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Biochemical influence of host plants on the biology of babul whitefly, *Acaudaleyrodes rachipora*

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Abstract

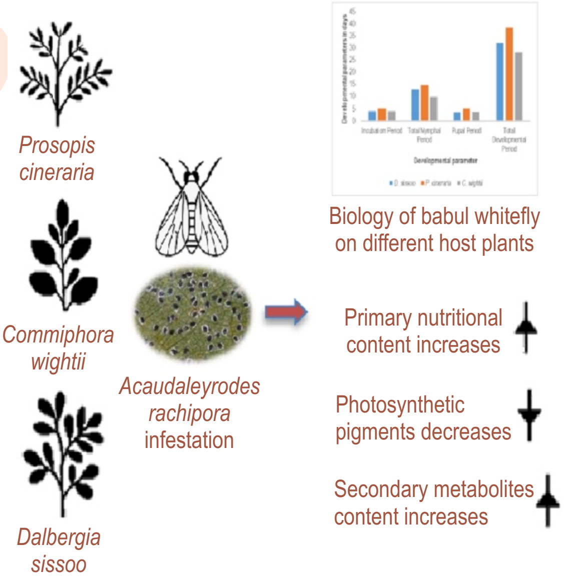
Aim: This study aimed to examine the nutritional impact, changes in the photosynthetic pigments, and biochemical alterations in Khejri (*Prosopis cineraria*), Guggal (*Commiphora wightii*), and Sisham (*Dalbergia sissoo*) plants infested by the babul whitefly (*Acaudaleyrodes rachipora*).

Methodology: Under controlled conditions, whitefly infestations were established on three host plants. The developmental parameters of *A. rachipora* (incubation period, nymphal duration, and total development time) were recorded. Biochemical assessments included quantification of proteins, sugars, starch, phenols, tannins, total antioxidants, and photosynthetic pigments (chlorophyll a, b, total chlorophyll, and carotenoids) in both infested and non-infested plants. Correlation analysis was conducted to evaluate the relationship between plant biochemicals and whitefly development.

Results: The longest developmental period (38.57 days) of whiteflies was observed on *P. cineraria* and the shortest (28.14 days) on *C. wightii*. Infestation increased protein (1.52 to 2.03 mg g^{-1}) and starch (2.73 to 5.03 mg g^{-1}) in *D. sissoo*. Photosynthetic pigments declined; chlorophyll a in *C. wightii* reduced from 6.12 to 2.01 mg g^{-1}. Phenol and tannin levels increased significantly following infestation, indicating the activation of induced biochemical defense responses.

Interpretation: Whitefly infestation alters host biochemistry, enhancing nutritional content while reducing photosynthetic pigments. Sugars and starch favored pest development whereas phenols and tannins acted as defensive compounds, influencing host suitability.

Key words: *Acaudaleyrodes rachipora,* Developmental biology, Host plant biochemistry, Photosynthetic pigments, Phenolic compounds



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Introduction

Interaction between herbivorous insects and their host plants is a dynamic process, that not only influences the biology of insect as well as the physiological responses of plant (Sharma *et al.,* 2021; Sharma and Singh, 2022; Adedayo *et al.,* 2025). Sap-feeding pests can induce various biochemical changes in plants that often reflect the plant's response to stress, defense mechanisms, or alterations in nutrient allocation (de Souza and Peñaflor, 2024). One such important group of pests are whiteflies, specifically the species *Acaudaleyrodes rachipora* (Singh) (Hemiptera: Aleyrodidae), commonly known as the Babul whitefly (Pandey *et al.,* 2007; Al-Nadawi and Sadiq, 2021). This pest infests various plant species, including important forest trees, agricultural crops, and ornamental plants (Pandey *et al.,* 2007). Like other sap-feeding insects, *A. rachipora* derive their nutrition from the plant phloem by piercing the plant’s epidermis with its specialized mouthparts, causing direct damage to the plant and altering its physiological processes (Díaz-Pérez *et al.,* 2023). The feeding activity of whiteflies leads to the secretion of honeydew, which encourages the growth of sooty mold, further exacerbating the negative impact on plant health (Manzari and Fathipour, 2021). Moreover, the relationship between whiteflies and their host plants often results in significant alterations in plant metabolism, primarily in the form of changes in nutritional content, photosynthetic efficiency, and secondary metabolite production (Perring *et al.,* 2018; Rizwan *et al.,* 2021; Singh *et al.,* 2022). These changes may not only influence the plant growth and development, but also its overall ability to withstand further insect damage and environmental stressors (Singh *et al.,* 2022).

Understanding the effects of *A. rachipora* infestation on host plants, particularly in terms of their developmental biology and associated biochemical changes, is critical for managing this pest and assessing the ecological impacts of its feeding behavior. Among the various host plants available to *A. rachipora*, leguminous tree species such as Sisham (*Dalbergia sissoo* Roxb. exDC) and Khejri (*Prosopis cineraria* (L.) Druce) are particularly noteworthy because of their ecological importance and widespread distribution (Sundararaj *et al.,* 1996, 2000; Al-Nadawi *et al.,* 2021). These species are also known to possess varying levels of resistance or susceptibility to pest infestations, potentially leading to differential impacts on insect biology (de Souza and Peñaflor, 2024). In contrast, non-leguminous species such as Guggal (*Commiphora wightii* (Arn.) Bhandari), though less common, also supports whitefly populations and provides an interesting comparative perspective on the interactions between whiteflies and different plant families.

The biochemical response of host plants to whitefly infestation is a complex process that involves several key metabolic pathways (Mwila *et al.,* 2017). Primary metabolites such as proteins, sugars, and starches play a fundamental role in plant growth and energy storage (Liu *et al.,* 2020) whereas secondary metabolites such as phenols, tannins, and antioxidants are often involved in plant defense mechanisms (Arun *et al.,* 2021). For example, increased protein and sugar levels in response to insect feeding can signify an altered allocation of resources, potentially enhancing the nutritional value of plant tissue for the insect (Manju *et al.,* 2021). Similarly, changes in the secondary metabolite concentrations can reflect the plant's attempt to counteract the stress imposed by the pest, either through physical deterrents such as tannins or by stimulating antioxidant pathways to mitigate oxidative damage caused by feeding (Singh *et al.,* 2022). Chlorophyll pigments, which are crucial for photosynthesis, are also commonly affected by insect feeding (Amini *et al.,* 2021; Barros *et al.,* 2021). Whitefly-induced reductions in chlorophyll content and overall photosynthetic efficiency have been documented in various plant species, highlighting the potential for reduced growth and productivity in infested plants (Schutze *et al.,* 2022). The loss of chlorophyll and other pigments can decrease the plant’s ability to harness solar energy, thereby affecting the overall health and vitality (Nansen *et al.,* 2021).

The current study aimed to bridge this gap by investigating the biology of *A. rachipora* on two leguminous hosts, *D. sissoo* and *P. cineraria* and one non-leguminous host, *C. wightii.* In addition, to examine the developmental biology of insect across these host plants, this study explored the biochemical changes induced in the host plants in response to whitefly infestation. These changes include alterations in the primary nutritional content (protein, sugar and starch), photosynthetic pigments (chlorophyll and carotenoids), and secondary metabolites (phenols, tannins and antioxidants). This study further investigated the association between these biochemical parameters and the biology of *A. rachipora*, including the impact of these changes on the developmental stages of the insect. Through a comprehensive analysis of both biology of *A. rachipora* and the biochemical responses of host plants, this study seeks to provide valuable insights into the complex interactions between herbivorous insects and their host plants. The findings may help elucidate the mechanisms underlying host plant susceptibility and resistance to whitefly infestations, offering new avenues for the development of integrated pest management strategies that consider both insect biology, and the plant physiological response to pest stress.

Materials and Methods

The study was conducted at the ICFRE–Arid Forest Research Institute (ICFRE–AFRI), Jodhpur, Rajasthan. The region is situated at 26.2677°N; latitude 73.0095°E longitude, characterized by an arid climate with extreme temperature fluctuations, low erratic average annual rainfall of 300 mm, and high evapotranspiration rates. Insects were collected during June and July 2022-2024, when temperatures typically ranged 32 to 44°C.

Raising of seedlings: The seedlings of *P. cineraria, D. sissoo* and *C. wightii* were raised in the nursery, starting with the preparation of smooth and well-levelled seed beds. The nursery soil was cleared of weeds and debris, loosened, and enriched with well-decomposed organic compost to enhance fertility and moisture retention. Seeds were sown uniformly at an appropriate depth with proper spacing. Regular irrigation was provided to maintain adequate moisture, and shading was applied during intense sunlight to protect young seedlings. After 30 to 45 days, once the seedlings were 10–15 cm long with a healthy root system, they were carefully uprooted and transplanted into polybags filled with a soil mixture composed of garden soil, sand and farmyard manure in 1:1:1 ratio. The seedlings in polybags were maintained under shade and irrigated regularly to promote acclimatization and root development, ensuring better survival and establishment after field planting.

Biology of babul whitefly: The study on the biology of *A. rachiphora* was conducted under controlled laboratory conditions to assess its developmental parameters on selected test seedlings. The experiment was carried out at the ICFRE-Arid Forest Research Institute (ICFRE-AFRI), Jodhpur, under regulated environmental conditions at 27±1°C, 60-70% relative humidity, and a 12 hr dark/12 hr light photoperiod. *A. rachipora* were initially collected from the infested leaves of *C. wightii* at the ICFRE-AFRI nursery, greenhouse, and field sites to ensure a diverse population representative of natural environment. The collected whiteflies were reared on the leaves of *D. sissoo, P. cineraria* and *C. wightii* seedlings. To maintain adequate moisture and prevent desiccation, the excised leaves from the test seedlings were placed in sterile glass Petri dishes (10 × 2 cm) lined with moist filter paper. The experimental design followed a completely randomized design (CRD), with each test seedlings replicated ten times. The observations were systematically recorded for key developmental parameters, including the incubation period, duration of first, second and third instars, total nymphal period, pupal period and total developmental period.

Preparation of sample: Naturally infested leaves from both healthy and *A. rachipora*-infested seedlings (90–95 days old) of each test species were collected for biochemical analyses. The collected leaves were ground in liquid nitrogen to obtain 1.5 g tissue samples, which were subsequently homogenized with 8 ml of phosphate buffer (50 mM, pH 7.4). The homogenate was centrifuged at 10,000 rpm for 25 min at 4°C, and the resulting supernatant was transferred to 2 ml Eppendorf tubes and stored at 20°C for further analysis. Each biochemical assay was conducted in triplicate following a completely randomized design to ensure accuracy and reproducibility.

Estimation of Primary phytochemicals

Total protein: The protein concentration was determined by the method of Bardford (1976) using bovine serum albumin a standard.

Total sugar: The total sugar content was estimated following the method of Dubois *et al.* (1956), using a standard glucose curve.

Starch: The starch content was estimated by the method of Clegg (1956) using standard glucose curve.

Photosynthetic pigment level estimation: The chlorophyll and carotenoid levels in both healthy and infested test seedlings were determined following the method described by Nayek *et al.* (2014). An ELISA reader was used to read the absorbance at 470, 645 and 663 nm wavelength. Chlorophyll and carotenoid contents were calculated by the strand formula given by Nayek *et al.* (2014).

Secondary nutritional content estimation

Total antioxidant: For total antioxidant analysis, 100 µl of plant extract was mixed with 200 µl of distilled water in individual 5 ml test tubes, with three replicates prepared for each sample. To each tube, 3 ml of total antioxidant reagent was added under dark conditions and mixed thoroughly. The reaction mixtures were incubated in a water bath at 90°C for 85 min. After incubation, 200 µl of each reaction mixture was transferred to a 96-well microtiter plate, and the absorbance was read at 700 nm using an ELISA reader. The total antioxidant content was quantified using a standard curve derived from ascorbic acid (Prieto *et al.,* 1999).

Total Phenol: The total phenol content was determined following the modified method of Singleton and Rossi (1965) using gallic acid standard curve.

Tannin: Tannin content was estimated by the method of Amorim *et al.* (2008) using gallic acid standard curve.

Statistical analysis: Biological and biochemical data were analyzed using R software version 4.4.1. Shapiro-Wilk test confirmed the normal distribution of data, allowing the application of One-way ANOVA to compare the treatment means. Differences among the means were evaluated by Least Significant Difference (LSD) test at a significance level of P < 0.05. Bartlett's test was conducted to ensure homogeneity of variances across the groups. Additionally, the relationship between biochemical components and biological parameters was assessed using Karl Pearson correlation analysis.

Results and Discussion

The present study revealed that the developmental biology of *A. rachipora* was significantly affected by the choice of host plant species. The incubation period of *A. rachipora* eggs was significantly longer on *P. cineraria* (5.34 days) than on *C. wightii* (4.12 days) and *D. sissoo* (4.10 days) (P=0.020). The first nymphal instar duration was significantly longer on *C. wightii* (4.00 days) than *D. sissoo* (3.22 days) and *P. cineraria* (3.12 days) (P<0.001), suggesting a host-mediated effect on molting and growth. Similarly, the second instar period was significantly longer on *D. sissoo* (4.56 days) in comparison other two hosts (P=0.028). The third instar was significantly longer on *P. cineraria* (6.26 days), nearly twice that on *C. wightii* (2.86 days), indicating substantial host-driven variation in late nymphal development (P< 0.001). Combining these instars, the total nymphal period and pupal period were both significantly longer on *P. cineraria*

(14.57 and 5.27 days) compared to *D. sissoo* and *C. wightii*, respectively. Overall, the total developmental time from egg to adult emergence was longest on *P. cineraria* (38.57 days) as compared to *D. sissoo* (32.05 days) and *C. wightii* (28.14 days) (Table 1). This pattern indicates that *P. cineraria* impose developmental constraints that extend the whitefly life cycle, potentially by providing less optimal nutritional or defensive conditions. Comparable host-specific effects have been documented in other whiteflies (Liu *et al.,* 2016; Pradhan *et al.,* 2020). *Bemisia tabaci* and *Trialeurodes vaporariorum* exhibited significant differences in life cycle duration and reproductive success when reared on different crop species, underlining the role of host quality in regulating pest population dynamics (Byrne and Bellows, 1991; Abubakar *et al.,* 2022).

The biochemical analysis of host plants showed clear evidence that *A. rachipora* infestation altered the key nutritional attributes (Table 2). The protein content in infested leaves was significantly higher in comparison to non-infested controls, with *D. sissoo* showing an increase from 1.52 to 2.03 mg g^{-1}, *P. cineraria* from 1.69 to 2.11 mg g^{-1}, and *C. wightii* from 1.04 to 1.35 mg g^{-1}. Soluble sugars and starch content were also significantly higher in infested leaves. Furthermore, the percent change over control result revealed that protein content increased by 33.55% in *D. sissoo*, 24.85% in *P. cineraria* and 29.81% in *C. wightii*. Similarly, sugar content was higher in infested plants, with increase of 23.54% in *D. sissoo*, 16.56% in *P. cineraria* and 25.97% in *C. wightii*. The most pronounced change was observed in starch content, which showed 84.25% increase in *D. sissoo*, 17.56% in *P. cineraria*, and 59.68% in *C. wightii,* demonstrated that A. rachipora feeding activity likely triggers metabolic adjustments that increase nutrient availability in host tissues, which is similar to trends reported for *B. tabaci* on cotton *Gossypium hirsutum* L., tomato Lycopersicum esculentum Mill, and poinsettia Euphorbia pulcherrima Wild (Jiao *et al.,* 2012; Sharma *et al.,* 2021). Such enrichment of host nutrients can enhance whitefly fecundity and shorten generation time, creating positive feedback for population build-up (Jiao *et al.,* 2018; Mrosso *et al.,* 2022).

In contrast, the photosynthetic pigment contents decreased significantly under infestation (Table 3). Chlorophyll a, chlorophyll b, total chlorophyll and carotenoid contents were significantly lower in infested plants across all three species ($P<0.001$). For instance the chlorophyll a in *C. wightii* decreased from 6.12 to 2.01 mg g^{-1}, indicating a severe reduction in the photosynthetic capacity. Furthermore, the percent change in photosynthetic pigment content was lower in seedlings infested with *A. rachipora* compared to controls. In *D. sissoo*, chlorophyll a content decreased by 47.52%, chlorophyll b by 24.63%, total chlorophyll by 35.94%, and carotenoids by 59.69%. In *P. cineraria*, chlorophyll a decreased by 32.83%, chlorophyll b by 27.55%, total chlorophyll by 30.20%, and carotenoids by 26.80%. In *C. wightii,* the chlorophyll a content decreased by 67.16%, chlorophyll b by 9.73%, total chlorophyll by –39.63%, and carotenoids by 44.38% respectively. These results demonstrate that *A. rachipora* feeding substantially reduces photosynthetic pigments, which may limit host plant photosynthetic capacity and overall vigor (Cheng *et al.,* 2018). This negative effect on

Table 1: Biology of *A. rachipora* in different host plant

Seedlings	Incubation period	Ist Instar	IInd Instar	IIIrd Instar	Total nymphal period	Pupal period	Total developmental period
				(in days)			
D. sissoo	4.10 ± 0.12^{b}	3.22 ± 0.10^{a}	4.56 ± 0.15^{b}	3.58 ± 0.14^{a}	12.85 ± 0.30^{b}	3.74 ± 0.11^{a}	32.05 ± 0.42^{b}
P. cineraria	5.34 ± 0.18^{a}	3.12 ± 0.09^{a}	4.01 ± 0.13^{b}	6.26 ± 0.16^{b}	14.57 ± 0.34^{a}	5.27 ± 0.14^{b}	38.57 ± 0.47^{a}
C. wightii	4.12 ± 0.13^{b}	4.00 ± 0.12^{b}	3.57 ± 0.08^{a}	2.86 ± 0.07^{c}	9.75 ± 0.25^{c}	3.84 ± 0.10^{a}	28.14 ± 0.39^{c}
P-Value	0.020	<0.001	0.028	<0.001	<0.001	<0.001	0.021
F-Probability	8.11	45.03	6.84	63.41	14.64	17.68	7.93
LSD	0.88	0.25	0.67	0.79	2.25	0.72	6.60

Table 2: Variations in primary nutritional content (mg g^{-1}) in test seedlings response to feeding by *A. rachipora*

Seedlings	Protein		Sugar		Starch	
	Control	Infested	Control	Infested	Control	Infested
D. sissoo	1.52 ± 0.08^{c}	2.03 ± 0.10^{a}	6.33 ± 0.15^{b}	7.82 ± 0.16^{a}	2.73 ± 0.01^{b}	5.03 ± 0.14^{a}
P. cineraria	1.69 ± 0.06^{b}	2.11 ± 0.09^{a}	5.98 ± 0.14^{b}	6.97 ± 0.15^{a}	3.53 ± 0.05^{b}	4.15 ± 0.10^{a}
C. wightii	1.04 ± 0.07^{d}	1.35 ± 0.08^{c}	4.12 ± 0.07^{c}	5.19 ± 0.12^{b}	3.72 ± 0.3^{a}	5.94 ± 0.15^{a}
P-Value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
F-Probability	23.55	60.87	54.64	11.28	14.00	45.58
LSD	0.23	0.19	0.56	1.41	0.50	0.47

Table 3: Variations in photosynthetic pigments (mg g^{-1}) in test seedlings response to feeding by *A. rachipora*

Seedlings	Chlorophyll a		Chlorophyll b		Total chlorophyll		Carotenoid	
	Control	Infested	Control	Infested	Control	Infested	Control	Infested
D. sissoo	4.04±011^{a}	2.12±0.09^{c}	4.14±0.12^{a}	3.12±0.11^{b}	4.09±0.10^{a}	2.62±0.08^{c}	3.20±0.13^{a}	1.29±0.12^{c}
P. cineraria	4.63±0.15^{a}	3.11±0.10^{b}	4.32±0.13^{a}	3.13±0.10^{b}	4.47±0.12^{a}	3.12±0.11^{b}	2.50±0.12^{b}	1.83±0.13^{b}
C. wightii	6.12±0.13^{a}	2.01±0.08^{c}	5.65±0.14^{a}	5.10±0.14^{a}	5.88±0.11^{a}	3.55±0.10^{b}	3.65±0.16^{a}	2.03±0.08^{b}
P-Value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
F-Probability	28.25	50.74	12.67	50.58	15.44	4.94	25.60	37.89
LSD	0.71	0.30	0.82	0.57	0.84	0.91	21.21	23.07

Table 4: Variations in secondary metabolites content (mg g^{-1}) in test seedlings response to feeding by *A. rachipora*

Seedlings	Phenol		Tannin		Total antioxidant	
	Control	Infested	Control	Infested	Control	Infested
D. sissoo	2.66±0.12^{c}	3.89±0.13^{b}	0.43±0.03^{b}	1.14±0.05^{a}	3.22±0.10^{c}	6.96±0.14^{a}
P. cineraria	3.63±0.11^{b}	4.59±0.10^{b}	0.31±0.03^{c}	0.94±0.04^{b}	4.70±0.11^{b}	5.11±0.15^{b}
C. wightii	4.46±0.13^{a}	5.87±0.11^{a}	0.23±0.02^{c}	1.46±0.03^{a}	5.63±0.13^{a}	6.42±0.7^{a}
P-Value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
F-Probability	34.77	37.42	37.00	21.44	63.74	26.27
LSD	0.54	0.60	0.07	0.20	0.54	0.66

LSD= least significant difference

photosynthetic pigments is consistent with the reports of Bughdady *et al.* (2020) for *B. tabaci* and Masuda *et al.* (2016), who showed that whitefly feeding leads to chlorophyll degradation and suppressed plant vigor. Recent studies by Amini *et al.* (2021) and Abubakar *et al.* (2022) further emphasized that stressed plants with compromised photosynthetic capacity may become more vulnerable to repeated pest attacks, creating a cycle of declining host resistance and increased pest load.

Infestation also induced significant increase in defensive secondary metabolites such as phenols and tannins across all hosts (Table 4). Phenolic content was significantly higher in infested plants, with *C. wightii* increasing from 4.46 to 5.87 mg g^{-1}. Tannin levels similarly increased with *C. wightii* showing maximum increase (0.23 to 1.46 mg g^{-1}). In *D. sissoo,* the phenol content increased by 46.24%, tannin by 165.12%, and total antioxidant by 116.15%. In *P. cineraria*, the phenol content increased by 26.45%, tannin by 203.23%, and total antioxidant by 8.72%. *C. wightii* showed 31.61% increase in phenols, substantial 534.78% increase in tannin content, and 14.03% increase in total antioxidant capacity, respectively. These results clearly indicate that *A. rachipora* feeding induces a strong defensive response in host plants by stimulating the accumulation of phenolic compounds, tannins and antioxidants, which can contribute to plant resistance against herbivory. Such elevations suggest that whitefly feeding activates inducible defense pathways (Lin *et al.,* 2019). Comparable trends have been reported in other insects; In a recent study, Hraish *et al.* (2023) reported increased phenolic and flavonoid levels in soybean genotypes resistant to *B. tabaci.* Mrosso *et al.* (2022) and Abd Allah *et al.* (2024) similarly demonstrated that polyphenol biosynthesis is a key component of host defense strategies against whiteflies in cucurbits and horticultural crops. Correlation analysis highlighted how these biochemical shifts relate to pest biology (Table 5). Among the significant findings, protein content showed a significant negative correlation with the incubation period (r = -0.90*, p< 0.05), suggesting that higher protein levels may reduce the duration of egg incubation, aligning with earlier observations by Li *et al.* (2016) and Bottega *et al.* (2017) on the influence of nutritional quality on insect development. Sugar content exhibited significant negative correlations with the first nymphal instar (r = -0.77*, p< 0.05), third nymphal instar (r = -0.99*, p< 0.05), and total nymphal period (r = -0.90**, p< 0.01), indicating that increased sugar levels may accelerate early development.

These findings support the concept that host plant nutritional qualityparticularly protein and sugar profiles collectively shape the population dynamics of phloem-feeding pests like whiteflies. Starch content was negatively correlated with the third nymphal instar (r=-0.84**, p<0.01) and pupal period (r=-0.95**, p<0.01), further suggesting a role in reducing developmental durations. Carotenoid levels negatively influenced the incubation period (r=-0.88**, p<0.01) and both second (r=-0.56*, p<0.05) and third nymphal instars (r=-0.77*, p<0.05), pointing towards their inhibitory effect on early pest

Table 5: Association of various biochemical constituents on the developmental biology of *A. rachipora*

Parameters	Incubation period (days)	First nymphal instar (days)	Second nymphal instar (days)	Third nymphal instar (days)	Total nymphal period (days)	Pupal period (days)	Total developmental period (days)
Protein	-0.90*	0.17^{NS}	0.53^{NS}	-0.79^{NS}	-0.41^{NS}	-0.92^{NS}	-0.66^{NS}
Sugar	-0.96^{NS}	-0.77 *	-0.14^{NS}	-0.99*	-0.90**	-0.95^{NS}	-0.99^{NS}
Starch	-0.93^{NS}	0.25^{NS}	0.46^{NS}	-0.84**	-0.48^{NS}	-0.95**	-0.72^{NS}
Chlorophyll A	0.82^{NS}	-0.94^{NS}	0.47^{NS}	0.91^{NS}	0.99^{NS}	0.78^{NS}	0.97^{NS}
Chlorophyll B	-0.62^{NS}	0.99**	-0.70^{NS}	-0.76^{NS}	-0.97^{NS}	-0.58^{NS}	-0.87^{NS}
Total chlorophyll	0.92	-0.85^{NS}	0.28^{NS}	0.97^{NS}	0.95^{NS}	0.89^{NS}	-0.89**
Carotenoid	-0.88**	-0.14^{NS}	-0.56*	-0.77*	0.38^{NS}	0.91^{NS}	0.64^{NS}
Phenol	-0.70^{NS}	-0.16^{NS}	-0.78**	-0.55^{NS}	-0.08^{NS}	-0.74^{NS}	-0.38*
Tannin	-0.41*	0.98^{NS}	-0.85^{NS}	-0.58*	-0.90*	-0.36^{NS}	-0.72**
Total Antioxidant	-0.53^{NS}	-0.36^{NS}	0.89^{NS}	-0.36^{NS}	0.12^{NS}	-0.58^{NS}	-0.17^{NS}

*, **Correlation coefficients significant at P = 0.05, 0.001; NS = non-significant

development. Mean while, the phenol content showed a significant negative correlation with the second nymphal instar (r= -0.78**) the total developmental period (r=-0.38*, p<0.05), and tannin content displayed significant negative correlations with the incubation period (r=-0.41*, p<0.05), third nymphal instar (r=-0.58*, p<0.05), total nymphal period (r=-0.90*) and total developmental period (r=-0.72**, p<0.01). These results confirm their role as effective biochemical defenses that slow down pest growth or reduce survival, as previously shown for *T. vaporariorum* and *B. tabaci* (Simmons *et al.,* 2005; Zhang *et al.,* 2021). Such inducible biochemical defenses, when combined with nutritional attributes, contribute significantly to host–pest interactions. Similar multi-faceted interactions have been reported in other major whitefly pathosystems, where pest resistance has been linked to nitrogen and sugar profiles as well as pesticide exposure (Silva *et al.,* 2019; Wang *et al.,* 2020).

The findings of this study underscore the importance of host plant selection in pest management strategies. Future research should aim to identify and develop resistant host genotypes, validate these interactions under natural field conditions, and integrate biochemical, molecular, and ecological approaches including the use of biological control agents and host resistance breeding to develop sustainable and effective management strategies for *A. rachipora* and related whitefly species in arid and semi-arid ecosystems.

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References

Abd Allah, Y.N., L.R. Amin, E.N. Haron and T.R. Amin: Efficacy of foliar spraying of squash (*Cucurbita pepo*) with some elicitors for certain biochemical traits for *Bemisia tabaci* (Hemiptera: Aleyrodidae) protection. *Egypt. J. Plant Prot. Res. Inst.,* **7**, 436–447 (2024).

Abubakar, M., B. Koul, K. Chandrashekar, A. Raut and D. Yadav: Whitefly (*Bemisia tabaci*) management (WFM) strategies for sustainable agriculture: A review. *Agriculture,* **12**, 1317 (2022).

Adedayo, A.A., R. Musser, M. Aanaenson and O.O. Babalola: The biochemical and molecular mechanisms of plants: a review on insect herbivory. *Plant Signal. Behav.,* **20**, 2439248 (2025).

Al-Nadawi, F.A. and F.H. Sadiq: Seasonal Occurrence and life tables Studies on Babul Black fly (Singh) (Hemiptera: Aleyrodidae) *Acaudaleyrodes rachipora* on Christ-thorn in Baghdad (*Zizyphus spina*). *J. Entomol.,* **48**, 383–386 (2021).

Amini, S.N., A. Golizadeh, B. Tafaghodinia, J. Razmjou and H. Abbasipour: Interaction between host plant morphological characteristics with life history of the greenhouse whitefly *Trialeurodes vaporariorum*. *Arthropod-Plant Interact.,* **15**, 875–885 (2021).

Amorim, E.L., J.E. Nascimento, J.M. Monteiro, P. Sobrinho, T.J.S. Araújo and U.P. Albuquerque: A simple and accurate procedure for the determination of tannin and flavonoid levels and some applications in ethnobotany and ethnopharmacology. *Funct. Ecosyst. Commun.,* **2**, 88–94 (2008).

Arun, K., E. Janeeshma, J. Job and J.T. Puthur: Physiochemical responses in coconut leaves infected by spiraling whitefly and the associated sooty mold formation. *Acta Physiol. Plant.,* **43**, 1–3 (2021).

Barros, P.P., I.X. Schutze, F.H. Iost Filho, P.T. Yamamoto, P.R. Fiorio and J.A. Demattê: Monitoring *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae) infestation in soybean by proximal sensing. *Insects,* **12**, 47 (2021).

Bottega, D.B., B.H. de Souza, N.E. Rodrigues, W.I. Eduardo, J.C. Barbosa and A.L. Júnior: Resistant and susceptible tomato genotypes have direct and indirect effects on *Podisus nigrispinus* preying on *Tuta absoluta* larvae. *Biol. Control,* **106**, 27–34 (2017).

Bradford, M.M.: A rapid and sensitive method for the quantitation of microgram quantities of protein utilizing the principle of protein dye binding. *Anal. Biochem.,* **72**, 248–254 (1976).

Bughdady, A., A.E. Mehna and T. Amin: Effectiveness of some synthetic insecticides against the whitefly, *Bemisia tabaci* on tomato, *Lycopersicon esculentum* Mill. and infestation impacts on certain photosynthetic pigments concentrations of tomato plant leaves. *J. Prod. Dev.,* **25**, 307–321 (2020).

Byrne, D.N. and T.S.J. Bellows: Whitefly biology. *Ann. Rev. Entomol.,* **36**, 431–457 (1991).

Cheng, G.X., R.J. Li, M. Wang, L.J. Huang, A. Khan, M. Ali and Z.H. Gong: Variation in leaf color and combined effect of pigments on physiology and resistance to whitefly of pepper (*Capsicum annuum* L.). *Sci. Hortic.,* **229**, 215–225 (2018).

Clegg, K.M.: The application of the anthrone reagent to the estimation of starch in cereals. *J. Sci. Food Agric.,* **7**, 40–44 (1956).

de Souza, L.A. and M.F. Peñaflor: Small but strong: herbivory by sap-feeding insect reduces plant progeny growth but enhances direct and indirect anti-herbivore defenses. *Oecologia,* **205**, 191–201 (2024).

Díaz-Pérez, J.C., T. McAvoy, X. Luo and S. Bag: Alternative methods to manage silverleaf whitefly [Gennadius] (Hemiptera: Aleyrodidae) in Zucchini (*Cucurbita pepo* L.). *J. Hortic. Res.,* **31**, 61–70 (2023).

Dubois, M., K.A. Gilles, J.K. Hamilton, P.T. Rebers and F. Smith: Colorimetric method for determination of sugars and related substances. *Anal. Chem.,* **28**, 350–356 (1956).

Harish, G.N., R. Singh, S. Sharma and G.K. Taggar: Resistance in soybean genotypes to whitefly *Bemisia tabaci. Indian J. Entomol.,* **86**, 1252–1257 (2023).

Jiao, X., W. Xie, S. Wang, Q. Wu, L. Zhou, H. Pan and Y. Zhang: Host preference and nymph performance of B and Q putative species of *Bemisia tabaci* on three host plants. *J. Pest Sci.,* **85**, 423–430 (2012).

Jiao, X., W. Xie, Y. Zeng, C. Wang, B. Liu, S. Wang and Y. Zhang: Lack of correlation between host choice and feeding efficiency for the B and Q putative species of *Bemisia tabaci* on four pepper genotypes. *J. Pest Sci.,* **91**, 133–143 (2018).

Li, F., T.L. Dudley, B. Chen, X. Chang, L. Liang and S. Peng: Responses of tree and insect herbivores to elevated nitrogen inputs: a meta-analysis. *Acta Oecol.,* **77**, 160–167 (2016).

Lin, D., Y. Xu, H. Wu, X. Liu, L. Zhang, J. Wang and Q. Rao: Plant defense responses induced by two herbivores and consequences for whitefly *Bemisia tabaci. Front. Physiol.,* **10**, 346 (2019).

Liu, X., Y. Zhang, W. Xie, Q. Wu and S. Wang: The suitability of biotypes Q and B of *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae) at different nymphal instars as hosts for *Encarsia formosa* Gahan (Hymenoptera: Aphelinidae). *Peer. J.,* **4**, e1863 (2016).

Liu, Y.H., M.M. Shah, Y. Song and T.X. Liu: Host plant affects symbiont abundance in *Bemisia tabaci* (Hemiptera: Aleyrodidae). *Insects,* **11**, 501 (2020).

Manju, K.P., K.V. Lakshmi, B.S. Babu and K. Anitha: Morphological and biochemical basis of resistance in okra to whitefly, *Bemisia tabaci* and okra yellow vein mosaic virus (OYVMV). *J. Entomol. Zool. Stud.,* **9**, 1719–1728 (2021).

Manzari, S. and Y. Fathipour: Whiteflies. In: Polyphagous Pests of Crops (Edt.: Omkar). *Springer Nature,* pp. 183–230 (2021).

Masuda, K., M. Kato and T. Saito: Reduction in carotenoid and chlorophyll content induced by the sweet potato whitefly, *Bemisia tabaci. Sci. Hortic.,* **200**, 102–104 (2016).

Mrosso, S.E., P.A. Ndakidemi and E.R. Mbega: Characterization of secondary metabolites responsible for the resistance of local tomato accessions to whitefly (*Bemisia tabaci,* Gennadius 1889) (Hemiptera) in Tanzania. *Crops,* **2**, 445–460 (2022).

Mwila, N., S. Rubaihayo, S. Kyamanywa, T.L. Odong, E. Nuwamanya, M. Mwala, S. Agbahoungba and A. Badji: Biochemical factors associated with cassava resistance to whitefly infestation. *Afr. Crop Sci. J.,* **25**, 365–385 (2017).

Nansen, C., M. Murdock, R. Purington and S. Marshall: Early infestations by arthropod pests induce unique changes in plant compositional traits and leaf reflectance. *Pest Manag. Sci.,* **77**, 5158–5169 (2021).

Nayek, S., I.H. Choudhury, N. Jaishee and S. Roy: Spectrophotometric analysis of chlorophylls and carotenoids from commonly grown fern species by using various extracting solvents. *J. Chem. Sci.,* **4**, 63–69 (2014).

Pandey, V.P., R. Sundaraju and S.I. Ahmed: Parasitoids and effect of weather factors on their parasitism on babul whitefly, *Acaudaleyrodes rachipora* (Singh) (Hemiptera: Aleyrodidae) infesting *Prosopis juliflora* in Indian arid zone. *J. Biol. Control,* **21**, 149–152 (2007).

Perring, T.M., P.A. Stansly, T.X. Liu, H.A. Smith and S.A. Andreason: Whiteflies: Biology, ecology, and management. In: Sustainable Management of Arthropod Pests of Tomato (Eds.: W. Wakil, G. E. Brust and T. M. Perring), Chapter-4, pp.73–110 (2018).

Pradhan, S.K., A.N. Shylesha and K. Selvaraj and V.B. Sumalatha: Comparative biology of invasive rugose spiralling whitefly *Aleurodicus rugioperculatus* Martin on three host plants. *Indian J. Entomol.,* **82**, 498–503 (2020).

Prieto, P., M. Pineda and M. Aguilar: Spectrophotometric quantitation of antioxidant capacity through the formation of a phosphomolybdenum complex: Specific application to the determination of vitamin E. *Anal. Biochem.,* **269**, 337–341 (1999).

Rizwan, M., S. Abro, M.U. Asif, A. Hameed, W. Mahboob, Z.A. Deho and M.A. Sial: Evaluation of cotton germplasm for morphological and biochemical host plant resistance traits against sucking insect pests complex. *J. Cotton Res.,* **4**, 1–8 (2021).

Schutze, I.X., P.T. Yamamoto, J.B. Malaquias, M. Herritt, A. Thompson, P. Merten and S.E. Naranjo: Correlation-based network analysis of the influence of *Bemisia tabaci* feeding on photosynthesis and foliar sugar and starch composition in soybean. *Insects,* **13**, 56 (2022).

Sharma, G., P.A. Malthankar and V. Mathur: Insect–plant interactions: a multilayered relationship. *Ann. Entomol. Soc. Am.,* **114**, 1–6 (2021).

Sharma, J. and B. Singh: Unravelling the category of host plant resistance in Aegilops tauschii Coss. against the bird cherry-oat aphid, *Rhopalosiphum padi* L. *Euphytica,* **218**, 108 (2022).

Silva, A.G.D., A.L. Boiça, P.R.D.S. Farias, B.H.S.D. Souza, N.E.L.

Rodrigues and S.A.M. Carbonell: Common bean resistance expression to whitefly in winter and rainy seasons in Brazil. *Sci. Agric.,* **76**, 389–397 (2019).

Simmons, A.M., C.S. Kousik and A. Levi: Combining reflective mulch and host plant resistance for sweetpotato whitefly (Hemiptera: Aleyrodidae) management in watermelon. *Crop Prot.,* **29**, 898–902 (2010).

Singh, V., S. Mandhania, A. Pal, T. Kaur, P. Banakar, K. Sankaranarayanan, S.S. Arya, K. Malik and R. Datten: Morpho-physiological and biochemical responses of cotton (*Gossypium hirsutum* L.) genotypes upon sucking insect-pest infestations. *Physiol. Mol. Biol. Plants,* **28**, 2023–2039 (2022).

Singleton, V.L. and J.A. Rossi: Colorimetry of total phenolics with phosphomolybdic-phosphotungstic acid reagents. *Am. J. Enol. Vitic.,* **16**, 144–158 (1965).

Sundararaj, R., M. Meeta and S.I. Ahmed: Aleyrodids infesting rose (*Rosa chinensis*) in Indian arid zone. *Hexapoda,* **12**, 19–24 (2000).

Sundararaj, R. and S. Murugesan: Occurrence of *Acaudaleyrodes rachipora* Singh (Aleyrodidae: Homoptera) as a pest of some important forest trees in Jodhpur (India). *Indian J. For.,* **19**, 247–248 (1996).

Wang, F., J. Liu, P. Chen, H.Y. Li, J.J. Ma, Y.J. Liu and K. Wang: *Bemisia tabaci* (Hemiptera: Aleyrodidae) insecticide resistance in Shandong Province, China. *J. Econ. Entomol.,* **113**, 911–917 (2020).

Zhang, Q., F. Yang, H. Tong, Y. Hu, X. Zhang, T. Tian, Y. Zhang and Q. Su: Plant flavonoids enhance the tolerance to thiamethoxam and flupyradifurone in whitefly *Bemisia tabaci* (Hemiptera: Aleyrodidae). *Pestic. Biochem. Physiol.,* **171**, 104744 (2021).