Vertical distribution of the greenhouse whitefly, *Trialeurodes vaporariorum* Westwood, within potato plant canopy

J Jumardi, M Melina and A Nasruddin

Plant Pest and Disease Department, Faculty of Agriculture, Universitas Hasanuddin, Makassar 90245, Indonesia.

E-mail: andinasruddin@yahoo.com

Abstract. The greenhouse whitefly, *Trialeurodes vaporariorum* Westwood (Hemiptera: Aleyrodidae) is one of the most important pests of horticultural crops worldwide. The presence of the insect in South Sulawesi was first reported in 2016 when it was seriously damaging field grown potato crops in Malino, causing a yield loss of up to 39%. As a new invasive pest in the region, its population and distribution must be continuously monitored. Effective monitoring can only be achieved if it is based on the knowledge of insect bio-ecology and behavior. Therefore, the purpose of this study was to determine the vertical distribution of *T. vaporariorum* within the plant canopy. A survey was conducted in a farmer’s potato plantation in Tinggi Moncong, Gowa Regency, South Sulawesi Province, Indonesia. The selected plantation was about 0.2 ha. Ninety plants were randomly selected throughout the field. Each plant canopy was divided into three parts: upper, middle, and lower parts. From each part of the canopy, two leaflets were randomly selected for egg, nymph, and adult counts. The adult number was determined in the field by slowly turning the leaves and all adults found on the lower leaf surface were counted and recorded. The leaves were then picked up and put inside of zip lock bags and brought to the lab for counting the eggs and nymphs under a dissecting microscope (200x). The results showed that about 81, 18, and 1% of the eggs were laid on the upper, middle, and lower parts of the canopy, respectively. Similarly, about 80, 17, and 3% of the adults were found on the upper, middle, and lower parts, respectively. In contrast, no nymphs were found in the upper part of the canopy but about 39 and 61% were found in the middle and lower parts, respectively. This information is very important in monitoring the pest on potato because we now know that for monitoring eggs and adults, the sample should be taken from the upper part of the canopy, whereas for monitoring the nymphs, samples should be taken from the middle and lower parts of the plant canopy.

1. Introduction

The greenhouse whitefly (GWF), *Trialeurodes vaporariorum* Westwood is a cosmopolitan pest that has been reported causing damages to many plant species in many countries [1]. In Indonesia, the pest has been found on several important crops, such as tomato (*Lycopersicum esculentum* Mill.) in West Java and Central Java Provinces [2]. However, in 2015 the insect caused serious damages on field-grown potato in Malino with a potential loss of 39% [3].

As a new invasive pest, the pest population should be continuously monitored for its abundance and distribution in that area. Thus, for this purpose, an efficient and effective monitoring method...
should be employed. In addition, the method is also useful for determining the pest abundance in an integrated pest management implementation [4].

Vertical distribution of a pest on its host is very important to understand in order to develop a monitoring system for the GWF. Different pest-host complexes have different vertical distribution patterns of the pest on their hosts. By knowing the plant parts that are preferred by the pest, the sampling can be directed towards that particular part of the plant [5]. For example, adult *Frankliniella occidentalis* on distributing evenly on all pepper plant strata (upper, middle, and lower canopy) but the larvae tended to concentrate on the upper canopy [6, 7]. Similarly, *Scirtothrips dorsalis* Hood on pepper was found the most on the upper part of the canopy, followed by the middle, and then the lower part of the canopy [8]. On the other hand, the green peach aphid, *Myzus persicae*, at the early stage of plant growth, it is evenly distributed in all plant strata. However, when the plant starts blooming, the amino acid concentration of the upper leaves increases, thus, the aphid redistributes itself to be more concentrated on the upper leaves [9].

Therefore, as a new invasive pest in South Sulawesi, within plant vertical distribution of the greenhouse whitefly on potato plants in the field is necessary to be understood in order to develop an effective sampling method for its population and distribution monitoring. Thus, the study was conducted to determine the vertical distribution of *T. vaporariorum* on field-grown potato in South Sulawesi.

2. Materials and methods

The study was conducted in Malino, Pattapang Village, Tinggimongcong District, Buluballea Environment, Gowa Regency, South Sulawesi from February to July 2019. The survey was carried out in the farmers’ potato field. A field of about 0.2 ha was chosen then divided into five plots. In each plot, three plants were randomly selected and from each plant, two compound leaves were randomly sampled from each part of the plant: lower, middle, and upper parts.

From each part of the canopy, two leaflets were randomly selected for egg, nymph, and adult counts. The adult number was determined in the field by slowly turning the leaves and all adults found on the lower leaf surface were counted and recorded. The leaves were then picked up and put inside of zip lock bags and brought to the lab for counting the eggs and nymphs per 1 cm$^2$ of lower leaf surface, under a dissecting microscope (200 x). The data were analyzed using ANOVA at 0.05 level and if a significant difference is detected then the treatment means were separated using Tukey’s test (P = 0.05).

3. Results

Within plant vertical distribution of adult GWF can be seen in table 1. There were significant differences in the number of adults amongst the plant canopy strata. In all observations, significantly more adult whiteflies found on the upper part of the canopy followed by the middle and then the lower canopy strata. The average numbers and percentages of adults across all the observation dates were 17.14, 3.81, and 0.63 or 81, 18, and 1% on the upper, middle, and lower canopy parts of the plant, respectively.

| Plant Part   | Observation | Mean   |
|--------------|-------------|--------|
|              | 1    | 2    | 3    | 4    | 5    | 6    | 7    | 8    |
| Upper leaf   | 28.4a | 19.7a | 39.2a | 6.2a | 9.3a | 8.7a | 11.0a | 14.4a | 17.1a |
| Middle leaf  | 6.3b  | 6.3b  | 5.4b  | 1.8b | 2.7b | 1.6b | 0.9b  | 3.6b  | 3.8b  |
| Lower leaf   | 1.0c  | 1.0c  | 0.4c  | 0.1c | 0.5c | 0.1c | 0.1b  | 0.0c  | 0.3c  |

Table 1. Within plant vertical distribution of the GWF adults on the upper, middle, and lower canopy strata of potato plant during the planting season 2019

The numbers in the same column followed by the same letter are not significantly different (Tukey’s, P = 0.05).
Table 2. Within plant vertical distribution of GWF eggs on the upper, middle, and lower canopy strata of potato plant during the planting season 2019

| Plant Part       | Observation | Mean   |
|------------------|-------------|--------|
|                  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Upper leaf       | 22.7a | 18.8a | 27.0a | 32.2a | 17.1a | 21.4a | 40.1a | 48.6a | 28.5a |
| Middle leaf      | 5.9b  | 7.3b  | 7.7b  | 4.4b  | 4.3b  | 9.8b  | 7.1b  | 2.8b  | 6.2b  |
| Lower leaf       | 1.4c  | 0.0c  | 0.2c  | 0.8c  | 0.5c  | 0.0c  | 0.2c  | 0.0c  | 0.4c  |

The numbers in the same column followed by the same letter are not significantly different (Tukey’s, P = 0.05).

The data are shown to have significant differences in the number of eggs amongst the plant canopy strata (Table 2). In all observations, significantly more whitefly eggs found on the upper part of the canopy followed by the middle and then the lower canopy strata. The average number of eggs across all the observation dates was 28.49, 6.18, and 0.39 or 80, 17, and 3% on the upper, middle, and lower canopy parts of the plant, respectively. The results also indicated significant differences in the numbers of nymphs amongst the plant canopy strata (Table 3). In all observations, no nymphs were found in the upper.

Table 3. Within plant vertical distribution of the GWF nymphs on upper, middle, and lower canopy strata of potato plant during the planting season 2019

| Plant Part       | Observation | Mean |
|------------------|-------------|------|
|                  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Upper leaf       | 0.0c | 0.0c | 0.0b | 0.0b | 0.0b | 0.0b | 0.0c | 0.0c |
| Middle leaf      | 3.4b | 1.7b | 3.8a | 7.1a | 5.6a | 4.5a | 8.8a | 6.5b | 5.2b |
| Lower leaf       | 11.7a | 7.2a | 4.6a | 7.7a | 5.7a | 6.0a | 9.1a | 13.2a | 8.2a |

The numbers in the same column followed by the same letter are not significantly different (Tukey’s, P = 0.05).

Part of the canopy, significantly more whitefly nymphs found on the lower than on the middle part of the canopy. The average number of nymphs across all the observation dates were 0, 5.19, and 8.16 or 0, 39, and 61% on the upper, middle, and lower parts of the plant canopy, respectively. The data of the numbers of adults, eggs, and nymphs averaged across the observation dates are shown in figure 1. Within plant vertical distribution of adults and nymphs followed the same tendency, most adults and adults were found on the upper stratum, followed by the middle and the lower strata. In contrast, most nymphs were found in the lower stratum, followed by the middle and the upper strata.

Figure 1. Vertical distribution of the eggs, nymphs, and adults of the greenhouse whitefly on potato plant
4. Discussion
Our results indicate that adult and egg distributions of the GWF followed the same pattern. The adults and eggs concentrated on the upper part of the plant canopy followed by the middle and lower parts of the canopy. In contrast, the significantly more nymphs found on the lower stratum of the plant canopy and as the canopy stratum moved upwards, the number of nymphs decreased and in the upper canopy stratum, no nymphs were found. This is in agreement with Martin et al., [10] that the distribution of whitefly puparia reflects where females laid eggs because all the non-adult whitefly stages, egg, nymph, and puparia remain on the same leaf where the eggs are laid.

Within plant vertical distribution of insects is affected by the nutrients available in each part of plant canopy stratum. For example, *M. persicae* evenly distributed in all plant canopy strata when the plant is young; however, when the plant starts blooming the thrips redistribute themselves and become concentrated on the upper leaves because the amino acid content of those leaves starts increasing [9]. The study results indicated that GWF adults were more prefer the upper leaves of potato plants (table 1, figure 1) which probably provide more suitable nutrients for the adults. While feeding on the upper leaves the female GWF laid eggs on the young leaves, hence the vertical distributions of eggs and adults were similar (table 2, figure 1). In contrast, most nymphs were found in the lower part of the canopy (table 3 and figure 1). This is probably due to the time needed for eggs to hatch to become crawlers is about 6 days [11]. By the time of the next observation, new upper leaves had been formed and become sample for observation while the nymphs were formed on the older leaves that were not sampled for adults and eggs in the next observation. In addition, UK [11] described the first nymphal instar or crawlers are very mobile in searching for a suitable part of the plant to form the second instar. The nutrient condition of the lower canopy was highly likely suitable for the nymphs than other strata of the plants so they moved down to the lower part of the canopy.

5. Conclusions
The results showed that GWF adults and eggs concentrated on the upper part of the canopy, while the nymphs were found the most on the lower part of the canopy. The practical implication of the research finding is that it can be used to improve the efficiency and effectiveness of the sampling methods in monitoring the abundance and the distribution of the GWF in the field. For GWF adult and egg survey on potato plants in the field, the upper leaves should be sampled, on the other hand, for the nymph survey, the lower leaves should be sampled.

References
[1] CABI 2016 *Trialeurodes vaporariorum* (whitefly, greenhouse) (Oxfordshire: Centre for Agriculture and Bioscience International)
[2] Hartono S and Wijinarko A 2007 Karakterisasi biologi molecular tomato infectious Chlorosis virus penyebab penyakit kuning pada tanaman tomat di Indonesia Jurnal Akta Agrosia 2 139-149
[3] Nasruddin A and Mound L A 2016 First record of trialeurodes vaporariorum westwood (Hemiptera: Aleyrodidae) severely damaging field grown potato crops in South Sulawesi, Indonesia Journal of Plant Protection Research 56 199-202
[4] Pedigo L P and Rice M E 2009 *Entomology and Pest Management Sixth Edition* (Illinois: Waveland Press) p 784
[5] Southwood T R E 1978 *Ecological Method With Particular Reference to The Study of Insect Population* (London: The English Language Book Society and Chapman and Hall) p 524
[6] Elimem M, Harbi A, Hafsi A, Othmen B A, Lahfif C, Limemssellemi E, Abbes K and Chermiti B 2017 Within plant vertical distribution of *Frankliniella occidentalis* Pergande (Thysanoptera; Thripidae) on greenhouse pepper crop: Effects of climatic conditions and implications for populations surveillance and control programs Journal of New Sciences 6 124-135
[7] Atakan E and Bayram A 2011 Distributions of western flower thrips (Thysanoptera, Thripidae) and its predatory bug Orius niger (Hemiptera, Anthocoridae) assessed by coloured sticky traps and plant samplings in cotton Archives of Phytopathology and Plant Protection 44 1595-1608

[8] Seal D R and Stansly P A 2000 Seasonal abundance and within plant distribution of melon thrips (Thysanoptera, Thripidae) on beans in southern Florida Proceedings of the Florida State Horticultural Society 113 201-205

[9] Cloyd R 2016 How You Can Stop Aphids By Understanding Their Interactions With Plants. Greenhouse Grower https://www.greenhousegrower.com/production/crop-inputs/how-you-can-stop-aphids-by-understanding-their-interactions-with-plants/ (Accessed on 21 August 2019)

[10] Martin N A and Dale I 1989 Monitoring greenhouse whitefly and parasitism: A decision approach New Zealand Journal of Crop and Horticultural Science 17 115-122

[11] White J 2018 Whiteflies in the Greenhouse (North Lexington: University of Kentucky)