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Research Paper

Spatio-temporal distribution of walnut aphids and associated natural enemies in temperate agro-ecological zone of Kashmir Valley

Danish Mushtaq[1*], A.A. Khan[1], Nawreen Mir[2], Z. H. Khan[1], Imran N. Khan[3], M. A. Mir[4], M. D. Shah[2], S.S. Pathania[1], Shaheen Gul[1], M. A. Parray[1], Zuhaib Farooq[1] and Danishta[1] Aziz

[1]*Division of Entomology;* [2]*Division of Plant Pathology;* [3]*Division of Agricultural Statistics;* [4]*Division of Fruit Science, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar, Srinagar-190025, Jammu and Kashmir (India)*
email: danishmushtaq2030@gmail.com*

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ABSTRACT

The valley of Kashmir is blessed with a climate suitable for raising a number of fruit and nut crops. Walnut is one such praised favourite nut of many. Walnut trees, one of Kashmir's most valuable crops, are, however, susceptible to diseases and insect pests that cause significant annual financial losses. As such, it is essential to understand the numerous causes of these problems. Aphids are one of the most common insect pests affecting walnuts. With the aim of studying the population dynamics and distribution of two walnut aphid species *viz*., *Chromaphis juglandicola* and *Panaphis juglandis*, the present study was conducted for two consecutive years 2021 and 2022, in Kashmir, India. For the study, three major walnut producing districts were selected and from each district three villages were surveyed for two years and each site was visited fortnightly. The data revealed that the population of both aphids increased gradually from April to 2nd fortnight of June and declined rapidly afterwards, reaching the lowest in September. Aphid numbers reached their highest level during the month of June. Moreover, the predatory natural enemies also helped in shaping the aphid population. A total of five natural enemies were also identified during the study.

Key words: Aphid, green lacewing, natural enemy, syrphid fly, walnut

Walnut (*Juglans regia L.*) also known as the Persian or English walnut, belongs to the Juglandaceae family and is called "Doan" in Kashmiri language. This species is widely recognized for its edible nuts and quality wood (McGranahan *et al*., 1987). It is the best-known member of the *Juglans* genus, which includes over 20 species like Eastern black walnut (*J. nigra*), heartnut (*J. ailantifolia var. cordiformis*) and butternut (*J. cinerea*). *J. regia* has a broad natural distribution from Eastern Europe through Western Asia to the Himalayan regions and China. During the 2023-24 growing season, global walnut production was approximately 2.8 million metric tons, with China as the leading producer (Anonymous, 2024). The global walnut market is projected to reach $8.7 billion by 2027 (Anonymous, 2024). In India, walnut cultivation spans 109 thousand hectares, with a production of 329 thousand Metric tons. Jammu and Kashmir UT is a major contributor, with 85.05% of its dry fruit area under walnut cultivation, producing 267162 metric tons from 80,726 hectares in 2021-22 (Anonymous, 2024b). India exported 638.07 metric tons of walnuts, valued at 2.02 crore INR, in 2023-24 (Anonymous, 2024a). In India, walnut cultivation is concentrated in Jammu and Kashmir, Uttarakhand, Himachal Pradesh, and Arunachal Pradesh. Jammu and Kashmir is the main hub, contributing around 98% of India's walnut production with a

productivity of 3.31 tons/ha (Anonymous, 2024b). The union territory has been designated as an "Agri. Export Zone for Walnuts" due to its significant role in walnut exports (Arranz *et al*., 2008). Cultivation is highly profitable in the region, with Udhampur district alone yielding a gross return of 85,555.75 INR per acre, making it a lucrative venture for local farmers (Bhagat *et al*., 2024). The monoculturized Kashmiri walnut is exposed to some pests and diseases that need to be intensively combated in the vast area. The sustainability of any ecosystem for harmful insects is significantly weakened by human activity (Khan *et al*., 2016). The effects of industrial wastes, recreational loading, and other factors reduce the durability of biocoenosis and contribute to massive growth of insects. Walnut trees are susceptible to pests and diseases such as walnut weevil (*Alcides porrectirostris* Marsha), walnut blue beetle (*Monolepta erythrecephale*), SanJose scale *(Quadraspidiotus pernicious* Comst), Dusky veined aphid (*Panaphis juglandis* Goeze) and walnut green aphid (*Chromaphis juglandicola* Kalt) (Khan *et al*., 2018).

Aphids are small, soft-bodied insects that can be winged or wingless. They reproduce sexually and develop through gradual metamorphosis and also through parthenogenesis. Aphids are sensitive to microclimates, affecting their location in plant parts or leaf surfaces (Yin *et al*., 2021). They play a crucial role as vectors for spreading plant diseases, particularly viral ones. Yield losses caused by aphids can directly range from 10-50% and indirectly from 20-80%, affecting plant health (Khan and Shah, 2017). Among the different pests prevalent in the walnut-producing areas, walnut aphids *viz. Panaphis juglandis* (Large walnut aphid) and *Chromaphis juglandicola* (Small walnut aphid) cause significant damage in walnut orchards by reducing tree vigour, nut size, yield, and quality. In addition to direct feeding damage, they excrete copious amounts of honey-dew that falls onto nuts, leaves and shoots. Small Walnut Aphid is a holocyclic monoecious aphid that spends all of its life upon walnut trees. It spends winter conditions as hibernating eggs (Nowierski*et al*., 1983). Exact amount of damage by this insect pest is unknown but colonies under leaves in high densities above 15 aphids/ leaf may cause leaf drop, fruits become sunburned and finally cause weakened trees and yield loss (Shelton and Davis, 1994; Mills *et al*., 2011. Small Walnut

Aphid has several natural enemies that can maintain populations well under economic levels (Pickle *et al*., 2015). *Trioxys pallidus* (Haliday) (Hym. Braconidae, Aphidiinae) is a specific parasitoid of developed stages of Small Walnut Aphid (Rakhshani *et al.,* 2004). The leaves are attacked by 2 species of aphids from the Aphididae family: *Panaphis juglandis* (Goeze, 1778) and *Chromaphis juglandicola* (Kaltenbach, 1843). The walnut green aphid, *Chromaphis juglandicola* Kaltenbach (Hemiptera: Aphididae), and the walnut dusky-veined aphid, *Panaphis juglandis* Goeze (Hemiptera: Aphididae), are sympatric species in same leaves usually in walnut orchards worldwide (Jaśkiewicz and Kmiec 2017, Jaworski and Hilszczański 2013, Wang *et al.* 2021). Both walnut aphid species feed on phloem but have different spatial niche separation within walnut leaves. *C. juglandicola* occurs on the lower surface of leaves (abaxial) whereas *P. juglandis* prefers the upper surface (adaxial) (Jaśkiewicz and Kmiec 2017). Although the phenomenon of the niche separation of the two walnut aphids is well reported, the reasons for this habitat selection are unclear (Lee *et al.,* 2018, Aqaverdi and Inqilab 2018). The specific symptoms caused by aphids are lag in the development of shoots and weak photosynthesis (Khan *et al*., 2020). Aphids also damage the generative organs and fruits. The fruits usually become smaller in trees suffering from sucking insects and they fall off.

In the present-day scenario, the growing demand for residue-free production of walnuts can be best achieved using natural enemies to manage walnut aphids effectively. Population studies are important not only due to the relationship between population density and damage and hence economic importance of a pest species (Dent, 2000), but also because these studies assess the relative significance of natural enemies regulating population levels (Manly, 1990; Price *et al*., 2014).

Also, Jaskiewicz and Cichocka (2004), Jaskiewicz and Kmiec (2007), Karczmarz (2010) studied the relative importance of both species of *C. juglandicola* and *P. juglandis* in Lublin, Poland. They reported that activity of both species was during May-October. Drought, temperatures above 30ºC and rain showers were reported as the most important factors in summer population declines. Being important crop pests, aphids support a rich assemblage of natural

enemies comprising parasitoids, fungal pathogens, and a broad spectrum of predators (Vollkl *et al*., 2007).

MATERIALS AND METHODS

The study was carried out by carrying an extensive survey which has been mentioned under the following heads:

Survey: Survey of various walnut growing areas of Kashmir valley was carried out to find out the prevalence of aphids in Walnut trees. The field surveys were conducted in three districts of Kashmir *viz*., Anantnag (33.7311° N, 75.1487° E, altitude: 1,601 m asl), Ganderbal (34.2165° N, 74.7719° E, altitude: 1,619 m asl) and Kupwara (34.5262° N, 74.2546° E, altitude: 1,615 m asl). During survey, the population dynamics, distribution and abundance of walnut aphids and its predators along with their mode of damage were recorded. From each district, three sites were selected, *viz*; Gopalpora, Nowgam and Kokernag in district Anantnag, Watlar, Yangoora and Wusan in district Ganderbal and Kulangam, Langate and Chogul in district Kupwara, based on the accessibility and availability of Walnut trees. The following sites were selected from district Anantnag, Kupwara and Ganderbal.

District	S. No	Selected location	No. of trees to be selected from each orchard	Samples (leaves) from each tree	Total samples (leaves) in each orchard
Anantnag	1	Gopalpora	5	20	100
	2	Nowgam	5	20	100
	3	Kokernag	5	20	100
Kupwara	1	Kulangam	5	20	100
	2	Chogul	5	20	100
	3	Langate	5	20	100
Ganderbal	1	Watlar	5	20	100
	2	Yangoora	5	20	100
	3	Wusan	5	20	100

Details of observations were recorded as under:

Population dynamics: For the study of population dynamics, the density of walnut aphids was recorded and co-related with biotic and abiotic factors.

Distribution: Distribution of different forms of aphids *viz;* apterous, alate and nymph and their natural enemy individuals present in each location were recorded.

Sampling methods: For present study, sampling was carried out fortnightly by selecting five trees randomly in each walnut orchard ecosystem. For each tree, 20 leaves were sampled/ selected from lower and middle canopy in each direction (east, west, north south) accounting a total 100 leaves at one site. The level of infestation and number of walnut aphids as well as predators were recorded. The collected material was viewed in a laboratory, under a stereoscopic microscope and the collected specimens of examined aphid species were counted (Blackman and Eastop, 2000).

RESULTS AND DISCUSSION

During the year 2021 and 2022, two aphid species and five predatory insects were found from walnut. The aphids were identified as *Chromaphis juglandicola* and *Panaphis juglandis*and the natural enemies as *Harmonia eucharis*, *Chrysoperla zastrowi* sillemi, *Sphaerophoria scripta*, *Coccinella septempunctata* and *Adalia tetraspilota*. The comprehensive investigation into the population dynamics of walnut aphids in District Anantnag during the year 2021 and 2022, as outlined in the Table 1 underscores the fluctuations in aphid populations across distinct locations and weeks. The pooled data revealed that highest (426.5/100 leaves) number of small walnut aphids (*Chromaphis juglandicola*), dusky veined aphid (*Panaphis juglandis*) 383.5/100 leaves and

natural enemies (35.50 /100 leaves) were recorded from Nowgam during the 35th Standard week. Whereas, the lowest (184.0 / 100 leaves) populations of small walnut aphid (*Chromaphis juglandicola*), dusky-veined aphid (*Panaphis juglandis*) 163.0/100 leaves from Nowgam and natural enemies 11.5/100 leaves from Gopalpora during 41st week. The in-depth analysis of walnut aphid populations in District Kupwara for the years 2021 and 2022, as presented in Tables 2 emphasizes the fluctuations witnessed in aphid numbers over various locations at weekly intervals. In summary, the pooled data showed that the highest (452.50 aphids /100 leaves) number of small walnut aphids (*Chromaphis juglandicola)* was recorded at Chogul during the 25th week, dusky-veined aphids (*Panaphis juglandis*) (350 aphids/100 leaves) at Kulangam during the 27th week, and the highest (39.50 /100 leaves) natural enemies at Langate during the 23rd week. Conversely, the lowest (162 aphids/ 100 leaves) populations of small walnut aphids (*Chromaphis juglandicola)* were recorded at Kulangam, dusky-veined aphids (*Panaphisjuglandis*) (150.5 aphids / 100 leaves) at Chogul and natural enemies (11.5/ 100 leaves) at Langate during the 41st week. The in-depth analysis of walnut aphid populations in District Ganderbal for the years 2021 and 2022, as presented in Table 3, emphasizes the fluctuations witnessed in aphid numbers over various locations and weekly intervals. The pooled data showed that the highest ((398.0, 345.0 aphids /100 leaves, and 35 natural enemies /100 leaves) number of small walnut aphids (*Chromaphis juglandicola)*, dusky-veined aphids (*Panaphi sjuglandis*) and natural enemies were recorded at Watlar, Watlar and Yangoora during the 23rd week respectively. Conversely, the lowest (116 aphids/ 100 leaves) populations of small walnut aphids (*Chromaphis juglandicola)* were recorded at Watlar, dusky-veined aphids (*Panaphis juglandis*) (96.50 aphids/ 100 leaves) at Watlar, and natural enemies (13/ 100 leaves) at Wusan during the 41st week. During the year 2021 and 2022, it was observed that highest mean number of Small walnut aphid, Dusk- veined aphid and natural enemies were recorded at district Anantnag followed by district Kupwara and the lowest population was recorded in district Ganderbal. (Fig. 1).

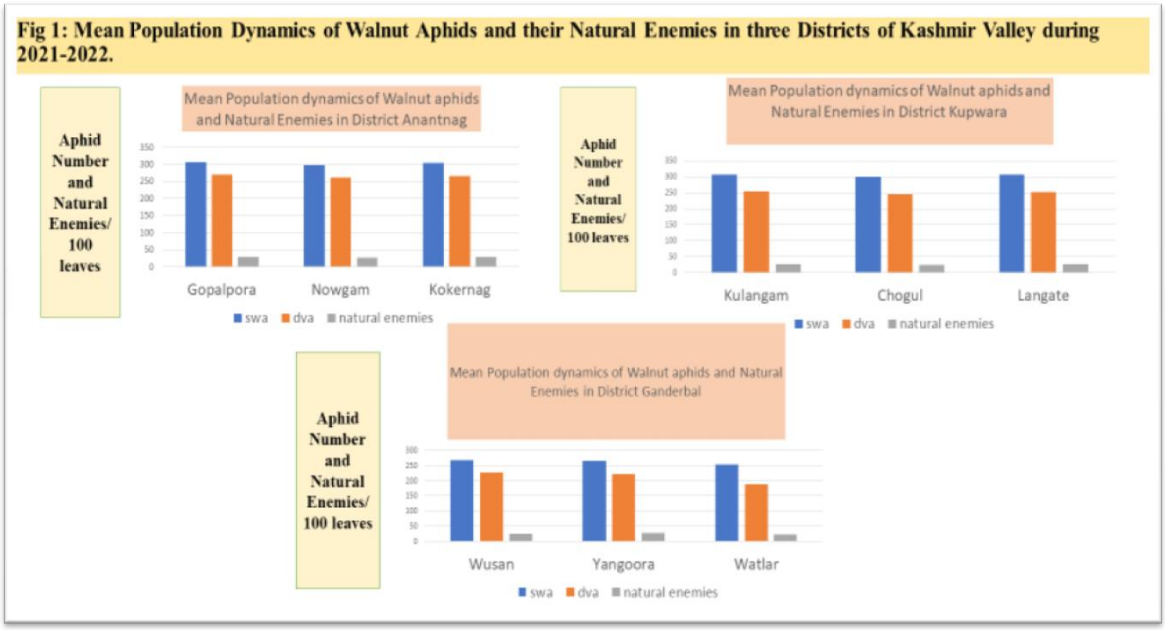

Fig. 1: Mean population dynamics of walnut aphids and their natural enemies in three districts of Kashmir Valley during 2021-2022

Aphids (Homoptera: Aphididae) are sap-sucking insects that are primarily a temperate group with some exceptions of tropical groups that are essentially asexual in reproduction. They frequently exist as obligate asexual lineages or even as asexual "species." There are already about 4000 species identified (Dixon *et al*., 1987), some of which are significant pests in horticulture, forestry, and agriculture. Aphids are a serious pest of crops, globally, that are crucial to agriculture. They

consume plant sap from phloem, causing the host plants' leaves to curl, turn yellow, and grow more slowly. They also serve as plant disease vectors for a variety of viruses. Aphids are responsible for loss in agriculture amounting to hundreds of millions of dollars. The management of aphids, done using chemical pesticides traditionally has now become difficult as approximately 20 species are now resistant to pesticides internationally as a result of indiscriminate and non-judicious use of chemical insecticides (Loxdale *et al*., 2020). In this context, looking into the nature to understand the diversity and ecological relationships to find the natural enemies and parasites of these pests is only going to help to tackle the current issue of insecticide resistance development. In the present study population dynamics of walnut aphids in three districts of Kashmir valley *viz.,* Anantnag, Ganderbal and Kupwara was studied for two consecutive years. The comparison of pooled data for the two years for three different sites of each district observed that the highest (452.50) mean population of small walnut aphids was observed in Chogul area of district Kupwara followed by Nowgam area of Anantnag district. The first alate of *Chromaphis juglandicola* appeared in the last week of April. This continued to increase from 1st fortnight of May to 2nd fortnight of June during 2021-22. Thereafter, population generally decreased from 1st fortnight of July to 2nd fortnight of August. This decline could be attributed to increase in temperature, rainfall and appreciable activity of biotic agents as recorded by Kmiec (2007) and Karczmarz (2012). The rainfall showed negative influence on aphid population which has earlier been hypothesised by many researchers (Kaakeh and Dutcher, 1993; and Abbassi *et al*., 2019). A negative correlation of aphid population with rainfall has also been recorded in Kashmir valley which further corroborates our findings. (Yaqoob *et al*., 2019). Moreover, temperature, leaflet age, amount of prior aphid feeding and coccinellid predation are known to be the most important factors influencing walnut aphid population changes (Sluss, 1967). Our results correlate with the findings of Gull and co-workers who observed the same trend in the population dynamics of small walnut aphids (Gull *et al*., 2023). Furthermore, the difference in the mean population of small walnut aphids amongst the three surveyed districts could be possibly because of the indirect insecticidal effect, given the walnut trees analysed during the study in district Ganderbal and Anantnag were in close proximity of chemically managed grape and apple orchards, respectively (Sánchez-Bayo, 2021). The year 2022 saw the highest number of *C. juglandicola*, primarily because of favorable meteorological conditions. Temperature was found to be the most determining factor influencing the population of aphids. The beginning of spring marks the increase in temperature in temperate conditions like that of Kashmir valley which in turn resulted in sporadic emergence of aphid pests during the whole course of study. The population of aphids showed little to no gain in September, and then overwintered from October to March. These results are in line with the findings of Khan and Shah (2018).

CONCLUSION

During the growing season of 2021 and 2022, extensive field surveys were conducted in three districts of Kashmir valley *viz*; Anantnag, Ganderbal and Kupwara to study the population dynamics, distribution, and abundance of walnut aphids and their predators along with their mode of damage. From each district, three sites were selected based on the accessibility and availability of Walnut trees. During 2021 and 2022, the highest mean number of Small walnut aphid and Dusky veined aphid was recorded in district Anantnag, followed by district Kupwara while as, the least population was recorded in district Ganderbal. Likewise, the mean number of *Sphaerophoria scripta, Harmonia eucharis* (Mul.) and *Chrysoperla zastrowisillemi* was also recorded and was found to follow the similar trend as that of the aphids. Subsequently, *Chromaphis juglandicola* was found to be the most dominant species associated with walnuts and amongst the natural enemies, *Spaherophoria scripta* took the lead. The present study highlights the need of proper management of walnut plants in order to harness the maximum economic benefits. This can only be made possible by the adoption of high-density plantation systems in walnut. The smaller plant size will make the management of walnut aphids convenient and economical. Moreover, there is a dire need of devising and adopting IPM modules so as to help the natural enemies of aphids thrive and thence, reduce the insecticide load.

Table 1: Population dynamics of walnut aphids in district Anantnag during the year 2021 and 2022 (Pooled)

SMW	Gopalpora			Nowgam			Kokernag		
	Aphid number/ 100 leaves		Natural enemies/100 leaves	Aphid number/ 100 leaves		Natural enemies/100 leaves	Aphid number/ 100 leaves		Natural enemies/100 leaves
	SWA	DVA		SWA	DVA		SWA	DVA	
17th week	242.50	217.00	21.50	241.00	217.50	23.00	228.00	214.50	22.50
19th week	265.00	236.00	26.50	249.50	229.50	28.00	263.00	233.00	27.50
21th week	214.00	186.50	23.50	207.00	178.50	24.50	220.50	183.00	25.00
23th week	310.50	287.00	27.50	308.00	271.50	30.50	325.00	280.00	28.50
25th week	370.00	319.00	30.00	346.00	304.50	34.50	360.50	312.00	33.00
27th week	401.50	360.50	37.00	402.00	351.00	37.00	408.50	365.00	34.00
29th week	356.00	264.00	27.00	298.00	261.50	31.00	307.00	263.00	30.50
31th week	414.00	366.00	31.50	303.50	259.50	33.50	310.00	269.50	32.50
33th week	340.00	298.50	34.00	339.50	292.50	35.50	341.50	295.50	31.00
35th week	322.50	284.00	33.00	426.50	383.50	34.50	420.00	374.00	34.00
37th week	330.00	286.50	29.00	321.00	281.50	31.00	332.00	283.00	33.00
39th week	264.00	228.00	21.50	253.50	223.00	23.50	263.50	229.00	24.50
41th week	187.50	171.00	11.50	184.00	163.00	13.50	192.00	171.50	14.00
MEAN	**309.03**	**269.54**	**26.37**	**298.42**	**262.85**	**29.23**	**305.50**	**267.15**	**28.77**
CI at 95%	40.28	36.56	3.99	43.04	37.91	3.84	42.31	37.36	3.75
SE	18.48	16.78	1.83	19.75	17.40	1.76	19.42	17.15	1.72

SMW= Standard Metrological week SWA= Small walnut aphid DVA= Dusky-veined aphid

Table 2. Population dynamics of walnut aphids in district Kupwara during the year 2021 and 2022 (Pooled)

SMW	Kulangam			Chogul			Langate		
	Aphid number/ 100 leaves		Natural enemies/100 leaves	Aphid number/ 100 leaves		Natural enemies/100 leaves	Aphid number/ 100 leaves		Natural enemies/100 leaves
	SWA	DVA		SWA	DVA		SWA	DVA	
17th week	201.00	179.50	18.50	204.50	173.00	15.50	199.50	172.00	19.00
19th week	276.50	230.00	24.00	284.50	225.50	26.00	276.00	236.50	28.00
21th week	255.00	209.00	23.00	259.00	198.50	23.50	260.50	209.50	26.00
23th week	405.00	314.00	36.50	408.00	307.00	37.50	407.50	319.50	39.50
25th week	445.50	338.50	37.50	452.50	322.50	37.00	447.00	330.50	38.00
27th week	429.00	350.00	32.00	428.50	329.50	30.50	427.00	341.50	38.00
29th week	341.00	335.00	34.50	331.50	326.00	34.50	343.50	337.50	38.00
31th week	239.00	205.00	22.50	230.50	194.50	20.50	238.00	205.00	26.00
33th week	335.00	241.00	27.50	322.50	235.50	26.00	325.50	244.00	27.50
35th week	365.50	257.50	26.00	307.50	249.00	25.00	355.50	251.00	29.00
37th week	287.50	269.00	22.00	260.00	266.00	20.50	287.00	270.00	21.50
39th week	256.50	218.50	18.00	242.00	218.00	17.50	252.00	223.00	19.00
41th week	162.00	154.00	13.50	164.50	150.50	12.00	165.50	157.50	11.50
MEAN	**307.58**	**253.92**	**25.81**	**299.65**	**245.81**	**25.08**	**306.50**	**253.65**	**27.77**
CI at 95%	53.05	38.51	4.52	52.96	36.60	4.87	52.63	37.75	5.28
SE	24.35	17.68	2.07	24.31	16.80	2.24	24.15	17.32	2.42

SMW= Standard Metrological week *SWA= Small walnut aphid *DVA= Dusky-veined aphid

Table 3 Pooled population dynamics of walnut aphids in district Ganderbal during the year 2021 and 2022

SMW	Wusan			Yangoora			Watlar		
	Aphid number/ 100 leaves		Natural enemies/100 leaves	Aphid number/ 100 leaves		Natural enemies/100 leaves	Aphid number/ 100 leaves		Natural enemies/100 leaves
	SWA	DVA		SWA	DVA		SWA	DVA	
17th week	181.50	153.00	14.50	182.00	148.00	15.50	184.50	140.00	17.50
19th week	211.50	199.00	20.00	208.50	192.50	20.50	211.50	186.00	23.00
21th week	255.00	194.00	20.00	253.50	188.50	19.50	269.50	184.00	22.50
23th week	387.00	344.50	34.00	386.00	340.00	35.00	398.00	345.00	34.50
25th week	371.50	287.50	33.50	372.00	282.50	34.00	381.00	241.00	34.00
27th week	304.00	256.00	32.00	304.00	249.50	32.50	315.00	216.00	33.00
29th week	248.50	217.50	27.50	244.50	212.00	28.50	257.00	175.50	25.50
31th week	325.00	265.50	33.50	321.50	258.50	33.00	288.00	201.00	26.50
33th week	256.00	226.50	32.00	255.50	221.50	32.50	243.00	186.50	20.50
35th week	271.50	251.00	25.50	271.00	246.50	26.50	238.00	191.00	17.50
37th week	269.00	231.50	23.50	268.50	224.50	24.00	223.50	168.00	18.00
39th week	227.50	182.00	22.00	225.00	177.50	23.50	181.00	139.00	16.00
41th week	174.00	149.50	13.00	174.00	144.50	13.50	116.00	96.50	13.25
MEAN	**267.85**	**226.58**	**25.46**	**266.62**	**222.00**	**26.04**	**254.31**	**188.25**	**23.04**
CI at 95%	39.50	33.14	4.42	39.56	33.02	4.39	47.55	31.47	4.47
SE	18.13	15.21	2.03	18.16	15.16	2.02	21.82	14.44	2.05

SMW= Standard Metrological week *SWA= Small walnut aphid *DVA= Dusky-veined aphid

CONFLICT OF INTEREST

All the authors affirm that there is no conflict of interest among them. All research activities comply with relevant legal, institutional and ethical standards.

AUTHOR CONTRIBUTION

All the authors contributed equally in this research article.

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