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Biochemical traits contributing to thrips resistance in chilli (*Capsicum annuum* L.) genotypes

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Abstract

The study carried out during Rabi and Summer 2023-24 at the College of Agriculture, Hassan, assessed twelve chilli genotypes for resistance to thrips under field and pot conditions. Thrips presence and leaf curl index (LCI) were measured at three crop stages, while biochemical parameters (total phenols and soluble sugars) were analysed in both healthy and infested leaves. Results showed notable differences among genotypes. Resistant types (2019/CHIVAR 6 and 2021/CHIVAR 14) consistently displayed lower thrips incidence (20-25% LCIs) and higher phenol and sugar levels. In contrast, susceptible types (Byadgi Kaddi and 2021/CHIVAR 13) showed higher thrips incidence (>65% LCI) and lower phenolic content. These findings suggest that phenolic compounds were key to biochemical resistance, while sugars may support defense metabolism indirectly. The resistant genotypes identified could serve as donors in breeding programs for thrips-resistant chilli varieties.

Keywords : Correlation, infestation, phenolic compounds, sugars, biochemical defence

Introduction

Chilli (*Capsicum annuum* L.) is a globally significant spice crop belonging to the family Solanaceae. known for its pungency and flavour, chilli is an essential ingredient in culinary preparations, consumed in fresh, dried, and processed forms. Rich in vitamins A and C, chillies are valued for their culinary attributes and medicinal properties, with capsaicin playing a pivotal role in cardiovascular health. India is the largest producer and exporter of chillies, with Karnataka being a key contributor, particularly from districts like Haveri, Gadag, Bellary, Dharwad, and Raichur. Despite its economic and nutritional importance, chilli production is constrained by various biotic stresses, notably the infestation of thrips (Scirtothrips dorsalis).

Thrips cause significant damage by lacerating and sucking the sap from leaves, flowers, and fruits, leading to reduced yield and quality. Additionally, they serve as vectors for viral diseases such as leaf curl, which further exacerbate yield losses. While chemical control methods remain prevalent among farmers, concerns regarding cost, pesticide resistance, and residual toxicity underscore the need for alternative pest management strategies. The biochemical basis of resistance offers a sustainable and eco-friendly solution by leveraging the inherent defense mechanisms of chilli plants. Biochemical constituents such as phenols, flavonoids, and total soluble sugars are known to act as antifeedants, repellents, or deterrents to pest activity. Understanding the biochemical basis of resistance in chilli plants can provide valuable insights for developing pest-resistant varieties. This approach reduces reliance on chemical pesticides but also supports sustainable agricultural practices. The present study aims to investigate the biochemical basis associated with resistance to thrips in chilli, contributing to the development of integrated pest management strategies.

Material and methods

Plant material

The experiment was conducted during rabi (Oct 2023-Jan 2024) and summer (Mar-Jun 2024) at the College of Agriculture, Hassan. Twelve chilli genotypes, including the susceptible check Byadgi Kaddi, were sourced from the AICRP on Vegetable Crops, University of Horticultural Sciences, Bagalkot.

Field screening

The field screening experiment was conducted using randomized complete block design (RCBD) with three replications. Each genotype was planted in a plot size of 3 m length and 2m breadth, maintaining a spacing of 60 cm between rows and 45 cm between plants. The experiment was executed under standard agronomic practices, without the application of insecticides, to ensure an accurate assessment of natural resistance.

Population density of chilli thrips

Population of thrips were recorded at three different cropping stages *viz*., pre flowering (30 Days after Transplanting), during flowering (60 DAT) and post flowering (90 DAT) stage from five randomly selected plants, by tapping the growing tip of the chilli plant on a white acrylic sheet and counting the thrips and was expressed as average number of thrips from three young shoots.

Mean per cent leaf curl index (MLCI)

The genotypes were visually rated for infestation of thrips based on the 'upward leaf curl' damage symptom. The observations on leaf curl symptoms were recorded from five randomly selected and tagged plants at the flowering stage from each plot as the infestation of thrips peak at this stage.

The data of leaf curl rating was converted into mean per cent leaf curl index using the formula given by Samota *et al*. (2018).

Table 1. Scale for scoring of chilli genotypes based on per cent leaf infested by thrips

Score	Damage
0	No symptoms
1	1-25 per cent of the leaves in a plant showing upward curling
2	26-50 per cent of leaves in a plant showing upward curling, moderately damaged
3	51-75 per cent of the leaves in a plant showing curling, heavily damaged, malformation of growing tips, reduction in plant height
4	More than 75 per cent of leaves showing upward curling, severe to complete destruction of growing tips, drastic reduction of plant height and severe malformation

$$\text{MLCI} = \frac{\text{Sum of scores of all plants X 100}}{\text{Total no. of plants observed x No. of score categories}}$$

The resistance reaction of chilli genotypes was classified into four categories based on the MLCI value, where

0 = highly resistant (HR),
0-10 = resistant (R),
11-25 = moderately resistant (MR),
26-5 = susceptible (S) and
51-100 = highly susceptible (HS) (Tewari *et al*., 1989).

Greenhouse test

Seedlings were raised under insect-free conditions in pro trays and transplanted six weeks after germination. Three plants per genotype were planted in 10x12-inch poly bags with three replications, following a randomized block design. The experiment was conducted in a polyhouse during Rabi 2023–24 and Summer 2023–24, with plant spacing of 60 cm between rows and 45 cm between plants. All plants were maintained using standard screen-house cultivation practices (Rossel and Ferguson, 1979). Thrips population was recorded at the flowering stage and subsequently expressed as MLCI.

Biochemical basis of resistance

Fully opened non-infested top leaves were collected randomly from the healthy plants of pot-grown (thrips-free) and fully opened infested top leaves were collected randomly from thrips-infested plants of field-grown (thrips-infested) chilli genotypes separately during the early morning hours (before 09:00 AM) to confirm the changes in biochemical constituents. Leaves were immediately immersed in liquid nitrogen to arrest proteolytic activity and stored at -20^{0}C until biochemical analysis. Biochemical parameters, such as total phenols and total soluble sugars, were estimated following standard protocols with necessary modifications. Total phenols were estimated by the Folin-Ciocalteu method (Malick & Singh, 1980), and total soluble sugars by the phenol-sulphuric acid method (Dubois *et al*., 1956; Sadasivam & Manickam, 1991).

Estimation of total phenols

For phenol extraction, 100 mg of leaf tissue was homogenized in 10 millilitres (ml) of 80 per cent (%) warm ethanol and incubated for one hour at room temperature. The extract was centrifuged at 6000 rpm for 15 minutes. The supernatant was evaporated to dryness on a water bath, and the residue was dissolved in 5 ml distilled water. For estimation, 0.1 ml of the extract was diluted to 3 ml with distilled water, and 0.5 ml of Folin-Ciocalteau reagent (1:1 diluted) was added. After 3 minutes, 2 ml of 20% sodium carbonate solution was added, and the reaction mixture was placed in a boiling water bath for one minute. After cooling, the absorbance was measured at 650 nm using a spectrophotometer. Total phenol content was calculated using a standard curve prepared with catechol and expressed as milligram per gram (mg g^{-1}) of sample.

Estimation of total soluble sugars (TSS)

For TSS extraction, 100 mg of leaf tissue was homogenized in 10 ml of 80 per cent warm ethanol and incubated for one hour on a magnetic stirrer. The extract was centrifuged at 6000 rpm for 15 minutes, and the supernatant was evaporated to dryness. The residue was dissolved in 5 ml distilled water. For estimation, 0.1 ml of the extract was diluted to 1 ml with distilled water, followed by the addition of 1 ml of 5% phenol reagent and 5 ml of concentrated sulfuric acid (98%). The mixture was incubated for 10 minutes at room temperature, followed by 20 minutes in a water bath at 30^{0}C. The absorbance was measured at 490 nm using a spectrophotometer. Total sugar content was quantified using a standard curve constructed with glucose and expressed as mg g^{-1} of fresh weight sample.

Data analysis

Biochemical differences between thrips-free and thrips-infested lines were analysed using the fold change, F test, and one-way ANOVA.

Results and discussion

Evaluation of chilli genotypes for thrips resistance

The study assessed 12 chilli genotypes across the rabi 2023-24 and summer 2023-24 seasons to evaluate their resistance against thrips. The resistance was measured in relation to two major biochemical parameters-phenol content and sugar content-which are known to play significant roles in plant defense. These parameters were analysed under infested and non-infested conditions. A significant variation was observed in the biochemical response of the tested genotypes, providing insights into the mechanisms governing resistance or susceptibility to thrips.

Thrips incidence and MLCI

Thrips incidence varied significantly across genotypes, with the highest infestation observed at flowering. The genotypes 2019/CHIVAR 6 and 2021/CHIVAR 14 recorded the lowest thrips populations with MLCIs of 20-25 per cent, while Byadgi Kaddi and 2021/CHIVAR 13 recorded the highest thrips incidence with MLCIs >65 per cent. Greenhouse screening validated the field observations, confirming the consistency of resistant and susceptible genotypes.

Total phenol content

The total phenol content in chilli genotypes during the rabi and summer 2023-24 seasons revealed significant differences across genotypes, resistance categories, and growing conditions. Moderately resistant (MR) genotypes consistently exhibited higher phenol accumulation and fold changes compared to susceptible (S) and highly susceptible (HS) genotypes.

During the rabi season, genotype 2019/CHIVAR 6 (MR) displayed highest phenol content increase from 6.45 milligram per gram (mg g^{-1}) in thrips-free conditions to 12.25 mg g^{-1} under infestation, resulting in a fold change of 1.89 suggesting an effective defense response. Among susceptible genotypes, 2019/CHIVAR 9 recorded a fold change of 1.66, with phenols increasing from 4.30 mg g^{-1} to 7.14 mg g^{-1}. In contrast, highly susceptible genotype 2021/CHIVAR 13 exhibited minimal increases, with a fold change of 1.08 (Table 2), reflecting a weaker defense mechanism.

The summer season further emphasized these trends. 2019/CHIVAR 6 and 2021/CHIVAR 7 showed substantial phenol increases of 2.36-fold and 3.10-fold, respectively, confirming their strong resistance under stress. Phenol levels in 2019/CHIVAR 6 increased from 3.30 mg g^{-1} to 7.80 mg g^{-1}, while 2021/CHIVAR 7 increased from 2.10 mg g^{-1} to 6.50 mg g^{-1}. Among susceptible genotypes, 2019/CHIVAR 9 exhibited a moderate response with a 2.10-fold change, while highly susceptible genotype 2021/CHIVAR 13 had lower fold changes of 1.19, indicating limited defense capabilities (Table 4).

Phenol content increased significantly under thrips infestation in resistant genotypes. For instance, 2019/CHIVAR 6 increased from 6.45 to 12.25 mg g^{-1} (1.89-fold) in rabi, and from 3.30 to 7.80 mg g^{-1} (2.36-fold) in summer. Similarly, 2021/CHIVAR 14 recorded 1.78–2.16 fold increases. Susceptible genotype 2021/CHIVAR 13 showed negligible changes (1.08–1.19 fold).

The increase in phenol content under infestation underscores its role in plant defense against thrips. Phenols were known to strengthen plant cell walls and act as precursors to secondary metabolites that deter pest attack. Genotypes with higher fold changes, such as 2019/CHIVAR 6 and 2021/CHIVAR 7, displayed enhanced resistance, suggesting that phenol accumulation could be an effective indicator of thrips tolerance. Conversely, genotypes like 2021/CHIVAR 13 with low phenol responses were more vulnerable, highlighting their limited biochemical adaptability (Nawalagatti *et al*., 1999).

Table 2. Total phenols and total sugars content and mean leaf curl index of chilli genotypes under pot-grown and field-grown conditions during rabi 2023–24

Sl. No	Treatment	RC	Pot-grown plants				Field-grown plants			
			Total phenols (mg g^{-1}) in leaves	Total sugars (mg g^{-1}) in leaves	MLCI (%)	Avg. no of thrips	Total phenols (mg g^{-1}) in leaves	Total sugars (mg g^{-1}) in leaves	MLCI (%)	Avg. no of thrips
1.	2019/CHIVAR 6	MR	6.45	23.50	6.33	7.10 (2.9) ^{c}	12.25	37.36	20.00	10.83 (3.30) ^{c}
2.	2021/CHIVAR 14		5.60	24.00	7.56	7.25(2.92) ^{c}	10.01	37.24	22.22	11.01(3.34) ^{c}
3.	2021/CHIVAR 7		4.80	20.00	12.22	7.70 (2.97) ^{bc}	9.04	34.42	22.45	11.53(3.40) ^{bc}
4.	2019/CHIVAR 9	S	4.30	17.00	15.70	9.60 (3.20) ^{abc}	7.14	24.42	42.22	14.40(3.78) ^{abc}
5.	2021/CHIVAR 12		4.00	14.00	17.03	9.55 (3.20) ^{abc}	5.65	20.33	40.00	14.35(3.78) ^{abc}
6.	2021/CHIVAR 10		4.56	19.00	16.01	9.75 (3.22) ^{abc}	5.76	24.58	42.22	14.58(3.81) ^{abc}
7.	2019/CHIVAR 7	HS	3.25	15.50	24.37	9.95 (3.25) ^{ab}	4.80	19.09	60.00	14.89(3.86) ^{ab}
8.	2018/CHIVAR 1		3.20	13.00	26.53	10.05 (3.26) ^{ab}	4.78	15.27	58.89	15.02(3.86) ^{ab}
9.	2018/CHIVAR 3		3.30	14.50	30.41	10.25 (3.28) ^{ab}	4.80	17.73	51.11	15.27(3.90) ^{ab}
10.	2021/CHIVAR 13		2.90	13.50	31.00	11.20 (3.38) ^{a}	3.25	14.24	68.89	17.70(4.28) ^{a}
11.	Byadgi Dabbi		3.00	14.56	30.41	11.80 (3.45) ^{a}	3.90	16.06	66.67	16.82(4.09) ^{a}
12.	Byadgi Kaddi (Check)		2.50	16.50	32.19	12.00 (3.48) ^{a}	3.15	18.19	71.11	17.53(4.21) ^{a}
	F test	*	*	*	*	*	*	*	*	
	SEM	0.14	0.57	1.33	0.15	0.27	0.86	0.86	0.07	
	CD at P=0.05	0.42	1.69	1.00	0.44	0.80	2.54	2.54	0.21	

*: Significant at 5% probability, RC – Resistant category, HS- Highly Susceptible, S- Susceptible, MR - Moderately Resistant; Figures in the parentheses are $\sqrt{x+0.5}$ transformed values

Total sugar content

The total sugar content in chilli genotypes during the rabi and summer 2023-24 seasons showed significant variations under thrips-free and thrips-infested conditions. These changes, expressed as fold change, were closely associated with the resistance categories of the genotypes. Moderately resistant genotypes consistently displayed a higher fold change in sugar content, indicating a robust biochemical response to thrips infestation. For instance, during rabi 2023-24, 2021/CHIVAR 7 exhibited the highest fold change (1.72), with total sugars increasing from 20.00 mg g^{-1} in thrips-free conditions to 34.42 mg g^{-1} under infestation. Similarly, 2019/CHIVAR 6 and 2021/CHIVAR 14 recorded significant fold changes of 1.59 and 1.55, respectively, reflecting their superior response to stress. Susceptible genotypes demonstrated moderate sugar content increases. During the rabi season, 2019/CHIVAR 9 and 2021/CHIVAR 12 exhibited fold changes of 1.43 and 1.45, respectively. Although this response was lower than that of MR genotypes, it still indicated some biochemical adaptability. In contrast, highly susceptible genotypes such as 2019/CHIVAR 7 and 2021/CHIVAR 13 showed minimal fold changes of 1.23 and 1.05, respectively, reflecting their limited capacity for sugar accumulation under thrips stress.

A similar pattern was observed during summer 2023-24. Moderately resistant genotypes, such as 2019/CHIVAR 6 and 2021/CHIVAR 14, maintained high fold changes of 1.67 and 1.61, respectively, while 2021/CHIVAR 7 recorded a 1.59-fold change. Among susceptible genotypes, 2019/CHIVAR 9 showed a fold change of 1.49, with sugar levels rising from 19.00 mg g^{-1} to 28.42 mg g^{-1}. Highly susceptible genotypes, including 2021/CHIVAR 13, exhibited the lowest fold change of 1.09, consistent with their rabi performance, confirming their inability to mount an effective biochemical response.

Resistant lines recorded moderate fold increases (1.55–1.67), whereas susceptible ones accumulated little (1.01–1.10 fold). This suggests resistant genotypes mobilize sugars more effectively under stress, likely to support phenol synthesis.

The consistent trends in both seasons highlight the importance of total sugar content as a biochemical marker of resistance. This suggests the association of sugar levels in response to the thrips incidence (Megharaj *et al.*, 2016). Moderately resistant genotypes showed the ability to accumulate sugars in response to thrips infestation, potentially aiding in osmotic regulation, energy supply, and the activation of defense mechanisms. Conversely, the limited sugar accumulation in highly susceptible genotypes indicates impaired stress responses, making them more vulnerable to thrips. Seasonal variations in sugar content, with slightly higher fold changes observed in the summer season, could be influenced by environmental factors such as temperature and light intensity, which regulate metabolic activity and sugar biosynthesis.

Correlation coefficient (r) of MLCI and the average number of thrips with the biochemical characters of chilli genotypes

The correlation analysis between the biochemical basis of chilli genotypes and the MLCI and average number of thrips revealed significant negative relationships. The correlation coefficient for total phenols was r =-0.726, suggesting a negative correlation with thrips incidence. This means that, as the total phenolic content of the chilli plants increased, the incidence of thrips decreased. Similarly, the correlation coefficient for total sugars was r = -0.683, also indicating a significant negative relationship with thrips incidence. Both correlations highlight a strong association between biochemical defenses in the plants and a reduction in the thrips population. The negative correlation between total phenols and thrips incidence indicated that higher phenolic content in chilli plants may play a key role in reducing thrips infestations. The findings on significantly negative correlation between phenol content in the chilli leaves and the incidence of thrips confirm with the results

Table 3. Total phenols and Total sugars content and Mean Leaf Curl Index of chilli genotypes under Pot-grown and Field-grown conditions during summer 2023–24

Sl. No.	Treatment	RC	Pot-grown plants				Field-grown plants			
			Total phenols (mg g^{-1}) in leaves	Total sugars (mg g^{-1}) in leaves	MLCI (%)	Avg. no of thrips	Total phenols (mg g^{-1}) in leaves	Total sugars (mg g^{-1}) in leaves	MLCI (%)	Avg. no of thrips
1.	2019/CHIVAR 6	MR	3.30	23.50	1.67	7.10 (2.95) ^{c}	7.80	39.36	20.00	12.44(3.56) ^{c}
2.	2021/CHIVAR 14		3.10	23.03	1.61	7.40 (2.99) ^{c}	6.70	37.24	22.42	12.84(3.62) ^{bc}
3.	2021/CHIVAR 7		2.10	23.30	1.59	7.85(3.04) ^{bc}	6.50	37.42	22.22	12.98(3.64) ^{bc}
4.	2019/CHIVAR 9	S	2.00	19.00	1.49	9.90(3.30) ^{abc}	4.20	28.42	33.33	15.31(3.93) ^{abc}
5.	2021/CHIVAR 12		2.80	18.20	1.44	9.80 (3.29) ^{abc}	4.80	26.33	48.89	15.78(3.99) ^{abc}
6.	2021/CHIVAR 10		2.90	18.44	1.44	10.05(3.32) ^{abc}	5.30	26.58	46.67	15.33(3.94) ^{abc}
7.	2019/CHIVAR 7	HS	3.00	13.50	1.34	10.45(3.36) ^{ab}	5.10	18.09	57.78	16.11(4.02) ^{ab}
8.	2018/CHIVAR 1		3.00	13.23	1.30	10.30 (3.35) ^{ab}	4.60	17.27	53.34	15.56(3.96) ^{abc}
9.	2018/CHIVAR 3		2.40	13.32	1.21	10.70 (3.38) ^{ab}	3.70	16.24	55.55	18.00(4.30) ^{abc}
10.	2021/CHIVAR 13		2.70	12.50	1.09	11.80 (3.50) ^{a}	3.20	13.73	80.00	16.09(4.04) ^{ab}
11.	Byadgi Dabbi		2.50	14.01	1.12	12.30 (3.55) ^{a}	3.90	15.70	68.89	16.89(4.14) ^{a}
12.	Byadgi Kaddi (Check)		1.90	12.99	1.01	12.70 (3.60) ^{a}	3.00	13.19	73.33	17.87(4.27) ^{a}
	F test	*	*	*	*	*	*	*	*	
	SEM	0.09	0.72	0.72	(0.14)	0.18	1.00	1.00	(0.05)	
	CD at P=0.05	0.27	2.13	2.13	(0.45)	0.52	2.94	2.94	(0.16)	

*: Significant at 5% probability, RC – Resistant category, HS- Highly Susceptible, S- Susceptible, MR - Moderately Resistant; Figures in the parentheses are $\sqrt{x}$+0.5 transformed values

reported by Roopa (2013), Megharaj *et al*. (2016), and Latha and Hanumanthraya (2018). The negative correlation (r =-0.726) suggests that phenolic compounds likely deter thrips or inhibit their ability to thrive on chilli plants. This is due to the toxic or repellent properties of phenols, which may affect the feeding, reproduction, or survival of thrips (Chaudhary and Pandya, 2019).

Similarly, the negative correlation between total sugars and thrips incidence (r =–0.683) suggests also associated with a reduced thrips population. The observations with respect to higher total sugar content in the leaves of resistant and moderately resistant chilli genotypes are in contrast with the findings of Roopa (2013). Elevated sugar levels strengthen the plant's physical structures, such as the cell walls, making it more difficult for thrips to feed or cause damage. Alternatively, sugars support the production of other defensive compounds, such as phenolics or secondary metabolites, which in turn reduce the plant's susceptibility to pests (Tibebu, 2018). In conclusion, these results suggest that both total phenols and total sugars play an important role in the biochemical defense of chilli genotypes against thrips. The negative correlations indicate that increased levels of these compounds were associated with a reduction in thrips incidence, potentially offering a natural resistance mechanism that could be explored further in breeding programs aimed at developing pest-resistant chilli varieties (Subash *et al*. 2013).

Conclusion

This study underscores the critical role of biochemical constituents, particularly phenolic compounds and sugars, in determining the resistance of chilli (*Capsicum* spp.) genotypes against thrips infestation. Chilli genotypes varied significantly in resistance to thrips, with resistant lines showing lower thrips incidence and leaf curl indices, and higher phenolic accumulation. Phenols were the key biochemical defence mechanism, while sugars contributed indirectly to resistance. Genotypes 2019/CHIVAR 6 and 2021/CHIVAR 14 were identified as promising resistant sources for future breeding programs. The findings reveal a significant association between higher phenolic content and reduced thrips incidence. These compounds likely contribute to the reinforcement of plant cell walls and the production of secondary metabolites with anti-feedant or toxic effects on thrips. Similarly, variations in total sugars and reducing sugars influence pest resistance, potentially through mechanisms affecting thrips feeding behavior, nutrition, or metabolic activity.

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