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Population abundance of the red scale insect *Aonidiella aurantii* (Hemiptera: Diaspididae) on different cardinal directions of guava trees

Moustafa Mohamed Sabry Bakry[1*], and Yaghoub Fathipour[2*]

ABSTRACT

The red scale insect, *Aonidiella aurantii* (Maskell) (Hemiptera: Diaspididae), is a major pest of guava trees. This study investigated the population abundance, preference, and dispersal patterns of *A. aurantii* in a guava orchard in the Armant district, Luxor, Egypt, over two consecutive years (2022/2023 and 2023/2024). Monitoring was conducted biweekly, revealing that *A. aurantii* infested guava leaves year-round at varying densities. The pest exhibited a strong preference for the upper surface of leaves in the basal layer of the southeastern quadrant, where population density remained consistently high throughout the study period. Using preference and dispersal indices, we evaluated sixteen canopy quadrant-layer-leaf surface combinations. The upper surface of basal leaves in the southeastern quadrant had the highest quantity ratio, preference index, relative abundance establishment rate, and dispersal index, confirming its suitability for *A. aurantii* compared to other canopy positions. These findings provide critical insights for optimizing sampling and targeted control strategies, supporting the development of an effective integrated pest management (IPM) program against *A. aurantii* in guava orchards.

Keywords: Scale insect pest, population density, population fluctuation, guava tree, preference index, Egypt.

INTRODUCTION

Aonidiella aurantii (Maskell) (Hemiptera: Diaspididae), also commonly known as the red scale insect, is a worldwide pest that attacks numerous types of host plants (Grafton-Cardwell *et al.*, 2021; Aroua *et al.*, 2024). It is considered the main pest that damages guava trees. Guava trees are especially susceptible to this invasive, extremely widespread, and devastating pest (Salman *et al.*, 2022). According to Miller (2005) and Abd-Rabou (2009), this species is present on leaves, main stems, fruits, and all parts of trees. It absorbs the sap of the plant by inserting its mouthparts into the plant's tissue, extracting sap from parenchyma cells, and inserting toxic saliva (Bakry, 2009; Bakry and Mohamed, 2015). The primarily infested

[1] Department of Scale Insects and Mealybugs Research, Plant Protection Research Institute, Agriculture Research Center, Giza, Egypt.
[2] Department of Entomology, Faculty of Agriculture, Tarbiat Modares University, Tehran, Islamic Republic of Iran.
*Corresponding authors; email: md.md_sabry@yahoo.com, and fathi@modares.ac.ir

guava leaves are attached to the surface and form a shelter for scales (Hang, 2012). This can lead to serious consequences, such as yellowing of leaves, leaf drop, tree deformities, branch death, unnatural growth in young plants, declining of the fresh branches, inadequate blooming, smaller and fewer juicy fruits, and finally mortality of younger trees (Abdel-Rahman, 2021; Gaber *et al*., 2024).

Under the cover of females, the majority of armored scale insects spend the winter laying their eggs, which hatch in the spring into mobile young crawlers that move to new feeding grounds (Draz *et al*., 2011). The flight, movement, and widespread pattern of insects are influenced by the cardinal orientations of trees. Insects tend to forage and move more in the east-west orientation than the south-north sites (Bancroft, 2005). This pest's scattering behavior helps develop pest monitoring strategies and recommendations. Based on their needs for shelter, insects attempt to settle on stems that provide the most suitable climatic conditions. The monitoring conducted at these sites aids in developing suitable pest management strategies (Karar *et al*., 2013; Bakry and Abdel-Baky, 2020).

The way a population interacts with its surroundings determines its distribution scheme. We may define and identify the population under study more accurately and with greater information if we are aware of this trend in the surroundings (Arbabtafti *et al*., 2021). The sampling technique used in pest management is chosen based on the type of pest and the management tactics employed (Surendra, 2019). Understanding the distribution status helps one comprehend how the pest interacts with other components of its ecosystem (Verberk, 2011). Additionally, it covers suitable information on the spatial change and the design of sampling programs (Tsai *et al*., 2000). A key component of pest management programs is the adoption of an appropriate sampling technique, which gives data on crop and insect circumstances to aid in decision-making (Adam *et al*., 2010).

This study aimed to investigate the population estimates of *A. aurantii* in different guava tree coordinates. There is little data present in the scientific literature about the population abundance, preference index, and dispersal indices of *A. aurantii*. Therefore, the goal of the current study is to determine the sampling methods of *A. aurantii* in a guava orchard and factors influencing its population density.

MATERIALS AND METHODS

1. Population estimates of *A. aurantii* individuals on guava trees

A. Experimental area

The investigation was undertaken from the beginning of June 2022 to mid-May 2024 on ten guava trees (local cultivar) in a private grove situated in Armant, Luxor region, Egypt (25º37'50" N, 32º29'52" E). The trees, naturally infested with *A. aurantii*, were 8 years old and on average 5 m high. They were selected and graded almost uniformly for vegetative growth, size, and height, and received the same agricultural practices. Over the sampling period, no chemical treatments or insecticides were applied before or during the study period.

B. Sampling methods

Ten trees were sampled bi-weekly over two consecutive years (2022/2023 and 2023/2024). The selected trees were divided into four basic quadrants (directions): southeast (1), southwest (2), northeast (3), and northwest (4). Each tree was also divided into two vertical strata according to tree height (basal and apical tree sections) (Fig. 1). In each quadrant and stratum, five guava leaves were randomly selected and collected (Fig. 1). A split-split-plot design with 10 replicates was used, with orientations (southeast, southwest, northeast, and northwest) were distributed in the main plots while the tree layers (apical and basal) were randomly distributed in the split plots and the leaf surfaces (upper and lower) were distributed in the sub-split-plots. Thus, all samples consisted of 19,200 leaves (5 leaves × 4 quadrants × 2 levels × 48 trees × 10 trees) over a period of 2 years from the terminal shoots of the trees. Each year had 9600 leaves. The samples were placed individually in plastic bags and transported to the plant protection laboratory for inspection by a stereomicroscope. The individuals of *A. aurantii* were identified by Prof. Dr. Fatima Mahroum, Agricultural Research Center, Plant Protection Research Institute, Giza, Egypt.

Both nymphs and females were thoroughly examined on both surfaces (upper and lower) of leaves. The nymphal stage, consisting of pre-adults and crawlers, was calculated together, and the female stage, consisting of virgin and gravid females, was also calculated together. At each bi-monthly period, guava leaf data were analyzed to determine the seasonal population fluctuation of *A. aurantii*.

C. Data analysis

The obtained data were analyzed as a split-split-plot design with three factors in a randomized complete block design (RCBD), with ten replicates, and the means were compared according to Tukey's honestly significant difference (HSD) test at the 5% probability level was used to determine the significance between the means of the coordinates, and it was implemented by the SPSS program **(SPSS Inc., 1999).**

2. Estimating the preference, and prevalence indices

A. Quantity ratio (QR): It is defined as the number of pest individuals at each site (a) divided by the number of pest estimates at all sites (A) in percentage (Tu *et al*., 2018).

$$\mathbf{QR = (a / A) \times 100}$$

B. Preference Index (PI) of *A. aurantii*

In this regard, *A* is the number of individuals in each site, and M is the average population of the site in all cardinal directions, vertical strata, and leaf surfaces of guava at each sampling date. If AI is greater than one shows high preference, AI is equal to one shows medium preference, and AI is lower than one shows low preference (Krisnawati *et al*., 2017).

$$PI = \frac{2A}{M + A}$$

C. Mean crowding intensity (M^*) (Lloyd, 1967)

In this equation, $\overline{x}$ and S^2 are mean and variance of population estimates in each studied site, respectively.

$$M^* = \overline{x} + \frac{S^2}{\overline{x} + 1}$$

D. Relative abundance establishment rate (RAER)

In this equation, Ci and Cn are respectively the total population of pest in each sampling stage in the i-th to n-th digit of the length of the sampling season, and n is the number of sampling times (Latifian *et al*., 2023).

$$RAER = \frac{\sum Ci}{\frac{\sum C_i + \cdots \sum C_n}{n}}$$

E. Non-preference index (NPI)

In this regard, R is the average of *A. aurantii* estimates in each site compared to the average total estimates of *A. aurantii* in the studied sites (Antônio *et al*., 2011).

$$NPI = [\frac{(100 - R)}{100 + R)}] \times 100$$

F. Diffusion index (DI)

In this regard, T was the average population of *A. aurantii* in each site in each sampling, and P was the average number of *A. aurantii* estimates in all studied sites (Antônio *et al*., 2011).

$$DI = \frac{(T-P)}{(T+P)} \times 100$$

RESULTS AND DISCUSSION

1. Population abundance of *A. aurantii* on guava trees

Population estimates and estimated dispersion indices of *A. aurantii* counts on cardinal quadrants, vertical strata, and leaf surfaces of guava tree and their interaction influences throughout the two consecutive years (2022/2023 and 2023/2024), as represented in Tables 1 and 2.

The findings showed that *A. aurantii* individuals were present on guava trees throughout the year, over the two years of study on both leaf surfaces, different layers, and all tree quadrants (Tables 1 and 2).

Over the two years, the southeast quadrant of the tree had greater population estimates, as a general average (68.54 and 67.00 individuals per leaf), followed by the southwest side (68.23 and 66.71 individuals per leaf). The northeast site was moderately affected (67.83 and 66.33 individuals per leaf). However, the lowest numbers were recorded in the northwestern quadrant (65.58 and 64.08 individuals per leaf), respectively (Table 1).

Statistical examination of the data exhibited that there were real variances in the mean *A. aurantii* counts between the cardinal quadrants (F= 58.29; df= 9; $p \leq$ 0.000) in the first year (2022/2023) and (F= 41.87; df= 9; $p \leq$ 0.000) over the second year (2023/2024).

The data reveal that the leaves collected from the southeastern quarter of the guava tree during the two years constituted (25.37-25.37%) of the overall total, followed by the southwestern side (25.25-25.26%), then the northwestern side (25.11-25.11%), then the northwestern quarter (24.27-24.26%), as presented in Fig. (2).

Overall, the proportions of *A. aurantii* estimates in the two years were similar, which may be due to the environmental conditions being roughly similar.

From the available data from two years of research, which focused primarily on significant differences, it appears that the southeastern quadrant of the guava tree is more susceptible than other quadrants to *A. aurantii* infestation, with the largest populations. The differences in distribution could be attributed to the interaction between the direction of the wind and the amount of time leaves are exposed to sunlight. This discovery makes sense given that the prevailing wind direction in the study area was northwest, pushing the newly emerged crawlers southeast, where they could congregate for growth, development, and feeding. With the difference in the plant host and the type of insect, Nabil *et al*. (2012) in Sharkia, Egypt, observed that *A. tubercularis* was concentrated on the eastern side of the mango trees. Mohammed (2020) in Beheira Governorate, Egypt, mentioned that *A. aurantii* prefers to concentrate on the south-east side of the sweet orange tree.

These differences in their distributions might be explained by the pooled impacts of wind direction and the length of time leaves are exposed to the sun (Eraki, 1998; Bakry, 2022). This is possibly due to the wind's north-to-south direction, which carries newly hatched crawlers and permits them to land on the leaves in those orientations (Bakry and Abdel-Baky, 2020).

Regarding the vertical distribution (strata) of *A. aurantii* on the guava tree, the basal stratum leaves of the tree were the most preferred strata by pest as a general average (78.63 and 76.78 of individuals per leaf), and the bottom stratum leaves were the least infestation by insects with an average (56.46 and 55.28 of individuals per leaf) during the two years, respectively, as presented in Tables (1 and 2).

Statistically, the analysis of variance indicated very large differences in *A. aurantii* estimates in different vertical layers of trees in the first year (F= 1070.9; df= 12; $p\leq$ 0.000) and in the second year (F= 1527.7; df= 12; $p\leq$ 0.000), as shown in Tables (1 and 2).

The data provided showed that the leaves collected from the apical stratum of the guava tree had the lowest percentages, reaching (44.90 and 44.03%) of the total number of pests. On the contrary, the basal stratum leaves of the tree had the highest percentages, ranging between (55.10 and 55.97%) during two consecutive years, as shown in Fig. (2).

In the context, the changes in pest distribution patterns can be observed in different layers on the tree, which can be linked to differences in environmental conditions, wind direction, sunlight, and other parameters. The basal leaves provide good shelter for insects, especially during feeding, activity, and growth, compared to the apical leaves on the guava tree. The variation in insect distribution patterns across different tree layers is due to weather changes, wind direction, amount of sunlight, and other factors. Additionally, the tree's middle layer leaves provide superb insect refuge, particularly during the delicate periods of insect formation, feeding, and growth. Previous results highlight the preference of *A. tubercularis* for the middle and lower leaves of the mango tree.

Previous findings highlight the preference of *A. aurantii* for the lower stratum leaves of the guava tree. These findings concur with those of Draz *et al*. (2011) from the El-Behaira Governorate in Egypt; however, they applied a different host and insect species. They also found that the purple scale insect population, *Lepidosaphes beckii*, favors the middle stratum of navel orange trees as a preferred location for feeding, developing, and adult and nymphal multiplication. According to Nabil *et al*. (2012), the tree's bottom level was greater than its top level in Sharkia, Egypt.

Based on the results of *A. aurantii* distribution estimates on guava leaf surfaces, the lower leaf surfaces were less infested with *A. aurantii*, with an overall average of estimates of (30.33 and 29.07 individuals) as compared to the upper leaf surfaces, with averages of (37.22 and 36.96 individuals), as shown in Tables 1 and 2).

Statistically, the data revealed the population counts between the leaf surfaces of the guava tree had significant differences in the first year (F= 1122.1; df= 24; $p\leq$ 0.000) and in the second year (F= 1050.2; df= 24; $p\leq$ 0.000) (Tables 1 and 2).

The percentage of insect estimates on the upper surface of the leaf was (58.20 and 58.14%) of the total number of individuals, while these values ranged between (41.80 and 41.86%) on the lower surface of the leaf throughout two years, respectively, as shown in Fig. (2).

In general, the pest density on leaf surfaces was similar for both years, and this similarity may reflect roughly similar environmental parameters, as shown in Tables 1 and 2.

This indicates that *A. aurantii* is photopositive, meaning that the upper surface of the leaf is exposed to more sunlight than the lower surface. The above findings confirm that *A. aurantii* prefers the upper surface of guava leaves to the lower surface.

With the difference in the plant host and the type of insect, Bakr *et al*. (2009) that *A. tubercularis* favored the upper surface of leaves. *A. tubercularis* pest favored the upper surface of leaves throughout cold months (winter months) and the lower surface of leaves over warm months (summer months), according to El-Metwally *et al*. (2011) in Damietta, Egypt. Additionally, Nabil *et al*. (2012) in Sharkia, Egypt, observed that in the top and bottom parts of the mango tree, the total number of alive stages of *A. tubercularis* were larger on the upper surface than those on the lower one. In Qaliobiya, Egypt, Sanad (2017) found that *A. tubercularis* preferred the upper leaf surface of mango leaves over the lower ones.

In terms of the combined impacts of different factors (canopy quadrants-strata-leaf surface) on the population estimates of *A. aurantii*, the findings showed that *A. aurantii* individuals prefer the upper surface over the basal layer leaves in the southeast quadrant (coordinates:

1.1.1) with an average of 45.15 and 44.69 individuals per leaf, respectively, during the two years (Tables 1 and 2).

In contrast, the lowest estimates of this pest on the lower surface were on the apical stratum leaves in the northwest quadrant (coordinates: 4.2.2), with an average of 25.54 and 24.48 individuals per leaf as compared to the other coordinates over the two years, respectively (Tables 1 and 2).

The interactive impacts between sixteen combinations of canopy quadrants-strata-leaf surface of guava trees had very significant effects on *A. aurantii* population estimates, with the L.S.D. values being 3.38 and 3.63 over both years, respectively (Tables 1 and 2) and illustrated in Fig. (3).

The lower leaf surface in the basal layer leaves in the northeast quadrant (coordinates: 3.1.2) had the highest values for variance, standard deviation, and standard error, the coefficient of variance percentages for *A. aurantii* sampling throughout the two years (Tables 1 and 2). On the contrary, the least values of dispersion indices for *A. aurantii* sampling were exhibited on the lower leaf surface in the apical layer leaves in the southwest quadrant (coordinates: 2.2.1) during the two years (Tables 1 and 2).

The highest values of coefficient of variance percentages for *A. aurantii* sampling were observed on the lower leaf surface in the basal layer leaves in the northeast quadrant (coordinates: 3.1.2) in the first year (2022/2023) and on the lower leaf surface in the basal layer leaves in the northwest quadrant (coordinates: 4.1.2) over the second year (2023/2024). However, the least percentages of coefficient of variance for *A. aurantii* sampling were exhibited on the lower leaf surface in the apical layer leaves in the southwest quadrant (coordinates: 2.2.1) during the two years (Tables 1 and 2).

2. Preference and prevalence indices

A. Quantity ratio (QR)

As seen in Table 3, the quantity ratio of *A. aurantii* estimations at various coordinates on the guava tree expresses the relative abundance of the insect at various sites. When comparing the various quadrants, the southeast quadrant (25.37%) displayed the highest percentage values of *A. aurantii* estimates for each study year. Conversely, the northwest quadrant achieved the lowest one (24.27 and 24.26%) for each of the two years, respectively.

In the context, the basal stratum had the greatest percentage values of *A. aurantii* estimates (58.20 and 58.14%) when compared to the other strata, respectively. However, the lowest one was achieved in the apical stratum for the two years, with respective scores of 41.80 and

41.86 percent. Simultaneously, the top leaf surface showed the greatest percentage values of *A. aurantii* estimates (55.10 and 55.97%) in comparison to the other surfaces. However, the lowest one was discovered in the lower surface for the two years, with respective values of 44.90 and 44.03 percent (Table 3).

The highest percentages of *A. aurantii* estimates were found in the upper surface of the basal layer leaves in the southeastern quadrant (coordinates: 1.1.1), with a percentage of 8.35 and 8.46%, compared to the different quadrants for both years, respectively. With regard to the interactive influences between sixteen combinations of canopy quadrants-strata-leaf surfaces of guava trees in the northwest quadrant (coordinates: 4.2.2), the lowest one was achieved on the apical stratum leaves, with 4.73 and 4.64 percentages for the two years, respectively, as shown in Table (3).

B. Preference Index (PI)

The preference index values for the southeast, southwest, and northeast coordinates of the guava tree, the basal layer of the trees, and the upper surface of the leaves were greater than one, indicating that these coordinates are preferred for insect activity. During the two years, the preference index values greater than one were recorded at the following coordinates (1.1.1, 1.1.2, 2.1.1, 2.1.2, 3.1.1, 3.1.2, and 4.1.1), indicting that these coordinates are more preferred by the *A. aurantii* individuals, as shown in Tables 3 and 4. However, the preference index values less than one were observed at the following coordinates (1.2.1, 1.2.2, 1.2.1, 1.2.2, 3.2.1, 3.2.2, 4.1.2, 4.2.1, and 4.2.2), indicting that these coordinates are less preferred by the *A. aurantii* individuals over the two years (Table 3).

C. Mean crowding intensity (M^*)

In comparison to the other quadrants, the southeast quadrant had the highest average crowding of *A. aurantii* counts in each study year (85.07 and 77.41, respectively). But for the two years, respectively, the northwest quadrant achieved the lowest one (83.26 and 75.25) (Table 3). When compared to the other layers, the basal tree stratum had the highest values of *A. aurantii* estimates (98.53 and 89.28), respectively.

On the other hand, the lowest one was achieved for the two years, respectively, in the apical tree stratum (70.13 and 64.07). In addition, the top leaf surface (44.96 and 42.37) had the greatest values of *A. aurantii* estimates compared to the other surfaces. However, during the two years, the lowest one occurred on the lower surface (42.32 and 36.92, respectively), as shown in Table (3).

D. Relative abundance establishment rate (RAER)

The highest values of the relative abundance establishment rate were recorded in the southeast quadrant, the basal tree layer, and the upper leaf surface as compared to the other quadrants, apical tree strata, and lower leaf surface.

Regarding the interactive impacts between sixteen combinations of canopy quadrants-strata-leaf surface of guava tree, the highest values of *A. aurantii* estimates accomplished in the upper surface of the basal layer leaves in the southeastern quadrant (coordinates: 1.1.1) with (0.79 and 0.91), compared to the different quadrants for both years, respectively. While the lowest one was exhibited in the upper surface were on the apical stratum leaves in the northwest quadrant (coordinates: 4.1.2) with (0.53 and 0.63) for the two years, respectively (Table 3).

E. Non-preference index (NPI)

The less preferred a site is to the insect, the higher its non-preference index value, and vice versa. The insect favors a certain spot more when its non-preference index value is lower. As shown in Table (3), the highest values of the non-preference index were achieved over the course of two years at the following coordinates: 1.22, 2.2.2, 3.2.2, and 4.2.2. This suggests that the *A. aurantii* individuals had a lower preference for these coordinates. As seen in Tables 3 and 4, the southeastern quadrant's upper surface of the basal layer leaves (coordinates: 1.1.1) had the lowest values of the non-preference index, indicating that the *A. aurantii* individuals prefer these coordinates.

F. Diffusion index (DI)

The more positively the prevalence index values are, the more the insect prefers this site; conversely, the more negatively the diffusion index values are, the less the insect prefers this site.

As shown in Table (3), the upper surface of the basal layer leaves in the southeast quadrant (coordinates: 1.1.1) had the highest and most positive prevalence index values over the course of the two years, suggesting that *A. aurantii* individuals favor these coordinates more. Conversely, the lower surface of the apical layer leaves in the northwest quadrant (coordinates: 4.2.2) showed the lowest negative values of the dispersal index for both years, indicating that *A. aurantii* individuals do not prefer these coordinates very much as shown in Table (3).

Overall, the study concluded that the upper surface of the basal layer leaves in the southeastern quadrant displayed the highest estimates of the quantity ratio, preference index, relative abundance establishment rate, and prevalence index, indicating that these coordinates are more preferred by the *A. aurantii* individuals during both years. However, the lower surface of the apical leaves in the northwestern quadrant of the guava tree recorded the lowest values for these indicators, revealing that the *A. aurantii* individuals have chosen different locations in both years.

Conclusions

To determine the distribution of insects on adjacent leaves in each direction to test the distribution hypothesis, this experiment was conducted to estimate the homogeneity of *A. aurantii* individuals on adjacent leaves at different locations on the tree and its effect on insect dispersal, distribution, and preference, as well as to see whether insect numbers follow a uniform pattern or are randomly distributed or clustered on adjacent leaves of guava trees over the two successive years (2022/2023 and 2023/2024).

The findings showed that the *A. aurantii* population was present on guava trees throughout the year, over the two years of study on both leaf surfaces, different layers, and all tree quadrants. *A. aurantii* individuals prefer the upper surface over the basal layer leaves in the southeast quadrant, where its population was always abundant throughout the year, over the two years of study. In this context, the interactive effects between sixteen combinations of canopy quadrants-strata-leaf surfaces of guava trees were evaluated using preference and prevalence indices.

The prevalence, distribution, preference, and diversity of red scale insects on guava trees can vary based on environmental factors, such as temperature, humidity, and the presence of natural predators. Typically, these insects are found clustered on the underside of guava leaves, where they feed on sap. They can be more prevalent in certain cardinal directions of the tree, depending on factors like sunlight exposure and wind patterns. Additionally, their distribution may vary across different vertical strata of the tree, with higher populations often found on lower branches. Preference to red-scale insects may also be influenced by factors like leaf health and nutrient levels. Overall, monitoring and management strategies should take these factors into account to effectively control red scale infestations.

The highest estimates of quantity ratio, preference index, relative abundance establishment rate, and prevalence index were exhibited in the upper surface of the basal layer leaves in the southeastern quadrant, indicating that these coordinates are more preferred by the *A. aurantii* individuals as compared to the other coordinates during both years.

Based on the above results, we suggest that guava producers check the upper leaf surface in the basal layer of the tree, specifically in the southeastern canopy quadrants, as a practical guide.

The above results provide comprehensive support for *A. aurantii* detection process. Such insights are critical for designing effective integrated pest management (IPM) programs and optimizing control measures against this economically significant pest.

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Table 1. Estimated dispersion indices of *A. aurantii* counts on guava trees over the first year (2022/2023).

Coordinates		Average counts per leaf	Dispersion indices							
			Max.	Min.	Range of mean	Median	Variance	Standard deviation	Standard error	Coefficient of variance (%)
Quadrant	Southeast	68.54 A	146.39	14.54	131.85	64.10	1064.36	32.62	3.33	47.60
	Southwest	68.23 A	146.48	13.56	132.93	63.27	1042.58	32.29	3.30	47.32
	Northeast	67.83 B	148.41	13.91	134.50	63.21	1083.55	32.92	3.36	48.53
	Northwest	65.58 C	146.41	14.62	131.80	58.62	1093.96	33.08	3.38	50.43
Strata	Basal	78.63 A	171.15	16.14	155.01	72.03	1486.09	38.55	3.93	49.03
	Apical	56.46 B	122.70	12.17	110.53	52.47	715.39	26.75	2.73	47.37
Leaf surface	Upper	37.22 A	84.95	9.33	75.62	34.67	251.04	15.84	1.62	42.57
	Lower	30.33 B	81.29	4.83	76.47	27.13	333.39	18.26	1.86	60.21
Quadrant -strata-leaf surface*	1.1.1	45.15 A	110.38	10.50	99.88	41.82	417.97	20.44	2.09	45.28
	1.1.2	34.43 BC	94.52	5.80	88.71	28.47	434.65	20.85	2.13	60.56
	1.2.1	31.24 CD	70.70	7.90	62.80	29.73	182.68	13.52	1.38	43.27
	1.2.2	26.26 EF	66.91	4.88	62.02	24.51	212.96	14.59	1.49	55.56
	2.1.1	44.51 A	96.39	10.75	85.64	42.81	355.44	18.85	1.92	42.35
	2.1.2	35.04 B	94.25	4.42	89.84	31.44	451.04	21.24	2.17	60.61
	2.2.1	30.81 CD	63.31	7.78	55.53	29.71	147.12	12.13	1.24	39.36
	2.2.2	26.10 EF	67.00	4.17	62.83	23.81	217.14	14.74	1.50	56.46
	3.1.1	43.47 A	100.86	10.82	90.04	39.89	328.57	18.13	1.85	41.70
	3.1.2	35.73 B	98.02	4.91	93.12	31.81	523.93	22.89	2.34	64.07
	3.2.1	30.02 D	65.66	7.68	57.98	28.97	167.59	12.95	1.32	43.12
	3.2.2	26.44 EF	66.93	4.41	62.52	23.19	231.68	15.22	1.55	57.56
	4.1.1	43.12 A	107.90	11.54	96.36	40.20	380.98	19.52	1.99	45.27
	4.1.2	33.07 BCD	93.98	5.84	88.14	24.79	495.01	22.25	2.27	67.28
	4.2.1	29.43 DE	64.43	7.68	56.75	27.71	159.20	12.62	1.29	42.87
	4.2.2	25.54 F	69.11	4.18	64.93	22.50	233.29	15.27	1.56	59.79

Explanations: * quadrant (1 = southeast, 2 = southwest, 3 = northeast, and 4 = northwest), vertical strata (1= basal, and 2 = apical) and leaf surfaces (1 = upper, and 2 = lower). Means followed by the same letter(s), in each column, are not significantly different at 0.05 level probability, by Tukey's HSD test.

Table 2. Estimated dispersion indices of *A. aurantii* counts on guava trees over the second year (2023/2024).

Coordinates		Average counts per leaf	Max.	Min.	Range of mean	Median	Variance	Standard deviation	Standard error	Coefficient of variance (%)
Quadrant	Southeast	67.00 A	130.78	22.91	107.87	64.11	94.90	16.54	78.36	43.14
	Southwest	66.71 A	132.19	21.36	110.83	62.03	82.76	9.15	73.62	29.71
	Northeast	66.33 B	138.50	21.92	116.57	63.03	60.97	12.44	48.53	29.59
	Northwest	64.08 C	132.57	23.03	109.53	57.87	62.24	7.70	54.55	23.37
Strata	Basal	76.78 A	154.25	25.44	128.81	71.31	882.86	29.71	3.03	38.70
	Apical	55.28 B	113.09	19.18	93.91	52.43	430.87	20.76	2.12	37.55
Leaf surface	Upper	36.96 A	74.02	14.70	59.32	34.86	163.10	12.77	1.30	34.56
	Lower	29.07 B	73.58	7.60	65.98	25.43	199.04	14.11	1.44	48.53
Quadrant -strata-leaf surface*	1.1.1	44.69 A	94.90	16.54	78.36	43.14	276.66	16.63	1.70	37.22
	1.1.2	33.02 BCD	82.76	9.15	73.62	29.71	248.46	15.76	1.61	47.74
	1.2.1	30.92 BCD	60.97	12.44	48.53	29.59	117.80	10.85	1.11	35.10
	1.2.2	25.37 E	62.24	7.70	54.55	23.37	127.58	11.30	1.15	44.51
	2.1.1	44.06 A	82.95	16.94	66.02	42.32	233.80	15.29	1.56	34.70
	2.1.2	33.45 BC	82.88	6.96	75.92	30.39	271.79	16.49	1.68	49.28
	2.2.1	30.75 BCD	54.81	12.26	42.55	28.94	99.72	9.99	1.02	32.47
	2.2.2	25.15 E	60.96	6.57	54.39	22.49	131.65	11.47	1.17	45.62
	3.1.1	43.42 A	86.81	17.05	69.75	41.16	222.66	14.92	1.52	34.36
	3.1.2	34.02 B	92.72	7.73	84.99	31.03	325.09	18.03	1.84	52.99
	3.2.1	29.74 CD	58.86	12.11	46.75	28.56	107.24	10.36	1.06	34.82
	3.2.2	25.47 E	65.57	6.95	58.61	23.42	142.71	11.95	1.22	46.90
	4.1.1	42.84 A	96.77	18.19	78.58	40.62	250.72	15.83	1.62	36.96
	4.1.2	31.61 BCD	86.36	9.20	77.17	25.00	299.25	17.30	1.77	54.72
	4.2.1	29.21 D	56.11	12.10	44.01	28.52	102.18	10.11	1.03	34.60
	4.2.2	24.48 E	60.99	6.58	54.41	21.13	138.48	11.77	1.20	48.06

Explanations: * quadrant (1 = southeast, 2 = southwest, 3 = northeast, and 4 = northwest), vertical strata (1= basal, and 2 = apical) and leaf surfaces (1 = upper, and 2 = lower). Means followed by the same letter(s), in each column, are not significantly different at 0.05 level probability, by Tukey's HSD test.

Table 3. Various models to evaluate preference and prevalence indices of *Aoinidella aurantii* per leaf in sampling units composed by combinations of canopy quadrants, vertical strata, and leaf surfaces of guava trees in the first (2022/2023) and second (2023/2024) years.

Coordinates		(QR)		(PI)		(M*)		(RAER)		(NPI)		(DI)	
		First	Second	First	Second	First	Second	First	Second	First	Second	First	Second
Quadrant	Southeast	25.37	25.37	1.01	1.01	85.07	77.41	0.72	0.84	49.75	49.75	0.73	0.73
	Southwest	25.25	25.26	1.01	1.01	84.51	77.19	0.70	0.82	49.75	49.75	0.51	0.51
	North east	25.11	25.11	1.00	1.00	84.81	77.17	0.70	0.81	49.75	49.75	0.21	0.23
	Northwest	24.27	24.26	0.99	0.99	83.26	75.25	0.63	0.73	49.76	49.76	-1.48	-1.50
Strata	Basal	58.20	58.14	1.08	1.08	98.53	89.28	0.69	0.80	49.71	49.71	7.58	7.53
	Apical	41.80	41.86	0.91	0.91	70.13	64.07	0.68	0.80	49.79	49.79	-8.94	-8.86
Leaf surface	Upper	55.10	55.97	1.05	1.06	44.96	42.37	0.71	0.81	49.72	49.72	4.85	5.63
	Lower	44.90	44.03	0.95	0.94	42.32	36.92	0.66	0.79	49.77	49.78	-5.38	-6.35
Quadrant -strata-leaf surface*	1.1.1	8.35	8.46	1.14	1.15	55.40	51.88	0.79	0.91	49.66	49.66	14.41	15.02
	1.1.2	6.37	6.25	1.01	1.00	48.05	41.54	0.65	0.77	49.74	49.75	0.96	0.01
	1.2.1	5.78	5.85	0.96	0.97	38.09	35.73	0.70	0.81	49.77	49.76	-3.90	-3.28
	1.2.2	4.86	4.80	0.87	0.87	35.37	31.40	0.71	0.84	49.80	49.81	-12.51	-13.08
	2.1.1	8.24	8.34	1.14	1.14	53.50	50.37	0.70	0.80	49.67	49.66	13.72	14.33
	2.1.2	6.48	6.33	1.02	1.01	48.91	42.58	0.70	0.84	49.74	49.75	1.84	0.66
	2.2.1	5.70	5.82	0.95	0.96	36.59	35.00	0.73	0.84	49.77	49.77	-4.58	-3.54
	2.2.2	4.83	4.76	0.87	0.86	35.42	31.38	0.65	0.77	49.81	49.81	-12.81	-13.52
	3.1.1	8.05	8.22	1.13	1.14	52.03	49.55	0.71	0.81	49.68	49.67	12.56	13.62
	3.1.2	6.61	6.44	1.03	1.02	51.39	44.58	0.71	0.85	49.73	49.74	2.81	1.51
	3.2.1	5.56	5.63	0.94	0.95	36.60	34.34	0.66	0.76	49.78	49.77	-5.88	-5.22
	3.2.2	4.89	4.82	0.88	0.87	36.21	32.07	0.70	0.83	49.80	49.81	-12.17	-12.90
	4.1.1	7.98	8.11	1.12	1.13	52.95	49.70	0.66	0.76	49.68	49.67	12.16	12.96
	4.1.2	6.12	5.98	0.99	0.98	49.04	42.08	0.53	0.63	49.75	49.76	-1.05	-2.17
	4.2.1	5.45	5.53	0.93	0.94	35.84	33.71	0.68	0.79	49.78	49.78	-6.87	-6.11
	4.2.2	4.73	4.64	0.86	0.85	35.68	31.14	0.63	0.75	49.81	49.81	-13.87	-14.84

Abbreviations: QR= Quantity ratio, PI= Preference Index, M*= Mean crowding intensity**,** RAER = Relative abundance establishment rate, NPI= Non-preference index, and DI= Diffusion index.

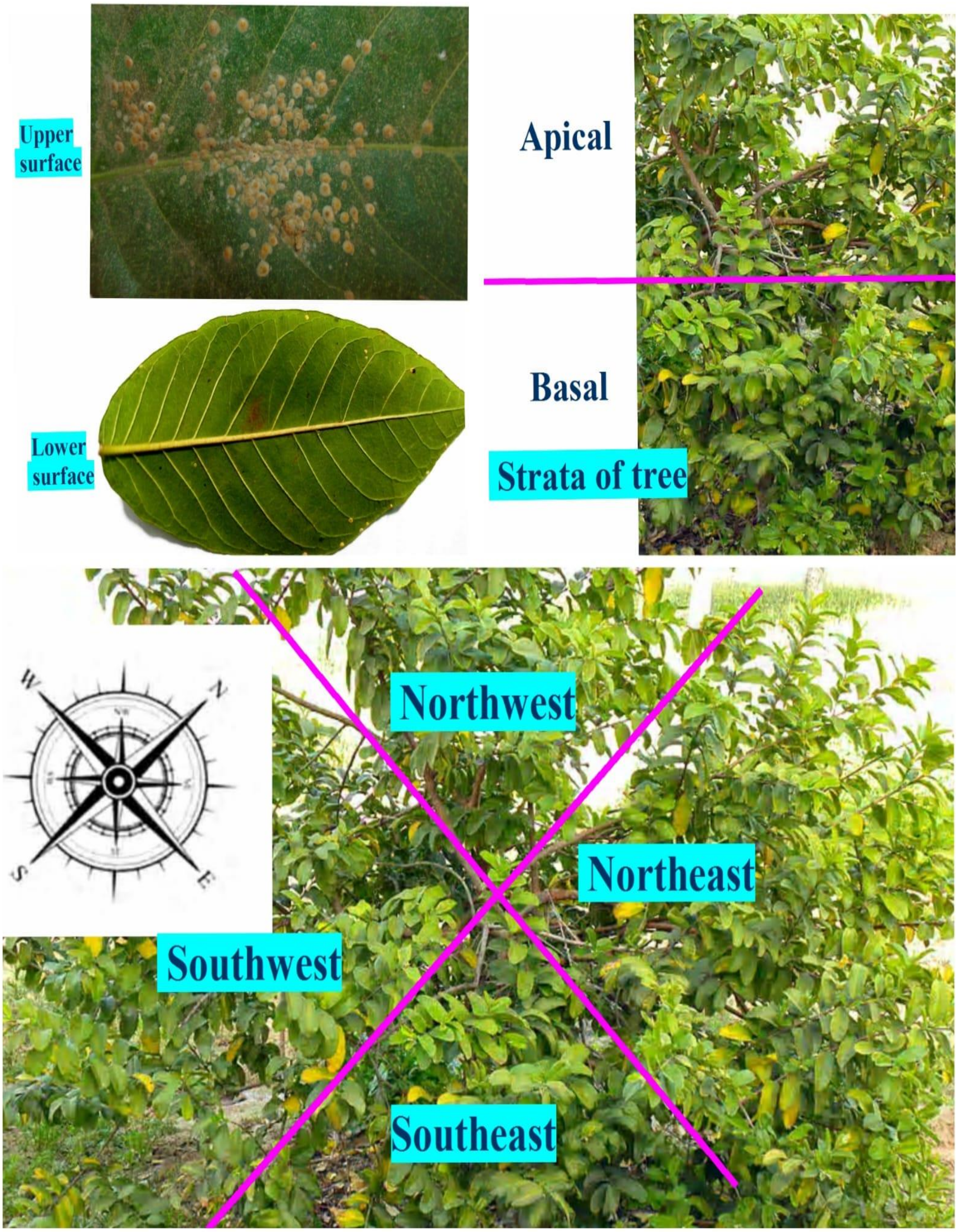


Fig. 1. Diagrammatic representation of guava trees divided into canopy quadrants, vertical strata, and leaf surfaces for *A. aurantii* sampling.

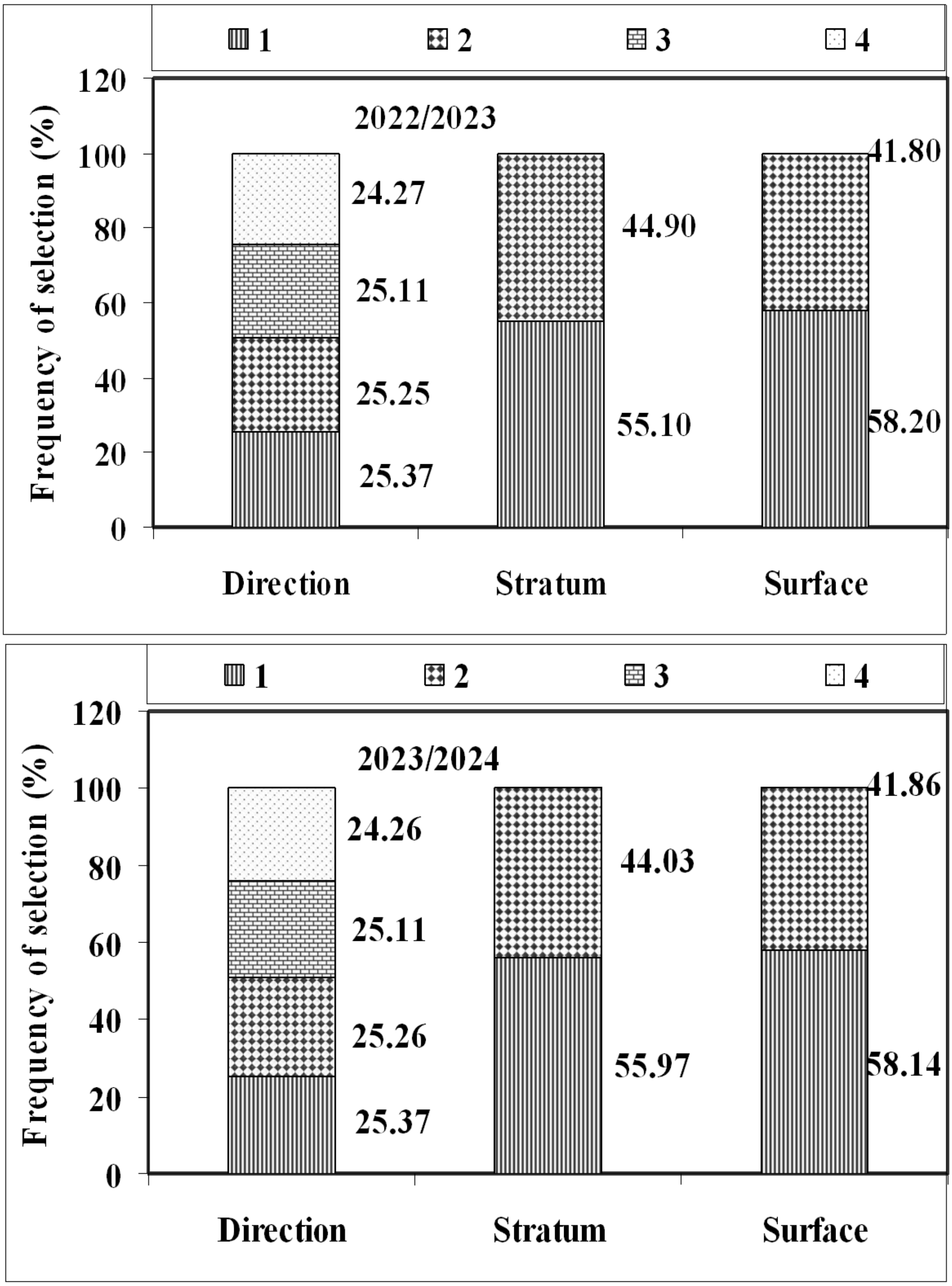
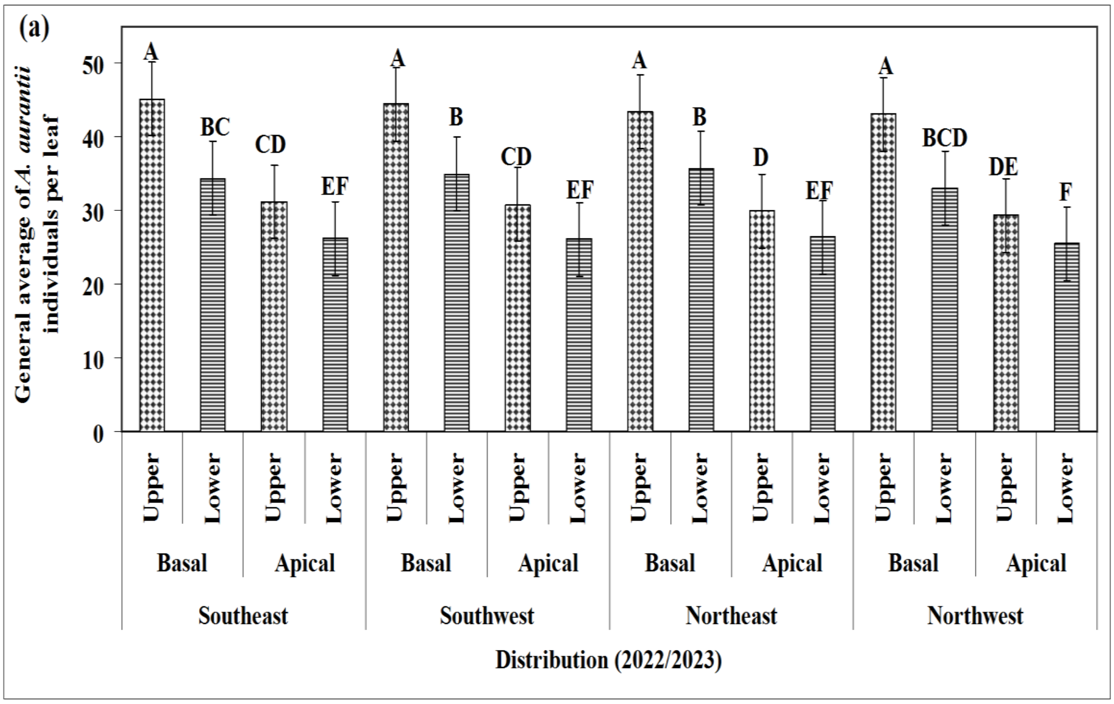


Fig. 2. The percentage of the frequency in which each directional coordinate (1 = southeast, 2 = southwest, 3 = northeast, and 4 = northwest), vertical strata (1= basal, and 2 = apical) and leaf surfaces (1 = upper, and 2 = lower) was estimated for *Aoinidella aurantii* sampling on guava leaves during 2022/2023 and 2023/2024 years.



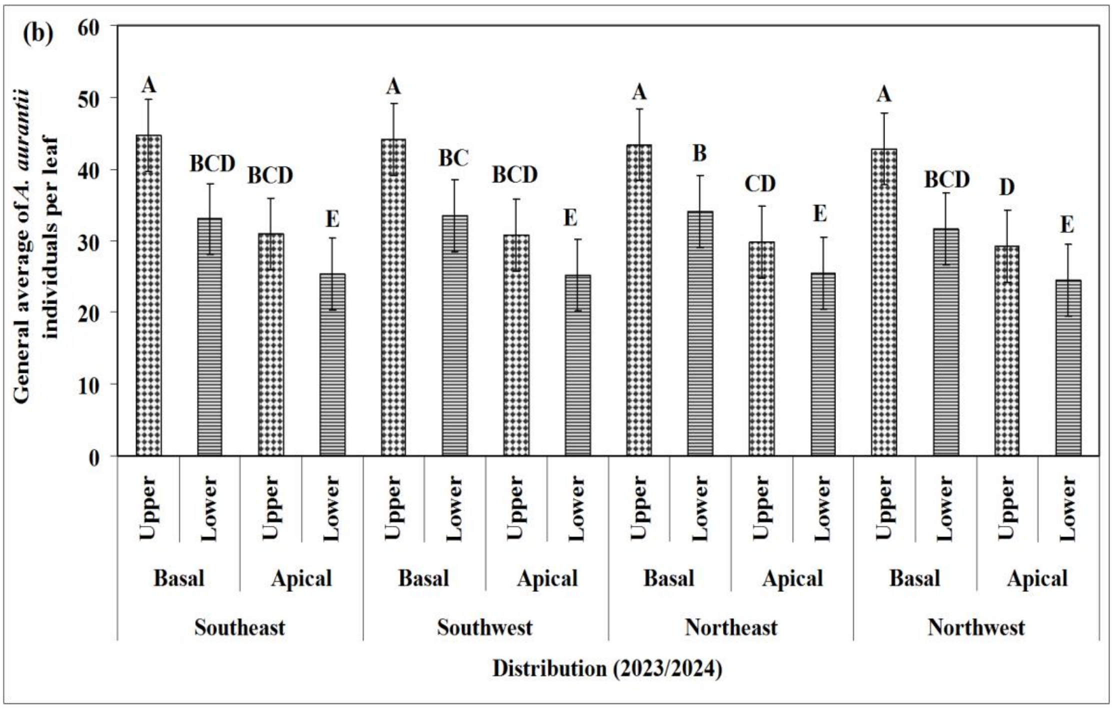


Fig. 3. Interactive impacts between sixteen combinations of canopy quadrants-strata-leaf surface of guava tree on *A. aurantii* estimates per leaf the two years of [2022/2023 (a) and 2023/2024 (b)]. Values indicated by different letters for the interactive impacts between sixteen combinations of canopy quadrants-strata-leaf surface of guava tree are statistically significant differences at $P \leq 0.05$ (Tukey's HSD test).