International Journal of Advanced Biochemistry Research

ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2025): 5.29
IJABR 2025; 9(8): 936-939
www.biochemjournal.com
Received: 20-06-2025
Accepted: 25-07-2025

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Bionomics of safflower aphid (*Uroleucon compositae* Theobald) on safflower crop

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DOI: https://www.doi.org/10.33545/26174693.2025.v9.i8l.5380

Abstract
An investigation into the life cycle of the safflower aphid, *Uroleucon compositae* Theobald, was carried out in a laboratory setting at the Department of Entomology, College of Agriculture, Raipur, Chhattisgarh, during the rabi season 2023-24. The aphid had progressed through four nymphal stages, starting with the first stage, which was elongated, wingless, transparent, and pale brownish or reddish in colour, changing to dark brown as it developed. The second instar nymph resembled the first instar in appearance, though slightly swollen, whereas the third instar featured round, reddish-black compound eyes that were significantly larger than those of the second instar. The fourth instar had a general appearance similar to that of the third. The nymphs measured 1.03 to 2.33 mm in length and 0.55 to 1.27 mm in width, lasting for a total of 7 to 12 days. This adult *U. compositae* insect had a shiny black body that was spindle-shaped to elongated and pyriform, measuring 2.41 to 2.75 mm in length and 1.11 to 1.27 mm in width, survived for 5 to 13 days, and produced 11 to 57 nymphs over its lifespan, with a generation period of 12 to 25 days.

Keywords: Safflower, aphid, *Uroleucan compositae*

Introduction
The safflower plant, known as *Carthamus tinctorius* L (Kusumbha, kusum, kardi), is classified as a cool-season crop and is a member of the Asteraceae family. In India, safflower (kusum, kusumba, kaldi) is cultivated for its vibrant blooms and for carthamin, the orange-red dye that is extracted from the flowers and seeds. The plant also holds significant value as an aromatic and medicinal plant, and it is cultivated as an oil crop because of its high oil content. The oil content of the seed varies between 24 and 36 per cent, with the oil being flavourless, colourless and nutritionally comparable to sunflower oil, while the seed contains 11-24 per cent protein and yields three primary products: oil, meal, and birdseed. Safflower is a versatile crop that is abundant in vitamin A, iron, phosphorus, and calcium. It is also used in the production of paints, varnishes, and linoleum.

India ranks second globally in terms of both the area it covers (14.67%) and the production of safflower it yields (9.02%). In India, safflower is cultivated over an area of 0.84 lakh hectares with a production of 0.67 lakh tonnes and a productivity of 679 kg per hectare. These states are mainly where the crop is grown: Telangana, Maharashtra, Andhra Pradesh, Karnataka and Gujarat. In Karnataka, safflower is cultivated on 0.35 lakh hectares and yields 0.28 lakh tonnes with a productivity of 921 kg/ha (Parameshnaik *et al.*, 2023) [5].

The area harvested, production, and yield of the safflower crop in Chhattisgarh declined from 2018-19 to 2022-23. The area harvested decreased from 0.3 thousand hectares in the 2018-19 period to 0.1 thousand hectares from 2020-21 onwards; production also fell from 0.1 thousand tons in both 2018-19 and 2019-20 to 0.0 thousand tons in subsequent years. The yield stayed fairly constant at 407-409 kg/ha until the 2020-21 season, after which it decreased substantially to 333-330 kg/ha over the last two years. In Chhattisgarh, the major safflower growing districts during 2019-20 are Balodabazar, Bemetara, Durg, Janjgir-Champa, Mungeli, Raipur, and Rajnandgaon (Anon, 2024) [1].

In India, safflower is infested by 36 species of insect pests, with the safflower aphid *Uroleucan compositae*, the cotton bollworm *Helicoverpa armigera*, and the leaf-eating caterpillar *Perigea capensis* being the three major pests.

The most damaging of these three pests is the safflower aphid, causing crop yields to decrease by 35-75 per cent during the infestation. Aphid infestation is a regular occurrence in late sown safflower in Chhattisgarh, and the infestation's intensity is extremely severe. In order to reach higher yields, prevent losses due to insect pests, and meet the oilseed demands of a rapidly expanding global population, it is essential to cultivate pest-resistant varieties/cultivars of safflower and ensure that pest populations do not exceed economic thresholds.

Materials and Methods

The experiment on the bionomics of safflower aphids was carried out in the Entomology Laboratory at the College of Agriculture in Raipur, Chhattisgarh, during the rabi season of 2023-24. The experiment was conducted under ambient temperature and relative humidity levels in a laboratory setting. Safflower leaves were placed in a petri dish with moist paper, and aphids were subsequently transferred to the dish for rearing (Yadav *et al.*, 2019) [9]. Daily records were taken of various observations, including different instars of the nymph, the duration of each nymphal instar, the total nymphal period, adult lifespan, the pre-reproductive period, the reproductive period, the post-reproductive period, fecundity, the intrinsic rate, and the total life span of the aphid. Observations of aphid morphometrics, specifically body length, body width, antennal length and cornicle length, were taken for various instars and adults using a stereo-zoom binocular microscope and the Axio-vision 2.8 software.

Results and Discussion

The present investigation into the bionomics of the safflower aphid *Uroleucon compositae* was conducted under laboratory conditions at the Department of Entomology, College of Agriculture, Raipur, Chhattisgarh, during the rabi season of 2023-24. The results are shown below.

Description and measurements of nymphs

The study on nymphal duration was conducted during Rabi 2023-24 and the results on the measurement of nymphs are tabulated in Tables 1 & 2.

The first instar nymph, as shown in Table 1, is initially elongated, delicate, and wingless, with a transparent, pale brownish or reddish appearance. It later develops an oval body shape and its colour shifts from light brown to brown. The compound eyes were situated near the base of the antennae, and were coloured reddish black. The antennae were longer than the body width but shorter than the body length, measuring between 0.93 and 1.04 mm, with an average of 0.99±0.03mm. The antenna had a five-segmented setaceous type. Three pairs of thoracic legs were thickly and uniformly covered with hairs, being well developed. The lengths of the fore, middle and hind legs ranged from 0.81 to 0.86, 0.84 to 0.94, and 0.97 to 1.11 mm, with averages of 0.84±0.05, 0.88±0.04, and 1.03±0.07 mm, respectively. Laterally near the tip of the abdomen, a pair of small cornicles was visible, measuring between 0.24 and 0.29 mm in length, with an average of 0.26±0.03 mm. The cauda length ranged from 0.07 to 0.09 mm, averaging 0.08±0.001 mm (Table 2). The body length of the first instar nymphs ranged from 1.03 to 1.32 mm with an average measurement of 1.19±0.07 mm, while the breadth was between 0.55 and 0.62 mm (Table 2), with an average of 0.56±0.02 mm. The corresponding length and breadth were more or less similar to the report of Shirisha *et al.* (2009) [7]. The duration of first instar nymphs was discovered to range from a minimum of 1.5 days to a maximum of 3.0 days, with an average of 2.26±0.32 days, as shown in Table 1. The report of Shirisha *et al.* (2009) [7] is similar to the present findings, indicating 2.14±0.39 days.

Table 1: Duration of different stage(s) of *U. compositae*

Stages	Duration {days(s)}		
	Min.	Max.	Mean c S.D.
Nymph			
I instar	1.5	2.5	2.26±0.32
II instar	1.5	3.0	2.49±0.60
III instar	1.5	3.0	2.79±0.31
IV instar	2.5	3.5	3.1±0.64
Total nymphal period	7	12	10.62±1.26
Adult			
Pre reproduction period	0.5	2.0	1.50±0.27
Reproduction period	4.0	10.0	8.65±1.84
Post-reproduction period	0.5	1.0	0.57±0.07
Adult longevity	5	13	8.91±1.62
Total lifespan	12	25	19.3±3.6
Fecundity Nymphs /female	11	57	39.8±6.1

Second instar nymph: Freshly moulted second instar nymphs were found to differ from the first instar in their comparative size and appearance. The nymph was dark brown in colour and slightly bulged. Compound eyes were similar to the first instar both in colour and shape. This instar was very active and avoided light. Measurement of the second instar nymphs revealed that each nymph varied from 1.35 to 1.53 mm with an average of 1.43±0.06 mm in length and 0.59 to 0.79 mm with an average of 0.68±0.04 mm in breadth. The cornicles were clearly cylindrical in shape and measured between 0.27 and 0.36 mm in length, averaging 0.31±0.03 mm, whereas the cauda ranged from 0.11 to 0.14 mm, with an average of 0.12±0.01 mm. The ranges for the lengths of fore, middle, and hind legs were between 0.90 to 1.17, 0.91 to 1.19 and 1.13 to 1.21 mm, with average lengths of 0.89±0.08, 0.99±0.04 and 1.19±0.16 mm, respectively. The five segmented antennae measured between 1.16 and 1.27 mm, with an average length of 1.21±0.04 mm, as shown in Table 2. Observations revealed the second instar nymph's duration spanned a minimum of 1.5 days to a maximum of 3.0 days, with an average duration of 2.49±0.60 days, as documented in Table 1.

Third instar nymph: the dark brown colouring of the third instar nymph was observed**.** The compound eyes were round, slightly larger than the second instar and a deep reddish black in hue. The morphometric study of the third nymphal stage found the length of each nymph to be between 1.59 and 1.98 mm, averaging 1.78±0.15 mm, and the breadth to be between 0.62 and 0.77 mm, averaging 0.70±0.17 mm (Table 2). Cornicle lengths ranged from 0.46 to 0.52 mm, averaging 0.49±0.02 mm, whereas cauda lengths ranged from 0.15 to 0.20 mm, with an average of 0.17±0.02 mm. The length of fore, middle and hind legs ranged from 1.15 to 1.51, 1.26 to 1.53 and 1.64 to 1.98 mm with averages of 1.27±0.14, 1.36±0.09 and 1.73±0.13 mm, respectively. The antennae ranged in length from 1.53 to 2.03 mm, averaging 1.68±0.18 mm (Table 2), with six distinct segments. The duration of third instar nymphs, as shown in Table 1, ranged from 1.5 to 3.0 days, with an

average duration of 2.72±0.31 days, close to the 2.32±0.45 days reported by Shirisha *et al.* (2009) [7].

Fourth instar nymph: The fourth instar nymph had a dark brown colouration and an elongated form. The compound eyes remained enlarged and had a blackish-red hue. The nymph was highly energetic and resembled an adult, except for the lack of deep black colour and fully developed wings. A morphometric study of the fourth nymphal instar yielded values showing a body length ranging from 2.12 to 2.33 mm, averaging 2.26±0.08 mm, and a breadth ranging from 0.85 to 0.99 mm, averaging 0.94±0.05 mm (Table 2). Visible to the naked eye, the cornicles measured between 0.63 and 0.71 mm, averaging 0.66±0.03 mm in length, whereas the cauda ranged from 0.30 to 0.32 mm, with an average of 0.31±0.008 mm. The lengths of fore, middle, and hind legs fluctuated between 1.65 to 1.72, 1.83 to 1.92, and 2.31 to 2.50 mm with an average of 1.68±0.03, 1.87±0.03, and 2.40±0.07 mm, respectively. The specimen had six segmented antennae, ranging from 2.15 to 2.34 mm in length, averaging 2.22±0.07 mm (Table 2). The fourth instar nymph's duration ranged from 2.5 to 3.5 days, with an average of 3.1±0.64 days as stated in Table 1, which corresponds well with Shirisha *et al.* (2009) [7] who reported 3.00±0.44 days.

The total nymphal period spanned from the first instar's emergence to the end of the fourth instar. The time span varied from 7 to 12 days, with an average duration of 10.62±1.26 days, as shown in Table 1. This aligns with Shirisha *et al.* (2009) [7], though slightly higher values were reported by Bhumannavar and Thontadarya (1981) [3], and Bade and Kadam (2001) [2], while lower values were noted by Rafik (1989) [6]. Variations are likely due to differences in climatic conditions. Moreover, the general colour patterns and morphological features are consistent with observations made earlier by Bhumannavar and Thontadarya (1981) [3], Rafik (1989) [6], Bade and Kadam (2001) [2], Singh and Singh (2007) [8], and Shirisha *et al.* (2009) [7].

Table 2: Measurement of various stages of *U. compositae*

Stage	Length			Width		
	Min.	Max.	Av. ± S.D.	Min.	Max.	Av. ± S.D.
I instar	1.03	1.32	1.19±0.07	0.55	0.62	0.56±0.02
II instar	1.35	1.53	1.43±0.06	0.59	0.79	0.68±0.04
III instar	1.59	1.98	1.78±0.15	0.62	0.77	0.70±0.17
IV instar	2.12	2.33	2.26±0.08	0.85	0.99	0.94±0.05
Adult female	2.41	2.70	2.58±0.13	1.11	1.27	1.20±0.06
Adult male	2.03	2.75	2.40±0.27	0.74	0.93	0.87±0.07

Description and measurement of adults

Apterate Adult: Adults were shining black in colour with spindle-shaped to elongated pyriform bodies. The compound eyes had a reddish-black hue and appeared bulged. The antennae were made up of six segments and were shorter than the body length, which ranged from 2.41 to 2.53 mm, with an average of 2.47±0.05 mm. Their legs were relatively sturdy, quite lengthy and covered in hair. The third pair of legs was longer than its preceding pairs. The lengths of the fore, middle, and hind legs differed by 2.08 to 2.17, 2.13 to 2.31, and 2.56 to 2.67 mm, respectively, averaging 2.10±0.03, 2.24±0.06, and 2.60±0.04 mm. The abdomen had a dark to black colour, a shiny appearance and was visibly swollen. Adult aphids possess a distinctive pair of long, brownish tubes known as cornicles. The lengths of cornicles ranged from 0.83 to 0.92 mm, averaging 0.85±0.03 mm, whereas cauda lengths ranged from 0.40 to 0.48 mm, averaging 0.44±0.03 mm (Table 2). Adults measured between 2.41 and 2.70 mm, with a mean length of 2.58±0.13 mm, and between 1.11 and 1.27 mm, with an average breadth of 1.20±0.06 mm, as shown in Table 2. A similar description of adult morphology was given by Bhumannavar and Thontadarya (1981) [3], Rafik (1989) [6], Eastop (2000) [4], Bade and Kadam (2001) [2], and Shirisha *et al.* (2009) [7]. The present measurements of apterate adults were also in close agreement with those reported by Shirisha *et al.* (2009) [7] (2.90±0.04 mm in length and 1.29±0.05 mm in breadth). The higher body size observed by Bhumannavar and Thontadarya (1981) [3] may be attributed to host plant and climatic conditions. The longevity of apterate adults ranged from 5 to 13 days with an average of 8.91±1.62 days, which was comparable to the reports of Shirisha *et al.* (2009) [7] but relatively shorter than 14.9±5.2 days recorded by Bhumannavar and Thontadarya (1981) [3] and 13.5±6.20 days by Bade and Kadam (2001) [2] on safflower. Such variation might be due to environmental differences.

Alate adult: The alate adult differed from the apterate adult in the possession of wings. The fore and hind wings were transparent and oblong in shape, with the forewing being longer and wider than the hind wing. Compared to the apterate adult, the alate adult was notably smaller in size, measuring between 2.03 and 2.75 mm in length, with an average of 2.40±0.27 mm, and between 0.74 and 0.93 mm in breadth, with an average of 0.87±0.07 mm (Table 2). The lengths of cornicles and cauda ranged from 0.54 to 0.64 mm and 0.15 to 0.19 mm, averaging 0.59±0.03 mm and 0.16±0.02 mm, respectively. The six-segmented antenna's length ranged from 1.98 to 2.19 mm, with an average measurement of 2.05±0.08 mm. The length of fore, middle and hind legs differed significantly, ranging from 2.01 to 2.22, 2.21 to 2.37 and 2.79 to 2.96 mm, with averages of 2.28±0.35, 2.30±0.05 and 2.86±0.06 mm, respectively (Table 2). The lifespan of adults ranged from a minimum of 5.0 days to a maximum of 13.0 days, with an average duration of 8.91±1.62 days as per Table 1. The present measurements of alate adults were in agreement with those of Shirisha *et al.* (2009) [7], who reported body dimensions of 2.53±0.16 mm in length and 0.81±0.06 mm in breadth, as well as similar values for antennae, cornicles, cauda and leg lengths.

Life cycle stages (Pre-reproduction, Reproduction and Post-reproduction)

Pre-reproduction: The minimum and maximum pre-reproduction periods were 0.5 and 2.0 days, with an average of 1.50±0.27 days, as shown in Table 1.

Reproduction period: The reproduction period was defined as the adult stage during which it produced offspring. A minimum of 4.0 days and a maximum of 10.0 days were recorded, with an average duration of 8.65±1.84 days as per Table 1.

Post-reproduction period: Following reproduction, the stage from adulthood to the point of death was referred to as the post-reproduction period. The duration was up to 1.0 days with an average of 0.57±0.076 days (Table 1).

The duration of respective stages of *U. compositae* recorded by Rafik (1989) [6] on safflower strongly supported the present findings. However, this period was noted higher by Bhumannavar and Thontadarya (1981) [3], and Bade and Kadam (2001) [2]. This difference might be due to host and environment.

Total life span: The total lifespan from birth to death spanned a minimum of 12.0 days, a maximum of 25.0 days, with an average of 19.3±1.92 days, as shown in Table 1**.** The more or less similar life span of *U. compositae* has been reported by Bade and Kadam, (2001) [2] and Shirisha *et al.* (2009) [7]. However, 10.66±1.01 (Bhumannavar and Thontadarya, 1981) [3] at Dharwad, 23 (Rathore and Pathak, 1983) and 25 (Dhembare, 1998) days of life period reported on safflower which deviated from the present investigation. These differences might be due to the effect of environmental conditions of the different location.

Fecundity: The reproductive potential of *U. compositae* was measured by counting the offspring of each adult aphid during its reproductive cycle. On average, each female produced between 11 and 57 offspring, with an average of 39.8±6.10 offspring (Table 1). Previous findings of Bindra and Bhumannavar and Thontadarya (1981) [3], Rafik (1989) [6], Bade and Kadam (2001) [2], Singh and Singh (2007) [8], and Shirisha *et al.* (2009) [7] collaborate this outcome. The *U. compositae* passed through four stages of nymph development.

Conclusion

The study found that the aphid, *U. compositae*, went through four nymphal stages. The newly hatched first instar nymph had an elongated, wingless, transparent and pale brownish or reddish appearance. As the nymph matured, its colour evolved from pale brown to dark brown. The antennae were longer than the body's width but shorter than its length. Observations revealed a cetaceous abdomen with a five-segmented pair of cornicles located on the posterior region. The second instar nymph was only slightly swollen, yet resembled the first instar nymph in terms of its overall appearance and morphological features. The third-stage nymph had a dark brown colour. The compound eyes were round, small and larger than those in the second instar and reddish-black in colour. The fourth-stage nymph had a resemblance to the third-stage nymph in its overall appearance and morphological features.

The first, second, third, and fourth instar nymph's length ranged from 1.03 to 1.32 (1.19±0.07) mm, 1.35 to 1.53 (1.43±0.06) mm, 1.59 to 1.98 (1.78±0.15) mm, and 2.12 to 2.33 (2.26±0.08) mm respectively, whereas its breadth ranged from 0.55 to 0.62 (0.56±0.02) mm, 0.59 to 0.79 (0.68±0.04) mm, 0.62 to 0.77 (0.70±0.17) mm, and 0.85 to 0.99 (0.94±0.05) mm.

The durations of first, second, third, and fourth instar nymphs were 2.26±0.32, 2.49±0.60, 2.79±0.31, and 3.1±0.64 days, respectively. The duration of the total nymphal period ranged from 7 to 12 days with an average of 10.62±1.26 days.

Adults of the *U. compositae* species exhibited a shiny black colouration with a spindle-shaped to elongated pyriform body. The specimen was equipped with well-developed cornicles, antennae, and three sets of legs. The dimensions of adult specimens were 2.41 to 2.70 (2.58±0.13) mm in length and 1.11 to 1.27 (1.20±0.06) mm in breadth. The adult lifespan was found to be between 5 to 13 days, averaging 8.91±1.62 days.

These periods prior to, during, and after reproduction were observed to range from 0.5 to 2.0 (1.50±0.27), 4 to 10 (8.65±1.84) and 0.5 to 1.0 (0.57±0.07) days, in that order. The duration of this generation period varied from 12 to 25 days, averaging 19.30±1.92 days.

Adults of the *U. compositae* species produce between 11 and 57 nymphs per life period, with an average of 39.80±6.1 nymphs.

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