

Original Research Article

Seasonal Incidence of Aphids and Coccinellids on Indian Mustard across Various Varieties and Sowing Dates, and Their Correlation

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 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 favorable for aphid multiplication did not support the enhancement of the population of predatory ladybird beetles. **Keywords:** Coccinellids, Ecological, *Lipaphiserysimi*, 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, mustard aphid (*Lipaphiserysimi*) is regarded as a national 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). Conversely, coccinellids (Coleoptera: Coccinellidae) serve as natural predators, preying on aphids and assisting in controlling their

populations. The balance between aphid infestation and the presence of coccinellids can significantly affect crop health and productivity. This research endeavors 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 were conducted during 2020-21 at Students' Instructional Farm (SIF), Chandra Shekhar Azad University of Agriculture and Technology, Kanpur. Geographically, Kanpur is situated at 25.26⁰ and 26.58⁰ North Latitude and 80.34⁰ 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 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 10 cm was maintained by thinning of the crop. The observations were recorded at weekly interval on ten tagged plants for seasonal incidence of aphid, while it was recorded at fortnightly intervals in from each replication/genotypes on 10 cm top shoot length the evaluation of different genotypes against aphid following the methodology of Bakhtia *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 physiological maturity of the crop.

Result and Discussion:

1.1: Seasonal incidence of mustard aphid (*Lipaphiserysimi*) 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 / replication from the appearance of aphid. The results on the intensity of pest and predator are being presented under here:

(i) Aphid intensity:

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

Table1: Seasonal incidence of aphid in relation to cultural practices during

Aphid incidence								
MS W	V1D1		V1D2		V2D3		V3D4	
	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 increase.

Maximum intrinsic multiplication of this pest was calculated being 25.1,49.4,67.3 and 104.3 aphids/plant in 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 2nd standard week (2nd week of January) to 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 decline trend, which vanished completely in 10th, 11th, 12th MSW on 13th November, 23rd November, 25th November and 10th December sown crop on the test varieties, respectively.

General equilibrium position (GEP) of aphid 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 found suitable with lowest aphid intensity against the late sown crop having 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 aphid /plant) against Azad mahak (60.4 aphids/plant) and Ashirwad (67.7 aphid/plant), which may be due the variation in sowing time of these cultivars.

This economic threshold level of aphid in mustard was reported be 16 to 22 aphid/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, average economic threshold level (ETL) of 19 aphid /plant was considered for Kanpur conditions in central Uttar Pradesh. The threshold level of this pest crossed in 2nd MSW on 13th November sown crop, in 3rd MSW on 23rd and 25th November sown crop and in 4th MSW on 10th December planted mustard on different varieties, respectively. Seasonal incidence of aphid on different varieties and sowing dates, the general equilibrium position (GEP) and economic threshold of aphid determined by earlier workers for Kanpur region have been illustrated in Fig.-1 to understand the status this pest. The general equilibrium position of 44.4, 57.0, 60.4 and 67.7 aphid/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 status of aphid in

mustard ecosystem as a key pest. The threshold level crossed the weekly incidence level in 2nd MSW on 13th November sown crop, in 3rd MSW on 23rd and 25th November sown crop and in 4th MSW on 10th December sown mustard crop, which qualifies for application of synthetic insecticide at ET level. In nut shell, 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 for minimizing the yield losses. This is a most important and applicable rule of integrated pest management (IPM) for a sustainable, economic and eco-friendly aspect of pest management strategy.

Substantial knowledge is required on 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 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. Economic threshold level helps to reduce the crop loss and insure 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 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 system particularly in a climate changing scenario. The ETL of aphid reached in different meteorological standard weeks in present studies. The pest management requires a sound knowledge of insect pest biology in relation to environmental parameters and application of pesticides before touching the ET level of the pest in present studies. The ET level of aphid (16 to 22 aphid /plant) was quite lower than the GEP of aphid (44.4 to 67.7 aphid /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.

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

infestation on different varieties of rapeseed and mustard sown at different date under medium land situation 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 the 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 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 crop had significantly lowest numbers of aphid as compared to late sown crops. Views of Das *et al.*(2018) regarded the minimum intensity of aphid recorded on early sown crop are in accordance to the present results, who reported lowest intensity of 69 aphid/plant observed on 18th November planted mustard. The essence of impact of sowing dates on the incidence of aphid in mustard can be drawn that the crop sown at recommended time received lower incidence of the pest and produced higher yields irrespective of varieties. Contrary to this, late sown mustard harbored higher intensity of the pest with lower production. The crop should be sprayed with synthetic insecticides as and when the pest reaches at economic threshold level to attain maximum seed production.

(ii) Population of coccinellids:

Population of coccinellids and grubs stage were noticed as per prescribed method and thus, the data obtained have been presented in Table-2&3Fig.2-5. The data portrayed in (Table-2) revealed that *Coccinellaseptempunctata*, *C. transversalis* and *C. repanda* constituted the main predatory species recorded in mustard ecosystem. Population of *Coccinellaseptempunctata*, *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 2nd sowing (23rd November) of variety Varuna, respectively. Variety Azad mahak sown on 25th Nov. harbored 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.

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 25th November and 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 high 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 in increasing trend with the delay in sowing of the crop. It was also observed that the enhancement in their population was not much prominent during January (1-4 MSW), but increased at a faster rate from 1st week of February (5th Meteorological Standard Weeks) onwards.

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

Population of coccinellids beetle (No/plant)												
MSW	V ₁ D			V ₁ D ₂			V ₂ D ₃			V ₃ D ₄		
	<i>C. sep.</i>	<i>C. trans</i>	<i>C. rep.</i>	<i>C. sep.</i>	<i>C. trans.</i>	<i>C. rep.</i>	<i>C. sep.</i>	<i>C. trans.</i>	<i>C. rep.</i>	<i>C. sep.</i>	<i>C. trans.</i>	<i>C. rep.</i>
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

Table 3: Population of coccinellids beetle (No/plant) in Indian mustard ecosystem

MSW	V ₁ D ₁		V ₁ D ₂		V ₂ D ₃		V ₃ D 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 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 population of adults were always higher in comparison to immature stages. The overall mean population of adults and grubs stages of lady bird beetle was 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.

Population of coccinellid beetles with specific species and immature stages can be drawn that their population increased slowly upto first week of February, which grew up 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 adult + 2.26 grubs/plant, 7.46 adult + 4.43 grubs/plant and 9.00 adult + 6.50 grubs/plant were observed up to mid February, which increased thereafter with maximum intensity of 8.30 adult + 5.40 grubs/plant, 8.66 adults + 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. Increasing in population of aphid 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 highest larval and adult population of coccinellids on the crop sown in the end of November in comparison of other sowing date. Kumare *et al.* 2020. Reported the highest population of *Coccinellaseptempunctata*. During first week of March and they also reported that this lady bird beetle increase gradually up to February and at a faster rate of during March. Koirala (2020) reported as the matter of fact that aphids thrive at temperature below 20°C, while coccinellids thrive above 20 °C, eventually lead 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)

Simple correlation coefficient (r) between actual intensity of aphid and its weekly intrinsic increase showed negative correlation with temperature, while a positive correlation was found with relative humidity. Sunshine hour has positive impact on the actual intensity, but showed a negative effect on its weekly intrinsic increase. Wind speed and evaporation rate had negative relationship with aphid multiplication, but a positive and negative effect on the weekly rise of aphid, respectively. The impact of weather factors was same in all the 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 an every 1°C decrease in average temperature in 1st, 2nd, 3rd, 4th, 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

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 exhibited the enhancement and reduction merely 2 to 4 aphids for all the sowing dates. Conclusively, it can be summarized on the basis of ongoing results that first week of February (5th MSW) was found most conducive for best multiplication of aphid (*Lipaphis erysimi*) with a maximum intrinsic increase of 25.1, 49.4, 67.7 and 104.3 aphid /plant during this week on 13th November, 23rd November, 25th November and 10th December sown varieties of Indian mustard, respectively. However, highest intensity of this pest being 120.8, 138.0, 148.7 and 176.1 aphid/plant were counted during mid of February (6th MSW) on respective sowing dates. Weather conditions responsible for 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 °c and min. 10.10-16.70 °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 crop in relation to aphid incidence is concerned, early sowing was found better in comparison to late sown crop, as the GEP of aphid was found to increase with the advancement in sowing date. Reproductive phase of early or timely sown crop before 15th November mismatched with the period of aphid appearance, while late sown crop after 15th November coincide with the appearance of aphid resulting in a higher incidence of aphid with lower production. This pest was found at declining trend after mid February due to the advancement in crop physiology along with the rise in average temperature (>19 °c), reduction average relative humidity (<65%), enhancement in sunshine (>5hrs.), higher wind speed (4 km/hrs.) and higher evaporation rate (>2mm/day). This phenomenon proved that the pest required succulent crop 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 have 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 10th February at 90 days after sowing. Maximum and

average temperature showed a positively non-significant effect, while minimum temperature showed a negatively non-significant effect on the population of aphid. **Singh and Lal (2012)** stated that mustard aphid incidence showed a non-significant positive correlation with maximum temperature humidity, rainfall, sunshine, and non-significant negative correlation with minimum temperature. **Shruthi et al. (2018)** stated positive effect between temperature and coccinellid population, whereas negative correlation was observed with relative humidity. **Sreedhar et al. (2021)** reported that aphid was positively correlated with maximum and minimum temperature and 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 impact of weather parameters on coccinellids was analyzed for all the for planting dates of Indian mustard (Table-4)

A positive correlation was found between the intensity of coccinellids and aphid, which was found to be 0.3076, 0.5008, 0.4432 and 0.6192 in case of the crop sown 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 beetle/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 aphid in the sowing dates, which can be well understood from the seasonal incidence of aphid in different sowing date (c.f. Table 4).

First appearance of aphid varied in different sowing dates, which touched to a maximum intensity of 120.8, 130.0, 148.7 and 176.1 aphid/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 aphid was

recorded during mid February (6th MSW), which favored the enhancement in population of predatory beetles. After mid February, the aphid population was observed at declining trend due to the advancement in crop stage towards maturity coupled with unfavorable weather parameters and availability of predatory beetles.

Weather parameters played an important role in host pest relationship. The crop remained in succulent stage upto mid February along with low population of coccinellid beetles and favourable weather parameters. These conditions were found congenial for best multiplication of aphid. Average temperature ranging 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 achieved 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 (6th 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 13th November, 23th November, 25th November and 10th December, respectively.

However, the weather conditions changed after mid February, onwards which were not conducive for the incidence of this pest, but the coccinellids were found in an increasing manner upto 1st week of March. Highest population of 8.30 adults+5.4 grubs/plant 8.66 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 declining trend. Average temperature between 18.70- 24.40°C (maximum 27.3-32.5°C and minimum 10.10°C-16.70°C) and average relative humidity ranging 48.5-69.0% (maximum 67-93% and minimum 30-42%) favored the biology of coccinellids from mid February to mid March, which decline 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 favor of coccinellids population in mustard. It revealed that average temperature <19°C and average relative humidity >70% proved to be congenial weather for a rapid multiplication of

aphid but unsuitable for coccinellids beetles, while average temperature $>19^{\circ}\text{C}$ 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 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 $12.25-18.70^{\circ}\text{C}$, $62-81\%$, $1.4-6.4$ hr/day, $2.3-4.87$ km/hr and $1.2-1.9$ mm/day did not favor the multiplication of coccinellids at a faster rate, while these weather factors favored the most for aphid multiplication. Slight change in environmental parameters took place after mid February, which provided rise in temperature with dryness, longer sunshine day, high wind velocity and higher evaporation rate. Average temperature, average relative humidity, sunshine wind speed and evaporation rate were recorded to be $18.70-24.40^{\circ}\text{C}$, $48.5-69.0\%$, >5 hrs/day, >3 km/hours, >2 mm/day after mid February, which suited best for increasing the population of predatory beetles, but found unfavorable for aphid multiplication. Weather parameters specifically average temperature below 19°C , average R.H. $>65\%$, shorter sunshine <5 hr/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 (aphid) pushed to faster increase in predator's 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 $<19^{\circ}\text{C}$ and average relative humidity $>65\%$ upto mid February favoured the aphid multiplication but did not suit to the predatory beetles, while average temperature $>19^{\circ}\text{C}$ 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 significant role in boosting up the aphid intensity upto mid of February and significant reduction in its population after this period, while it had vice versa impact on predatory coccinellids.

Work of Lal *et al.* 2014 finds similarity with the present studies, who reported that population of *Coccinellaseptempunctata* was recorded positively significantly correlation with temperature and sunshine hours and negative correlation with relative humidity and rainfall. Kalasariya *et al.* (2017) observed a highly significant positive correlation ($r = 0.908$) between

predator and aphid. Dwivedi *et al* (2018). noticed that the appearance of *Coccinella* species positively correlated with temperature. Regarding the appearance of predatory beetles during first week of January reported by Mishra and Kunwat (2018) gets full support. Pradhan *et al.*(2020). Reported positive impact of temperature on coccinellids population, while relative humidity showed 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
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 date 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
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

4.4: Effect of aphid on plant growth traits in Indian mustard

Data on various plant growth parameters that i.e. branches/plant, raceme length, siliqua/plant, seeds/siliqua, test weight and seed yield were recorded on Varuna, Azad mahak and Ashirwad varieties sown on 13th November, 23rd November, 25th November and 10th December 2020 as per the described methodology. Simple correlation coefficient (r) values were computed between the aphid incidence and yield attributes. The regression equations were also developed between the aphid incidence and crop growth parameters. Thus, the results obtained are being depicted in Table- 6 and 10 which are being interpreted as under:

The yield attributing characters and aphid intensity were recorded in different varieties sown on various dates (Table-6) significantly lowest aphid intensity was observed on cv. Varuna sown on 13th November against the maximum intensity of 67.7 aphids/plant noticed in cv. Ashirwad sown on 10th December. However, the crop sown on 23rd November and 25th November along with 25th November and 10th December harbored at per intensity of this pest. Similarly the crop sown on 13th November produced significantly superior no of branches/plant (76.6) and raceme length (67.0) cm, which were reduce significantly in latter sowing dates. Siliqua/plant, seed/siliqua and test weight showed only numerical variation among the dates. Significantly superior seed yield being 1420 kg/ha was recorded from mustard variety Varuna

sown on 13th November which decreased in subsequently sowing dates in respective of varieties. However, the varieties planted on 23rd November and 25th November produced as per seed yield. Indian mustard variety Ashirwad yield significantly minimum being 740 kg/ha. The impact of varieties and sowing dates had a clear cut impact on pest incidence as well as the crop growth parameters, which are ultimately responsible for seed production of the crop, thus it can be inferred that the crop sown on 13th November harbored significantly mini aphid intensity with better crop growth there by producing significantly maximum seed yield of 1420 kg/ha. However, the late sown crop was most preferred by the pest with poor crop growth and ultimately poor harvest of the seed.

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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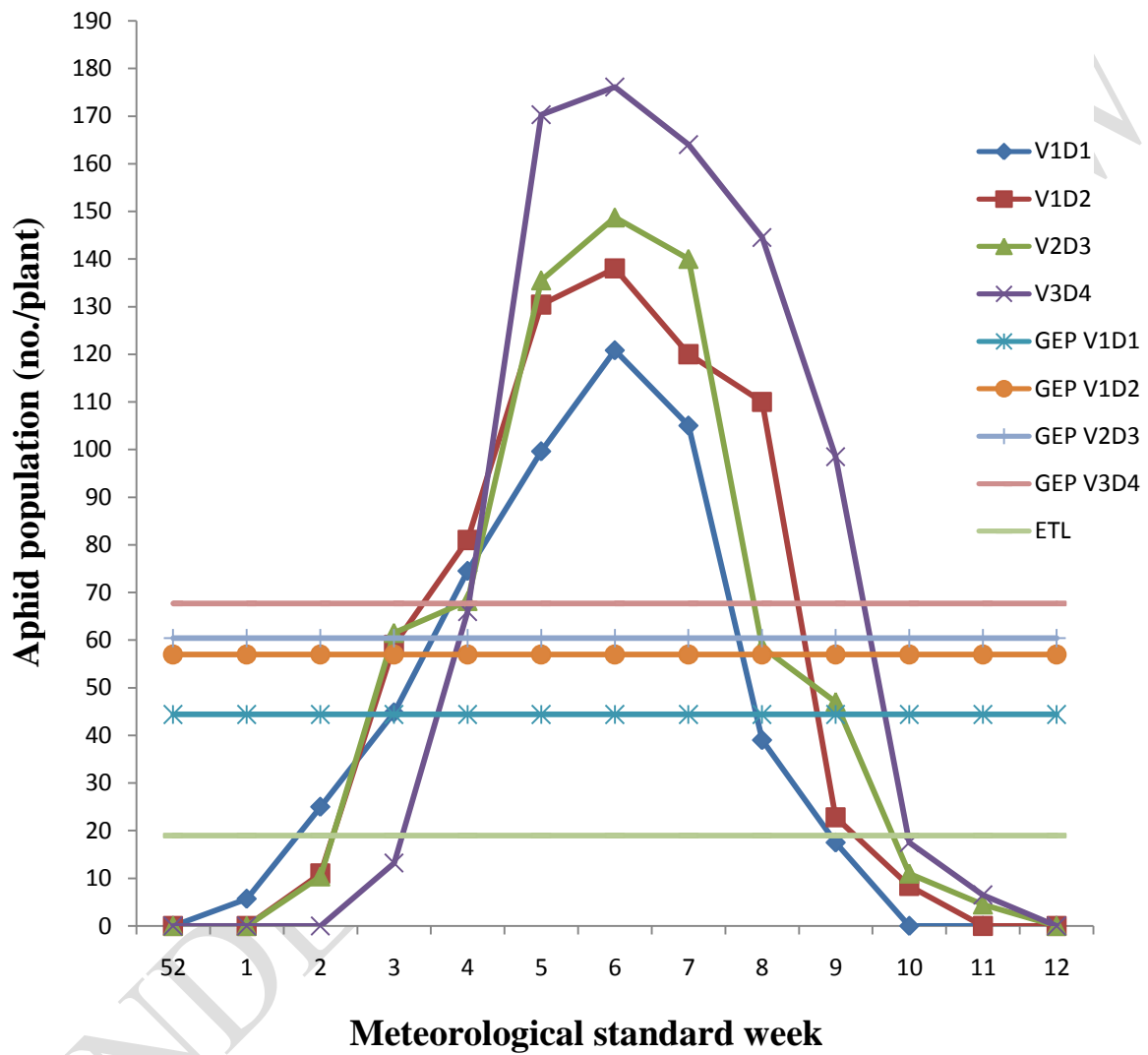


Fig.1: Aphid intensity on varieties of Indian mustard sown at different dates during 2020-21

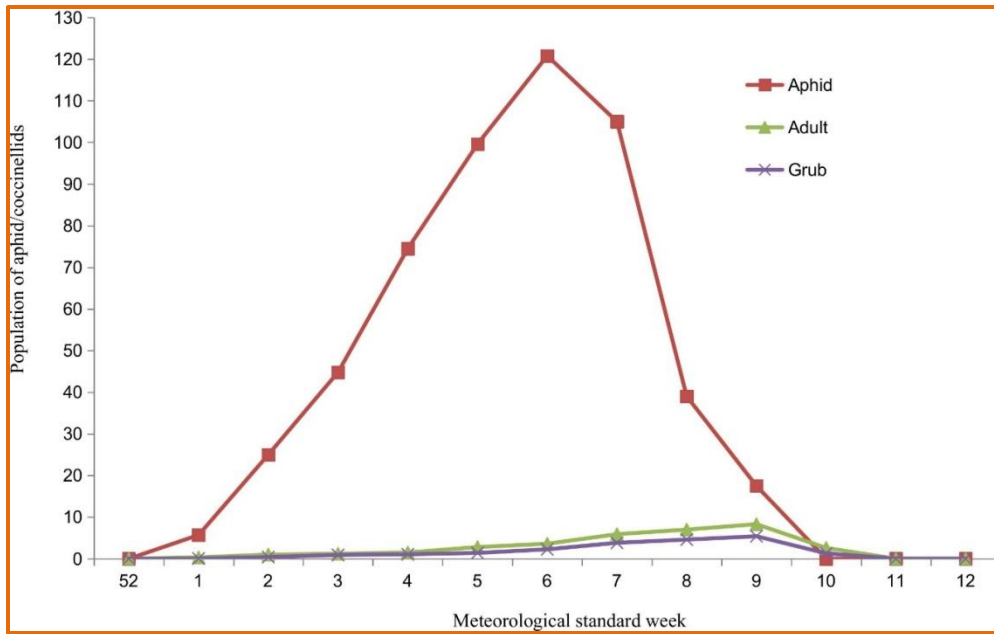


Fig.2. Population of aphid and coccinellid on cv. Varunas on 13 November, 2020

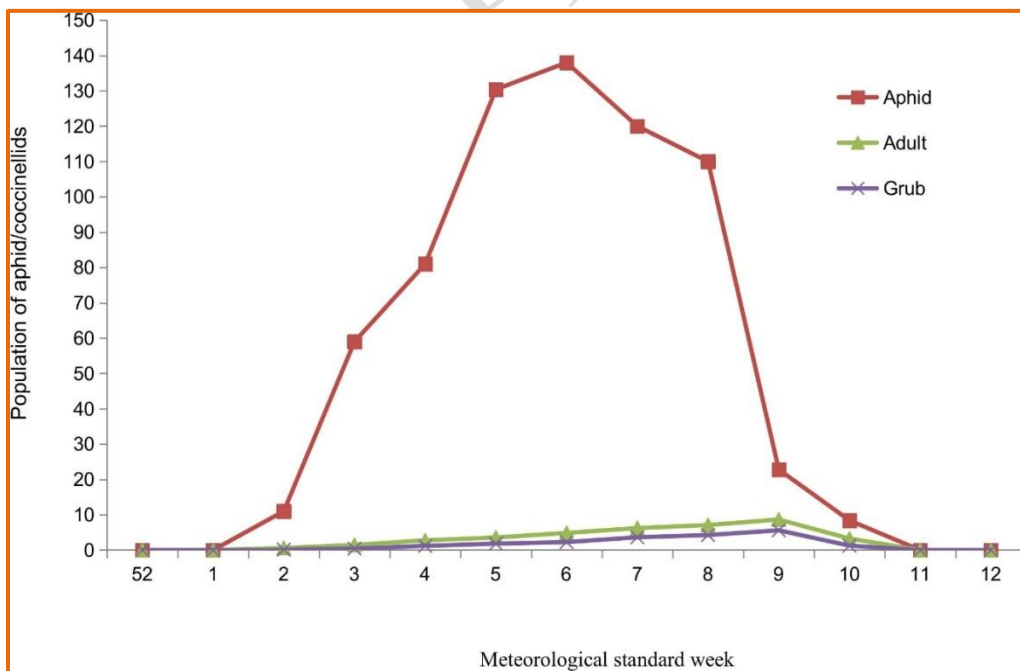


Fig.3. Population of aphid and coccinellids on cv. Varuna sown on 23 November, 2020

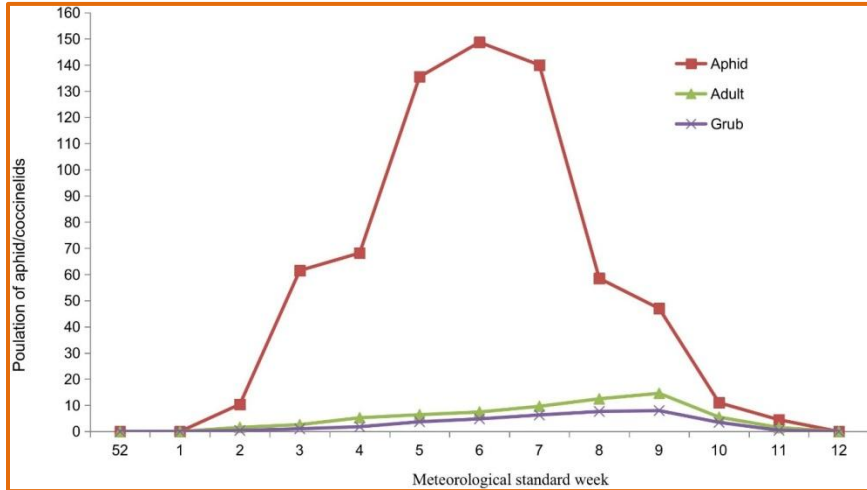


Fig.4. Population of aphid and coccinellids on cv. Azad Mahak sown on 25 November, 2020

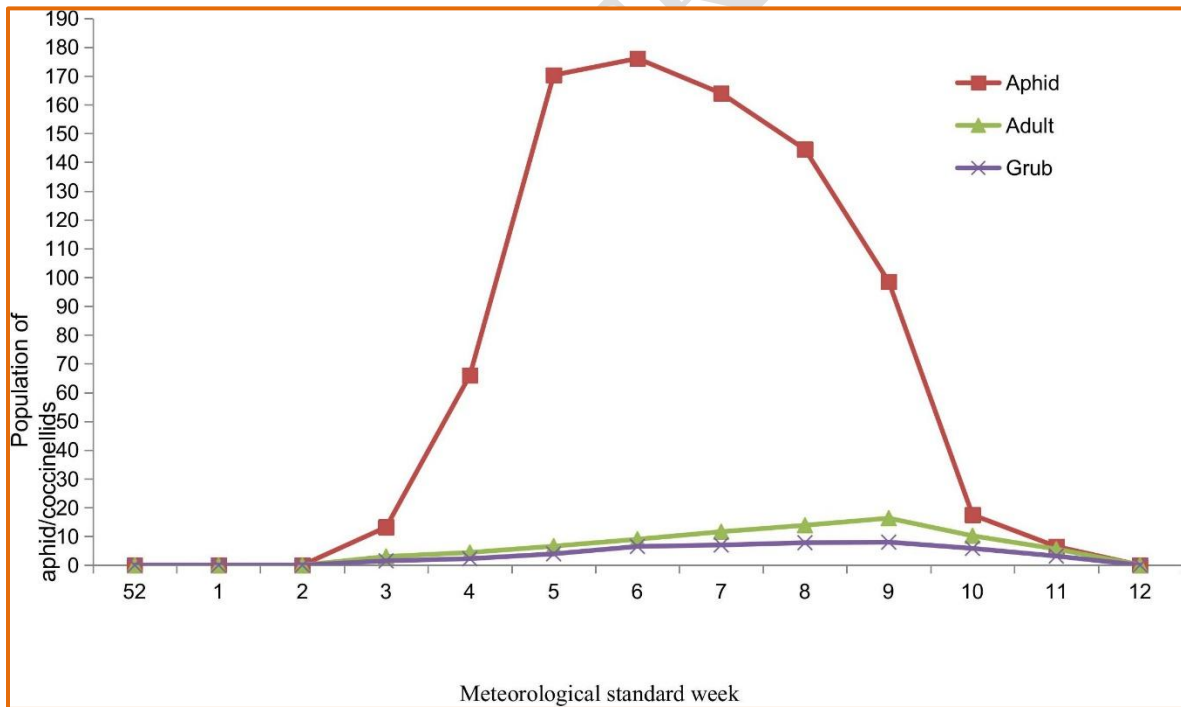


Fig.5. Population of aphid and coccinellids on cv. Ashirwad sown on 10 December, 2020

UNDER PEER REVIEW