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Research Article

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Assessment of Mustard Genotypes against Aphid Attack (*Lipaphis erysimi* Kalt.) under Natural Field Conditions of Muzaffarpur (Bihar)

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Abstract

Mustard is one of the main oilseed crops in India as it is a major source of edible oil after groundnut. Both biotic and abiotic factors mustard aphid (*Lipaphis erysimi* Kalt.) is one of the serious damaging factors for the crop. In order to identify mustard genotypes with high levels of resistance to the mustard aphid with an emphasis on host plant resistance and minimal chemical use, and to check the per cent oil content as well as the protein percentage after the infestation of the pest in different genotypes, an experiment was carried out for two consecutive years namely: 2017 - 18 and 2018 - 19 during rabi season. For this, forty advanced mustard breeding genotypes with two checks viz., RH 7846 and pusa mustard 25 as tolerant and susceptible were taken, keeping in mind about the seed yield losses and oil content of mustard. It was observed that none of the genotypes were found to be highly resistant (HR) against the mustard aphid. However, two genotypes (namely RGN 444 and I79 PAU) recorded as resistant (R) in both the cropping seasons. The other parameters like seed yield (kg/ha), test weight (1000 seeds weight in g), lipid (oil) and protein percentage (%) were also calculated for few selected genotypes showing differential reactions. The lipid and protein content were recorded maximum in the R genotype, RGN 444 with 27.76%, 27.81% and 22.12%, 22.01% in 2017 - 18 and 2018 - 19, respectively. The minimum values of 19.67, 19.62% protein and 25.12, 25.03% lipid content were recorded in the genotype, NPJ 208 where the infestation level was high. The integration of aphid resistant types, identified in this work, can be used in mustard cultivation and serve as a source for aphid resistance in subsequent breeding efforts.

Keywords

Aphid, Sucking pests, Screening, Susceptible, Zero hunger, Crop production

Introduction

In India, rapeseed-mustard is cultivated over an area of 6.23 m ha with production of 9.33 mt and productivity of 15 q/ha during 2018 - 19 [1]. Mustard is cultivated in areas of marginal as well as sub marginal productivity. These are generally mixed with wheat, barley, pea, gram, sugarcane etc. but in areas with advanced agronomy, it is sown as a solo crop [2]. After groundnut, mustard is supposed to be the main oilseed crop in India as it is a major source of edible oil. Hence, it ranks second in area as well as production after groundnut. It is an annual herb and is also consumed as vegetable and fodder as well [1]. Three varieties of mustard are considered for their values as condiments namely brown mustard (*Brassica juncea*), pale yellow or white mustard (*Brassica hirta*), and black mustard (*Brassica nigra*). Mustard belongs to the family Brassicaceae and is considered to be self-pollinated but sometimes, cross pollination also takes place via insects, wind and gravity. Mustard crops are supposed to be attacked by several pests

[3]. A number of pests are supposed to attack mustard crop of which "saw fly (*Athalia lugens proxima*), flea beetle (*Plutella xylostella*), pod borer (*Crocidolomia binotalis*), cabbage butterfly (*Pieris brassicae*) and aphids (*L. erysimi, Brevicoryne brassicae* and *Myzus persicae*)" are among the main pests. Of all these pests, mustard aphid (*L. erysimi* Kalt.) is the most dominant one as it attacks the crop right from the seedling stage till maturity of the crop [2].

Mustard aphid or turnip aphid is whitish green or pale green with two rows of dark band on thorax and abdomen with size ranging from 1.4 mm to 2.4 mm. It belongs to the family aphididae and order hemiptera [4]. It lives on the underside of the leaves, inflorescence, young shoots and pods of growing plants causing rolling, yellowing, chlorosis, shortening of young shoots, distortion, lesions and shortening of the plants overall. Mustard aphid sucks the cell sap due to which curling and discoloration of leaf takes place and these results in dying of the plant. It also secretes honey dew like substance therefore, interfering in the photosynthesis. Due to its attacking nature mustard aphid has been categorized as "National Pest". Mustard aphid not only reduces the yield but also decreases the oil content up to 66.87% [5]. Management practices like cultural and biological control are not very well known to farmers against this pest and they rely mainly on chemical control. While insecticidal spray is effective at preventing insect pest damage to crops, its indiscriminate and excessive use has many negative consequences, such as environmental pollution, higher production costs, food poisoning, and pest resurgence, which undermine the goal of achieving sustainable agricultural production. In light of these factors, employing R genotypes represents the most effective strategy for addressing the issue of pests and aphid resistant cultivars need to be evaluated and identified. Therefore, in view of the above context and the losses caused by this insect in terms of yield and oil content, an experiment was conducted in order to identify aphid resistant or tolerant sources from a total of forty advanced breeding genotypes (Table 1) under field conditions, including two checks viz., RH 7846 and pusa mustard 25 used as tolerant and susceptible varieties, respectively.

Table 1: Details of forty mustard genotypes used in the present study.

Genotype number	Genotype name
G1	RGN 444
G2	RH 919
G3	PRO 5222
G4	RGN 330
G5	DRMR-15-9
G6	RH 1369
G7	LES 54
G8	DRMRIJ 15-85
G9	RH 1301
G10	RH 1514
G11	NPJ 208
G12	KMR (L) 15-5
G13	CS 13000-3-1-1-4-2
G14	CS -56
G15	CS 15000-1-1-1-4-2
G16	CS 900-1-2-2-1-3
G17	PDZ5
G18	PR 2012-12
G19	SKM 1104
G20	NPJ-208
G21	CS 508-1P2
G22	KMR (E) 16-1
G23	LES 55
G24	PDZ 8
G25	PDZ 4
G26	RMWR-09-2-1
G27	Rohini
G28	I 79 (PAU)
G29	RMT 10-9-1
G30	Pusa bold
G31	Divya 88
G32	RH 1301
G33	RGN 337
G34	PDZ-1
G35	RL MCP 626
G36	44-S-46
G37	PHR-126
G38	DRMRIJ 16-3
G39	PRD-2013-8
G40	45-S-35
G41*	RH 7846
G42**	PM 25

Note: *Tolerant check - G41 and **susceptible check - G42.
Source: ACRP on rapeseed-mustard, Bharatpur (Rajasthan).

Materials and Method

Research area and source of mustard genotypes

The research work was conducted at the experimental field of Tirhut College of Agriculture, Dholi, Muzaffarpur, Bihar, during the last week of November in two seasons, 2017 - 18 and 2018 - 19. The experiment was laid out in randomized block design under natural field conditions with three replications. Application of FYM or compost @7.5 t/ha during final land preparation and was incorporated in the soil. The crops were sown at a spacing of 30 cm and 10 cm. All the forty test genotypes were closely examined at regular intervals after germination for gap filling. The genotypes were obtained from Directorate of Rapeseed Mustard Research (ICAR-DRMR), Rajasthan. An attempt was made to categorize distinct mustard types according to their resistance/susceptibility to aphids, namely, HR, R, moderately resistant (MR), moderately susceptible (MS), susceptible (S), and highly susceptible (HS).

Observations and data collection

The observations with regard to number of aphids were recorded from ten randomly selected plants at weekly intervals during morning hours (before 9 am) starting from 50 days after sowing till maturity of the crop, i.e., at full flowering stage and pod formation stage. The field was left for natural aphid infestation and no insecticides were applied in order to ensure their natural population. At flowering stage, the population of aphids including both nymphs and adults was considered by taking the top 10 cm branch in a brown color envelope and was counted with the help of a camel hairbrush separately in the lab. The data so obtained were used to work out the

average number of aphids per plant for both the years. The total number of infested and healthy plants was counted in the selected plants from all the three replications in all genotype for calculation of per cent infestation. All the forty genotypes were finally categorized based on aphid population count and per cent infestation and the scoring of data was given on a 0 - 5 scale as per the methodology adopted by Bakhetia and Sandhu [6] (Table 2). The percent infestation was determined by following standard procedure [7] as:

$$Percentage\ of\ plant\ infested = \frac{\text{Number of infested plants}}{\text{Total number of plants}} x\ 100$$

Determination of lipid percentage (%)

1000 seeds (test weight) from each genotype were taken for lipid (oil) extraction in a Soxhlet lipid extractor using two solvents, chloroform AR (CDH, India) and methanol AR (CDH, India) (2:1 v/v). The weighed samples of the seeds were preserved for this purpose inside pouches of Whatman number 1 filter paper (Whatman, UK), which were tagged, weighed, and stapled to prevent mixing up and material loss during extraction. The solvent extractions were carried out for 12 h, and the materials were dried, and then weighed once more. The variations in weight before extraction and the sample weight after extraction were noted. In order to determine the lipid content of the extracts, it was expressed as a percentage of its dry weight for samples [8, 9]. Sample weight before extraction = W1 sample weight after extraction = W2, lipid amount in the sample W = (W1 - W2).

Sample weight before extraction = W1 sample weight after extraction = W2, lipid amount in the sample W = W1 - W2.

$$\text{Lipid percentage} = \frac{W}{W1} X\ 100$$

Determination of protein percentage (%)

The protein content (%) of mustard seeds from selected 13 genotypes based on their reactions against mustard aphid was determined using the Kjeldahl method [8-10]. Five grams each of mustard seed from these samples were digested using a heating/digestion block and a packet of Kjeldahl digestion mixture 200 as a catalyst. Following digestion, materials were distilled with 30% (w/v) NaOH using a steam distillation apparatus. Ammonia from the distillation was captured using boric acid (4%). Using an N-Point indicator, the distillate was titrated with 0.2 N (normality) of HCl. Using a nitrogen-to-protein conversion factor of 6.25, protein content (%) was estimated from the recorded nitrogen concentration (N in %).

Results and Discussion

The mean number of aphids during the year 2017 - 18 was calculated and it ranged from 90 to 320 aphids, while during 2018 - 19, the range varied from 92 to 335 aphids. The results thus obtained are presented in table 3. It was observed that none of the genotypes were found HR against mustard aphid (*L. erysimi* Kalt.). For both the years, only two genotypes namely G1 and G28 (RGN 444 and I79 (PAU) were found to be R with a few differences in the mean number of aphids (15.79 in 2017 - 18 and 19.35 in 2018 - 19 in case of RGN 444, while for I79 (PAU), the values are 18.92 in 2017 - 18 and 19.35 in 2018 - 19) (Table 4). The genotype (NPJ 208) was observed to be infested in maximum amount with 320 number of aphids in 2017 - 18 and 335 in 2018 - 19. These results are supported by few scientists who examined and reported similar findings for the following varieties - NRCM 120 (1.22 aphids), NRCM 353 (1.22 aphids) and Rayad 9602 (1.23 aphids). These genotypes were recorded with the lowest aphid infestation index and proved to be HR (Table 5). The variety, Vardan (with 1.42 aphids) also showed lower aphid index and was grouped under R category, whereas genotypes such as GM-2 (1.78 aphids), HYOLA-401 (1.69 aphids), GM-3 (1.83 aphids) and GM-1 (1.80 aphids) were categorized as S. On the basis of aphid infestation index, it was concluded the genotype SKM-0401 was the least S with 1.47 aphids' infestation per plant followed by the genotypes SKM0518, SKM-0445, SKM-0301 and SKM-0533 with 1.52, 1.53, 1.57 and 1.60 aphid infestation index, respectively [6], which supported the present findings.

Out of the 40 genotypes screened for aphid infestation under field conditions, 20 genotypes namely DRMRIJ 15-85, DRMR-15-9, RMT 10-9-1, PR 2012-12, PRO 5222, CS 15000-1-1-1-4-2, CS-56, pusa bold, PDZ-8, Divya 88, Rohini, PDZ 4, RL MCP 626, RH 919, RGN 330, RH 1369, RH1514, PDZ 5, RH 7846, PM25 were found to be MS during the first experimental season (2017 - 18), while for the second season (2018 - 19), 11 genotypes namely PRO 5222, DRMR-15-9, PUSA BOLD, PDZ 5, DRMR-15-9, RH 1514, RMT 10-9-1, RL MCP 626, RH 919, RH 7846, PM25 were categorized as MS. Similarly, the following genotypes such as LES 54, CS 13000-3-1-1-4-2, CS 900-1-2-2-1-3, SKM 1104, CS 508-1P2, RMWR-09-2-1, RH 3101, RGN337, 44-S-46, 45-S-35, PHR-126, DRMRIJ 16-3, KMR € 16-1, RH 1301, PDZ-1, PRD-2013-8, LES 55 belonged to the S category in 2017 - 18, while the genotypes belonging to this category were PDZ 8, CS 15000-1-1-1-4-2, PR 2012-12, Divya 88, RGN 330, ROHINI, NPJ-208, DRMRIJ 15-85, LES 54 in 2018-19. On the other hand, genotypes CS 13000-3-1-1-4-2,

Table 2: Scoring and categorization of mustard genotypes.

Scale	Plant reaction to aphids	% infestation of plants by aphids	Mean number of aphids/10 cm inflorescence
0.1 - 1.0	HR	0 - 10%	0 - 20
1.1 - 2-0	R	> 10 - 20%	> 20 - 100
2.1 - 3.0	MS	> 20 - 30%	> 100 - 200
3.1 - 4.0	S	> 30 - 40%	> 200 - 300
4.1 - 5.0	HS	> 40%	> 300

Table 3: Mean number of *L. erysimi* infestation on mustard genotypes under field conditions during 2017 - 18 and 2018 - 19.

Genotype number	Genotype name	Mean number of aphids/10 cm inflorescence (2017 - 18)	Mean number of aphids/10 cm inflorescence (2018 - 19)
G1	RGN 444	90.00	92.00
G28	I 79 (PAU)	93.00	95.00
G8	DRMRIJ 15-85	180.2	160.2
G5	DRMR-15-9	130.4	177.5
G29	RMT 10-9-1	133.32	180.36
G18	PR 2012-12	180.15	187.1
G3	PRO 5222	139.8	189.00
G15	CS 15000-1-1-1-4-2	170.2	189.3
G14	CS-56	140.3	193.9
G30	Pusa bold	142.82	199.1
G24	PDZ 8	174.6	200.32
G31	Divya 88	170.24	201.2
G27	Rohini	182.2	200.4
G25	PDZ 4	193.1	205.8
G35	RL MCP 626	147.3	205.7
G2	RH 919	160.6	210.3
G4	RGN 330	190.2	210.25
G6	RH 1369	170.00	220.3
G10	RH 1514	155.42	200.1
G17	PDZ5	157.7	230.45
G7	LES 54	201.4	253.5
G13	CS 13000-3-1-1-4-2	224.4	269.2
G16	CS 900-1-2-2-1-3	246.1	278.2
G19	SKM 1104	237.1	220.8
G21	CS 508-1P2	245.3	240.42
G26	RMWR-09-2-1	205.3	267.2
G32	RH 1301	220.32	276.1
G33	RGN 337	240.1	278.5
G36	44-S-46	232.1	278.9
G40	45-S-35	244.6	200.32
G37	PHR-126	247.5	287.4
G38	DRMRIJ 16-3	250.4	299.00
G22	KMR (E) 16-1	252.4	290.6
G9	RH 1301	260.15	298.6
G34	PDZ-1	260.3	299.2
G39	PRD-2013-8	262.00	299.5
G23	LES 55	267.7	299.6
G11	NPJ 228	304.00	300.00
G12	KMR (L) 15-5	305.00	320.00
G41*	RH 7846	102.00	107.00
G42**	PM 25	180.00	198.00
G20	NPJ-208	320.00	335.00

Note: Values presented in the table are after square root transformation (mean value = 10 plants/inflorescence); *tolerant check and **susceptible check.

CS 900-1-2-2-1-3, SKM 1104, PDZ 4, RMWR-09-2-1, RH 1301, RGN 337, 45-S-35, PHR-126, RH 1369, CS 508-1P2, RH 1301, PDZ -1, 44-S-46, DRMRIJ 16-3, KMR (E) 16-1, LES 55, PRD-2013-8.NPJ 208, KMR (L) 15-5 were recorded as HS during both the seasons, 2017-18 and 2018-19. Due to the infestation by mustard aphid, there were variations to a great extent in the test weight (i.e., the weight of 1000 seeds) of all the 40 screened genotypes. The minimum seed yield for the two seasons was observed at 1.44 g (1000 seeds) and 1.23 g (1000 seeds) in the genotype, NPJ-208. Whereas, the maximum weight of test weight was recorded at 4.78 g and 4.45g in 2017 - 18 and 2018 - 19, respectively for the genotype, I79 (PAU). The reduction in the seed weight might be due to the plant sap being sucked up by the aphids which reduces the boldness of mustard seeds as well as the oil content [9-12] (Table 6).

The damage due to insect pest is one among the various major biotic factors leading to low productivity in different cultivated crops [13]. At times of heavy infestation by the mustard aphid (*L. erysimi*), they cause extensive seed yield loss and high reduction in oil content in mustard plants [14]. The present result is also in accordance with the results of several other scientists who works with different Brassica varieties

Table 4: Percentage infestation of mustard genotypes by mustard aphid (based on mean % infestation) under field conditions during 2017 - 18 and 2018 - 19.

Genotype number	Genotype name	Percentage infestation (2017 - 18)	Percentage infestation (2018 - 19)
G1	RGN 444	15.79	18.42
G28	I 79 (PAU)	18.92	19.35
G8	DRMRIJ 15-85	23.68	22.58
G5	DRMR 15-9	24.32	25.64
G29	RMT 10-9-1	25.64	26.67
G18	PR 2012-12	26.32	27.5
G3	PRO 5222	26.67	28.13
G15	CS 15000-1-1-1-4-2	27.27	29.41
G14	CS -56	27.5	30.00
G30	Pusa bold	28.13	30.00
G24	PDZ 8	28.21	30.3
G31	Divya 88	28.21	30.77
G27	Rohini	28.95	30.77
G25	PDZ 4	29.41	31.58
G35	RL MCP 626	29.41	31.58
G2	RH 919	30.00	32.35
G4	RGN 330	30.00	32.35
G6	RH 1369	30.00	32.43
G10	RH 1514	30.00	32.5
G17	PDZ5	30.00	33.33
G7	LES 54	32.43	33.33
G13	CS 13000-3-1-1-4-2	33.33	33.33
G16	CS 900-1-2-2-1-3	33.33	33.33
G19	SKM 1104	33.33	33.33
G21	CS 508-1P2	33.33	33.33
G26	RMWR-09-2-1	33.33	33.33
G32	RH 1301	33.33	33.33
G33	RGN 337	33.33	34.29
G36	44-S-46	33.33	34.38
G40	45-S-35	33.33	35.00
G37	PHR-126	34.29	35.14
G38	DRMRIJ 16-3	34.38	35.29
G22	KMR (E) 16-1	35.14	35.29
G9	RH 1301	35.29	35.29
G34	PDZ-1	35.29	35.48
G39	PRD-2013-8	35.29	36.67
G23	LES 55	35.48	38.71
G11	NPJ 228	41.03	39.39
G12	KMR (L) 15-5	41.18	44.44
G42**	PM 25	20.20	21.22
G41*	RH 7846	20.01	20.12
G20	NPJ-208	45.16	48.39

Note: Values presented in the table are after square root transformation (mean value = 10 plants/inflorescence); *tolerant check and **susceptible check.

Table 5: Categorization of mustard genotypes based on percentage infestation and score during 2017 - 18 and 2018 - 19.

S. No.	Category	Genotypes in 2017 - 18	Genotypes in 2018 - 19
1	HR	NIL	NIL
2	R	G1, G28	G1, G28
3	MS	G8, G5, G29, G18, G3, G15, G14, G30, G24, G31, G27, G25, G35, G2, G4, G6, G10, G17, G42, G41	G3, G5, G30, G17, G10, G29, G2, G35, G42, G41
4	S	G7, G13, G16, G19, G21, G26, G32, G33, G36, G40, G37, G38, G22, G9, G34, G39, G23	G24, G15, G18, G14, G31, G4, G27, G20, G8, G7, G13, G16, G19, G25, G26, G32, G40, G33, G37, G6, G21, G9, G34, G38, G22, G23, G39
5	HS	G11, G12, G20	G11, G12

Table 6: 1000 seed weight (test weight) of infested mustard genotypes and yield during 2017 - 18 and 2018 - 19.

Genotype number	Genotype name	Test weight (g) (2017 - 18)	Test weight (g) (2018 - 19)	Yield (kg/ha) (2017 - 18)	Yield (kg/ha) (2018 - 19)
G1	RGN 444	4.36	4.11	998	987
G28	I 79 (PAU)	4.78	4.45	1010	1002
G8	DRMRIJ 15-85	3.78	3.82	989	982
G5	DRMR-15-9	4.2	3.69	1003	987
G29	RMT 10-9-1	4.18	3.76	1001	989
G18	PR 2012-12	3.76	3.6	998	990
G3	PRO 5222	4.00	3.6	986	978
G15	CS 15000-1-1-1-4-2	3.7	3.45	978	965
G14	CS -56	3.98	3.4	987	978
G30	Pusa bold	4.00	3.7	987	980
G24	PDZ 8	3.6	3.3	898	978
G31	Divya 88	3.69	3	901	878
G27	Rohini	3.4	3.1	876	861
G25	PDZ 4	3.4	3	879	867
G35	RL MCP 626	3.6	3.02	870	870
G2	RH 919	3.7	3.2	880	878
G4	RGN 330	3.4	2.97	898	892
G6	RH 1369	2.8	2.6	899	901
G10	RH 1514	3.8	3.1	980	996
G17	PDZ5	3.9	3	982	999
G7	LES 54	3.00	2.82	990	998
G13	CS 13000-3-1-1-4-2	2.98	2.76	989	998
G16	CS 900-1-2-2-1-3	2.4	2.3	985	992
G19	SKM 1104	2.89	2.76	990	998
G21	CS 508-1P2	2.62	2.54	998	999
G26	RMWR-09-2-1	3.23	3.13	987	990
G32	RH 1301	2.91	2.3	987	996
G33	RGN 337	2.78	2.56	1000	1004
G36	44-S-46	2.73	2.99	998	980
G40	45-S-35	2.76	2.59	990	997
G37	PHR-126	2.49	2.32	989	990
G38	DRMRIJ 16-3	2.5	2.4	989	1000
G22	KMR (E) 16-1	2.4	2.03	985	1002
G9	RH 1301	2.44	2.02	986	1000
G34	PDZ-1	2.43	2.10	987	989
G39	PRD-2013-8	2.72	2.33	992	1002
G23	LES 55	2.67	2.59	987	999
G11	NPJ 228	1.98	1.71	1001	1009
G12	KMR (L) 15-5	1.96	1.87	1003	1010
G42**	PM 25	3.11	3.09	989	978
G41*	RH 7846	3.76	3.47	976	980
G20	NPJ-208	1.44	1.23	1008	1000

Note: Values presented in the table are after square root transformation (mean value = 10 plants/inflorescence); *tolerant check and **susceptible check.

and reported high resistance against this aphid while different species of *Brassica* showed diversity in relation to *L. erysimi* from HS to highly tolerant [15-17]. The above findings are also supported by Dilawari et al. [18], who reported that different germplasms or accessions showed differential reactions ranging from HS to highly tolerant when tested against the insect and it was concluded that R varieties had lower aphid infestation [19]. The present study also revealed that no genotypes were immune to this highly damaging aphid species, which is in accordance with the results of other workers who reported that no promising Brassica and allied genotypes can be regarded as immune to mustard aphid [19, 20]. There are reports of concerted efforts being made earlier in order to assess the resistance or susceptibility nature of several oleiferous rapeseed-mustard species by observing aphid setting (population) or infestation and production of alate progenies in the species, *L. erysimi* after inoculation via infested inflorescence under field conditions [21].

Several other workers have also conducted similar research in different regions of India for screening varietal resistance against mustard aphid for utilization of the R sources in further insect resistance breeding programs [22]. In the present study, out of 40 genotypes screened, the number of genotypes categorized as HR, R, MR, S and HS were (0, 0), (2, 2), (20, 10), (17, 27) and (3, 2) during 2017 - 18 and 2018 - 19, re-

spectively. This indicated the severity of aphid infestation once the incidence starts in the field and the presence of aphids significantly restricted the productivity of rapeseed-mustard cultivation.

In one of the similar works conducted in Pakistan, 240 mustard accessions were screened and 16 of them were found to be R, 88 as MR, 102 were recorded as S and the remaining 39 were HS [23, 24]. Another study revealed that three varieties namely, NRCM 120, NRCM 353 and Rayad 9602 were found to be HR with lowest aphid infestation and one variety (Vardan) was R and four varieties (GM-2, HYOLA-401, GM-3 and GM-1) were under the categories, S and HS [25, 26]. The results of the experiment are in close agreement with another study which concluded that the genotypes NM-1, NM-2 and NM-3 were R with minimal aphid population while, genotypes DLJ-3, Chaliate and E-9 showed S response to aphid infestation [24, 14]. The lipid percent (oil content) and the protein contents of few selected genotypes from each category were also analyzed. It was observed that the infested genotypes contained less protein percentage as compared to the normal percentage of oil and protein, i.e., 31.78 to 36.32% and 32.48 to 36.37% respectively.

The results are presented in table 7, where RGN 444 was reported to have the highest lipid as well as protein content (%) in both the experimental years (27.76 - 27.81 in 2017 - 18 and 22.12 - 22.01 in 2018 - 19). On the other hand, the lowest lipid and protein percentage was recorded in the genotype NPJ 208 with lipid percentage 25.12 during 2017-18 and 25.03 in 2018 - 19 and the protein percent was reported to be 19.67 in 2017 - 18 and 19.62 in 2018 - 19. The results showed that the aphid infestation affected not only the yield but the lipid and protein contents of the seeds as well. The genotype, RGN 444 recorded the least aphid infestation amongst all the forty genotypes tested during both the experimental years, which attributed to the highest values of these two proximate analyses. Similarly, the maximum aphid infested genotype (NPJ 208) recorded the least lipid as well as protein percentage (mentioned in table 7). The lipid and protein percentage for all the tested genotypes are presented in a graphical form and shown in figure 1 and figure 2. This observation is well supported by other workers who have conducted experiments with similar objectives [27, 23].

At times of heavy infestation, *L. erysimi* causes maximum seed yield loss and reduction in the oil content, which is the

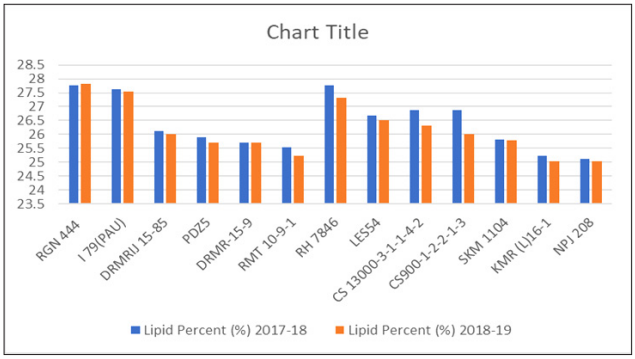

Figure 1: Comparison of lipid percentage in 13 selected genotypes during 2017 - 18 and 2018 - 2019.

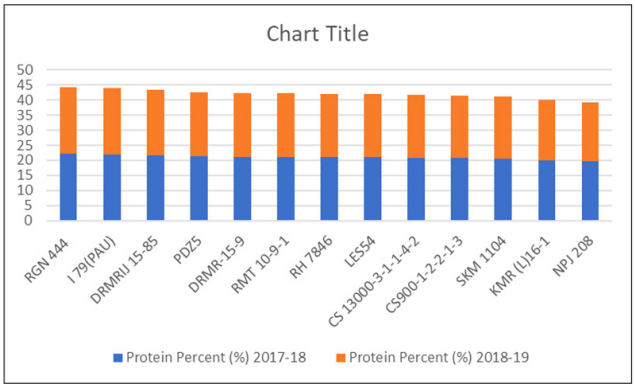

Figure 2: Comparison of protein percentage of 13 selected genotypes during 2017 - 18 and 2018 - 2019.

Table 7: Lipid (oil content %) and protein content (%) of few selected mustard genotypes after *L. erysimi* infestation during 2017 - 18 and 2018 - 19.

S. No.	Genotype number	Genotype name	Lipid percentage		Protein percentage	
			2017 - 18	2018 - 19	2017 - 18	2018 - 19
1	G1	RGN 444	27.76	27.81	22.12	22.01
2	G28	I 79 (PAU)	27.62	27.54	21.98	21.97
3	G8	DRMRIJ 15-85	26.12	26.01	21.76	21.69
4	G17	PDZ5	25.89	25.71	21.32	21.12
5	G5	DRMR-15-9	25.72	25.70	21.21	21.13
6	G29	RMT 10-9-1	25.54	25.23	21.09	21.07
7	G7	LES54	26.67	26.52	20.98	20.96
8	G13	CS 13000-3-1-1-4-2	26.87	26.32	20.84	20.81
9	G16	CS900-1-2-2-1-3	26.88	26.00	20.76	20.72
10	G19	SKM 1104	25.81	25.79	20.55	20.45
11	G22	KMR (L) 16-1	25.23	25.03	20.00	19.97
12	G20	NPJ 208	25.12	25.03	19.67	19.62
13	G41*	RH 7846*	27.77	27.32	21.00	20.99
14	G42**	PM 25**	-	-	-	-

Note: *Tolerant check and **susceptible check; Selection of genotypes based on the reactions against aphids, which includes all the five categories (highly resistant, resistant, moderate, susceptible, and highly susceptible).

most delimiting factor in mustard cultivation. Injudicious use of chemical pesticides has led to many problems including the development of resistance in several species of insect pests, eradication of bio-control agents, environmental pollution, and health hazards [14, 23, 28]. The development of insecticide resistance in various species of insect pests has compelled the entomologists and researchers to search and opt for other alternative strategies for management, which mainly integrates well with different control methods and are eco-friendly. The responses of the mechanism of host plant resistance towards insect behaviour has been explained in previous studies, which reported that plants conferring antixerotic mechanism may produce volatiles induced pest repellence against the insects [29]. Furthermore, S plants may also emit foul odours and cause insect movement to cease in close proximity to the odour source (host). The interaction between the odours emitted by plant sources, the effects of the environment on these odours, the perception of the odours by the insects and the resultant insect behaviours are all linked together and play a major role in insect responses towards the host plant in terms of resistance or susceptibility reactions [16, 27]. In the present study, different mustard genotypes expressing differential reactions towards *L. erysimi* might have different levels of secondary volatiles, where the R entries exhibited higher levels and the S ones showed lower level. In this regard, screening, and evaluation of mustard plants from different sources against mustard aphids, i.e. exploitation of host plant resistance, need to be carried out in order to identify the R sources for utilization in breeding programmes, which has become one of the major pre-requisites in sustainable insect pest management.

In terms of seed yield losses, the lowest yield was registered in the genotypes (G35, G27, G25) RL MCP 626 (870 kg/ha), followed by Rohini (876 kg/ha) and PDZ 4 (879 kg/ha) during 2017-18, respectively and in the next year (2018 - 19), these same three genotypes showed the minimum seed yield with 870 kg/ha, 861 kg/ha and 867 kg/ha (Table 6), which were found to be MS to aphids. Alternatively, the genotypes I 79 (PAU), RGN 444, DRMR-15-9 (G28, G1, G5) produced the highest yields in both the experimental years with 1010, 1002 kg/ha, 1000, 1004 kg/ha and 1003, 997 kg/ha, respectively (Table 6). These genotypes were grouped under R (I 79 PAU) and moderate (RGN 444, DRMR-15-9) categories (Table 5). These results are in line with [4] in which mustard varieties were reported to have yield losses significantly higher in S cultivar, Crusher (43.83%) and lower in R cultivar, T-16-401 (11.08%) against cabbage aphid (*B. brassicae*) in *Brassica* [30]. It has also been reported that aphids alone cause significant reduction of seed yield and oil content about 65 to 96 per cent and 15%, respectively [31, 32], which is evident in the current findings. Furthermore, the present results align with the findings of other researchers who observed that the decrease in seed yield varied not only among different varieties but also within the same variety across different experimental seasons or years [4, 20, 32].

This variability can be attributed to the fluctuating weather conditions experienced in each year in different regions of India. Conducting varietal screening to assess resistance to aphids and the stability of seed output in both aphid-infested and protected environments will facilitate the identification of tolerant cultivars against aphid infestation. The damage caused by the attack of insect pest on oilseed crops limits the seed yield, which ultimately reduces the oil production [7]. The present experiment was aimed at identification of aphid resistance sources from the available and commonly cultivated mustard genotypes. Although no HR genotypes were detected, two genotypes were observed to be under the R category (G1 and G28 i.e., RGN 444 and I 79 PAU) (Table 5). Some of the genotypes were MS while maximum of the genotypes was under S and HS category. The maximum infestation was reported in NPJ-208 (320-335 mean numbers of aphids) during both research trials and hence the seed weight as well as protein and lipid percent was also reported to be at minimum (Tables 6 and 7). Meanwhile, the minimum infested genotype with mean number of aphid (90 - 92) for both the years was observed in RGN444, which also recorded the highest seed weight, lipid, and protein content. Hence, genotypes like RGN 444, I 79 (PAU), DRMRIJ 15-85 can be recommended for utilization as the parent material in mustard breeding programs against mustard aphid.

Conclusion

When considering the issue of pesticide resistance, it is important to note that the use of chemicals may not always be effective and might even have detrimental effects. In the current era of Integrated Pest Management (IPM), the utilization of R types against insect pests is widely regarded as the most advantageous, preferable, cost-effective, and feasible approach advised for growers, particularly in accordance with the requirements of host plant resistance. The utilization of aphid-resistant genotypes namely RGN 444, I-79 (PAU), DRMR-15-9, and DRMR IJ-15-85, as identified in this study, can be integrated into mustard production. These cultivars can serve as potential donors for incorporating aphid resistance in advanced breeding programmes. Additional studies can be undertaken to explore the underlying mechanisms of resistance in these particular genotypes. It is advisable to consider the cultivation of R genotypes that exhibit the highest oil and protein contents on a broad scale. The study revealed that the magnitude of losses was predominantly determined by the degree of synchrony between the peak flowering of genotypes and the peak population of aphids.

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Conflict of Interest

None.

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