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Plant resistance in chillies *Capsicum* spp against whitefly, *Bemisia tabaci* under field and greenhouse condition

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Abstract
Present studies were conducted on chillies *Capsicum* spp against whitefly in field and greenhouse screening. Forty five chillies accessions were subjected to field screening against whitefly, *Bemisia tabaci*. Varietal resistance is further evaluated in the greenhouse condition by studying the categories of resistance on whitefly. Accessions selected as ‘‘promising’’ for resistance (low whitefly populations) and susceptible accessions were reevaluated at greenhouse condition. Ten accessions of *Capsicum* were screened against whitefly, under greenhouse condition for categorization of the mechanism(s) of resistance. Accessions P2, P4, ACC1 and ACC12 were found to be less preferred for adult settlement, whereas accessions P1, P3, P5, ACC10, ACC26 and ACC27 were the most preferred one. In resistant accessions of chillies accumulative reduction in pest population was noticed by reduced rate of reproduction and increased developmental period. The number of eggs laid and the percentage of nymphal and adult emergence were low on resistant accessions *viz.*, ACC12 (4.33 no of eggs /pair/leaf, with 76.92 % hatchability), P2 (5 no of eggs /pair/leaf, with 80% hatchability), P4(5.33 no of eggs /pair/leaf, with 81.25 % hatchability) and ACC1(4.67 no of eggs /pair/leaf, with 85.71 % hatchability). In population build-up study, significantly lower numbers of progeny were observed on accessions ACC12 (0.33 adults/pair/leaf), P2 (0.67 adults/pair/leaf),) and ACC1 (0.67 adults/pair/leaf),). Conversely, the number of progeny produced by F_2 was significantly greater on ACC 10 (7.93 adults/pair/leaf)). The accession P2, P4, ACC1 and ACC12 has displayed strong antixenotic and antibiotic effect against whitefly, *Bemisia tabaci*.

Keywords: Chillies, host plant resistance, whitefly, *Bemisia tabaci*

1. Introduction
Chilli (*Capsicum annuum* L., 2n = 24) (Solanaceae) has originated from South and Central America [74]. It is a vital spice due to its pungency, taste, appealing colour and flavor and has its unique place in the diet as a vegetable cum spice crop. India is a major producer, exporter and consumer of chillies in the world and production of chillies in India is about 1492 million tonnes from an area of 775 million ha with an average productivity of 1.9 million tonnes per ha [33]. In Tamil Nadu, the estimated production of chillies is 23.06 million tonnes from an area of 50.67 million ha [33]. Chillies suffer from ravages of several biotic stresses by the occurrence of pests and diseases in tropical and subtropical regions of India. The crop is infested by more than 21 insect and non-insect pests [21] particularly, whitefly transmitted geminiviruses (WTGs) (begomoviruses). The chilli leaf curl disease (ChiLCuD), caused by Chilli leaf curl virus (ChiLCuV) and transmitted by *B. tabaci* is a serious challenge to yield of chillies in south India [16]. The severity (100% crop loss) of the problem could be realized from the fact that in the recent years, farmers have withdrawn chilli cultivation in India [40].
The whitefly, *B. tabaci* lays whitish eggs usually in circular groups, on the underside of leaves, and is anchored by a pedicel which is inserted into a fine slit made by the female in the tissues. The eggs turn brown on age and hatch after 5-9 days at 30°C depending very much on host species, temperature and humidity [3]. A female whitefly can lay 300-400 eggs in her four weeks lifespan [13]. On hatching, the first instar, or "crawler", is flat, oval and scale-like and nymphal stage that is mobile. The crawlers find a suitable feeding location on the lower surface of the leaf, settle for feeding with its legs are lost in the ensueing moult and thus the nymphs becomes sessile. The first three nymphal stages last 2-4 days each and the fourth nymphal stage, called the 'puparium', lasts about 6 days, dependent on temperatures [3].

The adult emerges through a "T"-shaped rupture in the skin of the puparium and copulation begins 12-20 h after emergence and takes place several times throughout the life of the adult. The female could live up to 60 d whereas male live shorter (9 and 17 d). The *B. tabaci* produces eleven to fifteen generations within one year [3].

The visible, direct damage caused by whiteflies are leaf deformation and honeydew secretion on which sooty moulds can grow as well as physiological disorders and irregular ripening of the fruits [45]. *B. tabaci* transmits more than 200 plant viruses efficiently [45] 90% of them are begomoviruses [47]. Viral infection starts at early plant growth stage as leaves curl towards midrib and become deformed. The characteristic field symptoms were upward curling, puckering and reduced size of leaves. Severely affected plants were stunted and produced no fruit [63].

The partial control of viruses may be achieved with the application of certain pesticides controlling the vectors, but complete and environmental safer protection from the virus through host plant resistance may be preferred and is an effective contribution to ChiLCuD and *B. tabaci* management. Host plant resistance (HPR) by using three functional categories: antibiosis, non-preference (antixenosis), and tolerance [55]. Antibiosis describes the negative influence of the plant on the biology of an insect attempting to use that plant as a host [67] and may be explained after reduced body size and mass, prolonged periods of development in the immature stages, reduced fecundity, or failure to pupate or eclose when trying to explore the host plant for nutrition. Antixenosis resistance occurs when the plant acts as a poor host and is not favored by the arthropod as food, shelter, or an oviposition site. Non-preference results in reduced colonization of a plant by arthropods, thus reducing losses caused by the pest [56, 67]. To cope with potential damage caused by *B. tabaci* in horticultural agroecosystems, the exploration of host plant resistance has been considered a promising alternative in sustainable agriculture [64]. Chillies have a considerable growing cycle (6 months or more). Whitefly HPR research has increased considerably since 1990, primarily due to the rise in importance and damage caused by the *B. tabaci* species complex. To explore the possibilities of developing whitefly resistant accessions, it is essential to identify resistance in chillies germplasm. Thus, the best way to reduce the whitefly population is to understand the resistant mechanisms [48] among the accessions. Hence the following objectives were undertaken, such as screening of chilli germplasms for whitefly *Bemisia tabaci* resistance under field condition, Greenhouse screening chilli germplasms for whitefly *Bemisia tabaci* includes antixenosis and antibiosis.

2. Materials and methods

2.1 Screening of Chilli Germplasms for whitefly *Bemisia tabaci* resistance under field condition

Field trial was conducted at Kullursanthai with a coordinate of 9.5427° N, 77.9810° E, Virudhunagar district, Tamil Nadu, India in summer planting season (January to June, 2016) to evaluate the resistance against whitefly, *B. tabaci* and ChiLCuD incidence. The trial was laid out in a randomized block design (RBD) with 45 genotypes and each genotype was considered as one treatment in a plot size of 5x4 m^2. Forty to forty five days old seedlings of forty five numbers of germplasms (Table 1) were transplanted on ridges and furrows at a spacing of 60 cm. The crop was maintained well by adapting standard agronomic practices as per the recommendations of Tamil Nadu Agricultural University except insect control. Each plot consisted of approximately 30 plants. From each plot ten plants were selected at random for the observations. Two replications were maintained. The adult population of *B. tabaci* were counted on the lower surface of three fully-opened trifoliate leaves, one each from the upper, middle and lower canopy using an hasting triplet 10X hand lens at weekly intervals in the morning between 6AM-7AM, when the whiteflies were not very active [12].

2.2 Greenhouse screening chilli germplasms for whitefly *Bemisia tabaci*

2.2.1 Insect culture

Adults of cotton whitefly, *B. tabaci* were collected from chillies (*C. annuum*) and cotton *(Gossypium* spp.) near Srivilliputhur, Virudhunagar district, Tamil Nadu, India and were cultured in the greenhouse of Insectary, Agricultural College and Research Institute, Madurai on mixed host plants of cotton (cultivar ARBH 1401), Black night shade (*Solanum nigrum*) and chillies (*C.annuum*) (cultivar: K2).

The plants were grown on cocopith and soil medium with proper fertigation and irrigation. The plants were maintained in cages 150cmx150cmx150cm and covered with 100 micron mesh cloth. Thirty to forty day old pest free fresh plants were introduced inside the culture cages every fortnight. For collection of naïve whitefly adults for use in experiments individual plants were caged for 3-4 days separately and the adults emerged and trapped inside the 100 micron mesh cloth cage were collected using glass tubes [25 by 150 mm (width and height)].

2.2.2 Plant material

The seeds of promising chillies test accessions from field screening were taken for greenhouse experiment studies *viz.*, P1, P2, P3, P4, P5, ACC1, ACC10, ACC12, ACC26 and ACC27.

Unless otherwise indicated all the experiments were performed in the greenhouse where plants were grown in cocopith and soil potting mix in 13cm dia x15 cm height mud pots. Plants were maintained at 30-35^0 C temperature and 70-80% of relative humidity. Antixenosis (non-preference), antibiosis, and tolerance resistance in chillies were determined by using modifications of the methods as described then and there.

2.2.3 Antixenosis (non-preference)

The procedure suggested by Firdaus *et al.*, [27] with modification was followed. Seeds of each accession were treated with 1% KNO_3 in a petridish for overnight and single seeds of each accession were planted at centre of a single pot (13cm dia x 15 cm height). At 4 to 6 leaf stage of seedling growth, three pots (replicates) for each accession were selected for uniform growth and pest free condition and were arranged in a completely randomized block design. Then each seedling was individually covered with in a glass chimney (6.5 cm dia x 15 cm height) in an inverted position with mouth to the bottom and base at the top that was lined with 100 micron mesh cloth to prevent the escape of adult whiteflies. To each pot 10 pairs of freshly emerged adults were released.

The number of adults (male and female) settled on individual plants were recorded at 4, 8, 12, 24 and 48 h after release (HAR). The experiment was repeated twice to confirm the results.

2.2.4 Antibiosis
2.2.5 Fecundity test
The modified method as described by [38] was followed. The test accessions were raised as described in antixenosis experiment. Ten pairs of newly emerged adult insects were released. Then, each seedling was individually covered with in a glass chimney (6.5 cm dia x 15 cm height) in an inverted position with mouth to the bottom and base at the top that was lined with 100 micron mesh cloth to prevent the escape of adult whiteflies. At 3, 5, 8 and 12 d after release (DAR), the adults were removed and eggs were counted.

2.2.6 Egg hatchability
The test accessions were sown in protrays (98cavities, width 300mm, length 485mm; depth 38mm, thickness 0.75mm) after treatment with 1% KNO_3 overnight soaking. When the seedlings reached six leaf stages, healthy seedlings were transplanted individually in mud pots (13cm diax 15 cm height). Ten days after transplanting (DAT), each plant was infested with five pairs of adult whiteflies to each seedling and covered with glass chimney as described in fecundity test. At 3 DAR the number of enclosed eggs and nymphs on each seedling was counted using destructive sampling method and the per cent hatchability of nymphs were observed [38].

2.2.7 Nymphal development
The test accessions were raised in small mud pots (13cm dia x 15 cm height). Seeds of each accession were treated with 1% KNO_3 in a petridish for overnight and single seed of each accession was planted at centre of a single pot (13cm dia x 15 cm height). When plants reached 30-day-old, the pots were arranged in a completely randomized block design in 5 replicates. Each plant was infested with five pairs of adult whitefly over the test seedlings. Then each seedling was individually covered with in a glass chimney (6.5 cm dia x 15 cm height) as described in fecundity test. At 10 DAR, the number of nymphs on each seedling was counted and recorded [38].

2.2.8 Population build-up
The method described by Jindal and Dhaliwal [37] was adopted with modifications. Test accessions were raised in protrays as previously described in hatchability test. Twenty days after germination, the healthy seedlings were transferred to (50 cm x 50 cm) grow bag covered with 45cmx45cmx45cm micron mesh cage. At 6 leaf stage (30 day old), each seedling was infested with five pairs of adult whiteflies to each accession. Totally 20 replicates were maintained. At 15 DAI, out of the 20 replicates, 10 were, used to estimate the F1 adult population and the remaining 10 replicates were left undisturbed for further monitoring of F2 population build-up. At the end of 30 DAI, destructive sampling was used to assess the progeny build up in each plant. When P1 produced its first nymph (F2), the time (in d) was recorded. The F_2 progeny build-up was recorded and expressed in numbers.

2.2.9 Statistical Analysis
Data from resistance category experiments were analyzed by using a one-way analysis of variance (ANOVA) [63]. The mean values were separated using Duncan's Multiple Range Test (DMRT) [22] (P=0.05).

3. Results
3.1 Screening of chilli germplasms for whitefly *Bemisia tabaci* resistance under field condition
In field screened results revealed that 0.12 and 0.20 adults/3leaves on P2 and ACC 12 accessions respectively followed by ACC 1 (0.22/ adults/3leaves) P4 (0.23 adults/3leaves), ACC 16 (0.32/ adults/3leaves) ACC18 (0.36 adults/3leaves) ACC 23 (0.37/ adults/3leaves) and P6 (0.38 adults/3leaves). These accessions were considered as resistant, while higher populations were observed on ACC 26 (0.83 adults/3leaves), ACC 26 (0.80 adults/3leaves), ACC 25 (0.60 adults/3leaves), ACC 10 (0.62 adults/3leaves) and ACC 08 (0.60 adults/3leaves). These accessions were considered as susceptible (Table 1). (F=6.70; df=44,; Pr > F = <.0001).

3.2 Greenhouse screening of chilli germplasms for whitefly *Bemisia tabaci*
3.2.1 Non-preference (Antixenosis)
3.3.2 Settling behaviour
The settling behavior of adults differed significantly among different accessions. The maximum number of adults had settled on susceptible accessions whereas less number of adult had settled on resistant accessions at different times of observations (Table 2; Fig.1) *viz*., 4 hours after release (HAR) (F=4160.92; df=9,: Pr > F = < 0.0001), 8 HAR (F=3808.64; df=9,: Pr > F = < 0.0001), 12 HAR (F=3355.32; df=9; Pr > F = < 0.0001), 24 HAR (F=3847.17; df=9,: Pr > F = < 0.0001) and 48 HAR (F=6381.16; df=9,: Pr > F = < 0.0001) among ACC10, ACC26, ACC27 and P5 after infestation (Fig.1). It was noticed that whitefly adults settled on resistant accessions with longest time intervals, whereas as on susceptible accessions most of the released whiteflies were seen settled on the plants (Table 2).

3.4 Antibiosis
3.4.1 Fecundity test
The fecundity of whitefly differed significantly among different accessions (P2, P4, ACC1 and ACC12) in each interval recorded at 3 days after release (DAR) (F=450.70: df=9,: Pr > F = < 0.0001), at 5 DAR (F=985.41; df=9,: Pr > F = < 0.0001), at 8 DAR (F=135.52; df=9,: Pr > F = < 0.0001), at 12 DAR (F=177.69; df=9,: Pr > F = < 0.0001) (Table 3). Significantly lower number of eggs were laid on ACC 12 (4.55 no/ leaf), P2 (4.58 no/ leaf), P4 (4.85 no / leaf) in comparison to the more number of eggs laid on ACC 10 (9.23 no/leaf) and ACC 26 (8.45 no/leaf) (Table 3).

3.4.2 Egg hatchability
The nymphal emergence was noticed to be significantly lower on resistant accession ACC12 (3.33 nymphs/leaf) followed by ACC 1 (4.00 nymphs/leaf) compared with susceptible accession ACC 10 (7.67 nymphs/ leaf) (F=401.72; df=9, Pr > F = <.0001) (Table 4).

The maximum egg hatchability was observed in susceptible accessions ACC 10 (95.83%) followed by ACC 26 (95.65%) and P5 (95.65%). However, significantly lower egg hatchability was observed in resistant accession ACC12 (76.92%) (F=15.94; df=9, Pr > F = <.0001).

3.4.3 Nymphal development
The nymphal development recorded had revealed significant variations among the accessions at 10 DAR (F=2602.78; df=9, Pr > F = <.0001) (Table 5). The number of nymphs developed was high on P5 (9.33 nymphs/leaf) and very low on ACC 12 (3.67 nymphs/leaf) followed by P2 (4.0 nymphs/leaf) (Fig. 2).

3.5 Population build-up
The population build-up of whitefly on test accessions

differed significantly with each other (Table 6 & Table 7). Significantly lower numbers of progeny were observed on accessions

ACC 12 (0.33 adults/ leaf) followed by ACC1 (0.67 adults/leaf) and P2 (0.67 adults/leaf). Conversely, the number of progeny produced by F_2 was significantly greater on P5 (8.17 adults/leaf) had high population build-up followed by ACC 10 (7.93 adults/leaf) (F=4972.94; df=9, Pr > F = <.0001) (Table 6). In addition, the mean prereproductive period (d) for F_2 production was significantly longer on accessions ACC12 (16.17 d), P2(15.83 d), P4 (15.33d) compared to susceptible accession P3 (13d) (Table 7).

4. Discussion

Host plant resistance (HPR) has offered the simple solution for insect pests and insect vector transmissible disease management on several agricultural and horticultural crops from time to time. Breeders are always in search of resistant parent material to develop improved resistant accessions of crops for introduction to cultivation against whitefly critical issues. The mechanisms of resistance need to be understood before the degree of resistance among plants could be ascertained. The whitefly, *B. tabaci*, a polyphagous insect pest that desap the plants is known to cause serious damage to chillies (*Capsicum* spp) by sucking the phloem juice and destabilizing the growth, but also attained destructive status by transmitting begomoviruses Schuste *et al*., [65].

Forty five chillies accessions were subjected to field screening against whitefly, *Bemisia tabaci* Out of the forty five accessions P2, P4, ACC1 and ACC12 accessions were considered as resistant, ACC26 and ACC27 were noticed as susceptible (Table 1). The accessions P2, ACC12 ACC1 and P4 had a whitefly population of 0.12, 0.20 and 0.22, 0.23 adults/3leaves respectively. The results are in line with Rajput *et al*., [60] has registered GCh 3 and GCh 1 genotypes as resistant which exhibited less than 3.88 whitefly/3 leaves and GCh 2, JCh 722, JCh 725, JCh 740, JCh 754, JCh 756, JCh 759, JCh 782, JCh 788 and JCh 800 genotypes as susceptible, which showed more than 3.88 whitefly/ 3 leaves in *C. annum* L. The accessions ACC26 and ACC27 had whitefly population of 0.83 and 0.80 adults/3leaves respectively. These accessions were considered as highly susceptible (Table 1). According to Sagar Tamang *et al*., [62] the lowest (0.23) number of whiteflies per leaf was observed in Sonali (B-1), lower than those of both Bireswar (WNM-34-1-1) and Sukumar (WBM-29), whereas, the highest (1.33/ leaf) was observed in Panna (B-105) during first season. Whereas, in second season lowest (0.65/ leaf) whitefly incidence was observed on Sonali (B-1) highest (1.83/ leaf) whitefly incidence was observed in Sukumar (WBM-29) followed by Panna (B-105) and Bireswar with 1.80 and 1.20 numbers per leaf, respectively in mungbean germplasms. Similarly, Boissot *et al*., [10] screened 80 genotypes of *Cucumis melo* L. for resistance to *B. tabaci* and observed that on the basis of insect density, three Indian accessions namely, PI 414723, PI 164723 and 90625 and one Korean accession, PI 161375 had field resistance. On those accessions, recorded 3.6 to 6 times fewer adults than the most susceptible genotypes (AR Top Mark).

Varietal resistance is further evaluated in the greenhouse condition by studying the categories of resistance on whitefly. The categorization of resistance in chillies (*Capsicum* spp) against whitefly *B. tabaci* there was formidable and significant difference among the chillies accessions for the two different categories of resistance *viz*., antixenosis (non-preference) and antibiosis.

From the present study it could be concluded that P2 P4, ACC1 and ACC12 were the least preferred one for whitefly adult settling (Fig.1). The settling behavior of the whitefly is much important for the insect to establish progenies by utilizing the host plants for feeding, oviposition and shelter. The non preference test performed under no choice condition has revealed that the whiteflies preferred only the most suitable chillies accessions and stay away, from the least preferred accessions. The preference by whitefly may be influenced by several factors. The cues emanating from the host plant mediate the preferences by the insects. The leaf architecture and colour Sippell *et al*., [68], leaf pubescence McAuslane [44], cuticle thickness Channarayappa *et al*., [15] and metabolites were known to play a role as repellent or attractant Chermenskaya *et al*., [18] for the whiteflies. Whiteflies choose the most suitable host not only because they can feed on it, but also because the offspring should be able to survive when they oviposit (Nomikou *et al*., [53]). Tomato young leaves were more susceptible to whitefly oviposition than old leaves in the in vitro tests of cultivar 9706 (Guo *et al*., [33]). Oviposition preference and host plant selection by the female whitefly has a profound effect on the fitness of its offspring (van Lenteren and Noldus [73]). Guo *et al*., [33] observed wild tomatoes had fewer whitefly eggs than cultivars, in both in vitro and in vivo experiments.

The results of the present investigation are from the no choice method of test and there is every chance that these varieties might not further be performed if given with a choice test. Earlier studies by Firdaus *et al.*, [27] suggested that those chillies accessions preferred under no choice condition were not preferred under a choice scenario. Further, Firdaus *et al.*, [27] had suggested that those difference for preference could be the outcome of the plants ability to produce repellents (or) expression of physical barriers that culminate with the avoidance by the whitefly. However, *B. tabaci* could live on the non preferred accessions with difficulties in its performance. It was reported that soybean whitefly, *Bemisia argentifolii* had a strong preference for hairy-leaf varieties of cotton and less preference for glabrous-leaf varieties (McAuslane) [44]. According to Berlinger [5], whiteflies had two different flight patterns: short distance and long-distance flights. Short-distance flights remained within the plant canopy and the insect traveled from plant to plant within a field. The short flights are less than 15 ft in distance and mainly involved the flight from the lower leaves, whereas, the long flights were from border to border of the chamber in search of suitable host plant where they prefer to lay eggs. In the present study, the adults showed no long-distance flights and they just remained consistent within the experimental arena (glass chimney). Also, Oriani *et al*., [55] from their study suggested that, high levels of antixenosis for oviposition was related to type IV glandular trichomes of tomato accessions against *B. tabaci.* LA716 (*Lycopersicon pennellii*), PI134417 and PI134418 (*Lycopersicon hirsutum* f. *glabratum*) had ovipositional nonpreference resistance to *B. tabaci* B biotype related to the presence of glandular trichomes, which can release allelochemicals (Toscano *et al*., [72] Muigai *et al.*, [44]; Fancelli *et al*.,) [25]. Also, Channarayappa *et al*., [15] have suggested that the trichome type V found on *Solanum habrochaites* is associated with a physical resistance to whitefly infestation and proliferation and would be helpful in prevention of the spread of viruses. Chu *et al.*, [19] observed that the density of stellate trichomes on under leaf surfaces was the basic factor influencing the varietal susceptibility to adult *B. tabaci* on cotton. In *Capsicum* spp. Firdaus *et al.*, [27] had found that there was not only a highly positive correlation of non-glandular trichome density with whitefly density and oviposition rate, but also suggested that the glandular trichomes had an important role in whitefly preference. However, trichomes were not the only architecture of the plant that influenced the whitefly preferences Firdaus *et al.*, [27]. According to the optimal oviposition theory, the oviposition preference of female herbivores is positively related to host suitability for offspring, i.e., females are expected to oviposit on high-quality hosts to maximize offspring fitness by Jaenike [35]; Gripenberg *et al*., [32]. Pepper genotypes (Qianhong, Zhongjiao, Hangjiao, Zhonghuahong which has high levels of resistant compound and low levels of nutrients) had antixenosis resistance to B whiteflies (Jiao *et al*., [36]).

Antibiosis seems to be the most noticeable category of resistance. Whitefly mortality on resistant plants could be caused by starvation resulting from chemical compounds such as secondary metabolites. Such a resistance mechanism to different kinds of phloem feeding/piercing insects has been reported in tomato, cotton and cassava (Bellotti and Arias [4]; Jindal *et al.*, [38]). Other plant secondary metabolites such as methyl-ketones and derivates of sesquiterpene carboxylic acid could have negative effects on population development of insects (Williams *et al*., [77]: Eigenbrode *et al*., [23]. These compounds could be present in the leaf mesophyll or they can be released as volatiles that could play a role as an repellent or antibiotic substance to herbivores (Antonious and Kochhar [1]; Chermenskaya *et al*., [18]). Repellent volatiles from host plants can substantially affect *B. tabaci* host choice and fitness (Bleeker *et al*., [8], [6], [7]: Shi *et al*., [67]: Chen *et al*., [17]). *Solanum habrochaites* strains (LA1777, PI134417) contain volatile organic compounds (Fridman *et al*., [30]) that have shown high levels of repellent and fumigant activity against adult whitefly (Muigai *et al.,* [50]). Resistant plants with trichomes producing the methyl ketone 2-undecanone, sesquiterpenes and acylsugars would impart stable resistance to *Bemisia argentifolii* (Mugai *et al.,* [50]). These expressions of resistance and their underlying chemical mediation are broad-based and should provide stable resistance. Thomas *et al*. [70] observed that, when the tryptophan decarboxylase (TDC) gene (isolated from *Cantharanthus roseus* (periwinkle) when expressed in transgenic tobacco, the 55-kD TDC enzyme and tryptamine accumulated had caused 97% reduction in *B. tabaci* reproduction. Production of tryptamine, its derivatives, or other products resulting from TDC activity may discourage whitefly reproduction (Thomas *et al*., [70]). Tomato-produced 7-epizingiberene and R-curcumene act as repellents to whiteflies (Bleeker *et al*., [8], [6] [7]. Shi *et al*., [67] found that the volatiles methyl salicylate and d-limonene from tomato repelled biotype Q. Similarly, the landrace genotypes of *Capsicum annuum* L Amaxito, Tabaquero, and Simojovel showed resistance to *B. tabaci* and observed more than 50% nymphal mortality, while in the commercial susceptible genotype Jalapeño mortality of *B. tabaci* nymphs was not higher than 20%. And also found that activity of chitinase enzyme generally was higher in non-infested plants with *B. tabaci* than those infested. Instead polyphenoloxidase (‘Amaxito’ and ‘Simojovel’) and peroxidase enzymes activities (‘Tabaquero’) increased in infested plants (Latournerie-Moreno *et al*., [41]).

In the present study, lower numbers of eggs were noticed on chillies accessions P2, P4, ACC1 and ACC12. The visual and olfactory cues (Prokopy and Owens [59]; Visser [75]) offer the directions for phytophagous insects to select their host plants. The ovipositional difference among the chillies accessions might be due to the morphological traits or the production of defense compounds in the leaves of such accessions. These traits are characterization of leaf surface, colour or odour that made the foliage less attraction to *B. tabaci*. (Walker and Perring, [76]). Gomez *et al*., [31] reported reduced number of *B. tabaci* eggs on chillies accessions.

As discussed previously the trichomes may play a major role in the ovipositional preference of whiteflies by Oriani *et al*., [55]. Further, the release of volatile compounds and defense against phytophagous insects may be another reason for reduced fecundity (Frantz *et al*., [29]; Kashiwagi *et al*., [39]). The number of eggs significantly varied among the chillies accessions. The lower eggs production received on ACC 12 (4.33 no/leaf) and ACC1 (4.67 no/ leaf) and the lower level of eggs hatchability found on ACC12 (76.92%). In a similar study Gomez *et al*., [31] had reported the lowest percentage of egg hatchability of *B. tabaci* on resistant chillies accessions. Another similar study reported that susceptible genotype showed 100.0% survival of nymphs, except for Sandy, with a 63.9% mortality rate during the young phase of whiteflies since sandy expressed high antibiosis levels against whitefly nymphs Baldin and Beneduzzi [2] in Squash *Cucurbita pepo* varieties.

Previous studies with other crops such as tomato (Oriani *et al*., [55]; Muigai *et al*., [51]; Fancelli *et al.*, [24]) cotton (Torres *et al*., [71]) and bean (Campos *et al*., [14]) had shown such differences in egg hatchability and (or) nymphal survival. Nombela *et al*., [53] and Rodriguez *et al*., [61] had found that oviposition of *B. tabaci* on tomato leaves was higher in those with higher sugar esters in the glandular exudates of type IV trichomes). In *Solanum pennellii*, acylsugars are major components of the exudates produced by glandular trichomes (Burke *et al.,* [11]; Fobes *et al*., [28]) and had shown to reduce oviposition of *B. tabaci* B biotype in a dosage-dependent approach (Liedl *et al.,* [42]).

The developmental time of insect pests may vary with the quality of the host plants and Coudriet *et al.* [20] had reported time difference to complete development by *B. tabaci*. The developmental period is much influenced by the plant texture, metabolites in the sap, plant nutrient status and plant volatiles (Nombela *et al*., [53]; Mansaray and Sundufu [43]; Pontes *et al*., [58]). Thus a shorter developmental time of *B. tabaci* and coupled with high survivorship of immatures may cause population to build-up faster to a threatening level (Mansaray and Sundufu [43]) in *B. tabaci.*

Population build-up gives a cumulative antibiosis effect of specific chilli accession. In the present study, the population build-up of *B. tabaci* on different chilli accessions was significantly different with each other. The accessions *viz.*, ACC1, ACC 12, P2 and P4 had recorded a lower progeny production and a prolonged nymphal prereproductive period (Table 6). Similarly, Jindal and Dhaliwal [37] registered that, when F2 generation whiteflies were released on test accessions such as LD694 recorded the significantly lowest ($0.28/cm^2$) number of eggs, which indicated it was least preferred for egg laying, followed by PA183 and LK861 in cotton.

According to Munthali [32], among several biological characteristics, the duration of development of an insect is most useful to categorize accessions as resistant and susceptible. Among the chillies accessions test of ACC 10, P5 and ACC 26 had high population build-up with a lower nymphal prereproductive period (Table 6) and are thus tend to be susceptible. The mean prereproductive period (d) for F_2 production was significantly longer on accessions ACC1, ACC 12, P2 and P4 when compared to susceptible accessions ACC 10 (12.67d) and P3 (13d). this difference in the developmental period may be related to the different environmental conditions used. According to Van Lenteren and Noldus [73], a shorter development time on a plant reflects the susceptibility of the host to the whitefly. Increased nymphal periods of whiteflies on resistant than on susceptible accessions of tomatoes (Muigai *et al*., [50]) and cucumber, the longest and the total developmental time on resistant varieties of beans (Berlinger, [5]; Boica and Vendramim [9]) for *B. tabaci* were reported. Biology of *B. tabaci* biotype B on six genotypes of cowpea, Rodrigues *et al.*, [61] found that the periods of development from egg to adult vary between 17.3 and 23.6 days. Similarly, varietal preference of *B. tabaci* in eight varieties of Squash *Cucurbita pepo* were studied, the variety Sandy (25.1days) showed the highest mean for total development period (egg-to-adult) of *B. tabaci* B biotype, followed by AF-2858 (20.2days). Fekri *et al.*, [26] appraised that egg-adult cycle of *B. tabaci* varied from 26.02 days (Ergon) to 26.66 days (CAL-JN3) on tomato. Zang *et al.*, [78] noticed that a *Bemisia argentifolii* B biotype culture maintained on cotton for 17 or 18 generations had a higher level of survival on cotton. Morillo and Marcano [48] also recorded differences in egg and nymphal periods and total life cycle of whiteflies on resistant and susceptible tomato accessions. Jindal and Dhaliwal [37] explained that LD694 was rated as resistant; LK861, Supriya, RS2013, CNH911 and PA183 as moderately resistant; IS-376/4/1/20/72, NHH44, TxMaroon2-78, Bt 6304 and RS2098 as moderately susceptible; and F846 as susceptible. LD694 was found to be resistant in three consecutive (F1, F2 & F3) generations of whitefly in cotton genotypes. In conclusion, we have identified chillies accessions that differ in whitefly resistance and preference.

5. Conclusion
Whitefly resistance and preference seem to be present in the accessions evaluated and the results revealed that the accession P2, P4, ACC1 and ACC12 has displayed strong antixenotic and antibiotic effect against whitefly, *Bemisia tabaci.*

6. Future perspectives
Whitefly resistance and preference seem to be present in the accessions evaluated, and this offers opportunities for doing genetic studies and breeding whitefly-resistant varieties.

7. Acknowledgements
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Table 1. Field screening of chillies accessions against whitefly *Bemisia tabaci*

Accessions	Whitefly count per trifoliate leaf*	Accessions	Whitefly count per trifoliate leaf*
P1	0.68 (1.09)[mno]	ACC14	0.40 (0.95) [efghij]
P2	0.12 (0.78)[a]	ACC15	0.43 (0.96)[fghijn]
P3	0.68 (1.09)[mno]	ACC16	0.32 (0.90)[bcdfg]
P4	0.23 (0.85)[abcd]	ACC17	0.52 (1.01) [hijkl]
P5	0.75 (1.12)[no]	ACC18	0.36 (0.93)[dfghi]
P6	0.38 (0.94)[efgh]	ACC19	0.53 (1.01)[ijklm]
P7	0.52 (1.01)[hijkl]	ACC20	0.45 (0.97)[fghijk]
P8	0.45 (0.97)[fghijk]	ACC21	0.41 (0.95) [efghij]
P9	0.42 (0.96)[fghij]	ACC22	0.50 (1.00) [hijkl]
P10	0.45 (0.97)[fghijk]	ACC23	0.37 (0.93) [cdefgh]
ACC01	0.22 (0.85)[abc]	ACC24	0.39 (0.94)[efghij]
ACC02	0.45 (0.97) [fghijk]	ACC25	0.60 (1.05)[klm]
ACC03	0.48 (0.99)[hikl]	ACC26	0.83 (1.15)[o]
ACC04	0.38 (0.94)[efghij]	ACC27	0.80 (1.14)[o]
ACC05	0.26 (0.87)[bcde]	ACC28	0.45 (0.97)[fghijk]
ACC06	0.43 (0.96)[fghij]	ACC29	0.30 (0.89)[bcdefg]
ACC07	0.53 (1.01)[jklm]	ACC30	0.47 (0.98)[fghijkl]
ACC08	0.60 (1.05)[klmn]	ACC31	0.38 (0.94)[efghij]
ACC09	0.52 (1.01)[hijkl]	ACC32	0.42 (0.96)[fghij]
ACC10	0.62 (1.06)[lmn]	ACC33	0.50 (1.00)[hijkl]
ACC11	0.40 (0.95)[efghij]	ACC34	0.42 (0.96)[fghij]
ACC12	0.20 (0.84)[ab]	ACC35	0.46 (0.98)[ghijkl]
ACC13	0.38 (0.94)[efghij]	SEd	0.0419
		CD(.05)	0.0845

Mean of two replications per trifoliate leaf *
The mean values were separated using Duncan's Multiple Range Test (DMRT) (Duncan, 1951) (P=0.05).
Values in parantheses are square root transformed.

Table 2: Non-preference for whitefly *Bemisia tabaci* adult settling among different chillies *Capsicum* spp accessions

	Settling response of whitefly*					Total number settled
Accessions	4 HAR	8 HAR	12 HAR	24 HAR	48 HAR	
P1	2.00 (1.58)[c]	3.00 (1.87)[d]	3.00 (1.87)[d]	1.00 (1.22)[b]	0.00 (0.71)[a]	9.00 (3.08)[c]
P2	1.00 (1.22)[b]	0.00 (0.71)[a]	0.00 (0.71)[a]	1.00 (1.22)[b]	5.00 (2.35)[e]	7.00 (2.74)[b]
P3	2.00 (1.58)[c]	3.00 (1.87)[d]	4.00n (2.12)[e]	1.00 (1.22)[b]	0.00 (0.71)[a]	10.00 (3.24)[d]
P4	1.00 (1.58)[b]	0.00 (0.71)[a]	1.00 (1.22)[b]	0.00 (0.71)[a]	4.00 (2.12)[d]	6.00 (2.55)[a]

P5	7.00 (2.74)^{g}	2.00 (1.58)^{c}	1.00 (1.22)^{b}	0.00 (0.71)^{a}	0.00 (0.71)^{a}	10.00 (3.24)^{d}
ACC 1	0.00 (0.71)^{a}	1.00 (1.22)^{b}	4.00 (2.12)^{e}	2.00 (1.58)^{c}	2.00 (1.58)^{c}	9.00 (3.08)^{c}
ACC 10	6.00 (2.55)^{f}	2.00 (1.58)^{c}	2.00 (1.58)^{c}	1.00 (1.22)^{b}	0.00 (0.71)^{a}	11.00 (3.39)^{e}
ACC 12	0.00 (1.87)^{a}	0.00 (0.71)^{a}	1.00 (1.22)^{b}	3.00 (1.58)^{d}	2.00 (1.58)^{c}	6.00 (2.55)^{a}
ACC 26	4.00 (2.12)^{d}	3.00 (1.87)^{d}	2.00 (1.58)^{c}	2.00 (1.58)^{c}	1.00 (1.22)^{b}	12.00 (3.54)^{f}
ACC 27	5.00 (2.35)^{e}	4.00 (2.12)^{e}	1.00 (1.22)^{b}	1.00 (1.22)^{b}	0.00 (0.71)^{a}	11.00 (3.39)^{e}
SEd	0.0161	0.0126	0.0111	0.0083	0.0113	0.0380
CD(.05)	0.0335	0.0262	0.0231	0.0173	0.0235	0.0793

* Mean of three replications, HAR - hours after release
The mean values were separated using Duncan's Multiple Range Test (DMRT) (Duncan, 1951). (*P*=0.05).
Values in parantheses are square root transformed

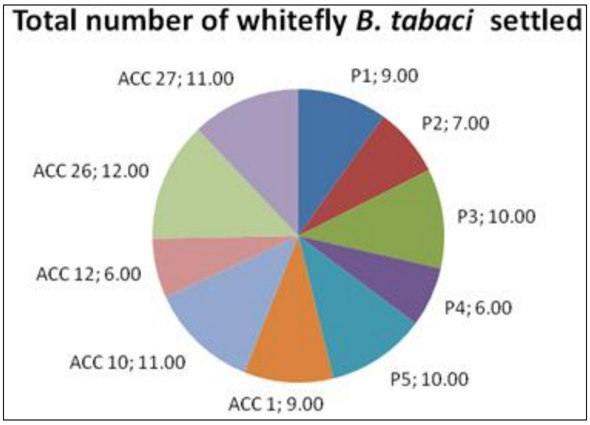

Fig 1: Non-preference for whitefly *Bemisia tabaci* adult settling among different chillies *Capsicum* spp accessions
Mean of three replications
The mean values were separated using Duncan's Multiple Range Test (DMRT) (Duncan, 1951). (*P*=0.05).
Values in parantheses are square root transformed

Table 3: Number of eggs laid by whitefly *Bemisia tabaci* on different chillies *Capsicum* spp accessions under greenhouse condition.

Number of eggs/leaf*					Average
Accessions	**3 DAR**	**5 DAR**	**8 DAR**	**12 DAR**	
P1	5.70 (2.49)^{e}	6.00 (2.55)^{d}	6.70 (2.68)^{d}	6.90 (2.72)^{c}	6.33
P2	3.00 (1.87)^{a}	4.10 (2.14)^{a}	5.50 (2.45)^{ab}	5.70 (2.49)^{ab}	4.58
P3	5.00 (2.35)^{d}	5.80 (2.51)^{c}	6.00 (2.55)^{c}	6.80 (2.70)^{c}	5.90
P4	3.30 (1.95)^{c}	4.40 (2.21)^{b}	5.80 (2.51)^{bc}	5.90 (2.53)^{b}	4.85
P5	7.80 (2.88)^{h}	7.80 (2.88)^{e}	8.30 (2.97)^{e}	9.70 (3.19)^{e}	8.40
ACC1	3.33 (1.96)^{c}	4.42 (2.22)^{b}	5.70 (2.49)^{abc}	5.80 (2.51)^{ab}	4.81
ACC10	7.70 (2.86)^{gh}	8.70 (3.03)^{g}	9.70 (3.19)^{g}	10.80 (3.36)^{f}	9.23
ACC 12	3.10 (1.90)^{ab}	4.20 (2.17)^{a}	5.40 (2.43)^{a}	5.50 (2.45)^{a}	4.55
ACC 26	7.40 (2.81)^{fg}	7.70 (2.86)^{e}	8.80 (3.05)^{f}	9.90 (3.22)^{e}	8.45
ACC 27	7.10 (2.76)^{f}	8.00 (2.92)^{f}	8.50 (3.00)^{ef}	8.80 (3.05)^{d}	8.10
SEd	0.0302				
CD(0.05)	0.0631				

* Mean of three replications, DAR – days after adult release
The mean values were separated using Duncan's Multiple Range Test (DMRT) (Duncan, 1951). (*P*=0.05).
Values in parantheses are square root transformed

Table 4: Per cent hatchability of nymphs of whitefly *Bemisia tabaci* on different chillies *Capsicum* spp accessions

Per cent hatchability of nymphs/pair/leaf*			
Accessions	**No. of eggs laid/leaf**	**No of nymphs emerged/leaf**	**Per cent hatchability**
P1	6.33 (2.61)^{e}	5.67 (2.48)^{d}	89.47 (71.08)^{d}
P2	5.00 (2.35)^{c}	4.00 (2.12)^{b}	80.00 (63.46)^{ab}
P3	6.67 (2.68)^{f}	6.33 (2.61)^{e}	95.00 (77.36)^{e}
P4	5.33 (2.42)^{d}	4.33 (2.20)^{c}	81.25 (64.35)^{abc}
P5	7.67 (2.86)^{g}	7.33 (2.80)^{j}	95.65 (78.43)^{e}
ACC1	4.67 (2.27)^{b}	4.00 (2.12)^{b}	85.71 (67.80)^{bcd}
ACC10	8.00 (2.92)^{h}	7.67 (2.86)^{j}	95.83 (78.94)^{e}
ACC 12	4.33 (2.20)^{a}	3.33 (1.96)^{a}	76.92 (61.33)^{a}
ACC 26	7.67 (2.86)^{g}	7.33 (2.80)^{j}	95.65 (78.43)^{e}
ACC 27	8.00 (2.92)^{h}	7.00 (2.74)^{f}	87.50 (69.35)^{cd}
SEd	0.0247	0.0271	2.4244
CD (0.05)	0.0515	0.0565	5.0572

* Mean of three replications
The mean values were separated using Duncan's Multiple Range Test (DMRT) (Duncan, 1951). (*P*=0.05).
Values in parantheses are square root transformed

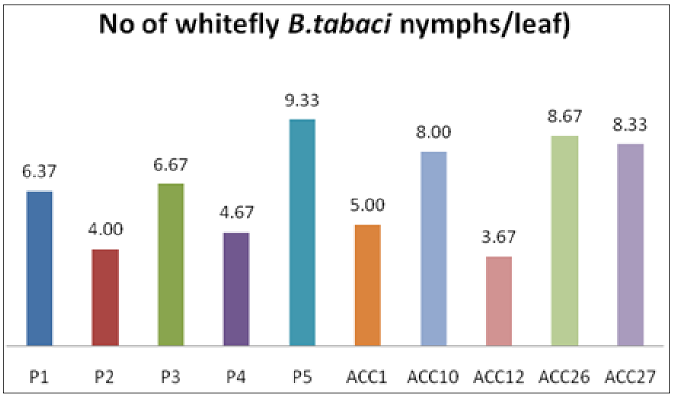

Fig 2: Number of nymphs of whitefly *Bemisia tabaci* developed on seedlings of chillies *Capsicum* spp accessions

* Mean of five replications
The mean values were separated using Duncan's Multiple Range Test (DMRT) (Duncan, 1951) (*P*=0.05), Values in parantheses are square root transformed

Table 5: Number of nymphs of whitefly *Bemisia tabaci* developed on seedlings of chillies *Capsicum* spp accessions

Accessions	No. of nymphs/leaf)*
P1	6.37 (2.62)^{e}
P2	4.00 (2.12)^{b}
P3	6.67 (2.68)^{f}
P4	4.67 (2.27)^{c}
P5	9.33 (3.14)^{j}
ACC1	5.00 (2.35)^{d}
ACC10	8.00 (2.92)^{g}
ACC 12	3.67 (2.04)^{a}
ACC 26	8.67 (3.03)^{i}
ACC 27	8.33 (2.97)^{h}
SEd	0.0113
CD(0.05)	0.0228

* Mean of five replications
The mean values were separated using Duncan's Multiple Range Test (DMRT) (Duncan, 1951). (*P*=0.05).
Values in parantheses are square root transformed

Table 6. Population build-up of whitefly *Bemisia tabaci* on chillies *Capsicum* spp accessions under greenhouse condition

Population build-up/ pair/leaf*						
F1		F2				
Accessions	**No of adult emerged**	**No of adult emerged**	**No of eggs**	**No of nymphs emerged**	**No of pupa**	**No of adult emerged**
P1	5.05 (2.36)^{d}	5.05 (2.36)^{d}	4.33 (2.20)^{d}	3.67 (2.04)^{c}	3.33 (1.96)^{c}	2.67 (1.78)^{d}
P2	2.33 (1.68)^{a}	2.33 (1.68)^{a}	2.00 (1.58)^{a}	1.67 (1.47)^{a}	1.00 (1.22)^{a}	0.67 (1.08)^{b}
P3	5.11 (2.37)^{d}	5.11 (2.37)^{d}	5.00 (2.35)^{e}	4.67 (2.27)^{d}	4.33 (2.20)^{d}	4.00 (2.12)^{e}
P4	2.99 (1.87)^{c}	2.99 (1.87)^{c}	2.67 (1.78)^{c}	2.33 (1.68)^{b}	1.67 (1.47)^{b}	1.00 (1.22)^{c}
P5	6.97 (2.73)^{ef}	6.97 (2.73)^{ef}	8.50 (3.00)^{g}	8.50 (3.00)^{f}	8.50 (3.00)^{g}	8.17 (2.94)^{h}
ACC1	2.60 (1.76)^{b}	2.60 (1.76)^{b}	2.33 (1.68)^{b}	1.67 (1.47)^{a}	1.00 (1.22)^{a}	0.67 (1.08)^{b}
ACC10	6.67 2.68)^{e}	6.67 (2.68)^{e}	8.27 (2.96)^{g}	8.27 (2.96)^{f}	8.27 (2.96)^{fg}	7.93 (2.90)^{g}
ACC 12	2.33 (1.68)^{a}	2.33 (1.68)^{a}	2.00 (1.58)^{a}	1.67 (1.47)^{a}	1.00 (1.22)^{a}	0.33 (0.91)^{a}
ACC 26	7.73 (2.87)^{g}	7.73 (2.87)^{g}	8.20 (2.95)^{g}	8.20 (2.95)^{f}	8.20 (2.95)^{f}	7.87 (2.89)^{g}
ACC 27	7.00 (2.74)^{f}	7.00 (2.74)^{f}	7.33 (2.80)^{f}	7.33 (2.80)^{e}	7.33 (2.80)^{e}	7.33 (2.80)^{f}
SEd	0.0286	0.0286	0.0318	0.0279	0.0231	0.0183
CD(0.05)	0.0597	0.0597	0.0663	0.0583	0.0483	0.0382

* Mean of ten replications
The mean values were separated using Duncan's Multiple Range Test (DMRT) (Duncan, 1951) (*P*=0.05).
Values in parantheses are square root transformed

Table 7: Mean of whitefly *Bemisia tabaci* F2 nymph prereproductive period (d) and No of progeny produced by P1 (F2) adults on chillies *Capsicum* spp accessions

Accessions	Mean ± SE F2 nymph prereproductive period (d)	Mean ± SE no. of progeny produced by P1(F2) adults/leaf*
P1	13.50±0.77^{cd}	1.78±0.02^{d}
P2	15.83±0.24^{a}	1.08±0.01^{b}
P3	13.00±0.55^{ade}	2.12±0.00^{e}
P4	15.33±0.40^{b}	1.22±0.01^{c}
P5	14.00±0.20^{cd}	2.94±0.02^{h}
ACC1	15.00±0.37^{c}	1.08±0.00^{b}
ACC10	12.67±0.49^{ae}	2.90±0.01^{g}
ACC 12	16.17±0.37^{ab}	0.91±0.00^{a}
ACC 26	14.17±0.49^{bd}	2.89±0.02^{g}
ACC 27	13.17±0.37^{ae}	2.80±0.01^{f}
SEd	0.0807	0.0183
CD(0.05)	0.1631	0.0382

* Mean of ten replications
The mean values were separated using Duncan's Multiple Range Test (DMRT) (Duncan, 1951). (*P*=0.05).
Values in parantheses are square root transformed

References

1. Antonious GF, Kochhar TS. Zingiberene and curcumene in wild tomato. Journal of Environmental Science and Health. 2003. 38:489-500.
2. Baldin ELL, Vendramim JD, Lourenção AL. Interaction between resistant tomato genotypes and plant extracts on *Bemisia tabaci* (Genn.) biotype B. Scientia Agricola. 2007; 64(5):476-481.
3. Bedford ID, Briddon W, Brown JK, Rosell RC, Markham PG. Geminivirus transmision and biological characterisation of *Bemisia tabaci* (Gennadius) biotypes from different geographic regions. Annals of Applied Biology. 1994; 125:311325.
4. Bellotti AC, Arias B. Host plant resistance to whiteflies

with emphasis on cassava as a case study. Crop Protection. 2001; 20:813-823.
5. Berlinger MJ. Host plant resistance to *Bemisia tabaci*. Agriculture, Ecosystems and Environment. 1986; 17:69-82.
6. Bleeker PM, Diergaarde PJ, Ament K, Schutz S, Johne B, Dijkink J *et al*. Tomato-produced 7-epizingiberene and R-curcumene act as repellents to whiteflies. Phytochemistry. 2011; 72:68-73.
7. Bleeker PM, Mirabella R, Diergaarde PJ, VanDoorn A, Tissier A, Kant MR *et al*. Improved herbivore resistance in cultivated tomato with the sesquiterpene biosynthetic pathway from a wild relative. PNAS. 2012; 109:20124-20129.
8. Bleeker PM, Diergaarde PJ, Ament K, Guerra J, Weidner M, Schutz S *et al*. The role of specific tomato volatiles in tomato-whitefly interaction. Plant Physiology. 2009; 151:925-935.
9. Boica AJ, Vendramim JD. Development of *Bemisia tabaci* (Gennadius,) (Homoptera, Aleyrodidae) in accessions of bean (*Phaseolus vulgaris* L.). Anais da Sociedade Entomolo´gica do Brasil. 1986; 15:231-238.
10. Boissot ND, Lafortune, Pavis C, Sauvion N. Field resistance to *Bemisia tabaci* in *Cucumis melo*. Hortscience. 2003; 38(1):77-80.
11. Burke BA, Goldsby G, Mudd JB. Polar epicuticular lipids of *Lycopersicon pennellii*. Phytochemistry. 1987; 26:2567-2571.
12. Butter NS, Vir BK. Morphological basis of resistance in cotton to the whitefly *Bemisia tabaci*. Phytoparasitica. 1989; 17(4):251-261.
13. Byrne DN, Bellows TS, Parrella MP. Whiteflies in agricultural systems. In Whiteflies: their Bionomics, Pest Status, and Management, ed. D Gerling, 1990, 227-261.
14. Campos OR, Crocomo WB, Labinas AM. Comparative biology of the whitefly *Trialeurodes vaporariorum* (West.) (Hemiptera-Homoptera: Aleyrodidae) on soybean and bean cultivars. Neotropical Entomology. 2003; 32:133-138.
15. Channarayappa C, Muniyappa V, Schweglerberry D, Shivashankar G. Ultrastructural changes in tomato infected with tomato leaf curl virus, a whitefly-transmitted Geminivirus. Canadian Journal of Botany. 1992; 70:1747-1753.
16. Chattopadhyay B, Singh AK, Yadav T, Fauquet CM, Sarin NB, Chakraborty S. Infectivity of the cloned components of a begomovirus: DNA beta complex causing chilli leaf curl disease in India. Archives of Virology. 2008; 153:533-539.
17. Chen G, Su Q, Shi X, Liu X, Peng Z, Zheng H, *et al*. Odor, not performance, dictates *Bemisia tabaci's* selection between healthy and virus infected plants. Front Physiology. 2017; 8:146.
18. Chermenskaya TD, Petrova MO, Savelieva EI. Laboratory and field evaluation of biological active substances of plant origin against greenhouse whitefly, *Trialeurodes vaporariorum* Westw. (Homoptera: Aleyrodidae). Archives Phytopathology Plant Protection. 2009; 42:864-873.
19. Chu CC, Natwick ET, Chen TY, Hennebury TJ. Analysis of cotton leaf characteristics affect on *Bemicia tabaci* (Homoptera: Aleyrodidae) biotype B colonization on cotton in Arizona and California. Southwestern Entomology. 2003; 28:235-240.
20. Coudriet DL, Prabhaker N, Kishaba AN, Meyerdirk DE. Variation in developmental rate on different hosts and overwintering of the sweet potato whitefly, *Bemisia tabaci* (Homoptera: Aleyrodidae). Environmental Entomology. 1985; 14:516-519.
21. Dey PK, Sarkar PK, Somchoudhury AK. Efficacy of different treatment schedules of profenofos against major pests of chilli. Pestology. 2001. 25(11):26-29.
22. Duncan DB. A significance test for differences between ranked treatment means in an analysis of variance. Va. J Sci. 1951; 2:171-189.
23. Eigenbrode SD, Trumble JT, Millar JG, White KK. Topical toxicity of tomato sesquiterpenes to the beet armyworm and the role of these compounds in resistance derived from an accession of *Lycopersicon hirsutum F. typicum*. Journal of Agricultural and Food Chemistry. 1994; 42:807-810.
24. Fancelli M, Vendramim JD, Lourenção AL, Dias CTS. Attractiveness and oviposition preference of *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae) biotype B in tomato accessions. Neotropical Entomology. 2003; 32:319-328.
25. Fancelli M, Vendramim JD, Friguetto RTS, Lourenção AL. Glandular exudate of tomato genotypes and development of *Bemisia tabaci* (Genn.) (Sternorryncha: Aleyrodidae) biotype B. Neotropical Entomology. 2005; 34:659-665.
26. Fekri MS, Samih MA, Imani S, Zarabi M. Study of host preference and the comparison of some biological characteristcs of *Bemisia tabaci* (genn) on tomato varieties. Journal of Plant Protection Research. 2013; 53(2):137-142.
27. Firdaus S, Van HA, Harpenas A, Supena JE, Visser R, Vosman B. Identification of silverleaf whitefly resistance in pepper. Plant Breeding. 2011; 130:708-714.
28. Fobes JF, Mudd J, Marsden M. Epicuticular lipid on the leaves of *L. pennellii* and *L. esculentum*. Plant Physiology. 1985. 77:567-570.
29. Frantz JD, Gardner J, Hoffmann MP, Jahn MM. Greenhouse screening of *Capsicum* accessions for resistance to green each aphid (*Myzus persicae*). Hort science. 2004; 39:1332-1335.
30. Fridman EJ, Wang Y, Iijima JE, Froehlich DR, Gang J Ohlrogge, Pichersky E. Metabolic, genomic, and biochemical analyses of glandular trichomes from the wild tomato species *Lycopersicon hirsutum* identify a key enzyme in the biosynthesis of methylketones. The Plant Cell. 2005; 17:1252-1267.
31. Gómez HB, Moreno LL, Sánchez ER, Gutiérrez AP, Gabriel RL. Morphological characterization of *Capsicum annuum* L. accessions from southern Mexico and their response to the Bemisia tabaci-Begomovirus complex. Chilean Journal of Agricultural Research. 2013, 73(4).
32. Gripenberg S, Mayhew PJ, Parnell M, Roslin T. A meta-analysis of preference performance relationship in phytophagous insects. Ecology Letters. 2010; 13:383-393.
33. Guo G, Jianchang Gao, Xiaoxuan Wang, Yanmei Guo, Snyder JC *et al*. Establishment of an in vitro method for evaluating whitefly resistance in tomato. Breeding Science. 2013. 63:239-245.
34. http://nhb.gov.in/area-pro/database-2015.
35. Jaenike J. Optional oviposition behavior in phytophagous insects. Theor Popul Biol. 1978; 14:350-356.
36. Jiao X, Wen X, Yang ZC, Wang B, Liu, Wang *et al*. Lack of correlation between host choice and feeding

efficiency for the B and Q putative species of *Bemisia tabaci* on four pepper genotypes. Journal of Pest Science. 2018; 91:133-143.

37. Jindal V, Dhaliwal GS. Elucidating resistance in cotton accessions to whitefly, *Bemisia tabaci*, by population build-up studies. Phytoparasitica. 2009; 37:137-145.
38. Jindal V, Dhaliwal GS, Dhawan AK. Mechanisms of resistance in cotton to whitefly *Bemisia tabaci* (Homoptera: Aleyrodidae): antibiosis. International Journal of Tropical Insect Science. 2008; 27:216-222.
39. Kashiwagi T, Mikagi E, Mekuria DB, Boru AD, Tebayashi S, Kim CS. Ovipositional deterrent on mature stage of sweet pepper, *Capsicum annuum*, against *Liriomyza trifolii* (Burgess) Z. Naturforsch. 2005; 60:739-742.
40. Kumar S, Sanjeet K, Major Singh, Ashok Kumar SB, Mathura R. Identification of host plant resistance to pepper leaf curl virus in chilli (*Capsicum* species)., Scientia Horticulturae. 2006; 110:359-361.
41. Latournerie ML, Ic-Caamal A, Ruiz-Sánchez E, Ballina-Gómez H, Islas-Flores I, Chan-Cupul *et al*. Survival of *Bemisia tabaci* and activity of plant defense-related enzymes in genotypes of Capsicum annuum L. Chilean Journal of Agricultural Research. 2015; 75(1):71-77.
42. Lied BE, Lawson DM, White KK, Shapiro JA, Cohen DE, Carson WC. Acylsugars of wild tomato *Lycopersicon pennellii* alters settling and reduces oviposition of *Bemisia argentifolii* (Homoptera, Aleyrodidae). Journal of Economic Entomology. 1995; 88:742-748.
43. Mansaray A, Sundufu AJ. Oviposition, development and survivorship of the sweet potato whitefly *Bemisia tabaci* on soybean, *Glycine max*, and the garden bean, *Phaseolus vulgaris.* Journal of Insect Science. 2009; 9:1-6.
44. McAuslane HJ. Influence of leaf pubescence on ovipositional preference of *Bemisia argentifolii* (Homoptera: Aleyrodidae) on soybean. Environmental Entomology. 1996; 25:834-841.
45. McCollum TG, Stoffella PJ, Powell CA, Cantliffe DJ, Hanif-KS. Effects of silverleaf whitefly feeding on tomato fruit ripening. Postharvest Biology and Technology. 2004; 31:183-190.
46. Morales FJ and Jones PG. The ecology and epidemiology of whitefly-transmitted viruses in Latin America. Virus Research. 2004. 100(1):57-65.
47. Morales FJ. Tropical whitefly IPM project. Advances in Virus Research. 2007; 69:249-311.
48. Morillo FE, Marcano RVB. Development of the whitefly on different genotypes of tomato. Agronomia Tropical Maracay. 1997; 47:271-286.
49. Moshe L, Michael F. Breeding for resistance to whitefly-transmitted geminiviruses. Annals of Applied Biology. 2002; 140:109-127.
50. Muigai SG, Schuster DJ, Synder JC, Scott JW, Bassett MJ, McAuslane HJ. Mechanisms of resistance in *Lycopersicon* germplasm to the whitefly *Bemisia argentifolii.* Phytoparasitica. 2002; 30:347-360.
51. Muigai SG, Bassett MJ, Schuster DJ, Scott JW. Greenhouse and field screening of wild *Lycopersicon* germplasm for resistance to the whitefly Bemisia argentifolii. Phytoparasitica. 2003; 31:1-12.
52. Munthali DC. Effect of cassava variety on the biology of *Bemisia afer* (Priesner and Hosny) (Hemiptera: Aleyrodidae). Insect Science and Its Application. 1992; 13:459-465.
53. Nombela G, Beitia F, Muñiz M. Variation in tomato host response to *Bemisia tabaci* (Hemiptera: Aleyrodidae) in relation to acyl sugar content and presence of the nematode and potato aphid resistance gene Mi. Bulletin of Entomological Research. 2000; 90:161-167
54. Nomikou M, Janssen A, Sabelis MW. Herbivore host plant selection: whitefly learns to avoid host plants that harbor predators of her offspring. Oecologia. 2003; 136:484-488.
55. Oriani MAG, Vendramim JD, Vasconcelos CJ. No-choice ovipositional non-preference of *Bemisia tabaci* (Gennadius) B biotype on tomato accessions. Sci. Agric. 2011; 68(2):147-153.
56. Painter RH. Insect resistance in crop plants. Mac-Millan, New York, 1951.
57. Pedigo LP. Entomology and pest management, 3rd ed. Prentice-Hall, Saddle River NJ, 1999.
58. Pontes WJT, Lima ER, Cunha EG, De Andrade PMT, Lobo AP. Physical and chemical cues affect oviposition by Neoleucinodes elegantalis. Physiological Entomology. 2010; 35:134-139.
59. Prokopy RJ, Owens ED. Visual detection of plants by herbivorous insects. Annual Review of Entomology. 1983; 28:337-364.
60. Rajput VS, Prajapati BG, Rebari GN, Choudhary Nirav. Screening of different genotypes against major insect pests of chilli (*Capsicum annum* L.) Journal of Entomology and Zoology Studies. 2017; 5(5):1552-1554.
61. Rodriguez LMJ, Garzo E, Bonani JP, Fereres A, Fernández MR, Moriones E. Whitefly resistance traits derived from the wild tomato *Solanum pimpinellifolium* affect the preference and feeding behavior of *Bemisia tabaci* and reduce the spread of Tomato yellow leaf curl virus. Phytopathology. 2011; 101:1191-1201.
62. Sagar Tamang, Venkatarao P, Gautam C. Varietal screening of mungbean cultivars for resistance/tolerance against insect pest under Terai Agro ecological zone of West Bengal. International Journal of Plant Protection. 2017; 10(1):7-13.
63. SAS Institute. SAS users guide: basics. SAS Institute, Cary, NC, 1985.
64. Senanayake DMJB, Mandal B, Lodha S, Varma A. First report of Chilli leaf curl virus affecting chilli in India. Plant Pathology, 2006, 56.
65. Schuster DJ, Mueller TF, Kring JB, Priece JF. Relationship of the sweetpotato whitefly to a new tomato fruit disorder in Florida. Hort Sci. 1990; 25:1618-20.
66. Sharma HC, Ortiz R. Host plant resistance to insects:an eco-friendly approach for pest management and environment conservation. Journal of Environmental Biology. 2002; 23:111-135.
67. Shi X, Chen G, Tian L, Peng Z, Xie W, Wu Q *et al*. The salicylic acid-mediated release of plant volatiles affects the host choice of *Bemisia tabaci*. International Journal of Molecular Sciences. 2016; 17:1048.
68. Sippell DW, Bindra OS, Khalifa H. Resistance to whitefly (*Bemisia tabaci*) in cotton (*Gossypium hirsutum*) in the Sudan. Crop Protection. 1987; 6:171-178.
69. Smith CM. Plant resistance to arthropods molecular and conventional approaches. Springer, Berlin, Germany, 2005.
70. Thomas JC, Deanna CA, Nessler C, Brown JK, Bohnert HJ. Tryptophan Decarboxylase, Reproduction of the Tryptamine, and Whitefly. Plant Physiology. 1995; 109(71):7-720.

71. Torres LC, Souza B, Amaral BB, Tanque RL. Biology and non-preference for oviposition by Bemisia tabaci (Gennadius) biotype B (Hemiptera: Aleyrodidae) on cotton cultivars. Neotropical Entomology. 2007; 36:445-453
72. Toscano LC, Boiça Júnior AL, Maruyama WI. Nonpreference of whitefly for oviposition in tomato genotypes. Scientia Agricola. 2001; 59:677-681.
73. Van Lenteren JC, Noldus LPPJ. Whitefly-plant relationships: behavioural and ecological aspects. In: D. Gerling (ed.), Whiteflies: Their Bionomics. Pest Status and Management. Intercept Ltd., Andover, 1990, 47-89.
74. Villalon B. Breeding peppers to resist virus diseases. Pl Dis. 1981; 65:557-561.
75. Visser JH. Host-plant finding by insects: orientation, sensory input and search patters. Journal of Insect Physiology. 1988; 34:259-268.
76. Walker GP, Perring TM. Feeding and oviposition behavior of whiteflies (Homoptera: Aleyrodidae) interpreted from AC electronic feeding monitor waveforms. Annals of the Entomological Society of America. 1994; 87:363-374.
77. Williams WG, Kennedy GG, Yamamoto RT, Thacker JD, Bordner J. 2-tridecanone naturally occurring insecticide from the wild tomato *Lycopersicon hirsutum f. glabratum.* Science. 1980; 207:888-889.
78. Zang LS, Chen WQ, Liu SS. Comparison of performance on different host plants between the B biotype and a non-B biotype of *Bemisia tabaci* from Zhejiang, China. Entomologia Experimentalis et Applicata. 2006; 121:221-227.