



Assessment of soybean (*Glycine max*) genotypes for resistance to *Bemisia tabaci* and its implications on yield

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ABSTRACT

The whitefly, *Bemisia tabaci* Gennadius (Hemiptera: Aleyrodidae), is a significant pest affecting pulse crops in north India, particularly soybean [*Glycine max* (L.) Merr.]. The study was carried out during the rainy (*kharif*) seasons of 2018 and 2019 at Punjab Agricultural University, Ludhiana, Punjab to investigate whitefly populations across 8 soybean genotypes. The study revealed that genotypes SL 1074 and SL 1028 had the lowest whitefly infestations, while DS 3105 exhibited high susceptibility. Whitefly populations, peaking at different stages, were positively correlated with temperature and relative humidity and negatively with rainfall. Significant variations in whitefly population densities were observed across different genotypes and canopy levels, with higher populations in the upper and middle canopies. The avoidable yield losses were estimated in three cultivars recommended for cultivation by the Punjab Agricultural University, with losses ranging from 18.12–27.28%. The insecticide thiamethoxam was effective initially, but whitefly populations increased three weeks after the spraying. Unprotected plots exhibited higher whitefly populations and greater yield losses. Negative correlations were found between whitefly populations and yield parameters, particularly with 100-seed weight. This study underscores the importance of cultivating resistant soybean varieties like SL 1074 and SL 1028 to manage *B. tabaci* and minimize yield losses.

Keywords: *Bemisia tabaci*, Evaluation, Resistance, Soybean, Weather correlation, Whitefly, Yield losses

Soybean [*Glycine max* (L.) Merr.], also known as miracle bean or golden bean, is an important oilseed crop cultivated under rainfed conditions in India. It is highly valued for its high protein (40%) and oil (20%) contents, meeting nearly half of the global demand. India accounts for 10% of the global soybean area, but contributing only 4% to the global production due to lower productivity rates caused by various biotic and abiotic factors (Agarwal *et al.* 2013). Insect pest damage is a significant factor limiting soybean production and productivity (Marabi *et al.* 2017). The whitefly, [*Bemisia tabaci* (Gennadius)], is becoming severe pest on soybean, causing potential yield losses up to 80% (Inayati and Marwoto 2012). Damage results in chlorotic spots, weakening, wilting, yellowing of leaves, and an overall reduction in the plant development (Vieira *et al.* 2013).

The farmers usually heavily rely on various kinds of insecticides for managing the whitefly incidence. However, the quick rate of resistance and resurgence development poses challenges, raises production costs and also disrupts the agricultural ecosystems (Murgianto and Hidayat 2017).

In recent years, the shift towards sustainable agriculture has emphasized the necessity for integrated pest management (IPM) strategies that minimize chemical inputs and enhance ecological balance. Host plant resistance is an important aspect of the IPM, offering a viable alternative to chemical control methods. The host plant resistance approach has proven effective in many crops, providing safer, economical, and long-term whitefly management, reducing crop losses, and supporting IPM (Gulluoglu *et al.* 2010). Successful whitefly management with resistant soybean genotypes has been demonstrated in Turkey (Gulluoglu *et al.* 2010). While *B. tabaci* poses a major biotic threat to soybean cultivation in India, especially in the northern regions (Sharma *et al.* 2014), studies on avoidable yield losses and soybean genotypes responses against whitefly remain limited. Therefore, present study was carried out to screen the soybean genotypes resistant to *Bemisia tabaci* and assess the yield losses in cultivars, to benefit the soybean growers.

MATERIALS AND METHODS

The present study was carried out during the rainy (*kharif*) seasons of 2018 and 2019 at Punjab Agricultural University, Ludhiana (30°54'16.5"N 75°47'48.5"E), Punjab. The package of practices advised by the Punjab Agricultural University except for the use of recommended insecticides

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was adopted to cultivate the soybean (Anonymous 2018). Two separate experiments were conducted to assess the impact of whitefly on soybean genotypes and estimate avoidable yield losses. In the first experiment, the response to whitefly was evaluated in 8 soybean genotypes: SL 688, SL 1028, SL 1074, SL 1113, PS 1347, PS 1572, DS 3105, and SL 958. The experiment was conducted in randomized block design (RBD) with three replications.

In the second experiment, avoidable yield losses associated with the whitefly-mediated direct damage were estimated in three soybean varieties recommended for cultivation in Punjab: SL 525, SL 744 and SL 958. The experiment was conducted in factorial randomized block design comprising 6 treatments with 5 replications. Each treatment included three protected plots, where infestation and damage from whitefly were prevented with a recommended insecticide spray (thiamethoxam 25 WG @100 g/ha), and three unprotected plots were maintained under natural whitefly infestation conditions without insecticide spray. Soybean genotypes/varieties were sown in four rows of 5 m row length plots, measuring 10 m² each.

Whitefly population: The population of whitefly (adults and nymphs) was evaluated weekly from 5 randomly selected plants in each treatment. The nymphal and adult whiteflies count was recorded as per the methodology adopted by the Harish *et al.* (2023). The genotype responses against the *B. tabaci* were categorized into various groups based on the methodology adopted by Chiang and Talekar (1980).

Yield loss estimation: The chemical protection method was adopted to estimate the avoidable yield losses. In protected plots, infestation and damage from whitefly were prevented with the recommended insecticide spray (thiamethoxam 25 WG @100 g/ha). The threshold level for the spraying was set to 15–20 whiteflies recorded in the upper canopy. The unprotected plots were maintained under natural whitefly infestation conditions and kept free from any insecticidal spray. At the harvest time observations on the number of pods, seeds/pod, 100-seeds weight and seed yield (kg/ha) of soybean were recorded from the protected and unprotected plots. The average of recorded observations was calculated and avoidable yield losses were worked out using the formula given by Pradhan (1964).

Data analysis: The data on the whitefly population (nymphs and adults), number of pods, seeds per pod and yield/ha were subjected to square root transformation. The data recorded in the yield losses experiment were analysed through ANOVA with factorial randomized block design (F-RBD) to determine the interaction between the protected and unprotected conditions. Pearson correlation analysis was performed to determine the relationship between the whitefly population and yield parameters. The whitefly population data recorded on soybean genotypes were evaluated in one-way ANOVA. The differences among treatments were determined by Tukey's HSD test (at a 5% level). To understand the influence of abiotic factors on the whitefly population, Pearson correlation analysis was performed between the whitefly population and weather

parameters. All the statistical analyses were performed using IBM SPSS 25.0.

RESULTS AND DISCUSSION

Genotypes response to whitefly population: In both *kharif* seasons, the incidence of adult whitefly populations on soybean initiated almost during the third week of July, continuing until the pod maturity stage of soybean [42 Standard Meteorological Week (SMW)]. The whitefly population dynamics (adults and nymphs) recorded during the study period displayed significant variations across the weeks. The peak number of whitefly adults/trifoliolate was observed at 69th SMW in *kharif* 2019 i.e. during the last week of August (35th SMW), which coincided with the flowering initiation stage. In *kharif* 2018, the maximum population of 49 adults/trifoliolate occurred at the beginning of the flowering stage (34th SMW/3rd week of August). The peak population of whiteflies occurred at 34th and 35th SMW (Marabi *et al.* 2017). A decline in the whitefly population during late crop growth stages is attributed to the unavailability of new foliage supporting population build-up (Murgianto and Hidayat 2017). The population levels of whitefly on collard plants were positively associated with the growth and availability of host plants. Once the plants matured and their quality usually declines, thus the whitefly population negatively affected (Liu 2000). The whitefly population on tomatoes was reported to be peaked during periods of high plant growth and declined as the plants matured, as the new foliage became less available (Subba *et al.* 2017). Nymphal populations peaked during the flowering initiation stage in *kharif* 2019 (159 nymphs/trifoliolate) and 2018 (150 nymphs/trifoliolate), decreasing after 40th SMW due to lower temperatures affecting whitefly biology and reproductive rates. Our results suggest that whitefly population naturally reduces in towards the crop cycle end. Our results thus highlight that the decline in the whitefly population during late crop growth stages is certainly attributed to the unavailability of new foliage, which is essential for their population build-up as it supplies required nutrients for the growth and development of whiteflies. These results are supported by the studies of Marabi *et al.* (2017) and Murgianto and Hidayat (2017). Similar trends were documented in cotton plants, where the whitefly population increased with crop growth and decreased as the crop reached the boll-development stage, indicating the importance of fresh foliage for whitefly population maintenance (Khanday *et al.* 2019).

Significantly higher whitefly numbers were observed in *kharif* 2019 compared to 2018, and both years exhibited significant variations in whitefly response across different genotypes (Table 1). Different genotypes exhibited varying levels of whitefly infestation throughout the growing season (Janu and Dahiya 2017). Whitefly adult preferences for specific genotypes showed significant variability, with varying numbers in upper, middle, and lower canopies during both the years. The nymphal and red-eyed nymphal populations also displayed genotypic

Table 1 Adult population of *B. tabaci* on soybean genotypes under field condition

Genotype	**Adults/trifoliolate leaf						#Mean	
	Upper canopy		Middle canopy		Lower canopy			
	2018	2019	2018	2019	2018	2019	2018	2019
DS 3105	28.65 ^a	32.31 ^a	14.50 ^a	15.46 ^a	7.31 ^a	7.58 ^a	16.82 ^a	18.45 ^a
SL 688	19.96 ^b	24.03 ^b	12.81 ^b	14.65 ^a	6.23 ^b	7.15 ^a	13.00 ^b	15.28 ^b
SL 958	18.31 ^b	22.97 ^{bc}	11.54 ^{bc}	13.51 ^{ab}	6.15 ^b	6.99 ^{ab}	12.00 ^b	14.49 ^b
SL 1113	18.23 ^b	20.58 ^c	10.72 ^{cd}	12.23 ^b	5.90 ^{bc}	6.71 ^b	11.62 ^b	13.17 ^c
PS 1347	15.76 ^c	17.12 ^d	9.38 ^{de}	10.29 ^c	5.18 ^{cd}	5.93 ^c	10.11 ^c	11.11 ^d
PS 1572	15.05 ^c	16.88 ^d	8.89 ^e	9.54 ^c	5.08 ^d	5.84 ^c	9.67 ^c	10.76 ^d
SL 1028	12.40 ^d	14.21 ^c	7.38 ^f	7.89 ^d	4.37 ^e	5.04 ^d	8.05 ^d	9.05 ^e
SL 1074	11.77 ^d	13.29 ^c	7.15 ^f	7.65 ^d	4.15 ^e	4.90 ^d	7.69 ^d	8.62 ^e

*Mean of three replications recorded over a period of 13 weeks; #Mean of the upper, middle and lower canopies.

Means within the column provided with the same letter are not significantly different ($P \leq 0.05$; ANNOVA and Tukey's test)

variations across different canopies in both *kharif* seasons (Table 2). Observations revealed higher proportions of whitefly adults and nymphs in the upper and middle canopy, respectively. Studies have shown that whitefly populations can vary within different parts of the plant canopy. For instance, whitefly adults and nymphs showed significant differences in distribution across upper, middle, and lower canopies in various genotypes of host plants. This differential distribution can be influenced by factors such as leaf age and quality (Ariyo *et al.* 2005). Singh and Singh (2019) also noted that whitefly populations varied across different canopy levels in greengram genotypes, with higher populations in specific genotypes. Genotypes SL 1074 and SL 1028 were categorized as moderately resistant, PS 1374 and PS 1572 as moderately susceptible, SL 688, SL 958, and SL 1113 as susceptible and DS 3105 as highly susceptible to *B. tabaci*. Research on soybean genotypes showed that whitefly population varied significantly across genotypes. Moderately resistant genotypes had significantly lower whitefly populations compared to susceptible ones. Leaf morphological characteristics, such as trichome density,

length and angle, leaf thickness and leaf shape influences the whitefly population densities (Harish *et al.* 2023). In summary, the variability in whitefly populations across different genotypes and canopy levels, along with significant year-to-year differences, highlights the complex interactions between whiteflies and their host plants, influenced by genetic, morphological, and environmental factors.

The correlation analysis between weather parameters and adult whitefly population revealed a non-significant correlation, except for rainfall and temperature playing a significant role in influencing whitefly dynamics. Gehlot *et al.* (2023) observed a significant negative correlation between whitefly population and rainfall, indicating that increased rainfall reduced the whitefly population. It was reported that whitefly populations on cotton were significantly positively correlated with minimum temperature and relative humidity, and negatively correlated with maximum temperature (Janu and Dahiya 2017). Multiple linear regression analysis indicated that all weather parameters collectively contribute to the variability in *B. tabaci* population, with R^2 values ranging from 0.63–0.83 during both *kharif* years. Sonkamble

Table 2 Nymphal population of *B. tabaci* on soybean genotypes under field condition

Genotype	*Nymphs/trifoliolate leaf						#Mean		*@Red-eyed nymphs	
	Upper canopy		Middle canopy		Lower canopy					
	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
DS 3105	16.70 ^a	16.84 ^a	70.43 ^a	73.00 ^a	45.69 ^a	46.89 ^a	44.27 ^a	45.57 ^a	22.84 ^a	22.6 ^a
SL 688	13.26 ^b	14.43 ^b	56.27 ^b	59.16 ^b	37.47 ^b	41.70 ^{ab}	35.67 ^b	38.43 ^{ab}	19.81 ^b	18.59 ^b
SL 958	10.50 ^{bc}	13.45 ^b	45.00 ^{bc}	57.98 ^b	30.70 ^{bc}	38.28 ^{bc}	31.88 ^b	36.57 ^b	18.85 ^{bc}	16.61 ^{bc}
SL 1113	11.90 ^c	13.00 ^b	49.75 ^c	51.80 ^b	33.99 ^c	33.79 ^c	28.73 ^{bc}	32.86 ^b	16.64 ^c	14.40 ^c
PS 1347	8.64 ^d	8.34 ^c	36.17 ^d	34.82 ^c	24.97 ^d	27.42 ^d	23.26 ^{cd}	23.52 ^c	11.56 ^d	11.49 ^d
PS 1572	7.09 ^e	7.79 ^c	32.02 ^d	32.18 ^c	21.34 ^d	24.99 ^d	20.15 ^d	21.65 ^{cd}	9.29 ^e	10.07 ^d
SL 1028	4.56 ^f	5.04 ^d	23.22 ^e	24.23 ^d	16.40 ^e	18.95 ^e	14.73 ^e	16.07 ^{de}	5.29 ^f	6.03 ^e
SL 1074	4.26 ^f	4.67 ^d	20.28 ^e	22.30 ^d	15.26 ^e	16.83 ^e	13.27 ^e	14.59 ^e	4.37 ^f	4.74 ^e

*Mean of three replications recorded over a period of 13 weeks #Mean of the upper, middle and lower canopies.

Means within the column provided with the same letter are not significantly different ($P \leq 0.05$; ANNOVA and Tukey's test); @ indicates middle canopy.

Table 3 Yield parameters of soybean varieties evaluated against whitefly under unprotected and protected conditions during *khariif* 2018 and 2019

Variety	Number of pods			Number of seeds/pod			100-seed weight			Seed yield kg/ha		
	Unprotected condition (UP)#	Protected condition (P)#	Mean	Unprotected condition (UP)#	Protected condition (P)#	Mean	Unprotected condition (UP)#	Protected condition (P)#	Mean	Unprotected condition (UP)#	Protected condition (P)#	Mean
kharif 2018												
SL 744	65.74 (8.16)	73.72 (8.64)	69.73 (8.35) ^B	2.23 (1.80)	2.41 (1.85)	2.32 (1.82)	10.65	13.48	12.07 ^C	1548	1738	1643 ^B
SL 958	70.59 (8.46)	78.55 (8.92)	74.56 (8.63) ^C	2.28 (1.80)	2.38 (1.84)	2.33 (1.82)	8.85	12.28	10.57 ^A	1635	2067	1851 ^C
SL 525	65.72 (8.17)	70.37 (8.45)	68.04 (8.25) ^A	2.10 (1.76)	2.51 (1.87)	2.30 (1.81)	9.84	12.80	11.32 ^B	1393	1867	1630 ^A
CD (<i>P</i> =0.05)	67.35 (8.26) ^a	74.21 (8.66) ^b		2.20 (1.78) ^a	2.43 (1.85) ^b		9.77 ^a	12.85 ^b		1526 ^a	1891 ^b	
	Variety = 0.12, P/UP = 0.15, Variety × P/UP = NS			Variety = 0.06, P/UP = NS, Variety × P/UP = NS			Variety = 0.45, P/UP = 0.55, Variety × P/UP = 0.77			Variety = 95.01, P/UP = 116.37, Variety × P/UP = 164.57		
kharif 2019												
SL 744	65.76 (8.17)	72.26 (8.56)	69.01 (8.31) ^B	2.16 (1.77)	2.33 (1.82)	2.24 (1.80)	9.82	12.05	10.93 ^B	1502	1858	1680 ^B
SL 958	70.83 (8.48)	76.93 (8.83)	73.88 (8.60) ^C	2.18 (1.78)	2.44 (1.85)	2.31 (1.82)	10.45	11.69	11.07 ^C	1627	2085	1856 ^C
SL 525	62.72 (7.98)	69.24 (8.38)	65.98 (8.12) ^A	2.04 (1.74)	2.31 (1.81)	2.17 (1.78)	8.70	12.78	10.74 ^A	1363	1727	1545 ^A
CD (<i>P</i> =0.05)	66.43 (8.19) ^a	72.80 (8.58) ^b		2.12 (1.76) ^a	2.35 (1.83) ^b		9.65 ^a	12.17 ^b		1498	1890	
	Variety = 0.16, P/UP = 0.19, Variety × P/UP = NS			Variety = 0.08, P/UP = NS, Variety × P/UP = NS			Variety = 0.29, P/UP = 0.36, Variety × P/UP = 0.51			Variety = 35.70, P/UP = 43.72, Variety × P/UP = 61.83		

Means in column provided with same uppercase letters, likewise same lower-case letters in rows are not significantly different ($P \geq 0.05$; ANNOVA and Tukey's test); #Figures in parentheses are $\sqrt{n+1}$ transformation.

and Rana (2019) conducted a study on soybean and found that the multiple linear regression analysis showed that weather parameters contributed significantly to the variability in whitefly population with R^2 values of 0.696 in 2014 and 0.926 in 2015.

Impact of whitefly infestation on soybean yield parameters: Comparatively, unprotected plots exhibited notably higher whitefly populations than protected plots (Table 3). Variety SL 958 consistently recorded the highest whitefly population, followed by SL 525 and SL 744 in both conditions. The insecticide (thiamethoxam 25 WG @100 g/ha) effectively reduced pest populations below the threshold initially, but three weeks post-spray, the population exceeded the threshold. Thiamethoxam and imidacloprid were effective in controlling whitefly populations in cotton and soybean, but their efficacy reduced over time, necessitating repeated applications. In a study on the bio-efficacy of thiamethoxam in soybean, it was found that it reduced whitefly populations effectively initially but required follow-up sprays to maintain low levels (Kalyan and Ameta 2016). The insecticides significantly reduced pest populations initially, but three weeks post-spray, the population often exceeded the threshold again (Torres and Ruberson 2004). The decrease in insecticide efficacy over time is attributed to factors such as reduced natural population of predators, decreased susceptibility of whiteflies, and the non-selective nature of certain insecticides which can affect beneficial insects as well (Gehlot *et al.* 2023).

Avoidable yield losses in unprotected plots ranging from 18.12–27.28% with variety SL 958 experienced the highest losses (27.28%), followed by SL 525 (20.45%) and SL 744 (18.12%). In a study Inayati and Marwoto (2012) observed the yield losses of up to 81% in untreated plots compared to significant yield protection in treated plots. Furthermore, the observed variations in yield could be attributed to cultivar traits as various genetic, morphological and biochemical factors affects the insect pest populations (Gulluoglu *et al.* 2010, Vieira *et al.* 2013, Harish *et al.* 2023).

Correlation data indicated negative associations between evaluated yield parameters and whitefly population, with significant negative correlations for 100-seed weight (Supplementary Table 1). Coefficient of determination (R^2) results suggests that whitefly adults' feeding damage has a more pronounced effect on 100-seed weight. Cruz *et al.* (2016) found that whitefly infestation negatively affected the number of pods/plant, number of seeds per plant, and dry weight of biomass. The tolerant soybean genotype KS-4202 showed less damage compared to susceptible varieties, but the overall impact on flower and pod production was significant in infested plants. Likewise, Marabi *et al.* (2017) found that whitefly infestations correlated negatively with soybean yield, with higher whitefly populations leading to significant declines in yield parameters. It was reported that soybean genotypes resistant to whitefly exhibited less yield loss compared to susceptible genotypes. High heritability and genetic advance in traits such as seed weight per plant were noted, suggesting that breeding for resistance can effectively

reduce yield losses (Sulistyo and Mejaya 2018). In summary, whitefly feeding activity during the reproductive stage of soybean plants significantly diminishes the flower and young pod production, leading to considerable yield losses.

This 2-year study highlights the impact of *B. tabaci* on soybean yield, with significant variations observed across genotypes and environmental conditions. Genotypes SL 1074 and SL 1028 showed moderate resistance, while DS 3105 was highly susceptible. Whitefly populations were influenced by weather parameters, particularly temperature and rainfall. Effective management requires integrating pest-resistant genotypes and timely insecticide applications. These findings underscore the importance of breeding for resistance and adopting sustainable pest management strategies to mitigate yield losses, and enhance soybean productivity in north India.

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