

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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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 Brennenman 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 Brennenman 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, whitefly 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 Stanley 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 laying 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 attributes either morphological attributes 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 attracting 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.

The observation at 40 - 45 DAS was done on leaf characters that consisted of leaf colour, chlorophyll content, leaf thickness, leaf hardness, trichome density, trichome length, trichome 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 measured 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 bottom 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

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 |



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 pupae 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 pupae 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. ILETTRI 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. ILETTRI 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 varied on chlorophyll a, chlorophyll

b, and carotenoid content. Chlorophyll a content varied from 8.67 to 16.07 mg/m², while chlorophyll b content varied from 6.44 to 9.81 mg/m², and carotenoids content was 50.92 to 69.89 mg/m² (Table 3). The chlorophyll content ratio of every genotype, which was the ratio between 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).

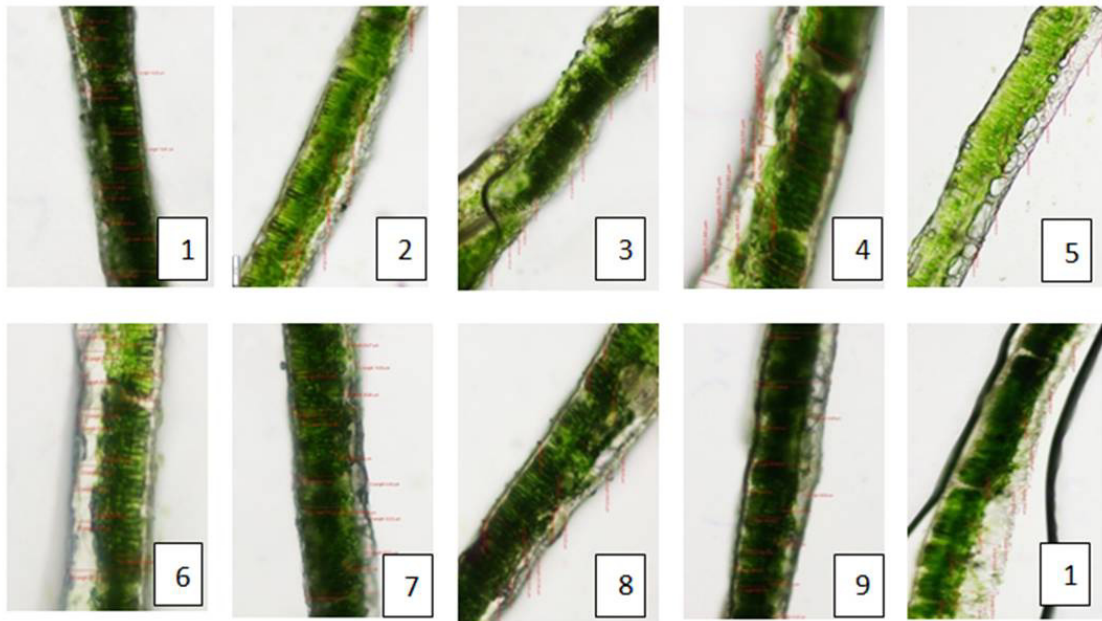


Figure 2. Transversal view of leaf anatomy of peanut genotypes

Peanut leaves consist of wax surface, epidermis surface, and mesophyll. There was no significant difference 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 among 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 cm²), 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

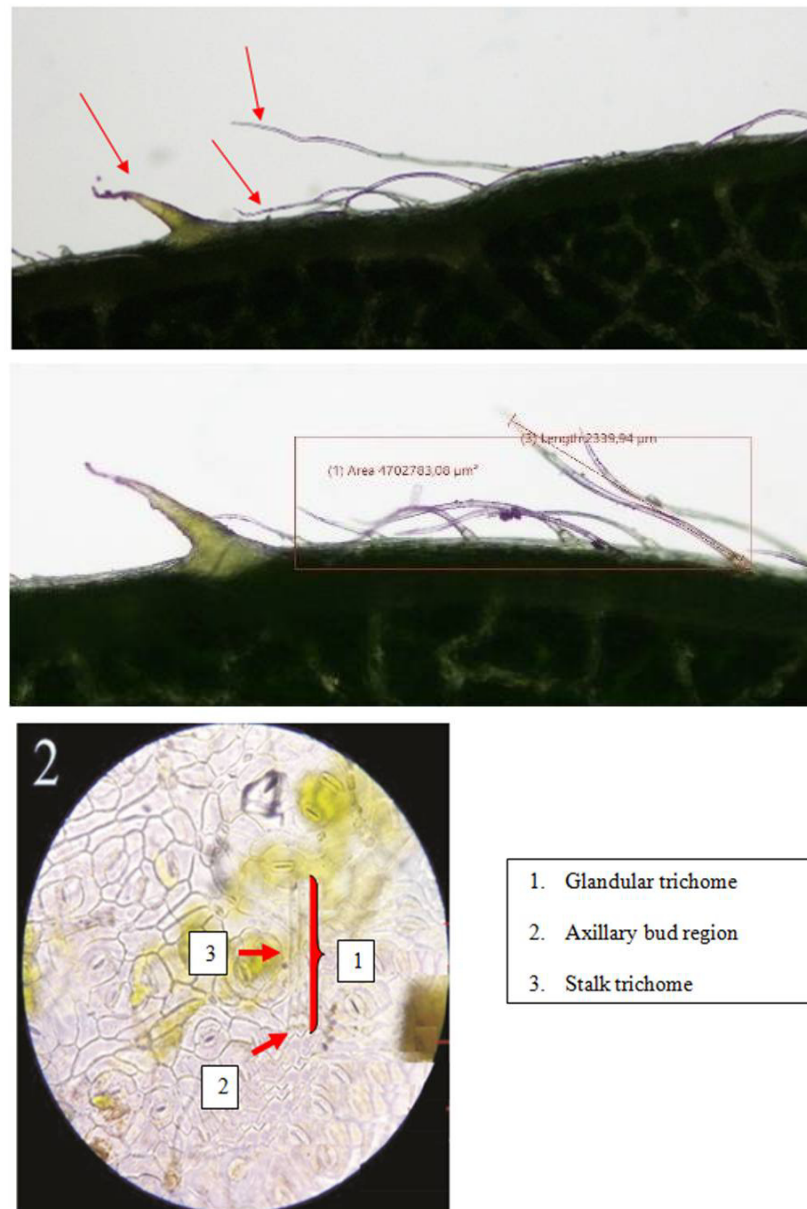


Figure 3. Trichome shape, trichome view area and stipitate trichome type

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 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 CO₂. Effectors were placed in mesophyll tissue, therefore thick mesophyll tissue has a lot of CO₂ 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 CO₂ from substomatal organ to carboxylase in the chloroplast. Thicker mesophyll resulted in higher CO₂ diffusion compared to thin mesophyll that affecting the photosynthesis result and whitefly preferences.

Leaves also contain many guard cells that has dense cytoplasm that are formed from abundant little vacuoles (Slewiniski *et al.* 2013). In the thinner leaf, the vacuoles become denser that will form harder leaf because it contained sclerophyll, 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, acetone and ester. In other species, wax surface derived from secondary metabolites *i.e.* pentacyclic terpenoid, 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 | Tl/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 high 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 |
| P _{ye} | 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, P_{ye} = 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 secretory 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 varieties.

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