

RESEARCH PAPER

Host Plant-Mediated Variation in Mustard Aphid (*Lipaphis erysimi* Kaltenbach) Abundance among Popular Rapeseed–Mustard Cultivars in Coastal Agroecosystem

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ABSTRACT

Rapeseed–mustard (*Brassica* spp.) is a globally important oilseed crop, and its interaction with herbivorous insects is largely regulated by the glucosinolate–myrosinase defence system. Hydrolysis of glucosinolates produces bioactive isothiocyanates that influence herbivore feeding behaviour, survival, and host acceptance. The mustard aphid, *Lipaphis erysimi* Kaltenbach, is a major constraint to rapeseed–mustard production, and its population dynamics are influenced by host genotype, biochemical composition, and plant characteristics. The present study was conducted to evaluate the performance of ten popular rapeseeds–mustard cultivars in relation to plant growth traits, glucosinolate content, and mustard aphid abundance under coastal agroecosystem conditions of Satjelia, Gosaba, South 24 Parganas, West Bengal, India. Data were analyzed using Duncan’s Multiple Range Test (DMRT), correlation analysis, and cluster analysis. Aphid infestation was minimal during the vegetative stage and increased substantially during the reproductive phase, attaining peak population during flowering. Significant variation was observed among cultivars for glucosinolate content, ranging from 78.8 $\mu\text{mol g}^{-1}$ in Binoy to 165.35 $\mu\text{mol g}^{-1}$ in Bhagirathi. Aphid abundance showed a negative association with glucosinolate concentration, indicating the role of glucosinolate-mediated defence in suppressing *L. erysimi* population development. Siliqua per plant and seeds per siliqua exhibited negative relationships with aphid abundance, whereas plant height, primary branches, siliqua length, and 100-seed weight showed positive associations. Cluster analysis revealed distinct grouping of cultivars based on morphological traits, glucosinolate content, and aphid response. The study highlights significant cultivar-dependent variation in mustard aphid abundance and demonstrates the importance of biochemical defence, particularly glucosinolate accumulation, in regulating aphid infestation. Glucosinolate-rich cultivars may serve as valuable resources for resistance breeding and sustainable integrated pest management strategies in rapeseed–mustard production systems.

HIGHLIGHTS

- ① Ten rapeseed–mustard cultivars showed distinct aphid infestation patterns.
- ② Aphid infestation peaked at flowering, reaching 37.1 aphids/10 cm shoot.
- ③ B54 (Agrani) recorded lowest peak aphid population, 15.4 aphids/10 cm.
- ④ Glucosinolate content ranged from 78.8 to 165.35 $\mu\text{mol g}^{-1}$.
- ⑤ Glucosinolates negatively correlated with aphid abundance ($r = -0.598$).
- ⑥ Kranti recorded highest seed yield of 6.65 q ha⁻¹.

Keywords: Aphid, glucosinolates, mustard, yield attributing characters

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Rapeseed–mustard (*Brassica* spp.) represents one of the most important oilseed crop groups worldwide and has a long history of cultivation in India owing to its distinctive pungency, nutritional value, and diverse industrial applications. The characteristic flavour and pungency of Brassica crops are primarily attributed to glucosinolate-derived hydrolysis products, which also play a crucial role in plant defence against herbivorous insects. Globally, rapeseed–mustard ranks among the major sources of vegetable oil after soybean and oil palm, contributing substantially to edible oil production and food security (Agnihotri and Prem, 2007; Yue and Liu, 2000). India's edible oil imports reached approximately 16 million tonnes, reflecting the substantial gap between domestic production and consumption requirements. Recent estimates indicate that global rapeseed production has expanded considerably, with cultivation extending over approximately 42–43 million hectares and global production reaching around 87–89 million tonnes during 2023/24–2024/25, with an average productivity exceeding 2.0 tonnes ha⁻¹. However, achieving higher productivity remains challenging due to several biotic constraints, particularly insect pest infestations.

Insect pests represent one of the major biological limitations affecting rapeseed–mustard production, with yield reductions of approximately 30% reported due to pest damage in India (Dhaliwal *et al.* 2004). More than forty insect species are associated with different growth stages of rapeseed–mustard crops (Dwarka *et al.* 2024), among which the mustard aphid, *Lipaphis erysimi* (Kaltenbach) (Hemiptera: Aphididae), is considered the most destructive and widespread pest across major mustard-growing regions (Bakhetia and Sekhon, 1989; Rawat *et al.* 2026). Aphid populations generally increase during the winter season, particularly from December to February, coinciding with the reproductive phase of the crop. Both nymphs and adults damage plants by continuously extracting phloem sap, resulting in reduced photosynthetic activity, impaired assimilate translocation, flower abortion, poor seed development, and substantial yield losses. Under severe infestation conditions, yield reduction ranging from 80.6 to 97.6% has been reported, demonstrating the destructive potential of this pest (Patel *et al.* 2009; Singh and Sharma, 2002).

Although aphids infest plants from seedling to maturity, the maximum economic damage generally occurs during flowering due to the high nutritional demand of both crop and insect populations (Patel *et al.* 2004).

Aphid population dynamics are governed by complex interactions among host plant quality, environmental conditions, and insect biological characteristics. Plant nutritional status, particularly nitrogen availability, strongly influences aphid performance by affecting developmental rate, fecundity, and adult longevity. Plants receiving higher nitrogen inputs often provide enhanced nutritional resources, resulting in shorter nymphal duration, increased reproductive potential, and prolonged survival of aphids (Fallahpour *et al.* 2015). Besides nutritional factors, host plant morphological and biochemical characteristics play a critical role in regulating herbivore abundance. Plants have evolved multiple defence mechanisms against herbivory, among which chemical defence mediated by secondary metabolites represents one of the most effective strategies.

Members of the family Brassicaceae possess a unique and diverse glucosinolate-based defence system comprising more than 200 different glucosinolate structures (Kostova and Kostov, 2012). Glucosinolates represent important phytochemicals involved in plant–insect interactions, functioning as constitutive and inducible defence compounds. Upon tissue disruption, glucosinolates are hydrolysed by the enzyme myrosinase to produce biologically active compounds, particularly isothiocyanates, which possess insect deterrent, toxic, and antimicrobial properties. However, herbivorous insects have evolved several adaptation mechanisms, including detoxification, sequestration, excretion, and behavioural avoidance, to overcome glucosinolate-mediated plant defence (Hopkins *et al.* 1998). Therefore, variation in glucosinolate concentration and composition among Brassica genotypes can significantly influence insect preference, feeding behaviour, survival, and population development. Recent studies have emphasized the importance of host plant resistance as an environmentally sustainable approach for managing mustard aphid by reducing insecticide dependence, conserving natural enemies, and enhancing the stability of production systems (Sinha *et al.* 2024; Geethanjali



et al. 2024). However, resistance expression is a complex phenomenon involving interactions among plant growth characteristics, biochemical defense compounds, genotype-specific traits, and environmental factors. Understanding the relationship between aphid infestation intensity, plant morphological attributes, and glucosinolate concentration is therefore essential for identifying resistant cultivars and developing effective integrated pest management strategies. Hence, the present experiment was undertaken to elucidate the interaction between mustard aphid (*L. erysimi*) population abundance, plant growth and yield attributes, and glucosinolate content among different rapeseed–mustard cultivars under coastal agroecosystem conditions.

MATERIALS AND METHODS

A field experiment was conducted during the crop season at the coastal saline agroecosystem of West Bengal, India, located at 22.16° N latitude and 88.80° E longitude. The experimental site represents a typical coastal environment characterized by saline soil conditions and distinct winter climatic conditions favourable for rapeseed–mustard cultivation. Ten commercially popular rapeseed–mustard cultivars representing different botanical groups were selected for evaluation. The tested materials comprised six *Brassica juncea* cultivars (Kranti, Krishna, Varuna, Seeta, Bhagirathi, and Pusa Bold), three yellow sarson cultivars (Binoy/B-9, Subinoy, and Jhumka), and one toria cultivar [B 54 (Agrani)]. The selected cultivars were sown using a seed rate of 5 kg ha⁻¹ with a row spacing of 30–40 cm and plant-to-plant spacing of 10–15 cm under recommended agronomic practices. Fertilizer application was maintained at the recommended dose of 100:50:50 kg ha⁻¹. The experiment was managed under natural pest infestation conditions without insecticidal intervention to allow comparative evaluation of cultivar-dependent aphid response.

Observations on plant growth characteristics, yield components, and mustard aphid (*Lipaphis erysimi* Kaltenbach) abundance were recorded from ten randomly selected plants through destructive sampling of a 1 m row length at different crop growth stages, viz., 30, 45, and 75 days after sowing (DAS) and at harvest. Aphid population was quantified as the number of aphids per plant/

shoot, while the evaluated plant parameters included plant height, number of primary branches plant⁻¹, siliquae plant⁻¹, silique length, seeds silique⁻¹, 100-seed weight, and final seed yield. The relative performance of different cultivars was assessed based on their growth characteristics, yield attributes, and aphid infestation level to determine their relative susceptibility or tolerance to *L. erysimi*. Statistical separation among cultivars was performed using Duncan's Multiple Range Test (DMRT) following analysis of variance.

Total glucosinolate concentration of the tested cultivars was estimated using the sinigrin (allyl glucosinolate) standard curve following the methodology described by Kumar *et al.* (2004). The relationship between cultivar-specific glucosinolate concentration and mustard aphid abundance was evaluated using Pearson's correlation coefficient analysis to determine the contribution of glucosinolate-mediated defence in regulating aphid population dynamics. The association between aphid abundance and plant morphological/yield attributes was examined using a simple correlation matrix. Cluster analysis was performed to determine genetic relatedness and similarity among cultivars based on combined morphological traits, glucosinolate concentration, and aphid infestation parameters. A dendrogram was generated using the DARwin 6.0.17 software package. All statistical analyses, including descriptive statistics, analysis of variance, correlation analysis, and significance testing, were conducted using SPSS Statistics version 21.0.

RESULTS

Performance of different cultivars of rapeseed and mustard according to yield attributes

The evaluated rapeseed–mustard cultivars exhibited limited variability in vegetative growth during the early stages of crop development. At 30 days after sowing (DAS), Bhagirathi attained the greatest plant height (25.9 cm), although differences among cultivars were not statistically significant ($P > 0.05$). A similar trend was observed at 45 and 75 DAS, indicating comparable early growth dynamics across the tested genotypes. By physiological maturity, however, numerical differences in plant height became more evident, with Krishna recording the tallest plants (83.9 cm), followed by

Table 1: Performance of different cultivars of rapeseed and mustard according to yield attributes

Variety	Plant height (cm)				Primary branches/ plant	Siliqua/ plant	Siliqua length (cm)	seeds/ siliqua	100 seed weight (mg)	Yield (q/ha)
	30 DAS	45 DAS	75 DAS	Harvest						
Kranti	22.9±3.84 ^a	54.1±3.84 ^a	76.3±12.79 ^a	79.4±12.57 ^a	2.0±0.67 ^a	129.7±8.13 ^a	5.7±0.56 ^a	11.2±1.92 ^b	268	6.65±0.56 ^a
Krishna	23.9±5.10 ^a	57.4±5.10 ^a	80.4±12.91 ^a	83.9±13.51 ^a	2.2±0.63 ^a	125.1±7.8 ^a	5.6±0.54 ^a	11.6±2.70 ^b	216	5.92±0.49 ^{ab}
Varuna	22.7±5.41 ^a	51.80±5.41 ^a	72.5±13.99 ^a	75.8±13.62 ^a	2.0±0.94 ^a	132.1±7.51 ^a	5.5±0.51 ^a	12.6±2.30 ^b	200	5.78±0.72 ^{ab}
Seeta	22.8±4.36 ^a	54.3±4.36 ^a	77.9±18.94 ^a	81.5±19.23 ^a	1.9±0.74 ^a	127±9.66 ^a	5.6±0.60 ^a	10.8±2.16 ^b	173	5.02±0.56 ^b
Bhagirathi	25.9±6.80 ^a	54.1±6.80 ^a	76.6±13.80 ^a	80.5±13.45 ^a	2.0±0.67 ^a	126.4±11.09 ^a	5.6±0.63 ^a	12.4±2.60 ^b	144	5.45±0.46 ^b
Pusa Bold	24.3±6.46 ^a	52.2±6.46 ^a	74.9±15.35 ^a	78.0±14.84 ^a	1.9±0.74 ^a	129.3±8.64 ^a	5.6±0.55 ^a	10.8±1.48 ^b	254	6.12±0.51 ^{ab}
Binoy	22.4±4.71 ^a	50.90±4.71 ^a	72.0±11.66 ^a	75.0±11.86 ^a	1.7±0.67 ^a	127.6±12.17 ^a	5.56±0.58 ^a	12.2±3.96 ^b	150	5.55±0.49 ^b
Subinoy	22.5±5.56 ^a	56.7±5.56 ^a	79.0±13.37 ^a	82.6±13.64 ^a	1.9±0.74 ^a	125.7±7.52 ^a	5.7±0.57 ^a	18.4±4.50 ^a	208	5.72±0.61 ^{ab}
Jhumka	23.1±4.12 ^a	49.8±4.12 ^a	70.8±13.39 ^a	74.7±12.98 ^a	1.9±0.57 ^a	132±12.08 ^a	5.6±0.57 ^a	19.8±4.49 ^a	132	6.16±0.54 ^{ab}
B 54	22.8±5.07 ^a	52.3±5.07 ^a	73.1±12.41 ^a	77.2±12.84 ^a	2.1±0.88 ^a	132.7±5.57 ^a	5.5±0.54 ^a	11.0±2.91 ^b	59	5.06±0.53 ^b

Subinoy (82.6 cm), Seeta (81.5 cm), Bhagirathi (80.5 cm), Kranti (79.4 cm), Pusa Bold (78.0 cm), B54 (Agrani) (77.2 cm), Varuna (75.8 cm), Binoy (75.0 cm), and Jhumka (74.7 cm). Nevertheless, these differences were not statistically significant (Table 1), suggesting that the cultivars possessed comparable genetic potential for vegetative growth under the prevailing experimental conditions.

The number of primary branches, an important determinant of reproductive sink capacity, also remained statistically similar among cultivars ($P > 0.05$), varying only from 1.9 to 2.2 branches plant⁻¹. Krishna produced the highest number of primary branches, whereas the remaining cultivars exhibited comparable branching patterns (Table 1). Likewise, no significant varietal differences were detected for the number of siliquae per plant or siliqua length. Although B54 (Agrani) numerically produced the highest number of siliquae and Krishna the lowest, these differences did not attain statistical significance. Siliqua length ranged from 5.5 cm in Varuna to 5.7 cm in Subinoy, indicating minimal variation among cultivars with respect to pod morphology (Table 1).

In contrast to vegetative traits, significant genotypic variation was observed for reproductive attributes associated with seed development. Seeds per siliqua differed significantly among cultivars, with Subinoy and Jhumka producing a greater number of seeds per pod than the remaining varieties, indicating superior reproductive efficiency. Similarly, 100-seed weight varied markedly among cultivars, reflecting substantial differences in seed filling capacity.

Kranti recorded the highest 100-seed weight (268 mg), whereas B54 (Agrani) exhibited the lowest value (59 mg), demonstrating pronounced varietal differences in assimilate partitioning and seed development.

Grain yield also varied considerably among the evaluated cultivars, highlighting differences in their productive potential under the prevailing agro-ecological conditions. Kranti produced the highest seed yield (6.65 q ha⁻¹), followed by Jhumka (6.16 q ha⁻¹), Pusa Bold (6.12 q ha⁻¹), Krishna (5.92 q ha⁻¹), Varuna (5.78 q ha⁻¹), Subinoy (5.72 q ha⁻¹), Binoy (5.55 q ha⁻¹), Bhagirathi (5.45 q ha⁻¹), and B54 (Agrani) (5.06 q ha⁻¹), while Seeta recorded the lowest yield (5.02 q ha⁻¹) (Table 1). The superior yield performance of Kranti appears to be primarily associated with its greater seed weight rather than differences in vegetative growth or pod production, underscoring the importance of seed filling efficiency as a major determinant of final productivity. Collectively, these findings suggest that although the tested cultivars exhibited largely comparable vegetative growth and pod characteristics, significant variation in reproductive traits, particularly seed weight and seeds per siliqua, contributed substantially to differences in grain yield under field conditions.

Glucosinolate content, aphid population dynamics, and their association with plant growth traits

Substantial genotypic variation was observed in leaf glucosinolate concentration among the



evaluated rapeseed–mustard cultivars (Table 2). Total glucosinolate content ranged from 64.74 $\mu\text{mol g}^{-1}$ in Binoy to 143.58 $\mu\text{mol g}^{-1}$ in B54 (Agrani), indicating considerable biochemical diversity among the tested genotypes. Despite this variation in glucosinolate concentration, the cultivars did not differ significantly ($P > 0.05$) in their overall susceptibility to mustard aphid (*Lipaphis erysimi* Kaltenbach) under field conditions. Nevertheless, distinct temporal patterns in aphid population dynamics were evident throughout the crop growth period. Aphid infestation remained negligible during the early vegetative state (30 DAS), increased rapidly with crop development, and reached its maximum during the flowering phase (45 DAS), coinciding with the period of greatest nutritional suitability of the host. Thereafter, aphid abundance progressively declined toward crop maturity. At the peak infestation period (45 DAS), Seeta harboured the highest aphid density (37.1 aphids per 10 cm apical shoot), whereas B54 (Agrani) supported the lowest population (15.4 aphids per 10 cm shoot). When averaged across all sampling dates, however, mean aphid abundance remained relatively low in all cultivars, with Kranti recording the highest mean population (15.40 aphids per 10 cm shoot), followed by Binoy (14.83), whereas Varuna exhibited the lowest mean infestation (6.87 aphids per 10 cm shoot) (Table 2).

Correlation analysis further demonstrated that aphid abundance was moderately and negatively associated with glucosinolate concentration ($r = -0.598$), suggesting that cultivars possessing higher glucosinolate levels tended to support lower

aphid populations (Table 3; Fig. 1). Although the relationship did not fully explain the observed variation in aphid abundance, it indicates that glucosinolates may contribute to host plant resistance by reducing host suitability for aphid colonization and population development. The inverse association observed in the present study is consistent with the hypothesis that Brassica secondary metabolites function as constitutive defence compounds that influence herbivore performance, although resistance is generally governed by the combined effects of multiple biochemical and morphological traits rather than glucosinolates alone.

Relationships between aphid abundance and plant growth attributes were comparatively weak. Aphid population exhibited negative correlations with plant height ($r = -0.144$), number of primary branches per plant ($r = -0.209$), siliques per plant ($r = -0.030$), and seeds per silique ($r = -0.205$), whereas silique length ($r = 0.212$) and 100-seed weight ($r = 0.253$) showed weak positive associations with aphid abundance (Table 3). However, none of these correlations were statistically significant ($P > 0.05$), indicating that variation in vegetative growth and yield-related traits had little direct influence on aphid population build-up under the prevailing field conditions. Collectively, these findings suggest that although glucosinolate concentration contributed to the suppression of aphid abundance, the relatively low infestation recorded across all cultivars and the absence of significant relationships between aphid density and growth parameters imply that aphid population dynamics were likely

Table 2: Intensity of aphid (*Lipaphis erysimi*) infestation in different cultivars of rapeseed and mustard and amount of glucosinolates estimated

Variety	Aphid (per 10 cm shoot)				Glucosinolates ($\mu\text{mol/g}$)
	30 DAS	45 DAS	75 DAS	Mean	
Kranti	8.2 $\pm$ 5.81 ^a	29.9 $\pm$ 26.57 ^a	7.1 $\pm$ 6.95 ^a	15.40	130.76
Krishna	7.6 $\pm$ 7.72 ^a	30.0 $\pm$ 38.79 ^a	4.1 $\pm$ 9.52 ^a	11.63	120.51
Varuna	9.0 $\pm$ 9.22 ^a	25.7 $\pm$ 31.47 ^a	2.5 $\pm$ 3.50 ^a	6.87	135.25
Seeta	10.2 $\pm$ 6.06 ^a	37.1 $\pm$ 32.76 ^a	7.9 $\pm$ 7.97 ^a	9.67	146.15
Bhagirathi	8.8 $\pm$ 11.98 ^a	29.1 $\pm$ 31.36 ^a	6.6 $\pm$ 9.57 ^a	4.77	165.35
Pusa Bold	9.0 $\pm$ 8.01 ^a	26.1 $\pm$ 19.75 ^a	5.3 $\pm$ 5.79 ^a	8.20	137.15
Binoy	10.1 $\pm$ 6.13 ^a	25.0 $\pm$ 11.43 ^a	2.5 $\pm$ 4.17 ^a	14.83	78.8
Subinoy	8.8 $\pm$ 4.96 ^a	24.3 $\pm$ 20.93 ^a	7.1 $\pm$ 7.76 ^a	7.20	113.45
Jhumka	8.2 $\pm$ 7.13 ^a	24.1 $\pm$ 18.18 ^a	6.6 $\pm$ 8.34 ^a	9.77	104.45
B 54	7.1 $\pm$ 3.51 ^a	15.4 $\pm$ 12.16 ^a	1.2 $\pm$ 1.16 ^a	8.63	151.9

Table 3: Correlation coefficient (r) between aphid population and plant characters

	PH	PBP	SPP	SL	SPS	HSW	GLS	AN
PH	1							
PBP	.486	1						
SPP	-.797**	.033	1					
SL	.602	.083	-.495	1				
SPS	-.190	-.250	.058	.190	1			
HSW	.396	-.006	-.335	.690*	-.138	1		
GLS	.341	.553	.092	.000	-.445	-.097	1	
AN	-.144	-.209	-.030	.212	-.205	.253	-.598	1

PH= Plant height, PBP= Primary branches/Plant, SPP= Siliqua/plant, SPS= Seed/siliqua, HSW= Hundred seed weight, GLS= Total glucosinolate content, AN= Aphid population.

** Correlation is significant at the 0.01 level (2-tailed).* Correlation is significant at the 0.05 level (2-tailed).

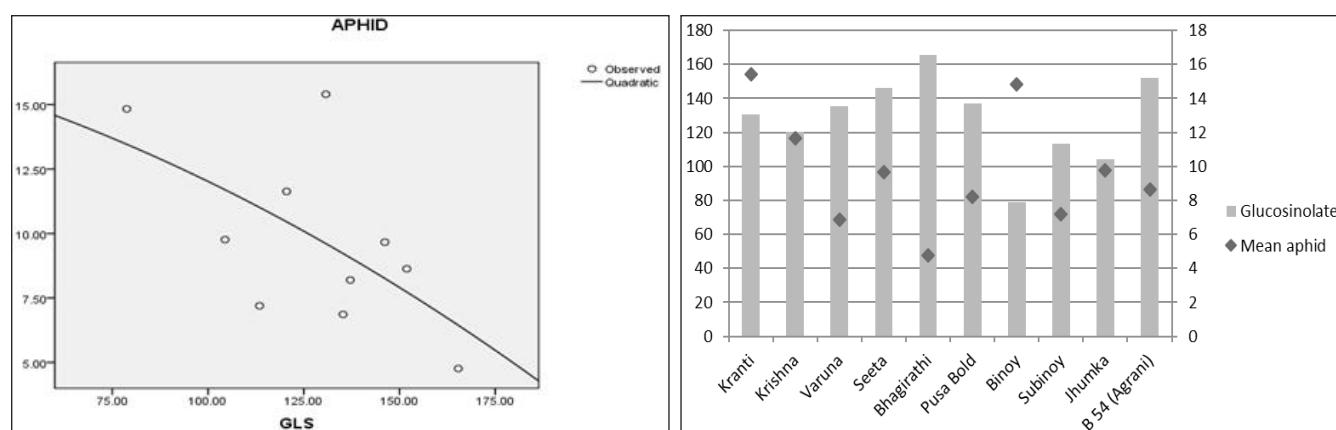


Fig. 1: Population abundance of aphid (*Lipaphis erysimi*) in respect of glucosinolate content

regulated by a complex interaction of biochemical defence mechanisms, genotype-specific responses, and environmental factors rather than by individual plant growth traits alone.

Cluster analysis of rapeseed–mustard cultivars based on plant growth traits and aphid infestation

Hierarchical cluster analysis based on plant growth characteristics, yield attributes, glucosinolate content, and mustard aphid (*Lipaphis erysimi* Kalténbach) infestation revealed distinct patterns of similarity among the evaluated rapeseed–mustard cultivars (Fig. 2). The ten cultivars were classified into five discrete clusters, indicating considerable genotypic diversity with respect to the combined agro-morphological and resistance-related traits. Cluster I comprised Subinoy, Krishna, and Varuna, suggesting a high degree of similarity among these cultivars in terms of their overall

phenotypic performance and aphid response. Cluster II included Pusa Bold and Kranti, indicating comparable expression of growth and yield characteristics together with similar levels of aphid infestation. Bhagirathi and Seeta were grouped into Cluster III, reflecting their close resemblance across the evaluated parameters, whereas Jhumka and Binoy constituted Cluster IV, representing another homogeneous group with similar morpho-agronomic characteristics and pest response.

In contrast, B54 (Agrani) formed a distinct solitary Cluster V, clearly separated from all other cultivars. The independent clustering of B54 (Agrani) indicates its unique phenotypic and biochemical profile, which was primarily characterized by the highest glucosinolate concentration and one of the lowest mustard aphid populations among the tested genotypes. This distinct separation suggests that B54 (Agrani) possesses a unique combination of defence-related and agronomic traits that differentiate it

from the remaining cultivars. Such divergence highlights its potential value as a genetic resource for host plant resistance breeding and for the development of aphid-tolerant rapeseed–mustard cultivars.

Overall, the clustering pattern demonstrates that cultivars sharing similar morpho-physiological characteristics and biochemical attributes also exhibited comparable responses to aphid infestation, emphasizing the importance of integrating multivariate approaches for identifying genetically diverse and agronomically superior germplasm. The clear discrimination of cultivars into distinct clusters provides valuable information for parental selection in breeding programmes aimed at simultaneously improving productivity and resistance to *L. erysimi*. Cultivars belonging to widely separated clusters, particularly B54 (Agrani) and members of the remaining clusters, may therefore serve as promising parents for exploiting genetic divergence and broadening the resistance base in future rapeseed–mustard improvement programmes (Fig. 2).

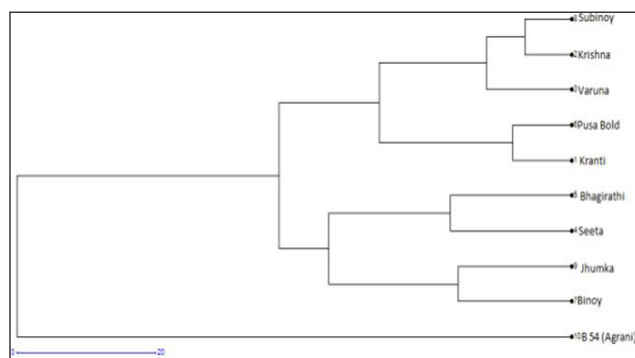


Fig. 2: Cluster analysis of different cultivars in respect of plant characters and aphid abundance

DISCUSSION

Variation in the abundance of mustard aphid (*Lipaphis erysimi* Kaltenbach) among the evaluated rapeseed–mustard cultivars reflects the complex interaction between host genotype and insect adaptation. Although the cultivars exhibited only limited differences in most morphological traits, considerable variation was observed in glucosinolate concentration and aphid population dynamics, suggesting that biochemical rather than structural traits played a dominant role in determining host suitability. Similar cultivar-

dependent differences in aphid colonization and population development have been reported across diverse Brassica germplasm, highlighting host plant resistance as a sustainable and environmentally compatible strategy for aphid management (Kumar & Sangha, 2013; Mishra & Singh, 2019; Gebretsadik *et al.* 2025).

Plant growth characteristics influence aphid abundance by modifying host quality, nutrient availability, and the microclimatic conditions within the crop canopy. Rapid vegetative growth and prolonged periods of succulent tissue development generally provide abundant phloem resources and favourable feeding sites, thereby facilitating aphid establishment and population increase (Pawar *et al.* 2019). Conversely, increasing aphid density progressively impairs plant growth through continuous phloem sap extraction, disruption of assimilate translocation, reduced photosynthetic efficiency, and impaired reproductive development, ultimately resulting in reduced plant height, fewer primary branches, decreased siliqua production, and yield losses (Singh *et al.* 2025; Khan *et al.* 2015). In the present investigation, however, plant height, primary branches, siliquae per plant, seeds per siliqua, and other growth attributes showed only weak and statistically non-significant correlations with aphid abundance, indicating that under relatively low natural infestation these morphological traits alone were insufficient to explain differences in aphid population build-up. Similar observations have been reported by Patil *et al.* (2004), suggesting that host biochemical composition often exerts a stronger influence on aphid performance than vegetative growth characteristics.

The Brassicaceae are characterized by a diverse array of secondary metabolites, including glucosinolates, phenolic compounds, flavonoids, carotenoids, and other defence-related phytochemicals that collectively contribute to constitutive and induced resistance against herbivorous insects (Bhandari *et al.* 2015). Among these metabolites, glucosinolates constitute one of the principal chemical defence systems in Brassica species. Sinigrin, the predominant allyl glucosinolate in many mustard cultivars, has received considerable attention because of its involvement in plant–insect interactions. Following tissue disruption,

sinigrin is hydrolysed by the endogenous enzyme myrosinase to produce allyl isothiocyanate and other biologically active compounds that deter herbivore feeding, reduce survival, and impair insect development (Liu *et al.* 2021; Gebretsadik *et al.* 2025). Although aphids inflict comparatively little tissue damage during stylet feeding, variation in glucosinolate concentration has nevertheless been shown to influence host preference, probing behaviour, fecundity, and population growth in Brassica-feeding aphids (Liu *et al.* 2021).

The substantial variation in glucosinolate concentration observed among the evaluated cultivars agrees with earlier reports of Sodi *et al.*, (2002) and Mawlong *et al.* (2017), who demonstrated considerable genotypic variability in glucosinolate accumulation within rapeseed–mustard germplasm. In the present study, glucosinolate concentration exhibited a moderate negative association with mustard aphid abundance, indicating that cultivars possessing higher glucosinolate levels generally supported lower aphid populations. Comparable relationships have been reported by Kumar and Sangha, (2013), Mishra and Singh, (2019), and Wu *et al.* (2021), who demonstrated that increased glucosinolate concentrations are associated with reduced aphid colonization and reproductive performance. The deterrent effect is primarily attributed to glucosinolate hydrolysis products, particularly allyl isothiocyanate, which reduce feeding activity and reproductive success (McCloskey and Isman, 1993; Liu *et al.* 2021). Earlier electrophysiological studies further demonstrated that elevated concentrations of allyl glucosinolate reduce stylet probing and feeding duration in *L. erysimi*, thereby limiting aphid establishment and population multiplication (Dilawari & Atwal, 1987). Nevertheless, glucosinolates alone are unlikely to determine resistance. Contemporary studies indicate that resistance to Brassica aphids is a quantitatively inherited trait arising from the combined effects of multiple constitutive and induced defence mechanisms. Reduced aphid abundance has been associated with increased epicuticular wax deposition, elevated concentrations of phenolics, flavonoids, tannins, and glucosinolates, together with enhanced activities of antioxidant enzymes and the myrosinase defence system, whereas susceptible

cultivars generally contain higher soluble sugar and amino acid concentrations that improve host nutritional quality and promote aphid reproduction (Wu *et al.* 2021; Liu *et al.* 2021; Gebretsadik *et al.* 2025). Furthermore, aphid infestation itself induces substantial metabolic reprogramming, including activation of myrosinase, increased antioxidant enzyme activities, accumulation of defence metabolites, and changes in photosynthetic pigments, reflecting dynamic activation of plant defence pathways during herbivore attack (Gebretsadik *et al.* 2025).

Environmental conditions further modulate host–aphid interactions by influencing both plant physiology and aphid population dynamics. Crop phenology, temperature, relative humidity, and seasonal weather patterns collectively determine the timing and magnitude of aphid outbreaks, often overriding inherent varietal differences under field conditions. Hasan and Singh, (2020) demonstrated that mustard aphid population dynamics vary significantly among cultivars but are strongly regulated by crop developmental stage and prevailing meteorological conditions. Consequently, varietal resistance should be interpreted as the outcome of interactions among genotype, plant biochemical defence, crop phenology, and environmental factors rather than as a consequence of any single morphological or biochemical characteristic.

Overall, the present findings indicate that variation in mustard aphid abundance among rapeseed–mustard cultivars are primarily associated with biochemical defence, particularly glucosinolate accumulation, whereas morphological growth parameters exert comparatively limited influence under moderate natural infestation. The negative relationship between glucosinolate concentration and aphid abundance reinforces the importance of secondary metabolites in host plant resistance and supports the integration of biochemical markers into Brassica resistance breeding programmes. However, because aphid resistance is governed by multiple interacting mechanisms, future breeding efforts should combine glucosinolate profiling with complementary defence traits and multi-environment evaluation to develop cultivars with durable and broad-spectrum resistance to *L. erysimi*.



CONCLUSION

The present study demonstrates that mustard aphid (*Lipaphis erysimi* Kaltenbach) remains one of the most economically important insect pests limiting rapeseed–mustard productivity, emphasizing the need for sustainable alternatives to intensive insecticide-based management. Among the traits evaluated, glucosinolate concentration emerged as the principal biochemical factor associated with reduced aphid abundance, supporting its role as an important component of host plant resistance. Cultivars with higher glucosinolate levels generally harboured lower aphid populations, indicating that constitutive chemical defences contribute significantly to reducing host suitability for aphid colonization and population development. In contrast, plant growth and yield attributes exhibited only weak and statistically non-significant relationships with aphid abundance, suggesting that morphological characteristics alone are insufficient predictors of aphid infestation under field conditions.

These findings further indicate that resistance to *L. erysimi* is a complex quantitative trait governed by the integrated effects of biochemical, physiological, and genetic factors rather than by any single plant characteristic. Therefore, biochemical traits, particularly glucosinolate content, should be considered alongside agronomic performance during cultivar evaluation and resistance breeding. The identification and deployment of rapeseed–mustard cultivars possessing enhanced constitutive defence mechanisms offer a promising strategy for suppressing aphid populations while reducing dependence on chemical insecticides. Integrating host plant resistance into breeding programmes and integrated pest management (IPM) frameworks will contribute to the development of environmentally sustainable, economically viable, and climate-resilient rapeseed–mustard production systems.

GENERATIVE AI DECLARATION

The author(s) confirm that there was no use of artificial intelligence (AI)-assisted technology for assisting in the writing or editing of the manuscript, and no images were manipulated using AI. The authors developed and verified all scientific content, data analysis, interpretation of results, and

conclusions. The authors take full responsibility for the accuracy, integrity, and originality of the work presented, and no AI tool was listed as an author.

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