The Role of Leaf Characters of Peanuts on Whitefly *(Bemisia Tabaci* Genn.) Infestation

Peran Karakter Daun terhadap Infestasi Kutu Kebul pada Kacang Tanah

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NASKAH DITERIMA 2 DESEMBER 2020 ; DISETUJUI UNTUK DITERBITKAN 29 DESEMBER 2020

ABSTRAK

Kutu kebul *Bemisia tabaci* Genn. merupakan salah satu hama utama pada tanaman kacang tanah. Karakter morfologi tanaman merupakan pertahanan awal suatu tanaman dalam menghadapi serangan hama. Kesesuaian antara karakter morfologi daun dengan perilaku serangga hama menentukan peletakan telur oleh imago kutu kebul *B. tabaci*. Penelitian ini bertujuan untuk mengetahui karakter morfologi daun kacang tanah yang menentukan kepadatan populasi kutu kebul. Penelitian dilaksanakan di rumah kaca pada Balai Penelitian Tanaman Aneka Kacang dan Umbi (Balitkabi) mulai bulan Nopember 2019 hingga Februari 2020. Penelitian menggunakan 10 genotipe kacang tanah yang disusun berdasar rancangan acak kelompok (RAK) dan diulang tiga kali. Variabel pengamatan adalah karakter daun, tebal lapisan lilin, epidermis, mesofil, dan daun total, luas daun, kerapatan trikoma, panjang trikoma, jumlah vena, warna daun, kandungan klorofil, dan populasi imago pada 50, 60, dan 70 hari setelah tanam (HST). Hasil penelitian menunjukkan bahwa tebal mesofil daun, tebal daun total, jumlah vena, dan panjang trikoma berbeda nyata antargenotipe serta menunjukkan korelasi positif dengan populasi kutu kebul. Sebagian besar genotipe kacang tanah mempunyai warna daun kuning kehijauan dengan kode 2880 U, dengan kandungan klorofil a, klorofil b, dan karotenoid pada daun masing-masing antara 86,65 – 160,73 mg/m2, 64,43 – 99,70 mg/m2, dan 690,82 – 1290,65 mg/m2. Sidik Lintas menunjukkan bahwa tebal daun, tebal mesofil, dan panjang trikoma berpengaruh langsung pada populasi kutu kebul, sedangkan jumlah vena berpengaruh tidak langsung. Dengan demikian, daun yang tebal dengan mesofil tebal, memiliki lapisan lilin dan trikoma panjang serta jumlah vena rapat lebih disukai imago kutu kebul untuk meletakkan telur.

Kata kunci: *Arachis hypogaea* L., *Bemisia tabaci* Genn, karakter daun

ABSTRACT

Whitefly *Bemisia tabaci* Genn. is one of the major insect pests in peanut. Morphological characters of the plants are important as the initial plant defence against this insect pest attack. Compatibility between the plant morphology and insect behaviour would dictate the egg-laying process by adult whitefly. The objective of this study was to identify the morphological leaf characters of peanut genotypes, which would determine the whitefly population. The activity was done at Iletri's greenhouse from November 2019 to February 2020. The treatments were ten peanut genotypes, which were arranged in a randomized block design with three replicates. Leaf characters *i.e*. the thickness of wax surface, epidermis, mesophyll, and total leaf were observed. Other variables, such as leaf area, trichome density, trichome length, vein density, leaf color, and chlorophyll content, as well as whitefly population at 50, 60, 70 days after sowing (DAS) were also recorded. The results showed that the mesophyll and leaf thickness as well as the trichome length and vein density were significantly different among genotypes and those variables positively correlated with whitefly population. The dominant leaf colour was detected at 2880 U code, which referred to yellowish green color. The *a* chlorophyll, *b* chlorophyll, and carotenoid contents ranged from 86.65 to 160.73 mg/m2, 64.43 to 99.70 mg/m2, and 690.82 to 1290.65 mg/m2, respectively. Whitefly population was directly and strongly affected by the thickness of leaf and mesophyll, and trichome length, while it was indirectly affected by the vein numbers. Any peanut genotype with thick leaves, thick mesophyll, waxy surface, and long trichomes as well as dense veins were preferred by adult whitefly insect pests for laying their eggs.

Keywords: *Arachis hypogaea* L., *Bemisia tabaci* Genn, leaf characters

INTRODUCTION

Peanut production in Indonesia has not been sufficient to meet the national demand. A number of biotic and abiotic factors limit the pod yields. Foliar diseases *i.e* rust (caused by *Puccinia arachidis* Speg.) and late leaf spot (caused by *Cercospora arachidicola*), as well as bacterial wilt (caused by *Ralstonia solanacearum*) are the prevalent biotic

factor that seriously reduce pod yields. Recently, sucking pests and pod eater pests are becoming an important biotic limiting factor in peanuts (Al-Saleh *et al*. 2007; Branch and Brenneman 2015; Lassiter *et al*. 2016). Thrips is the main sucking-insect pest with huge yield reduction as a result of direct attack (sap sucking) and indirect attack through its role as vector of *Tomato Spotted Wilt Virus* (Al-Saleh *et al*. 2007; Branch and Brenneman 2015; Lassiter *et al.* 2016). Instead of thrips, root nematode is also important pest with serious pod yield reduction (Lassiter *et al*. 2016). Whitefly is known as vector of viral diseases in peanut plants. The presence of whitefly in peanut plants that resulted in a big yield loss was firstly recognized in India and Florida, USA in 1986 and 1987, respectively (Lynch and Simmons 1993; Perring *et al*.1993; McAuslane *et al*. 1995), and this insect pest seriously damage peanut crops (Hilje and Stanley 2008; Barbedo 2014). This huge loss of pod yield is the main reason for peanut breeders in Florida, USA to breed a new variety of peanut tolerant to whitefly (McAuslane *et al*. 1995). In recent 12 years, whitely is becoming an important insect pest for peanut crops in Indonesia because its attack resulted in big yield losses and gave the maximum pod yield of 0.75 t/ha (Kasno 2015).

Whitefly is an important pest for soybean in Indonesia and severe whitefly attack resulted in totally yield loss of soybean grains (Inayati dan Marwoto 2012). This huge yield loss of 85-100% also occurred for soybean in India (Marabi *et al*. 2017). *B. tabaci* is highly polyphagous insect pest as it is infesting various crops such as food crops (soybean, peanut), ornamental crops, vegetable crops (tomato, radish) and cotton.

Bemisia tabaci belongs to Ordo Hemiptera, Family Aleyrodidae. The life cycle of *B. tabaci* is started from eggs which then hatched and develop to nymphs. The nymphs grow and then develop to pupae that stay for some days before they turn to adult insect. The whitefly metamorphosis is ultimately affected by weather especially air temperature and relative humidity (Gerling 1990; Barbedo 2014). During development stages, whitefly actively feed the phloem saps of leaves and excrete a large amount of sugarly rich honeydew which is a complex mixture of sugars, organic acids, amino acids, and some lipids (Leroy *et al*. 2011).

As a sap sucking pest, whitefly imposes both direct and indirect damage of host plants by direct feeding as well as vector for a number of viruses (Hilje and Stansly 2008; Inbar and Gerling 2008; Wang *et al*. 2017). When the nymphs and adults whiteflies suck the phloem sap of leaves, it directly affects biochemical, physiological, and growth processes of host plants (Bacci *et al*. 2007; Hilje and Stanley 2008; McAuslane 2018), and excrete a large amount of honeydew which is an excellent medium for microbial growth. This organic compound also helps the development of sooty or black mold at the upper leaves surface thus reduces host plant photosynthesis (Mizaki *et al*. 2013; Tsueda *et al*. 2014).

There are three resistance mechanisms of plants to pest infestation: antixenosis, antibiosis, and tolerance. Antixenosis or non-preference has an effect on insect behaviour as it consists of physical barrier presence in host plants such as trichome density, leaf thickness and hardness, and thorn (Lopez-Castillo *et al*. 2018). Suitability between plant morphology and insect has effect on continuity of insect life (Khalil 2015; Cheng 2018).

The development of whitefly population in plants is determined by the compatibility between whitefly behaviour and the host plants. Whiteflies will choose a host plant for lying eggs, feeding, and developing life stages. The host selection is a critical phase for whiteflies. In general, the selection process of host plant consists of three steps which are a) selection before landing. In this initial step, whiteflies are guided by visible colour for choosing or determining the host plants as they are attracted in dark yellow/green colours. For this activity, *olfactory* and *gustatory* of whiteflies body play a role; b) selection after landing. This activity is done by using its stylet. The stylet will penetrate into the leaves through stomata, makes an intracellular movement in mesophyll tissues, which is causing plasmolysis of parenchyma cells, and it stops at the phloem tissues; and c) selection for feeding and laying eggs. In laying eggs, female whiteflies choose the young leaves, and eggs are dominantly laid onto the lower leaf surface. This is probably based on the differences in chemical content of the leaves (Painter, 1951; Gerling, 1990; Smith, 2005; Walker *et al*. 2010).

Once whiteflies infest the host plants, the plants make a respond by using their defence atributes either morphological atributes or chemical compounds. The morphological characters such as the colour, thickness, and hardness of leaves, waxy cuticle, the thickness of leaf epidermis cells, phloem tissue density, and leaf trichomes are the first direct defence system of plants and serves as repellent, insect trap, toxin, anti-feedant that affect insect biology (War *et al*. 2012; Wang *et al*. 2017). Leaf colour is one of plant components that crucial in atracting insect pests, and it should be used as the main selection criteria developing peanut leaf colour associated with egg-laying (Cheng *et al*. 2018).

The cuticle layer has a structure composed of covalently bonded macromolecules derived from chitin and various lipids called wax layers (Yeats and Rose 2013). Cuticle tissue is used as a defence tool of peanut plants from insect attack. Trichome which is derived from the elongated epidermal cell plays a role in plant resistance to insect pests. Trichome types are consisting of glandular and non-glandular shapes (Bickford, 2016). The objective of the research was to identify the morphological leaf characters of peanut genotypes determining the whitefly population.

MATERIALS AND METHODS

The experiment was conducted from November 2019 until January 2020 at a greenhouse of Indonesian Legumes and Tuber Crops Research Institute (Iletri) in Malang, East Java Province, Indonesia. A randomized block design with three replicates was applied, where ten peanut genotypes (Table 1) used as treatment.

Growing media for plants consisted of a mixture of soil and organic fertilizer with 6:1 ratio (v/v) and 7 kg of mixed soils was packed in a 25 × 30 cm polybag for each treatment. Two to three peanut seeds of each genotype were sown in a polybag and fifteen days later, thinned into one plant in each polybag. All 30 polybags (10 genotypes × 3 replicates) were placed in a (2 m × 2 m × 2 m) screen cage, where every 10 polybags (10 genotypes) were put in a group, so there were 3 groups which represented 3 replications.

Two months prior whiteflies infestation, it was reared on cotton plants in a screen cage (2 m × 2 m × 2 m) to obtain a similar age of *B. tabaci* imago with enough amounts of population of at least 1200 adults as a number of 40 adults whitefly would be infested in each polybag. New adult of *B. tabaci* from rearing then were infested to 45 days old peanut plants for four days according to method proposed by Vieira *et al*. (2011). The air temperature and relative humidity of greenhouse was maintained at around 30°C and 60%, respectively.

Table 1. List of peanut genotypes used in experiment. ILETRI greenhouse, growing season November 2019-January 2020

Code	Genotype	Type
G1	Tl/T3-12-C-174-85-30-20	Spanish
G2	GH5-116-21	Spanish
G3	Tk1/Mcn-12-C-2-11-146-231	Spanish
G4	Tk1/Mcn-12-C-2-5-140-163	Spanish
G5	Tasia 1 cultivar	Spanish
G6	Tasia 2 cultivar	Spanish
G7	Talam 1 cultivar	Spanish
G8	Takar 2 cultivar	Spanish
G9	Domba cultivar	Valencia
G10	Singa cultivar	Valencia

The observation at 40 - 45 DAS was done on leaf characters that consisted of leaf colour, chlorophyll content, leaf thickness, leaf hardness, trichome density, thrichome length, thrichome shape, vein number and leaf area. Whilst the number of eggs, nymphs, and pupae of *B. tabaci* were observed every 10 days interval starting at 50 up to 70 DAS. The observations were done at the oldest leaf in the main stem from four different plants for each treatment. Those observations used the binocular microscope.

Leaf colour was observed using a colour-chart method proposed by The Plus Series Pantone. The first tetrafoliate at the main stem that has been fully opened was used for that observation (Figure 1). The chlorophyll content was measured using a spectrophotometer following a method of Lichtenthaler (1987). The quantitative determination of chlorophyll (Chl) *a*, Chl *b*, and carotenoids in a whole pigment extract of green plant tissue was determined using spectrophotometer in 470 nm of wave length. Leaf thickness consists of wax surface, epidermis cell, and the mesophyll. Were measuremed from three leaves from every plants. Leaves samples were transversally cut by microtome then observed under binocular microscope. Leaf hardness was measured using a penetrometer. Samples were taken from the oldest tetrafoliate on the lowest part of the main stem with three leaves from every plant. Samples for trichome observation had the similar criteria with leaf hardness. Number of trichomes was observed on certain area under binocular microscope as well as its shape and length. Trichome shape was grouped into glandular and non-glandular. Number of secondary veins and their distances were observed from the lower leaf surface. Leaf samples were taken from fully opened tetrafoliate in the top, middle, and buttom of the main stem. Every sample was photographed using a camera then the leaf area was observed using software ImageJ.

Statistical analyses were carried out using SAS® software developed by SAS Institute. The data were subjected to analysis of variance (ANOVA) to test the significance (at $P < 0.05$) of observed parameters among peanut genotypes. The means were compared using the Least Significant Difference Test (LSD). Morphological leaf characters were compared across genotypes and correlations

Figure 1. Leaf peanut position use for sample observation (source: personal photo).

were used to identify a possible relation between whitefly population and leaf characteristics of different genotypes. Path analysis was used to identify direct and indirect effects between whitefly population and leaf characters of different genotypes.

RESULTS AND DISCUSSION

Whitefly population on peanuts

Whitefly population consisted of eggs, nymphs, and pupaes were found at a leaf, and fluctuated the population densities among peanut genotypes (Table 2). First observation showed that there was no significant different on population of whitefly between genotypes, but the population increased at the second and third observation. At 60 DAS, the highest population was showed at G9 (34.33 insects/tetrafoliate), while the lowest was found at G6 (8.89 insects/tetrafoliate) and G7 (8.44 insects/tetrafoliate). At 70 DAS, whitefly population in genotypes G8, G9, and G10 increased rapidly, while G7 showed consistently lowest population in all observation date.

There were differences in population pattern among genotypes. Six genotypes (G1, G3, G4, G7, G9 and G10) showed an increasingly whitefly population in line with plant age. Otherwise, whitefly population on G8, G9, and G10 genotypes started to increase at 70 DAS. The other four genotypes (G2, G5, G6 and G8) showed reducing population at 60 DAS, but it was increased at 70 DAS. Only G3 had relatively steady population from 50 until 70 DAS. Whitefly infestation caused abnormal leaf growth such as curly and necrotics, and also produced honeydew covering the upper leaf surface. That influenced photosynthesis process on peanut.

Table 2. Number of eggs, nymphs, and pupaes at 50, 60, and 70 DAS of infested peanut genotypes. ILETRI greenhouse, November 2019-January 2020

Code	Genotype	Population		
		50 DAS	60 DAS	70 DAS
G1	Tl/T3-12-C-174-85-30-20	10.67	14.45	30.78 c
G2	GH5-116-21	12.78	10.55	21.82 c
G3	Tk1/Mcn-12-C-2-11-146-231	13.44	13.99	14.09 c
G4	Tk1/Mcn-12-C-2-5-140-163	7.33	9.99	13.90 c
G5	Tasia 1 cultivar	10.34	10.22	17.03 c
G6	Tasia 2 cultivar	12.66	8.89	15.95 c
G7	Talam 1 cultivar	4.67	8.44	12.32 c
G8	Takar 2 cultivar	29.33	25.78	143.97 a
G9	Domba cultivar	13.56	34.33	117.13 ab
G10	Singa cultivar	7.78	18.67	77.58 b
Average		12.26	15.53	46.46
Genotype effect		ns	ns	**
LSD		19.41	16.95	42.91
CV (%)		36.39	26.11	26.50

Note: number followed by different letters were significantly different significantly different st p=0.01; ns = no significant. LSD = Least Significant Different

Table 3. Chlorophyll a, chlorophyll b, and carotenoids contents on leaf of peanut genotypes. ILETRI greenhouse, November 2019-January 2020

Code	Genotype	Chlorophyll a (mg/m^2)	Chlorophyll b (mg/m^2)	Carotenoids (x+c)	Ratio (a+b)/(x+c)
G1	Tl/T3-12-C-174-85-30-20	10.46	7.26	61.79	0.29
G2	GH5-116-21	11.26	7.38	68.80	0.27
G3	Tk1/Mcn-12-C-2-11-146-231	10.25	6.44	60.09	0.28
G4	Tk1/Mcn-12-C-2-5-140-163	9.80	6.80	65.95	0.25
G5	Tasia 1 cultivar	9.48	8.24	65.95	0.27
G6	Tasia 2 cultivar	14.97	9.97	94.93	0.26
G7	Talam 1 cultivar	11.77	7.59	69.89	0.28
G8	Takar 2 cultivar	16.07	9.81	97.70	0.26
G9	Domba cultivar	11.03	7.31	64.98	0.28
G10	Singa cultivar	8.67	8.57	50.92	0.34

Table 4. The thickness of wax surface, epidermis, mesophyll, and leaf of peanut genotypes. ILETRI greenhouse growing season November 2019-January 2020

Code	Genotype	Thickness (μm)			
		Wax surface	Epidermis	Mesophyll	Leaf total
G1	Tl/T3-12-C-174-85-30-20	1.00	1.77	18.1 de	24.9 d
G2	GH5-116-21	1.00	1.98	21.3 a	29.0 a
G3	Tk1/Mcn-12-C-2-11-146-231	1.00	1.91	18.6 cde	25.7 d
G4	Tk1/Mcn-12-C-2-5-140-163	1.17	1.95	20.1 cd	28.3 abc
G5	Tasia 1 cultivar	1.00	1.86	18.0 de	25.4 d
G6	Tasia 2 cultivar	1.00	1.95	17.7e	26.1 cd
G7	Talam 1 cultivar	1.07	1.92	18.4 cde	26.7 bcd
G8	Takar 2 cultivar	1.00	1.99	19.2 bcde	28.2 abc
G9	Domba cultivar	1.09	1.75	20.8 ab	28.4 ab
G10	Singa cultivar	1.00	2.00	19.6 abcd	28.0 abc
Average		1.04	1.91	19.2	26.0
effect of genotype		ns	ns	**	**
LSD		-	-	1.73	2.20
CV (%)		7.99	8.45	6.21	5.60

Note: number followed by different letters were significantly different (p>0.05). **, ns = significantly different at p=0.01; ns = no significant. LSD = Least Significant Different

Leaf characters of peanut

Leaf colour was grouped base on *colour chart* from The Plus Series Pantone (Pantone.com. 2020). Nine genotypes showed similar colour with 2280 code in colour chart. This code represents yellowish green colour arranged from yellow 012 (39.40%), green (25.48%), black (10.12%), and trans-white colour (25.00%). Only one genotype, G9, showed different leaf colour, coded 2279, that arranged from yellow 012 (30.44%), green (19.68%), black (7.82%), and trans-white (42.06%). This genotype showed a lighter leaf colour than the other nine genotypes.

Chlorophyll consists of three different types namely chlorophyll a, chlorophyll b, and carotenoids. All genotypes variated on chlorophyll a, chlorophyll b, and carotenoid content. Chlorophyll a content varied from 8.67 to 16.07 mg/m^2, while chlorophyll b content varied from 6.44 to 9.81 mg/m^2, and carotenoids content was 50.92 to 69.89 mg/m^2 (Table 3). The chlorophyll content ratio of every genotype, which was the ratiobetween chlorophyll a and b, ranged from 0.019 to 0.025. The ratio of chlorophyll a and b to total carotenoids (a+b)/(x+c) is an indicator of the greenness of leaves. Normally the ratio value ranged between 4.2 and 5 in sun loving and sun-exposed plants, and between 5.5 and 7.0 in shade lovers and shade-exposed plants. Lower values are indicator of senescence, stressed, and damage of the plant and photosynthetic apparatus (Lichtenthaler and Buschmann 1987).

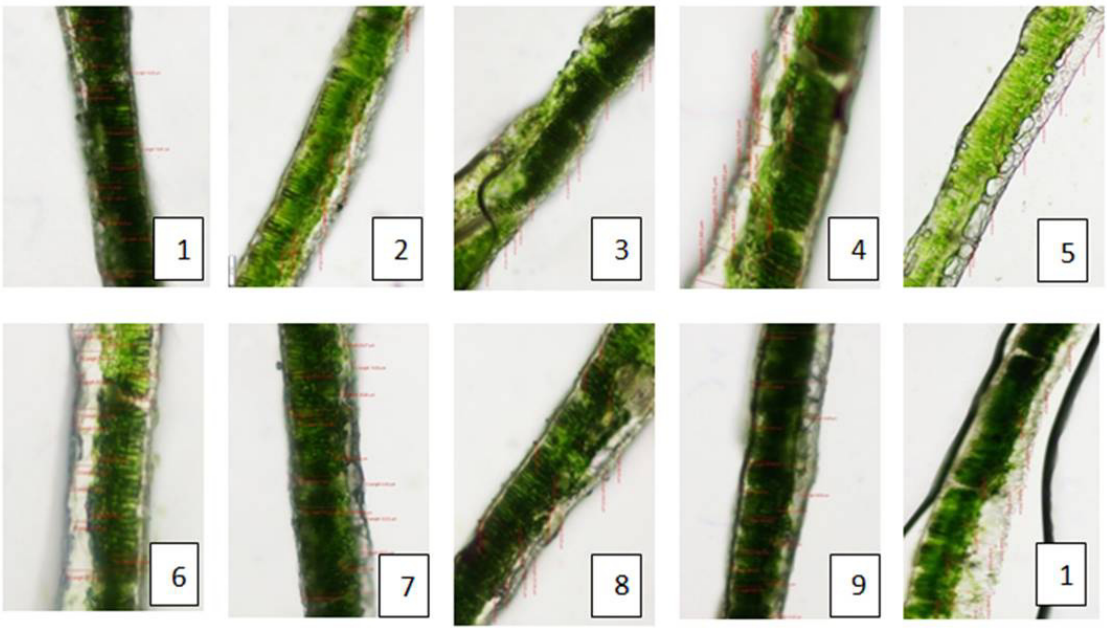

Figure 2. Transversal view of leaf anatomy of peanut genotypes

Peanut leaves consist of wax surface, epidermis surface, and mesophyll. There was no significant different on wax surface between genotypes tested, ranged 0.0100 to 0.0117 mm. Similar to wax surface, epidermis thickness was also not significantly different, ranged 0.0175 to 0.0200 mm (Table 4).

Mesophyll thickness was significantly different away genotypes and genotype G2 showed the thickest mesophyll, while G5 was the thinnest. Leaf thickness that arranged from wax surface, epidermis cell, and the mesophyll varied among genotypes. G2 had the thickest leaf followed by G8, G9, and G10. G1 showed the thinnest leaf followed by G3, and G5 (Table 4 and Figure 2).

There was no significant difference of leaf hardness among genotypes. The leaf hardness ranged between 0.14 and 0.19 Kgf. The hardest leaf was observed in genotype G4 (Table 5). The leaf hardness correlated with the number of guard cells (Table 8).

Trichome density did not affect whitefly population. Trichome density of peanut genotypes ranged from 1.33 to 4.00/square view. Similar to trichome density, trichome length showed none significantly difference between genotypes. Two genotypes, G2 and G7, showed shorter trichomes compared to the other genotypes, while G9 showed the longest trichome (Table 6). All genotypes had identical shape of trichome that was glandular (Figure 3).

Veins arrangement (venation) that consist of numbers of secondary vein and its distance varied among genotypes, but the significant different only showed on vein distance, which has tighter veins. Genotype G1 showed large vein space of 13.60 mm, followed by G7 (13.42 mm), while G2 and G9 showed narrower space vein of 8.47 mm and 7.75 mm respectively (Table 7).

Leaf area was significantly different among genotypes. Genotype G8 presented largest leaf area (13-40 cm^2), while G5 showed the narrowest leaf area. Beside of narrow leaf area, the genotypes of G1, G3, and G5 also had thin leaf.

Correlation between leaf characters and whitefly population

Leaves characters such as leaf thickness, wax surface, mesophyll thickness, and trichome length had positive correlation with whitefly population. Moreover, there was correlation between leaf anatomy and leaf morphology. For example, leaf thickness was positively correlated with mesophyll thickness (r = 0.695**) and with the vein number (r = 0.465**). Mesophyll thickness had positive correlation with vein number (r = 0.449*). Besides being positively correlated, some leaf characters also showed negative correlations. For example epidermal thickness was negatively correlated with vein number (r = -0,4*). Trichome number was negatively correlated with leaf area as well as trichome length with vein space (r = -0,369* and r = -0.378*). It means, whitefly prefer thicker leaf with thicker mesophyll and wax surface as well as longer trichome (Table 9). This finding confirmed to the work done by Khalil *et al.* (2017), that adult whitefly population positively correlated with hair density of leaf lamina

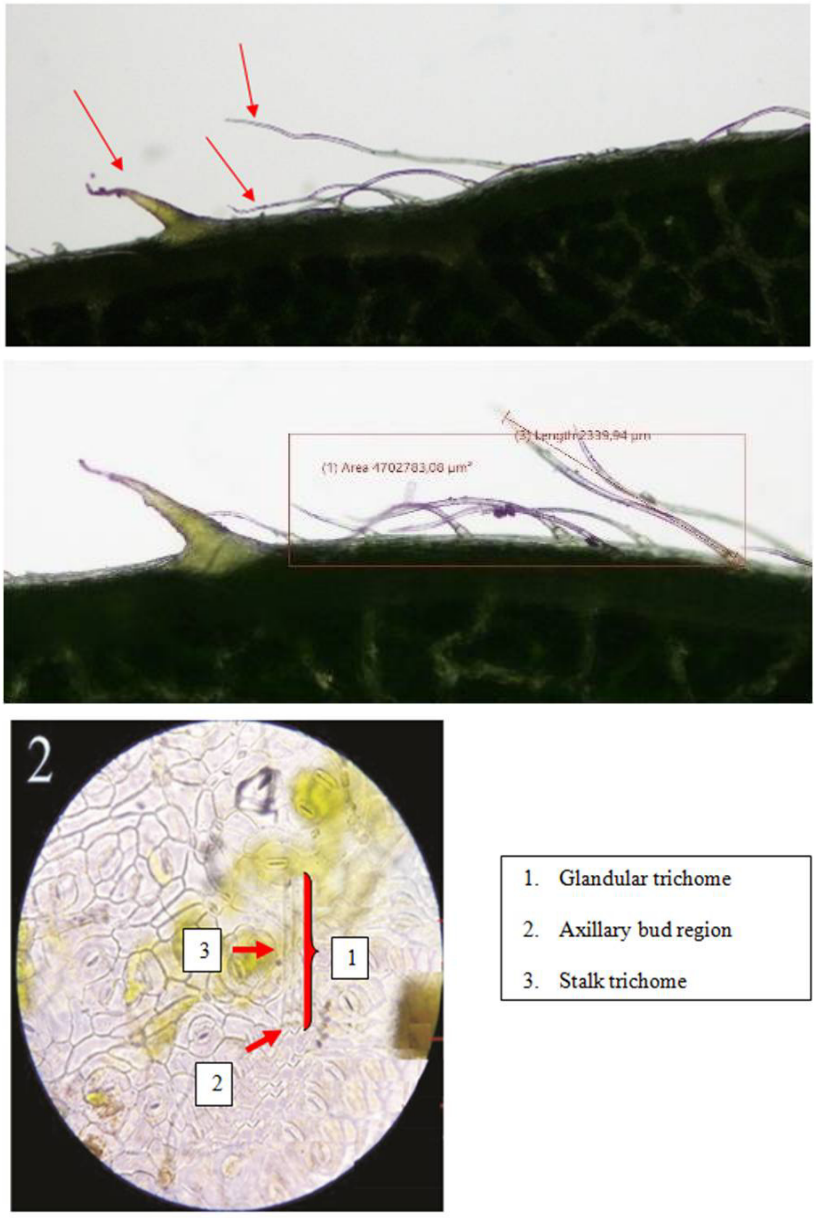

Figure 3. Trichome shape, trichome view area and stipitate trichome type

and vein. However, Zia *et al.* (2011) found that trichome length negatively correlated with whitefly population in midrib.

Path analysis was performed to find out the direct and indirect effect of leaf morphology and anatomy on whitefly population (Table 10). Leaf thickness, wax surface, mesophyll thickness, and trichome length showed high and positive direct effect, while vein number showed high but negative direct effect. According to Singh and Chaudary (1979), if the coefficient between x and y is almost as high as the direct effect, then the coefficient *t* was truly measures the correlation between x and y, therefore the selection base on x is precise. If the coefficient correlation between x and y is positive but the direct effect is negative, then the indirect effect is the cause of the correlation. In this case, leaf thickness, wax surface, mesophyll thickness, and trichome length have closely correlation with whitefly population and those four characters were recommended for forecasting the whitefly population determinant. However, vein number character could be ignored to whitefly population forecast because had negative direct effect.

Generally, genotypes that showed high whitefly population have a thick leaf and this character become plant defence tools against pest attack. In contrast, whitefly prefers a thick leaf. Khalil *et al.* (2017) reported that leaf thickness has positively correlated with nymph and adult thrips on cotton plants. Thick leaf is preferred because whiteflies are from Ordo Hemiptera that has stylet to suck phloem

Table 5. Leaf hardness of 10 peanut genotypes. ILETRI greenhouse, November 2019-January 2020

Code	Genotype	Leaf hardness(Kgf)	Code	Genotype	Leaf hardness(Kgf)
G1	Tl/T3-12-C-174-85-30-20	0.15	G6	Tasia 2 cultivar	0.15
G2	GH5-116-21	0.16	G7	Talam 1 cultivar	0.15
G3	Tk1/Mcn-12-C-2-11-146-231	0.14	G8	Takar 2 cultivar	0.17
G4	Tk1/Mcn-12-C-2-5-140-163	0.19	G9	Domba cultivar	0.15
G5	Tasia 1 cultivar	0.17	G10	Singa cultivar	0.16
Average		0.16^{tn}			
LSD 5%			-		
CV(%)		10.62			

Note: ns = no significant different. LSD = Least Significant Different

Table 6. Trichome density and shape of peanut genotypes. ILETRI greenhouse, November 2019-January 2020

Code	Genotype	Trichome density/view area	Trichome length (mm)	Trichome type
G1	Tl/T3-12-C-174-85-30-20	2.33	0.783	Glandular
G2	GH5-116-21	3.00	0.765	Glandular
G3	Tk1/Mcn-12-C-2-11-146-231	3.67	0.783	Glandular
G4	Tk1/Mcn-12-C-2-5-140-163	4.00	0.802	Glandular
G5	Tasia 1 cultivar	1.33	0.795	Glandular
G6	Tasia 2 cultivar	2.33	0.800	Glandular
G7	Talam 1 cultivar	2.33	0.761	Glandular
G8	Takar 2 cultivar	1.33	0.796	Glandular
G9	Domba cultivar	2.00	0.837	Glandular
G10	Singa cultivar	3.67	0.779	Glandular
Average		1.68	0.790	
CV (%)		30.71	5.709	

to get nutrition. After landing in leaf surface, stylet sucks epidermis tissue until reaches the phloem. During this process, whitefly stylet makes watery saliva that arranged from effectors consists of COO_2. Effectors were placed in mesophyll tissue, therefore thick mesophyll tissue has a lot of COO_2 that preferred by the whitefly. Watery saliva has a function to strengthen the stylet as well as for stylet protection (Hogenhout and Bos 2011). Mesophyll also important in photosynthesis process because has function as a diffusion site for CO_2 from substomatal organ to carboxylase in the chloroplast. Thicker mesophyll resulted in higher CO_2 diffusion compared to thin mesophyll that affecting the photosynthesis result and whitefly preferences.

Leaves also contain many guard cells that has dense citoplasm that are formed from abundant little vacuoles (Slewinski *et al*. 2013). In the thinner leaf, the vacuoles become denser that will form harder leaf because it contained sclerophyl, and it plays an important role in plant defence against herbivore by reducing leaf palatability and digestion therefore reducing the tissue damage (War *et al*. 2012).

Wax surface affected the whitefly population through decline the water loss on nonstomatal tissue, as a guard in transpiration process, and as a part to defence insect/pathogen attack (Guhling *et al*. 2005; •nidarèiè *et al.* 2008). Wax surface content was affected by plant species, ontogeny, and environmental growth condition. Wax surface contents were derivated from fatty acid, alkaline, aldehyde, alcohol, aceton and ester. In other species, wax surface derived from secondary metabolites *i.e.* pentasyclic titerpenoid, flavanoid, and tocopherol (•nidarèiè *et al*. 2008; Yeats dan Rose 2013). This present study showed that wax surface on leaf had positive correlation with trichome length therefore, it affected the whitefly population. Path analysis showed that direct effect from the wax surface was supported by indirect effect trichome length and the value is 0—393>0—255. Therefore, trichome length was dominantly affected the whitefly population. Longer trichome helps the adult whitefly to laying eggs. Longer trichomes also protect eggs from natural enemies attack and maintain the high temperature for eggs hatching. This condition is favourable for whitefly where longer trichome is preferred for laying eggs (Al Bitar *et al*. 2014;

Table 8. Vein distance, vein number and leaf area of 10 peanut genotypes. ILETRI greenhouse, November 2019-January 2020

Code	Genotype	Vein distance(mm)	Vein number	Leaf area (cm^2)
G1	TI/T3-12-C-174-85-30-20	13.62 a	16.67	6.39 g
G2	GH5-116-21	8.47 c	19.00	8.39 de
G3	Tk1/Mcn-12-C-2-11-146-231	12.22 ab	17.33	6.71 fg
G4	Tk1/Mcn-12-C-2-5-140-163	9.58 bc	19.67	7.53 ef
G5	Tasia 1 cultivar	10.55 abc	17.67	6.08 g
G6	Tasia 2 cultivar	8.86 bc	18.00	8.45 de
G7	Talam 1 cultivar	13.43 a	18.00	11.20 b
G8	Takar 2 cultivar	9.01 bc	18.67	13.40 a
G9	Domba cultivar	7.75 c	20.66	8.87 cd
G10	Singa cultivar	9.33 bc	17.00	9.66 c
Average		10.28	18.26	8.67
Effect of genotype		*	ns	**
LSD		3.722	-	0.96
CV (%)		9.66	9.65	12.56

Note: number followed by different letters were significantly different (p>0.05). *, **= significantly different at p=0.05; p=0.01; ns = no significant. LSD = Least Significant Different

Table 9. Correlation between leaf morphology characters of peanut genotypes with whitefly population. ILETRI greenhouse, November 2019-January 2020

Character	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	Y
X1	1.00	0.346	0.120	0.695**	-0.030	-0.100	-0.034	-0.305	0.465**	0.257	0.427*
X2		1.00	0.128	0.229	0.032	0.165	0.393*	-0.117	0.200	-0.026	0.18*
X3			1.00	-0.019	0.213	0.274	0.076	-0.183	-0.403*	-0.082	0.044
X4				1.00	0.151	0.139	0.096	-0.314	0.449*	-0.106	0.398*
X5					1.00	0.188	0.264	-0.220	0.103	-0.272	0.122
X6						1.00	0.092	0.035	-0.026	-0.369*	-0.185
X7							1.00	-0.378*	0.265	0.060	0.380*
X8								1.00	-0.332	0.91	-0.282
X9									1.00	0.169	0.198
X10										1.00	0.162
Y											1.00

Note: X1= leaf thickness, X2= wax surface, X3= epidermal thickness, X4= mesophyll thickness, X5=leaf hardness, X6=trichome number, X7=trichome length, X8=vein space, X9= vein number, X10=leaf area, Y= whitefly population, **= significant at 0.01 level, * = significant at 0.05 level.

Wagner dan Doak 2017). In otherwise, length trichome has negative correlation with light absorbance. The longer the trichome, the lower the light absorption and whitefly preferred to low light intensity (Bickford 2016). In addition, trichome length has negative correlation with vein number. It means narrow space vein then vein number is hight 20.66 (G9). The whitefly population on genotypes that had many veins also higher because veins were used to egg-laying.

Trichome length was negatively correlated with the vein number and vein space. Sharma and Singh, (2002) reported that trichome density has negative correlation with vein number and not correlated with leaf hopper eggs-laying. In this research, peanut genotypes showed narrow vein space and then the vein number was high. At peanut genotype that showed higher whitefly population, the vein numbers were higher too. This indicate that vein number was important for whitefly for laying eggs. The similar argument supported by Sharma and Singh (2002), that main vein number, lateral vein, and sub lateral vein have positive correlation with leaf hopper eggs-laying.

Longer trichome and narrow leaf also supported with the glandular type of trichome. Glandular type showed by trichome that growing at out epidermis tissue. This type consists of two or more cells and has variation in its shape and size. Glandular type trichome has three variations shape *i.e.* peltate,

Table 10. Path analysis direct and indirect effect of leaf morphology of leaf peanut and whitefly population. ILETRI greenhouse, November 2019-January 2020

Character	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	Y
X1	**0.215**	0.346	0.120	0.695	-0.030	-0.100	-0.034	-0.305	0.465	0.257	0.427*
X2	0.346	**0.255**	0.128	0.229	0.032	0.165	0.393	-0.117	0.200	-0.026	0.418*
X3	0.120	0.128	**-0.97**	-0.019	0.213	0.274	0.076	-0.183	-0.403	-0.082	0.044
X4	0.695	0.229	-0.019	**0.279**	0.151	0.139	0.096	-0.314	0.449	-0.106	0.398*
X5	-0.030	0.032	0.213	0.151	**0.105**	0.118	0.264	-0.220	0.103	-0.272	0.122
X6	-0.100	0.165	0.274	0.139	0.188	**-0.228**	0.092	0.035	-0.026	-0.369	-0.185
X7	-0.034	0.393	0.076	0.096	0.264	0.092	**0.296**	-0.378	0.265	0.060	0.380*
X8	-0.305	-0.117	-0.183	-0.314	-0.220	0.035	-0.378	**-0.068**	-0.32	0.091	-0.282
X9	0.465	0.200	-0.403	0.449	0.103	-0.026	0.265	-0.332	**-0.253**	0.169	0.198
X10	0.257	-0.026	-0.082	-0.106	-0.272	-0.369	0.060	0.091	0.169	**0.110**	0.162
Pye	V1-0.459 = V0.541 = 0.736										

Note: X1= leaf thickness, X2= wax surface, X3= epidermal thickness, X4= mesophyll, X5= leaf hardness, X6= trichome number, X7= trichome length, X8= vein space, X9= vein number, X10= leaf area, Y= whitefly population, **= significant at 0.01 level, * = significant at 0.05 level, Pye = external effect. Bold numbers showed direct effect and other side number showed indirect effect.

capitates, and patelliform. The peltate-type trichome possesses a stalk, which is usually formed by two cells, and a large multicellular secretary head. Capitates and stipitate type usually consists of stalk and head. The stalk usually consists of two cells, but a head usually consists of eight cells. In otherwise, trichomes were homogenous along and was axillaries bud at first cell (Froes *et al*. 2015). Stipitate type of trichome was found in all peanut genotypes (Figure 3). Glandular trichome consist of some metabolite compounds i.e. flavonoids, terpenoids, and alkaloids. It has functioning to insect poison, repellent or traps to another organism.

CONCLUSIONS

Whitefly prefers thick leaves, thick mesophyll, long trichome, and tight vein space to laying the eggs. This study provided important information about leaf characters for the future whitefly resistant breeding. Genotypes Tl/T3-12-C-174-85-30-20 (G1); Tk1/Mcn-12-C-2-11-146-231 (G3), Tasia 1 cultivar (G5) and Tasia 2 cultivar (G6) are merit to be used as parent materials in breeding for whitely resistant varities.

ACKNOWLEDGMENTS

The authors would like to acknowledge Indonesian Agency for Agricultural Research and Development for scholarship and research funding, and also to Indonesian Legumes and Tuber Crops Research Institute for all facilities in doing research. We would like to thanks to Dr. Agustina Asri Rahmianna for helping in translating the paper.

REFERENCES

Al Bitar, L., Gorb, S. N., Zebitz, C. P. W., and Voigt, D. 2014. Egg adhesion of the codling moth *Cydia pomonella* L. (Lepidoptera, Tortricidae) to various substrates: II. Fruit surfaces of different apple cultivars. Arthropod-Plant Interactions 8(1): 57–77.

APROSOJA (Associação dos Produtores de Soja e Milho do Mato Grosso). (2017). Mosca-branca causa perdas nas lavouras de soja no MT. Retrieved from http://ruralcentro.uol.com.br/noticias/mosca-brancacausa-perdas-nas-lavouras-de-soja-no-mt-84060

Bacci L., A.L. Crespo, T.L. Galvan, E.J. Pereira, M.C. Picanço, G.A. Silva, and M. Chediak. 2007. Toxicity of insecticides to the sweetpotato whitefly (Hemiptera: Aleyrodidae) and its natural enemies. Pest Manag. Sci. 63:699-706.

Barbedo, J. G. A. 2014. Using digital image processing for counting whiteflies on soybean leaves. Journal of Asia-Pacific Entomology 17(4): 685–694.

Bickford, C. P. 2016. Digital Kenyon: Research, Scholarship, and Creative Exchange Ecophysiology of leaf trichomes Ecophysiology of leaf trichomes Running title: Leaf trichome ecophysiology. Functional Plant Biology 43(9): 807–814.

Branch W.D and T.B. Brenneman. 2015. Stem Rot (White Mold) and *Tomato Spotted Wilt* Resistance among Peanut Genotypes. Peanut science Journal 42:18-22.

CABI and EPPO. 1998. *Cowpea mild mottle* 'carlavirus'. http://www.cowpeamildmottlevirus/cabi.com. Acessed 24 Mei 2011.

Cheng G.Xin, Ru-J Li, M. Wang, L.J. Huang, A. Khan, M. Ali, and Z.H. Gong. 2018. Variation in Leaf Color and Combine Effect of Pigments on Physiology and Resistance to Whitefly of Pepper (*Capsicum Annuum*

L.). Scientia Horticulturae 229: 215–25.

Froes , F. F. P. de C., Gama, T. do S. S., Feio, A. C., Demarco, D., and de Aguiar-Diass A. C. A. 2015. Structure and distribution of glandular trichomes in three species of Bignoniaceae . In Acta Amazonica Vol. 45: 347–354.

Gerling D. 1990. Whiteflies: their bionomics, pest status and management. Intercept Limited.

Guo-Xin Cheng, Ru-Jian Li, Min Wang, Liu-Jun Huang, Abid Khan, Muhammad Ali, and Zhen-Hui Gong. 2018. Variation in leaf color and combine effect of pigments on physiology and resistance to whitefly of pepper (Capsicum annuum L.). Scientia Horticulturae 229 : 215–225.

Guhling, O., Kinzler, C., Dreyer, M., Bringmann, G., and Jetter, R. 2005. Surface Composition of Myrmecophilic Plants: Cuticular Wax and Glandular Trichomes on Leaves of Macaranga tanarius. Journal of Chemical Ecology 31(10): 2323–2341.

Gulluoglu L, H. Arioglu, and C. Kurt. 2010. Field evaluation of soybean cultivars for resistance to whitefly (*Bemisia tabaci* Genn.) infestations. Afr. J. Agric. Res. 5 (7): 555-560.

Hilje L. and P. A. Stansly. 2008. Living ground covers for management of *Bemisia tabaci* (Gennadius)(Homoptera: Aleyrodidae) and *tomato yellow mottle virus* (ToYMoV) in Costa Rica. Crop Protec. 27:10-16.

Hilje L, F. and J. Morales. 2008. Whitefly bioecology and management in Latin America. In: Capinera J, editor. Encyclopedia of Entomology. Springer, New York.

Hoddle M. 2013. The biology and management of the silverleaf whitefly, *Bemisia argentifolii* Bellows and Perring (Homoptera: Aleyrodidae) on greenhouse grown ornamentals. http:www.biocontrol.ucr.edu/bemisia.html.

Hogenhout, S. A. and Bos, J. I. B. 2011. Effector proteins that modulate plant–insect interactions. Current Opinion in Plant Biology 14(4): 422–428.

Inayati, A. dan Marwoto. 2012. Combination of insectiside aplication and superior variety to whitefly attack and yield soybean. J. Pen. Pert. 31:13–21. [In Indonesian]

Inbar M. and D. Gerling. 2008. Plant-Mediated interactions between whiteflies, herbivores, and natural enemies. Ann. Rev. of Entomol. 53:431-448.

Kasno A, Suharsono, Trustinah. 2015. Response of groundnut genotypes to whitefly. Buletin Palawija 13 (1): 64-73 [in Indonesian]

Khalil H., A. B. M. Raza, M. Afzal, M. A. Aqueel, M. S.Khalil, and M. M. Mansoor. 2017. "Effects of Plant Morphology on the Incidence of Sucking Insect Pests Complex in Few Genotypes of Cotton." Journal of the Saudi Society of Agricultural Sciences 16 (4): 344–49.

Lassiter B.R., , D.L. Jordan, G.G. Wilkerson , B.B. Shew, and R.L. Brandenburg. 2016. Influence of Planting Pattern on Pest Management in Virginia Market Type Peanut (*Arachis hypogaea* L.). Peanut science Journal 43: 59-66.

Leroy PD, Wathelet B, Sabri A, Francis F, Verheggen FJ, Capella Q, Thonart P, Haubruge E. 2011. Aphis-host plant interactions: does aphid honeydew exactly reflect the host plant amino acid composition? Arthropod-Plant Interactions 5: 193-199.

Lichtenthaler, H. K., and Buschmann, C. 1987. Chlorophylls and carotenoids: measurement UNIT F4. 3 and characterization by UV-VIS spectroscopy. Curr. Protoc. Food Anal. Chem (4): 1–3.

López-Castillo, M. Laura, S. E. Silva-Fernández, R. Winkler, D. J. Bergvinson, J. T. Arnason, and S. García-Lara. 2018. Postharvest Insect Resistance in Maize. Journal of Stored Products Research 77: 66–76.

Lynch R.E., A.M Simmons. 1993. Distribution of Immatures and Monitoring of Adult Sweetpotato Whitefly, *Bemisia tabaci* (Gennadius) (Homoptera: Aleyrodidae), in Peanut, Arachis hypogaea. Environ. Entomol. 22:375-380.

Marabi RS, SB Das,AK Bowmick, R Pachori, Vibha dan HL Sharma. 2017. Seseonal Population Dynamics of Whitefly (*Bemisia tabaci* Gennadius) on Soybean. J of Entomolgy and Zoology Studies 5(2) : 169-173.

McAuslane H.J., D.A Knauft, dan F A Johnson. 1995. Evaluation of Peanut Breeding Lines for Resistance to Silverleaf whitefly (Homoptera: Aleyrodidae). The Florida Entomol. 78:75-81.

McAuslane H,J. and H.A Smith. 2018. Sweetpotato whitefly B Biotype *Bemisia tabaci* (Genadius) (Insecta:Hemiptera:Aleyrodidae). Univ. of Flourida. pp 8.

Mizaki, J., W.N Stiller, and L.J Wilson. 2013. Identification of host plant resistance to silverleaf whitefly in cotton: Implications for breeding. Field Crops Res. 154:145–152.

Mohammed A. Al-Saleh , Hassan A. Melouk, dan Phillip Mulder. 2007. Reaction of Peanut Cultivars to *Tomato Spotted Wilt Virus* (TSWV) Under Field Conditions and Their Response to Mechanical Inoculation by TSWV Under Greenhouse Conditions. Peanut science Journal 34:44-52.

Murgianto, F dan P.Hidayat. 2017. Whitefly Infestation and Economic Comparison of Two Different Pest Control Methods on Soybean Production. Planta Tropika 5 (2): 110-115.

Perring, T., A. D. Cooper, R. J. Rodriguez, C. A. Farrar, and T. S. Bellows JR. 1993. Identification of a whitefly species by genomic and behavioral studies. Science 259: 74-77.

Slewinski, T., Zhang, C., and Turgeon, R. 2013. Structural and functional heterogeneity in phloem loading and transport . In Frontiers in Plant Science (4): 244.

Tsueda, H., T. Tsuduki, and K. Tsuchida. 2014. Factors that affect the selection of tomato leaflets by two whiteflies, *Trialeurodes vaporariorum* and *Bemisia tabaci* (Homoptera: Aleyrodidae). Appl. Entom. and Zoo. 49(4):561–570.

Wagner, D. and Doak P. 2017. Oviposition, larval survival and leaf damage by the willow leaf blotch miner, Micrurapteryx salicifoliella, in relation to leaf trichomes across 10 Salix species. Ecological Entomology 42(5): 629–635.

Walker, G.P., T. M. Perring, T.P Freeman. 2010. Life History, Functional Anatomy, Feeding and Mating Behavior. P.A Stansly and S.E Naranjo (*eds*), Bemisia: Bionomics and Management a Global Pest. Springer Science+Business Media B.V.

Wang, X. Wei, P. Li, and S. S. Liu. 2017. Whitefly Interactions with Plants. Current Opinion in Insect Science 19: 70–75.

War, A. R., Paulraj, M. G., Ahmad, T., Buhroo, A. A., Hussain, B., Ignacimuthu, S., and Sharma, H. C. 2012. Mechanisms of plant defense against insect herbivores. Plant Signaling & Behavior 7(10): 1306–1320.

Yeats, T. H. and Rose, J. K. C. 2013. The Formation and Function of Plant Cuticles. Plant Physiology,163(1): 5 – 20.

• nidarèiè, D., Valiè, N. and Trdan, S. 2008. Epicuticular wax content in the leaves of cabbage (*Brassica oleracea* L. var. capitata) as a mechanical barrier against three insect pests. Acta Agric. Slov 91(2): 361–370.