1172
	Ave.	y=16.086+0.492x	0.3481	y=16.265+0.693x	0.3249
R.H.	Max.	y=91.383-1.682x	-0.3046	y=90.928-2.450x	-0.3009
	Min.	y=52.223-2.359x	-0.3642	y=51.437-3.359x	-0.3461
	Ave.	y=70.192-0.858x	-0.1624	y=69.937-1.237x	-0.1584
Sunshine		y=03.108+0.490x	0.5352	y=3.225+0.704x	0.5126
Wind velo.		y=03.470+0.092x	0.1947	y=3.526+0.117x	0.1618
Evaporation		y=01.723+0.061x	0.0794	y=1.739+0.091x	0.0624
Second sowing date					
Aphid		y=01.865+0.026x	0.5008	y=00.995+0.014x	0.4072
Temp.	Max.	y=22.870+1.175x	0.2142	y=23.118+1.153x	0.2587
	Min.	y=09.483-0.189x	-0.0284	y=09.501-1.930x	-0.0419
	Ave.	y=16.768+0.306x	0.2262	y=16.812+0.549x	0.2604
R.H.	Max.	y=91.361-1.489x	-0.2641	y=91.047-1.011x	-0.3363
	Min.	y=52.149-2.073x	-0.3223	y=51.608-3.558x	-0.3824
	Ave.	y=70.207-0.766x	-0.1457	y=69.891-1.247x	-0.1628
Sunshine		y=02.96+0.480x	0.5502	y=03.225+0.747x	0.5545
Wind velo.		y=3.452+0.087x	0.1932	y=03.481+0.147x	0.2128
Evaporation		y=1.712+0.058x	0.0705	y=1.742+0.091x	0.0905
Third sowing date					
Aphid		y=03.807+0.036x	0.4432	y=1.836+0.025x	0.4896

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Temp.	Max.	y=22.534+0.467x	0.2231	y=22.470+0.848x	0.2875
	Min.	y=09.199+0.113x	0.0330	y=9.310+0.165x	0.0280
	Ave.	y=16.444+0.228x	0.2687	y=16.401+0.418x	0.3102
R.H.	Max.	y=92.242-1.309x	-0.2878	y=91.460-1.548x	-0.2850
	Min.	y=52.824-1.309x	0.3163	y=53.060-3.450x	-0.3950
	Ave.	y=70.377-0.469x	-0.1379	y=70.740-0.949x	-0.1960
Sunshine		y=02.823+0.301x	0.5465	y=2.843+0.523x	0.6132*
Wind velo.		y=03.330+0.072x	0.2599	y=3.490+0.772x	0.1673
Evaporation		y=01.667+0.041x	0.0877	y=1.663+.0749x	0.1336
Fourth sowing date					
Aphid		y=03.839+0.044x	0.6192*	y=01.958+0.028x	0.7068*
Temp.	Max.	y=20.964+0.623x	0.4185	y=20.970+1.089x	0.4023
	Min.	y=08.226+0.239x	0.1498	y=08.396+0.374x	0.1073
	Ave.	y=14.855+0.407x	0.5517	y=14.980+0.684x	0.5170
R.H.	Max.	y=93.639-1.050x	-0.3749	y=92.780-1.617x	-0.2940
	Min.	y=55.245-1.450x	-0.4375	y=55.173-2.524x	-0.4198
	Ave.	y=73.736-0.890x	-0.3731	y=73.827-1.556x	-0.3693
Sunshine		y=73.736-0.890x	0.6915*	y=2.220+0.547x	0.7127*
Wind velo.		y=03.342+0.058x	0.2399	y=3.468+0.680x	0.1483
Evaporation		y=1.431+0.069x	0.3108	y=1.419+0.125x	0.3098

NB: Significant at 5% and 1% level of significance, respectively

Conclusion:

The research likely highlighted the implications of the study's findings for farmers and agricultural practices. This could include recommendations on optimal sowing times and variety selection to minimize aphid infestations and enhance natural pest control. These conclusions would be based on the specific data, analyses, and methods employed in the research paper, and may vary depending on the scope and findings of the actual study. It's always essential to refer to the original research paper for precise and detailed conclusions.

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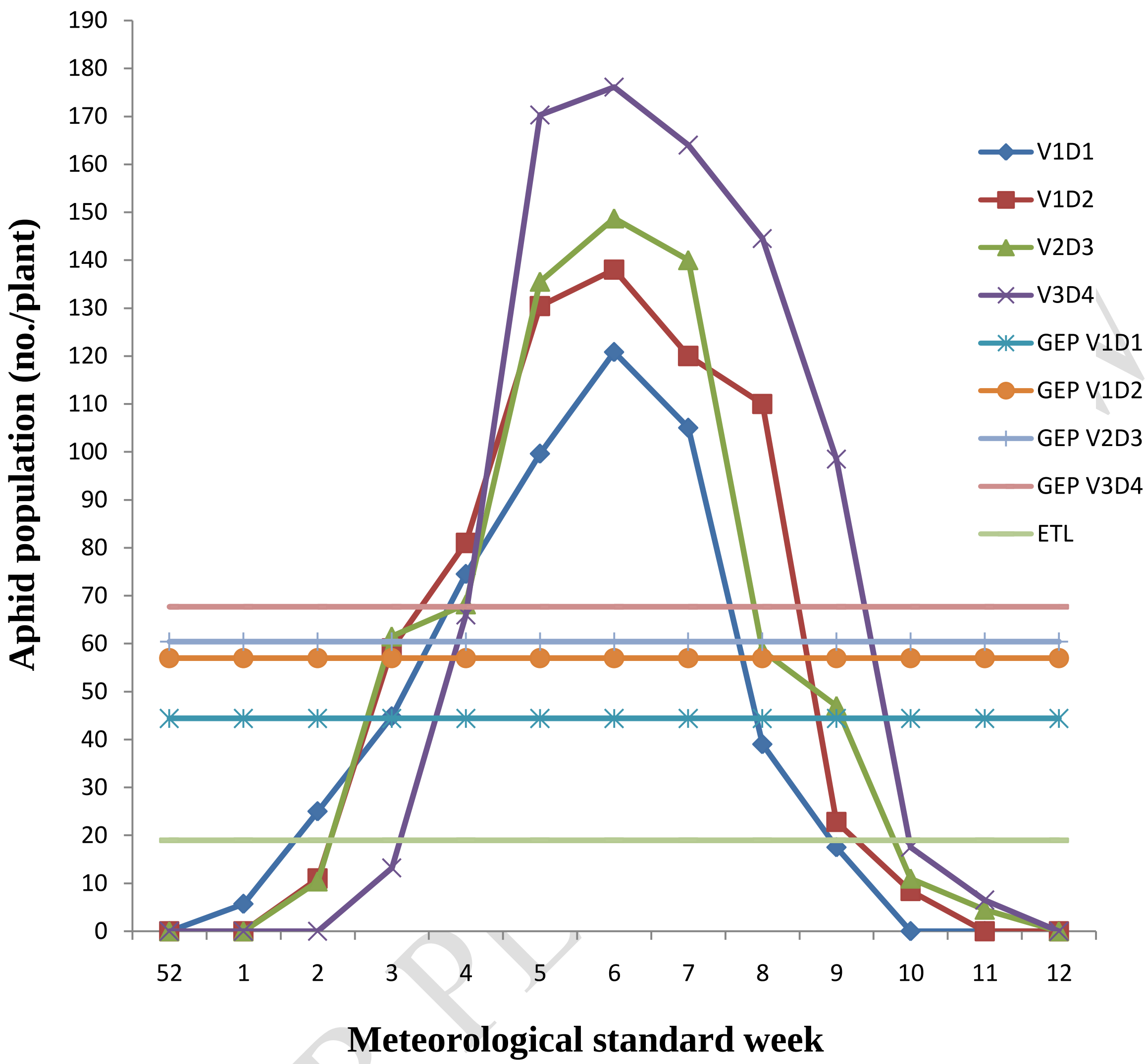

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Fig.1: Aphid intensity on varieties of Indian mustard sown on different dates during 2020-21

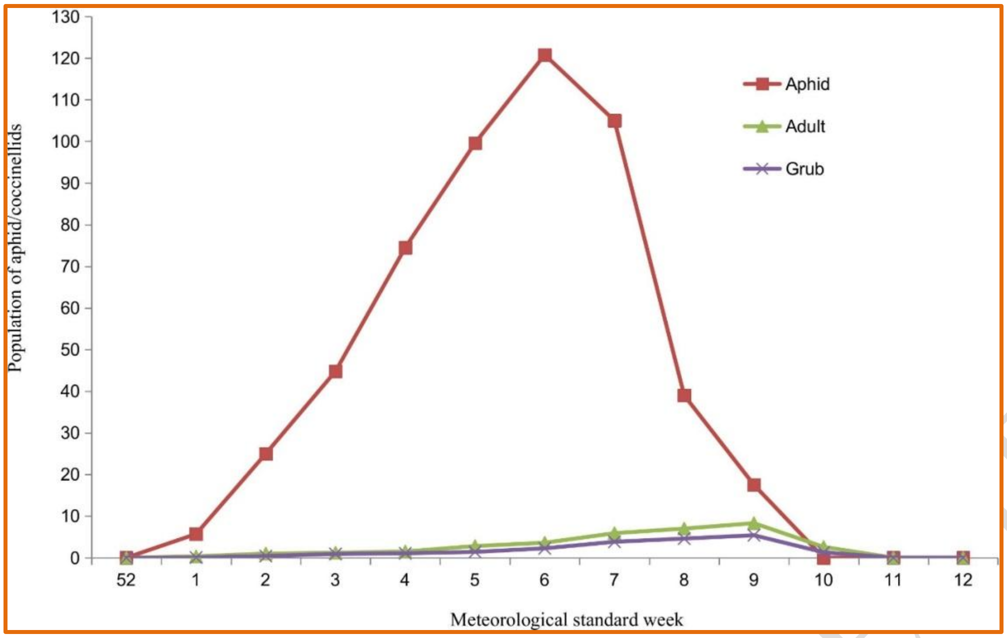

Fig.2.Population of aphids and coccinellids on cv.Varunasown on 13th November, 2020

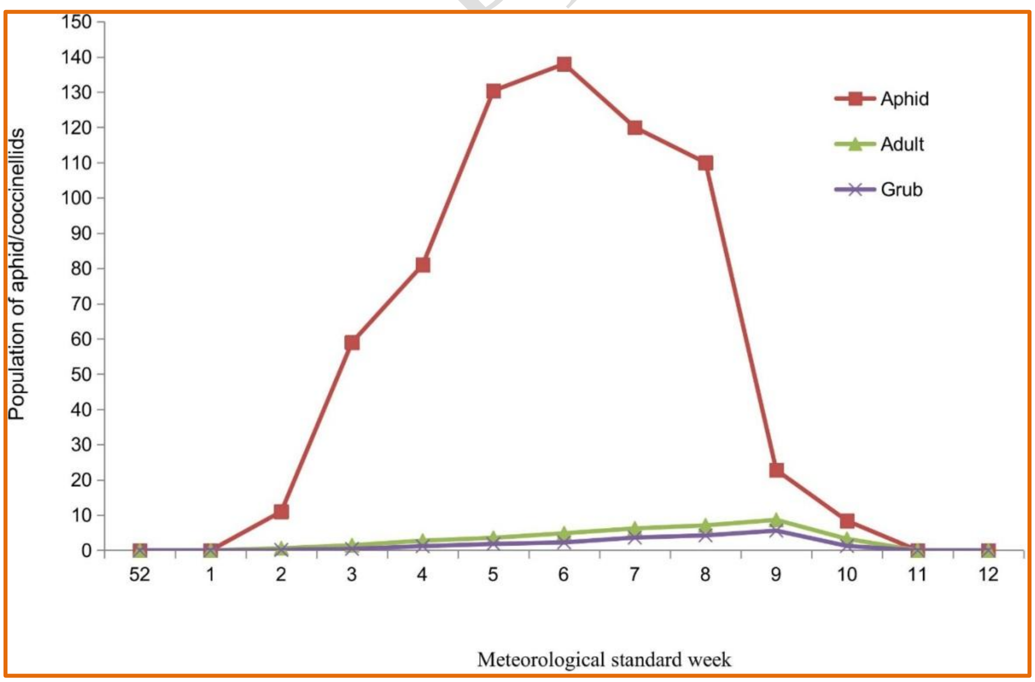

Fig.3. Population of aphids and coccinellids on cv. Varuna sown on 23 November, 2020

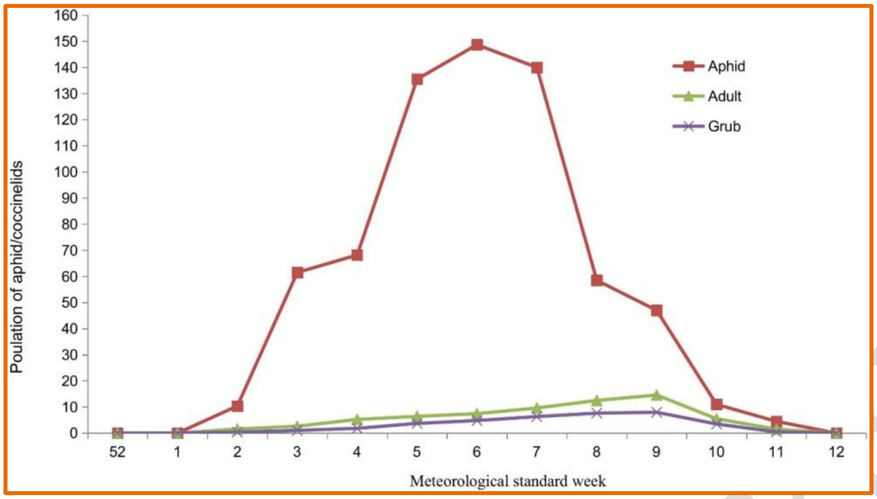

Fig.4. Population of aphids and coccinellids on cv. Azad Mahak sown on 25th November, 2020

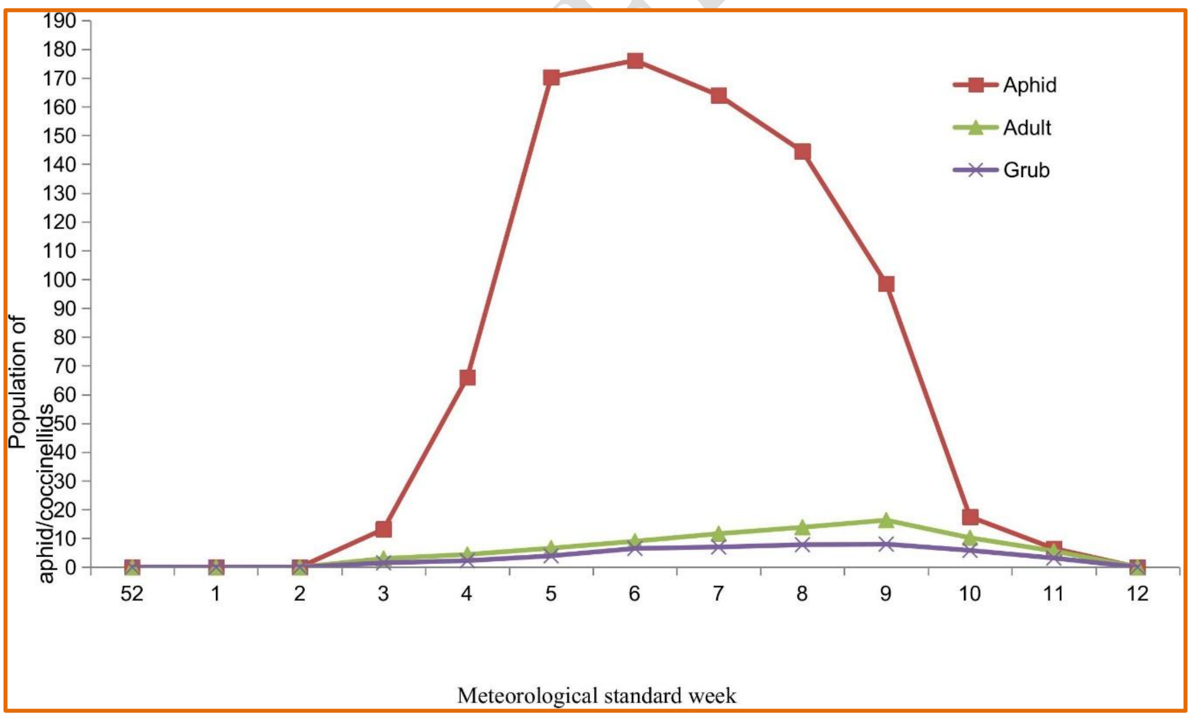

Fig.5. Population of aphids and coccinellids on cv. Ashirwad sown on 10th December, 2020

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