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# Analysis of Mechanism of Resistance in *Brassica juncea* (L.) Czern. & Coss. against Mustard Aphid, *Lipaphis erysimi* (Kalt.)

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**Abstract**

Eight parents belonging to *B. juncea* along with their eight $F_1$ and $F_2$ cross progenies were grown under field and screen house conditions to screen for their resistance to mustard aphid infestation. The plants having white colored petals (RWH-1) and glossy foliage B 85 (G) were found resistant while, BSH 1, susceptible check with bright yellow colored flowers and compactly packed floral buds on receme was infested heavily. Higher amount of protein (Pusa Bold and DIRA 313), total soluble sugars (Pusa Bold) and oil content (Pusa Bold and RLM 619) were positively associated with average peak aphid population per plant, while phenol B 85 (G) and RWH—1 and glucosinolates B 85 (G) and T 6342 were related with low incidence of mustard aphid. However, no such relationship could be established in their $F_1$ and $F_2$ progenies. Yield attributing traits of various hosts were not directly related with the peak population of mustard aphid over them. The 'C' scaling test indicated dominance × dominance type of gene interactions for mustard aphid resistance in RH 30 × RLM 619, RH 30 × DIRA 313 and RLM 619 × RH 30 crosses.
**Key words : Mustard aphid, *Lipaphis erysimi,* Resistance, Gene interaction, Glucosinolate.**

India continues to face shortage of edible oil due to high population growth rate (1.7%), rapid urbanization and increased per capita consumption of about 11.55 to 12.10 kg per year during 2004-05 (Rao 2008). Among oilseed crops, rapeseed and mustard rank at second place after groundnut in terms of area and production in the country but their average productivity is not keeping abreast with increase in population. Out of many factors, mustard aphid, *Lipaphis erysimi* (Kalt.) is one of the major constraints in profitable cultivation of rapeseed – mustard crops. Heavy depredation of yield due to mustard aphid incidence have been reported (Rohilla et al. 1987, Bakhetia and Sekhon 1989). The control of mustard aphid by the use of systematic insecticides is quite easy (Bakhetia and Sekhon 1989, Singh et al. 1994, Gazi et al. 2001, Sarwar et al. 2003) but its rapid multiplication and quick reinfestation from the neighboring fields necessitates repeated insecticidal application, involving high cost of control besides ecological imbalance and various direct and indirect health hazards. The resistant varieties are the fundamental and widely accepted tools of integrated pest management (Painter 1951, Panda and Khush 1995). Pest resistant cultivars have been successfully used in IPM systems of insect-pest to curtail the use of hazardous and broad spectrum insecticides. However, the role of plant resistance in the management of mustard aphid has not been properly looked into. Very little efforts have been made to breed aphid resistant varieties of oilseed brassicae (Kumar et al. 1990 Kumar et al. 1994). Thus, these studies were made to study the role of genetic factors of resistance in *B. juncea* (L.) Czern & Coss. against Mustard aphid *L. erysimi.*

## Methods

Eight parents from *B. juncea*, i.e. three resistant T 6342, B 85 (glossy) and RWH -1 (white flowered) and five high yielding susceptible (RH 30, RLM 619, DIRA 313, Rohini and Pusa Bold), were selected and crosses viz., RH 30 × RLM 619, RH 30 × DIDA 313, RLM 619 × RH 30, Rohini × T 6342, Pusa Bold × B 85 (G), RH 30 × T 6342, RWH-1 × T 6342 and DIRA 313 × RWH-1 were utilized for these studies. The parents (single row of 3 m), their $F_1$ (single row of 3 m) and $F_2$ progenies (four rows of 3 m) were grown under field and screenhouse conditions and replicated three times. Standard susceptible check BSH 1 was sown after every 10 lines.

*Population Build Up of Mustard Aphid, L. erysimi on Breeding Material*

In each entry, 10 plants per replication were selected and tagged at random. These plants were observed for appearance of aphid and then population build up on these plants was recorded at weekly intervals till harvest or disappearance of aphids.

*Morphological Traits.* The observations on leaf color, stem color, flower color, compactness of flower buds (compact, semi-compact, loose) and plant height (cm) were recorded and compared with peak aphid population of different parents and their $F_1$ and $F_2$ progenies.

*Biochemical Traits.* Biochemical analysis for major constituents viz., phenol, protein, glucosinolates and total soluble sugars was carried out at inflorescence stage for each entry. The plant samples were sun dried for 3 days and then oven dried at 80 C for 24 hours. The samples were ground into powder and analyzed for these said parameters. The nitrogen content was estimated by following the conventional Kjeldhal's method. Protein content was calculated by multiplying the nitrogen content by 6.25. The phenol content was determined following Swain and Hill (1959). Total soluble sugar (%) and glucosinolates (%) were estimated by following the methods given by Hulme and Narain (1931) and McGhee et al. (1965), respectively. The oil content in seeds was determined by N. M. R. Nuclear Magnetic Resonance (NMR). The data of these biochemical constituents were compared with peak aphid population on the entries.

*Yield Attributing Traits.* At harvest, five plants from each entry were randomly selected for recording data on main shoot length, number of siliqua on main shoot, siliqua length, seed per siliqua, yield per plant (g) and 1,000-seed weight (g)

*Analysis of Gene Interactions for Mustard Aphid, L. erysimi in Different Crosses of Brassica*

The gene interactions were analyzed using 'C' sealing test given by Mather (1949)

$$C = 4\,\overline{F_2} - 2\,\overline{F_1} - \overline{P_1} - \overline{P_2}$$

$$V(C) = 16V(\overline{F_2}) + 4V(\overline{F_1}) + V(\overline{P_1}) + V(\overline{P_1})$$

$$S.E.C. = \sqrt{V(C)}$$

$$t\,(Cal.) = \frac{C}{\sqrt{V(C)}}$$

The scaling tests A, B, C and D were applied to know which type of gene effects were involved in the inheritance of resistance against any pest of a crop. Since in the present endeavour only $P_1$, $P_2$, $F_1$ and $F_2$ generations were available , therefore, only 'C' test was applied to reveal the above fact.

*Sereening of Advanced Breeding Material under Screenhouse Conditions*

The experiment was carried out in CRD by growing three plants per pot (30 cm diameter) of each genetic material in 10 replicates. At flowering initiation stage, the plants were infested with five aphids per plant by release technique. The observations on the aphid population per plant were recorded at weekly intervals and the gene interactions between mustard genotypes and aphid were worked out.

## Results and Discussion

*Influence of Morphological Traits on Mustard Aphid, L. erysimi Population*

The observations on morphological traits, namely leaf color, stem color, flower color, compactness of flower and plant height of resistant and susceptible entries and their $F_1$ and $F_2$ progenies along with peak aphid population (Table 1) indicated that maximum aphid population (142.5 aphids/plant) was recorded on variety BSH 1 having bright yellow colored and compactly packed flower buds, while the lowest aphid population, i.e. 15.6 and 16.1 aphids/plant was observed on the parents RWH–1 and B 85 (G), respectively, having white flowers and pale green glossy leaves and stem, respectively. In the $F_2$ progenies, the crosses involving RWH-1 and B 85 (G) as one of the parents showed low incidence of mustard aphid. Higher plant heights, i.e. 148 and 176.4 cm were of B 85 (G) and Pusa Bold, respectively, which had 16.1 and 92.5 aphids/plants, respectively. Other morphological traits of parents and their cross progenies could not be related to peak aphid population.

**Table 1.** Morphological traits of elite entries and crosses of brassicae and peak population of mustard aphid, *Lipaphis erysimi* (Kalt.).

| | Morphological traits | | | | | |
|---|---|---|---|---|---|---|
| Entries | Leaf color | Stem color | Flower color | Flower compactness | Plant height (cm) | Average peak aphid population per plant |
| **Parent** | | | | | | |
| RH 30 | Pale green | Pale green | Yellow | Semi compact | 165.0 | 64.7 |
| RLM 619 | ,, | ,, | ,, | ,, | 169.2 | 74.0 |
| DIRA 313 | ,, | ,, | ,, | ,, | 174.8 | 74.5 |
| Rohini | ,, | ,, | ,, | ,, | 162.4 | 78.5 |
| Pusa Bold | ,, | ,, | ,, | ,, | 176.4 | 92.5 |
| T 6342 | ,, | ,, | ,, | ,, | 161.5 | 17.4 |
| B 85 (G) | Pale green glossy | Pale green glossy | ,, | ,, | 148.0 | 16.1 |
| RWH-1 | Pale green | Pale green | White | ,, | 159.6 | 15.6 |
| BSH 1 (Sus. check) | ,, | ,, | Bright yellow | ,, | 153.2 | 142.5 |
| **$F_1$** | | | | | | |
| RH 30 × RLM 619 | Pale green | Pale green | Yellow | Semi compact | 169.4 | 73.3 |
| RH 30 × DIRA 313 | ,, | ,, | ,, | ,, | 177.5 | 86.8 |
| RLM 619 × RH 30 | ,, | ,, | ,, | ,, | 166.5 | 103.5 |
| Rohini × T 6342 | ,, | ,, | ,, | ,, | 164.5 | 60.2 |
| Pusa Bold × B 85 (G) | ,, | ,, | ,, | ,, | 170.1 | 48.3 |
| RH 30 × T 6342 | ,, | ,, | ,, | ,, | 165.8 | 51.5 |
| RWH–1 × T 6342 | ,, | ,, | ,, | ,, | 160.4 | 28.8 |
| DIRA 313 × RWH-1 | ,, | ,, | ,, | ,, | 167.0 | 65.5 |
| **$F_2$** | | | | | | |
| RH 30 × RLM 619 | Pale green | Pale green | Yellow | Semi compact | 170.2 | 107.5 |
| RH 30 × DIRA 313 | ,, | ,, | ,, | ,, | 175.0 | 124.5 |
| RLM 619 × RH 30 | ,, | ,, | ,, | ,, | 164.4 | 134.5 |
| Rohini × T 6342 | ,, | ,, | ,, | ,, | 160.4 | 85.0 |
| Pusa Bold × B 85 (G) | Pale green/ Pale green glossy | Pale green/ Pale green glossy | ,, | ,, | 155.2 | 67.2 |
| RH 30 × T 6342 | Pale green | Pale green | ,, | ,, | 157.5 | 67.0 |
| RWH– 1× T 6342 | ,, | ,, | Yellow/white | ,, | 161.6 | 25.7 |
| DIRA 313 × RWH-1 | ,, | ,, | Yellow/white | ,, | 172.0 | 80.5 |

This might have happened due to non-preference mechanism of resistance to mustard aphid because of off-color of petals and foliage. However, this phenomenon did not exist for longer period as the aphids preferred to feed on them, when other suitable hosts were not available. The studies are in concurrence with the findings of several workers (e.g., Rohilla 1989, Singh et al. 1991, Singh et al. 1997).

### *Influence of Biochemical Constituents on Mustard Aphid, L. erysimi Population*

All the parents and their cross progenies had lower peak aphid population (15.6 to 134.5 aphids/plant) as compared to the susceptible check i.e. BSH 1 (142.5 aphids/plant) which had significantly low amount of phenol (2.20%) and glucosinolate (5.87%) and high protein (14.01%), total soluble sugars (14.23%) and oil content (47.5%) as compared to other entries (Table 2).

*Phenol.* The phenol content in various parents varied significantly being higher in B 85 (G) and RWH-1 compared to remaining parents, and harbored low number of aphids i.e. 16.1 and 15.6 per plant, respectively.

**Table 2.** Biochemical constituents of elite entries and crosses of brassicae and peak population of mustard aphid *L. erysimi* (Kalt.).

| Entries | Biochemical constituents Phenol (%) | Protein (%) | Glucosinolates (%) | Total soluble sugars (%) | Oil content | Average peak aphid population per plant |
|---|---|---|---|---|---|---|
| **Parent** | | | | | | |
| RH 30 | 2.39 | 15.22 | 6.23 | 12.27 | 40.33 | 64.7 |
| RLM 619 | 2.54 | 14.62 | 6.43 | 12.31 | 44.07 | 74.0 |
| DIRA 313 | 2.02 | 15.70 | 6.77 | 12.92 | 43.53 | 74.5 |
| Rohini | 2.29 | 15.08 | 5.98 | 12.55 | 38.37 | 87.2 |
| Pusa Bold | 2.42 | 15.97 | 6.67 | 14.83 | 44.67 | 92.5 |
| T 6342 | 2.41 | 15.35 | 7.06 | 11.01 | 40.10 | 17.4 |
| B 85 (G) | 2.84 | 15.63 | 5.39 | 10.93 | 38.53 | 16.1 |
| RWH-1 | 2.60 | 13.74 | 6.38 | 11.23 | 40.83 | 15.6 |
| BSH 1 (Sus. check) | 2.20 | 14.01 | 5.87 | 14.23 | 47.50 | 142.5 |
| **$F_1$** | | | | | | |
| RH 30 × RLM 619 | 2.50 | 15.70 | 5.16 | 11.74 | 42.57 | 73.3 |
| RH 30 × DIRA 313 | 2.49 | 16.67 | 5.15 | 13.62 | 39.07 | 86.8 |
| RLM 619 × RH 30 | 2.74 | 15.87 | 6.23 | 12.78 | 42.37 | 103.5 |
| Rohini × T 6342 | 2.56 | 15.23 | 6.74 | 13.28 | 43.57 | 60.2 |
| Pusa Bold × B 85 (G) | 2.97 | 15.33 | 6.81 | 13.93 | 41.23 | 48.3 |
| RH 30 × T 6342 | 2.03 | 15.10 | 5.97 | 11.37 | 40.93 | 51.5 |
| RWH – 1 × T 6342 | 2.06 | 14.67 | 5.87 | 12.52 | 42.83 | 28.8 |
| DIRA 313 × RWH-1 | 2.55 | 14.25 | 6.37 | 12.07 | 42.63 | 65.5 |
| **$F_2$** | | | | | | |
| RH 30 × RLM 619 | 2.42 | 15.00 | 4.82 | 11.10 | 43.17 | 107.5 |
| RH 30 × DIRA 313 | 2.17 | 15.50 | 4.51 | 11.83 | 43.57 | 124.5 |
| RLM 619 × RH 30 | 2.56 | 14.87 | 5.39 | 11.72 | 43.63 | 134.5 |
| Rohini × T 6342 | 2.84 | 14.03 | 5.07 | 12.08 | 41.63 | 85.0 |
| Pusa Bold × B 85 (G) | 2.82 | 15.90 | 6.41 | 12.98 | 42.07 | 67.2 |
| RH 30 × T 6342 | 2.07 | 14.38 | 4.55 | 12.08 | 42.40 | 67.0 |
| RWH – 1 × T 6342 | 2.53 | 13.23 | 4.37 | 10.06 | 42.73 | 25.7 |
| DIRA 313 × RWH–1 | 2.21 | 14.77 | 6.00 | 12.27 | 42.23 | 80.5 |
| CD ($P$ = 0.05) | 0.27 | 0.54 | 0.52 | 0.86 | 1.23 | |

In the $F_1$ progenies, the phenol content varied significantly ranging from minimum 2.03 (RH 30 × T 6342) to maximum of 2.97% [Pusa Bold × B 85 (G)]. No relation could be established between phenol content of $F_1$ progenies and peak aphid population. Almost similar trend was observed in $F_2$ progenies.

*Protein.* The protein content was significantly low, i.e. 13.74% in RWH-1 and more, i.e. 15.97 and 15.70% in Pusa Bold and DIRA 313 and it was related to low and high aphid population i.e. 15.6 and 92.5 aphids/plant on RWH – 1 and Pusa Bold, respectively. In $F_1$ progenies too, the protein content varied significantly being minimum of 14.25 to 15.33% in the crosses involving one of the parents as resistant (28.8 to 65.5 aphids/plants) and maximum, i.e. ranging from 15.70 to 16.67% in the susceptible × susceptible (S × S) crosses. In $F_2$ progenies, the protein contents varied significantly ranging from minimum of 13.23% in cross RWH-1 × T 6342 having lowest aphid population (25.7 aphids/plant), to maximum of 15.9% in cross Pusa Bold × B 85 (G). In general, the crosses having high protein content harbored high aphid population.

*Glucosinolates.* The glucosinolates content varied significantly amongst parents, i.e. ranging from 5.39% [B 85 (G)] to 7.06% (T 6342) and both the parents were having low aphid population, i.e. 16.1 and 17.4 aphids/plant, respectively. In $F_1$ progenies, the glucosinolates content varied significantly being

**Table 3.** Yield attributing traits and yield of elite lines and crosses of brassicae and peak population of mustard aphid, *Lipaphis erysimi* (Kalt.).

| Entries | Yiel attributing traits | | | | | | Average peak aphid population per plant |
|---|---|---|---|---|---|---|---|
| | Main shoot length (cm) | Siliquae per main shoot | Siliqua length (cm) | Grains per siliqua | 1000 seed weight (g) | Yield per plant (g) | |
| **Parent** | | | | | | | |
| RH 30 | 77.5 | 42.3 | 4.2 | 11.6 | 5.1 | 20.7 | 64.7 |
| RLM 619 | 70.1 | 45.4 | 4.1 | 11.3 | 4.4 | 19.8 | 74.0 |
| DIRA 313 | 77.0 | 42.3 | 4.0 | 11.8 | 4.7 | 19.1 | 74.5 |
| Rohini | 74.5 | 51.7 | 3.7 | 11.3 | 4.9 | 19.2 | 78.5 |
| Pusa Bold | 74.1 | 40.2 | 4.4 | 12.4 | 6.2 | 20.9 | 92.5 |
| T 6342 | 72.3 | 45.1 | 4.1 | 13.1 | 3.7 | 15.6 | 17.4 |
| B 85 (G) | 81.5 | 46.4 | 4.1 | 14.0 | 2.8 | 11.1 | 16.1 |
| RWH-1 | 79.9 | 45.2 | 4.2 | 13.0 | 3.7 | 15.3 | 15.6 |
| BSH 1 (Sus. check) | 42.6 | 27.1 | 5.5 | 13.5 | 3.4 | 13.1 | 142.5 |
| **$F_1$** | | | | | | | |
| RH 30 × RLM 619 | 74.5 | 42.1 | 4.4 | 4.4 | 12.5 | 24.6 | 73.3 |
| RH 30 × DIRA 313 | 55.9 | 35.4 | 3.9 | 4.8 | 11.1 | 21.4 | 86.8 |
| RLM 619 × RH 30 | 71.9 | 45.2 | 3.7 | 4.4 | 11.5 | 24.2 | 103.5 |
| Rohini × T 6342 | 79.6 | 46.4 | 3.5 | 3.7 | 11.8 | 23.8 | 60.2 |
| Pusa Bold × B 85 (G) | 84.2 | 51.0 | 4.3 | 3.1 | 13.2 | 18.4 | 48.3 |
| RH 30 × T 6342 | 68.9 | 51.6 | 4.0 | 3.8 | 12.2 | 24.6 | 51.5 |
| RWH–1 × T 6342 | 96.4 | 58.3 | 4.1 | 3.5 | 14.4 | 20.3 | 28.8 |
| DIRA 313 × RWH–1 | 79.4 | 42.7 | 4.1 | 4.2 | 13.9 | 17.4 | 65.5 |
| **$F_2$** | | | | | | | |
| RH 30 × RLM 619 | 80.2 | 45.2 | 4.2 | 11.4 | 4.8 | 30.4 | 107.5 |
| RH 30 × DIRA 313 | 62.0 | 33.3 | 3.8 | 10.5 | 4.8 | 19.1 | 124.5 |
| RLM 619 × RH 30 | 76.9 | 43.6 | 3.9 | 11.2 | 4.7 | 19.3 | 134.5 |
| Rohini × T 6342 | 86.2 | 48.0 | 3.9 | 11.3 | 4.3 | 17.4 | 85.0 |
| Pusa Bold × B 85 (G) | 83.8 | 49.9 | 4.1 | 12.1 | 5.0 | 17.4 | 67.2 |
| RH 30 × T 6342 | 77.5 | 46.7 | 4.0 | 10.1 | 4.1 | 18.2 | 67.0 |
| RWH–1 × T 6342 | 85.3 | 41.2 | 4.1 | 11.5 | 3.7 | 17.1 | 25.7 |
| DIRA 313 × RWH–1 | 70.6 | 42.4 | 3.9 | 14.4 | 4.3 | 17.1 | 80.5 |
| CD ($P$ = 0.05) | 6.4 | 5.3 | 0.2 | 1.1 | 0.7 | 4.8 | |

minimum of 5.15% (RH 30 × DIRA 313) and maximum of 6.81% [Pusa Bold × B 85 (G)]. However, minimum and maximum aphid populations were observed on the crosses RWH-1 × T 6342 (28.8 aphids/plant) and RLM 619 × RH 30 (103.5 aphids/plants), respectively. In $F_2$ progenies, the crosses RH 30 × RLM 619 and RH 30 × DIRA 313 having significantly low glucosinolates content, i.e. 4.82 and 4.51%, respectively, had higher aphid population (107.5 to 124.5 aphids/plant) compared to 67.2 and 80.5 aphids per plant on the crosses Pusa Bold × B 85 (G) and DIRA 313 × RWH-1 having high glucosinolates content, i.e. 6.41 and 6.0%, respectively. However, no conspicuous relationship was established between glucosinolates content and peak mustard aphid population.

*Total Soluble Sugars (TSS).* Total soluble sugar content differed significantly between parents being low, i.e. 10.93 to 11.23% in resistant parents to high of 12.31 to 14.83% in aphid susceptible parents. In general, the parents having low level of total soluble sugars harbored low aphid population and vice-versa. However, in $F_1$ and $F_2$ progenies although, the total soluble sugar contents varied significantly but no such relationship could be established between TSS contents and aphid population.

*Oil Content.* Parents viz., DIRA 313, RLM 619 and Pusa Bold having significantly higher oil content, i.e. 43.53, 44.07 and 44.67% respectively also

**Table 4.** C scaling test and gene interactions for mustard aphid, *Lipaphis erysimi* (Kalt.) in eight crosses of brassicae under field conditions. *Significant at 5 per cent.

| Cross | V (C) I Peak | V (C) II Peak | SE (C) I Peak | SE (C) II Peak | t (cal) I Peak | t (cal) II Peak | Gene interaction I Peak | Gene interaction II Peak |
|---|---|---|---|---|---|---|---|---|
| RH 30 × RLM 619 | 3164.83 | 2304.06 | 56.26 | 48.00 | 2.57* | 2.73* | Non-allelic | Non-allelic |
| RH 30 × DIRA 313 | 4822.29 | 1305.88 | 69.44 | 36.14 | 2.66* | 3.23* | Non-allelic | Non-allelic |
| RLM 619 × RH 30 | 1844.91 | 900.82 | 42.95 | 30.01 | 4.46* | 3.70* | Non-allelic | Non-allelic |
| Rohini × T 6342 | 26084.92 | 9093.40 | 161.51 | 95.36 | 0.77 | 1.80 | - | - |
| Pusa Bold × B 85 (G) | 17912.16 | 5925.90 | 133.84 | 76.98 | 0.48 | 0.51 | - | - |
| RH 30 × T 6342 | 9088.34 | 8726.95 | 95.33 | 93.42 | 0.87 | 0.95 | - | - |
| RWH-1 × T 6342 | 555.15 | 258.47 | 23.56 | 16.08 | 0.52 | 1.64 | - | - |
| DIRA 313 × RWH-1 | 18286.74 | 18923.00 | 135.23 | 137.56 | 0.73 | 0.87 | - | - |

supported higher aphid population, i.e. 74.5, 74.0 and 92.5 aphids/plant, respectively, whereas all the three resistant parents, i.e. T 6342, B 85 (G) and RWH-1 had low oil content (38.53 to 40.83%). In $F_1$ progenies, the oil content of the crosses varied significantly between 39.07% (RH 30 × DIRA 313) and 43.57% (Rohini × T 6342) and no clear relationship was established between aphid population and oil content of the host. In $F_2$ progenies, low oil content (42.07%) was recorded in the cross Pusa Bold × B 85 (G) whereas, significantly high oil content (43.63%) was recorded in the cross RLM 619 × RH 30. Obviously, the crosses susceptible × susceptible (S × S) having high oil content (43.17 to 43.63%) had high aphid population (107.5 to 134.5 aphids/plant) as compared to the rest of the crosses.

The results of the study are in concurrence with the findings of Malik (1981). Weibull and Melin (1990), Ram Dhari et al. (1994) and Raj et al. (1996). However, the conspicuous impact of these biochemical parameters could not be ascertained as of the parents in their $F_1$ and $F_2$ progenies on average number of mustard aphid per plant. Probably, the gene pool was limited and variations in biochemical constituents were not wide. So, their impact on aphid population could not be visualized in progenies. This needs further in depth studies by taking more number of diversed genotypes of rapeseed mustard and their allies to reach on any conclusion.

### *Influence of Yield Attributing Traits and Yield on Mustard Aphid, L. erysimi Population*

*Main Shoot Length.* The main shoot length was significantly low i.e. 42.6 cm in BSH 1 (susceptible check) supporting maximum aphid population (142.5 aphid/plant), while parents with more shoot length supported comparatively low aphid population. However, in $F_1$ and $F_2$ progenies, S × S crosses possessed higher aphid populations and their main shoot length was also more. Contrary to it, the cross RWH-1× T 6342 having minimum aphid population also had significantly longer main shoot length in $F_1$ and $F_2$ progenies (Table 3).

*Siliquae Per Main Shoot.* Number of siliquae (27.1 per main shoot) on BSH 1 (susceptible check) was significantly lower as compared to rest of the parents. The number of siliquae per main shoot did not differ significantly among different parents except Rohini in which the number was significantly more (51.7). In $F_1$ and $F_2$ progenies, the number of siliquae per main shoot of different crosses varied significantly ranging from 35.4 to 58.3 and 33.3 to 49.9, respectively, and it could not be related to aphid population.

*Siliqua Length.* The siliqua length was more (5.5 cm) in BSH 1. It varied significantly ranging from 3.7 (Rohini) to 4.4 cm (Pusa Bold) in various parents. Among crosses, it varied from 3.5 (Rohini × T 6342) to 4.4 cm (RH 30 × RLM 619) in $F_1$ progenies and 3.8 (RH 30 × DIRA 313) to 4.2 cm (RH 30 × RLM 619) in different $F_2$ progenies. The parameter also did not establish any relationship with aphid population on different hosts.

*Grains Per Siliqua.* Number of grains per siliqua varied from 11.3 to 14.0 in various parents. In general, number of grains per siliqua was more in resistant parents. Similarly, in $F_1$ progenies, the number of grains per siliqua varied significantly nanging from 11.1 (RH 30 × DIRA 313) to 14.4 grains per siliqua (RWH-1 × T

**Table 5.** C scaling test and gene interaction for mustard aphid, *Lipaphis erysimi* (Kalt.) in eight croses of brassicae under screen house conditions. *Significant at 5 per cent.

| Cross | V (C) | SE (C) | t (cal) | Gene interaction |
|---|---|---|---|---|
| RH 30 × RLM 619 | 2935.85 | 54.17 | 4.15* | Non-allelic |
| RH 30 × DIRA 313 | 2088.46 | 45.70 | 2.14* | Non-allelic |
| RLM 619 × RH 30 | 2624.73 | 51.23 | 5.93* | Non-allelic |
| Rohini × T 6342 | 89417.61 | 299.03 | 0.07 | - |
| Pusa Bold × B 85 (G) | 65948.16 | 256.80 | 0.22 | - |
| RH 30 × T 6342 | 38519.30 | 196.26 | 0.06 | - |
| RWH-1 × T 6342 | 18068.51 | 134.42 | 0.73 | - |
| DIRA 313 × RWH-1 | 25272.95 | 158.97 | 0.62 | - |

6342) and generally, the crosses having higher number of grains per siliqua harbored lower number of aphids per plant and vice-versa. But this relationship was not established in $F_2$ progenies where the number of grains per siliqua varied significantly ranging from 10.1 (RH 30 × T 6342) to 14.4 grains (DIRA 313 × RWH-1).

*Seed Weight Per 1,000 Seeds.* Thousand seed weight did not show any impact on the aphid population which varied significantly ranging from 2.8 B 85 (G) to 6.2 g (Pusa Bold). Among crosses, it varied from 3.1 Pusa Bold × B 85 (G) to 4.8 (RH 30 × DIRA 313) for $F_1$ progenies and 3.7 (RWH-1 × T 6342) to 5.0 g Pusa Bold × B 85 (G) for $F_2$ progenies. In general, the crosses involving the susceptible high yielding varieties as one of the parents or both the parents as aphid susceptible high yielding varieties, had higher 1,000-seed weight.

*Yield Per Plant.* The susceptible check BSH 1 and early maturing parents viz. B 85 (G) and RWH-1 and an aphid tolerant parent, i.e. T 6342 yielded poor as compared to the rest of the parents. In $F_1$ progenies, the yield of various crosses varied significantly ranging from 17.4 (DIRA 313 × RWH-1) to 24.6 g per plant (each of RH 30 × RLM 619 and RH 30 × T 6342) and was not related with peak aphid population. In $F_2$ progenies, the yield per plant did not differ significantly between different crosses ranging form 17.1 to 20.4 g per plant.

### *Analysis of Gene Interactions (C Test) for Mustard Aphid, L. erysimi in Different Crosses of Brassica*

The significant value for C test indicated the dominance × dominance type of gene interactions in the crosses RH 30 × RLM 619, RH 30 × DIRA 313 and RLM 619 × RH 30 (Tables 4, 5). In the remaining crosses, the C test was observed to be non-significant.

The significant value of C test in some progenies indicated the presence of dominance × dominance type of gene interactions in the three crosses (RH 30 × RLM 619, RH 30 × DIRA 313 and RLM 619 × RH 30) out of eight crosses. The best breeding strategy to incorporate resistance in the present rapeseed-mustard material would be the approach of heterosis breeding. But *B. juncea* is self pollinated crop, therefore, heterosis breeding will be difficult. So, only answer would be to opt biparental mating in the $F_2$ generation and selection in subsequent generations for high yield and tolerance to mustard aphid. Almost similar results have been reported by Goomber and Labana (1983) and Kumar et al. (1990, 1994). However, Singh et al. (1990) reported that both additive and non-additive gene effects were important for genetic control of mustard aphid resistance in Indian mustard.

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