

Chromosomal studies on various species of Aphids infesting different host plant species

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Abstract

Aphids are small, polyphagous insect pests, harmful to plants, commonly found in gardens, wild plants, and on vegetable crops and agricultural fields. They damage host plants by feeding on its sap. Aphid pests have a fascinating biology and cytology that makes research subject interesting.

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They show polymorphism, viviparity and generational telescoping of their generations. There are number of karyotypic variations caused by fragmentation and fusion of holocentric chromosomes. Even within single species, aphids typically display an exceptional degree of karyotypic diversity. Aphid chromosomes infesting nine species of host plants have been examined in the present investigation. Out of these 9 species 2 species namely *Aphis fabae solanella* (2n=7, 8) and *Lipaphis erysimi* (2n=9, 10) showed karyotypic variations. At metaphase stage chromosomal lengths, both actual and relative as well as total complement length (TCL) were assessed. Aphid species showed varying chromosomal measurements: *Apis craccivora* had the shortest chromosome, while *Aphis gossypii* had the longest; *Sitobian chanikiwitii* had the highest total complement length, and *Aphis fabae* and *Aphis gossypii* had the shortest relative lengths of chromosomes. Based on the relative lengths data, karyotypes and idiograms were constructed.

Keywords: Aphids, karyotype, idiogram, total complement length

Introduction

There are over 5,000 known species of aphids worldwide (Bass and Nauen, 2023) [2]. These species vary in appearance, behavior, and host plant preference (Albornoz *et al.*, 2023) [1]. Plant sap are the primary food source for aphids, which are small, soft-bodied phytophagous insects. They are commonly found in gardens, on house plants, and in agricultural fields (Stankevych, Horiainov and Horiainova, 2023) [9]. These insects reproduce quickly, with female giving birth to live young one with or without mating depending on the season (Kłoskiewicz and Świątek, 2023) [4]. This allows aphid populations to grow rapidly and infest plants in large number. Each species may have specific characteristics and interactions with plants and other organisms in their ecosystem. They feed on sap of plants by inserting their piercing and sucking mouthparts into plant tissues (Stec, Kordan and Gabryś, 2021) [10]. This can cause the plant to weaken and become stressed hence decrease the productivity of the plant. Moreover, aphids release an oily substance called honeydew, which attract ants and promote black mold growth as well as other secondary infections (Lu *et al.*, 2022) [5]. Sexual behavior in aphids is controlled by the XX female: XO male system (Jaquiéry *et al.*, 2012) [3]. From all fertilized eggs of sexual females, parthenogenetically females are produced. As parthenogenetically developed eggs mature, the behavior of X chromosomes determines whether they develop into males or females (Ogawa and Miura, 2014) [8]. In a single

maturation split, oocytes lose half of their parental female's X chromatin, resulting in males. In species with prolific sexual reproduction, aphids tend to have a high degree of karyotypic variation (Mukherjee, 2012) [7]. Aphids have holocentric chromosomes whose fusion and fragmentation, results in karyotypic variation (Manicardi, Nardelli and Mandrioli, 2015) [6]. Chromosomal studies on different species of aphids have provided a foundation for understanding their genetic diversity, adaptation, and evolutionary processes (Trocza *et al.*, 2021) [11]. These research endeavors persist in enhancing our understanding of aphid biology and carry significance for agriculture and the control of pests. In this current study a total of 9 aphid species were employed to evaluate their chromosomal variations.

Material and methods

1. Sample collection

In present investigation, study on aphid chromosomes infesting different host plants was conducted. The aphids were collected during April to November from Hamirpur district (latitude 31.52°N, 76.44°E and altitude of 738 meters above sea level) of Himachal Pradesh. We collected the aphids from flower buds, undersides of young leaves, and green stems and placed them in polythene bags. Aphid biology was also observed and recorded at the infestation site.

2. Cytological studies

Parthenogenetic viviparous females were used for studying the chromosomes. We used somatic embryonic tissue for chromosomal studies. The embryos were subjected to a pre-treatment of 30 minutes in a solution containing 0.7% trisodium citrate. Embryos that had previously undergone this treatment were then immersed in a solution composed of one-part acetic acid to three parts ethanol for a duration of 15-20 minutes at room temperature.

After fixation the embryos were submerged for 4 to 5 minutes in 45% acetic acid. The blunt ended forceps was used to gently tap the coverslip. A razor blade's edge was employed to carefully remove the coverslip from the slide following this both the slide and coverslip were dried within a chamber devoid of dust particles. Dried slides were stained with 2% Giemsa for 40 to 45 minutes. By rinsing the slides and cover slips with distilled water excess of stain was washed off. Slides and cover slips were air dried at room temperature. After mounting the slides in DPX, they were left overnight in an oven at 60°C. These were permanent slides.

The permanent slides were then observed under research binocular microscopes. For photomicrography, well spread chromosomes plates were selected and observed under LEICA DFC-320 camera. An ocular micrometer was used to measure the length of the chromosomes. Total complement lengths were calculated based on their actual lengths. A relative length for each species was calculated based on actual data. On the basis of relative lengths, idiograms were constructed. For species identification, keys develop by Blackman and Eastop (1984) were used.

Results

Aphid species along with their host plant and diploid chromosome number shown in Table 1. Shiny black-colored aphids of *Aphis craccivora* were concentrated on the spikelets of *Phragmites australis*. There were eight diploid chromosomes, $2n=8$. Brown colored aphids of *Aphis fabae solanella* were collected from the stem, leaves and flower of *Solanum nigrum*. Aphids were ant attended. It was found that $2n$ was eight. Dark green coloured aphids of *Aphis gossypii* were collected from the ventral surface of young leaves, shoots and fruit of *capsicum annum*. Grey green-colored aphids of *Lipaphis erysimi* were present on the

apical shoots, leaves and flowers of the *Brassica compestris*. There were ten diploid chromosomes in this organism ($2n=10$). Yellowish green-colored aphids of *Macrosiphum euphorbiae* were present on the apical shoots and flowers of *Tagetes erecta*. It was determined that the diploid number of chromosomes was ten ($2n=10$). Bluish green-coloured aphids of *Rhopalosiphum maidis* were collected from the dorsal surface of the leaves of *Panicum dichotomiflorum*. There were ten diploid chromosomes ($2n=10$) in the cell. Bluish green-colored aphids of *Sitobion chanikiwiti* were collected from the flower and leaves of the *Avenula pratensis*. We found that $2n$ is eighteen ($2n=18$). Yellowish green-colored aphids of *Takecallis taiwanus* were collected from the unrolled leaves and new shoots of *Bambusa* sp. $2n$ was found to be sixteen ($2n=16$). Brown coloured aphids of *Toxoptera odinae* were collected from the leaves and shoots of the *Capsicum* species. There were eight diploid chromosomes ($2n=8$) found in the sample. For all these nine species of aphid's karyotype, and idiogram were constructed, shown in (Table 2). Mean actual length (MAL), Total complement length (TCL) and Relative length (RL) were measured in 9 aphid species infesting different host plants (Table 3). Out of these, the minimum MAL of shortest chromosome was reported in *Aphis craccivora* (0.75 ± 0.01) followed by *Lipaphis erysimi* (0.76 ± 0.11) and maximum MAL was reported in *Toxoptera odinae* (1.93 ± 0.22). Similarly, minimum MAL of longest chromosome was reported in *Macrosiphum euphorbiae* (2.23 ± 0.01) followed by *Takecallis taiwanus* (2.60 ± 0.15) and maximum MAL was reported in *Aphis gossypii* (4.32 ± 0.10). The TCL was reported maximum in *Sitobian chanikiwiti* (47.58 ± 0.48) followed by *Takecallis taiwanus* (32.48 ± 1.30) and the results of minimum TCL were significantly similar in *Aphis fabae* and *Aphis gossypii* i.e., 19.80 ± 1.04 . The minimum RL of shortest chromosome was reported in *Sitobian chainikiwiti* (1.61 ± 0.02) followed by *Lipaphis erysimi* (4.04 ± 0.01) and maximum RL of shortest chromosome was reported in 2 aphid species *Aphis fabae* and *Aphis gossypii* i.e., 8.44 ± 0.91 . Similarly, the minimum RL of longest chromosome was reported in *Takecallis taiwanus* (4.60 ± 0.08) followed by *Sitobian chainikiwiti* (1.61 ± 0.02) and maximum RL of longest chromosome was reported in *Aphis craccivora* (21.04 ± 0.79).

Table 1: Depicting aphid species along with their host plant and diploid chromosome numbers

Sr. No.	Aphid species	Host Plant	Chromosome Number (2n)
1.	<i>Aphis craccivora</i> Koch	<i>Phragmites australis</i>	8
2.	<i>Aphis fabae solanella</i> Theobald	<i>Solanum nigrum</i>	7, 8
3.	<i>Aphis gossypii</i> Glover	<i>Capsicum annum</i>	8
4.	<i>Lipaphis erysimi</i> (Kaltenbach)	<i>Brassica compestris</i>	9, 10
5.	<i>Macrosiphum euphorbiae</i> (Thomas)	<i>Tagetes erecta</i>	10
6.	<i>Rhopalosiphum maidis</i> (Fitch)	<i>Panicum dictomiflorum</i> ,	12
7.	<i>Sitobion chanikiwiti</i>	<i>Avenula pratensis</i>	18
8.	<i>Takecallis taiwanus</i> (Takahashi)	<i>Bambusa</i> sp.	16
9.	<i>Toxoptera odinae</i> (van der Goot)	<i>Capsicum</i> sp.	8

Table 2: Represents somatic chromosome number, karyotype, and idiogram of different aphid species as given below






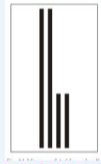
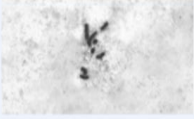

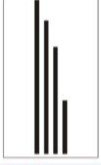



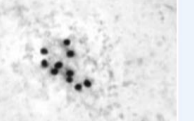


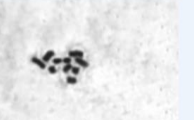





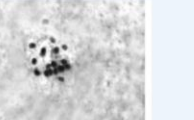


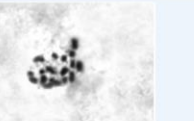


		
<p>1. Somatic metaphase plate of <i>Aphis craccivora</i></p>	<p>2. Karyotype</p>	<p>3. Idiogram</p>
		
<p>4. Somatic metaphase plate of <i>Aphis fabae solanella</i></p>	<p>5. Karyotype</p>	<p>6. Idiogram</p>
		
<p>7. Somatic metaphase plate of <i>Aphis gossypii</i></p>	<p>8. Karyotype</p>	<p>9. Idiogram</p>
		
<p>10. Somatic metaphase plate of <i>Lipaphis erysimi</i></p>	<p>11. Karyotype</p>	<p>12. Idiogram</p>
		
<p>13. Somatic metaphase plate of <i>Macrosiphum euphorbiae</i></p>	<p>14. Karyotype</p>	<p>15. Idiogram</p>
		
<p>16. Somatic metaphase plate of <i>Rhopalosiphum maidis</i></p>	<p>17. Karyotype</p>	<p>18. Idiogram</p>
		
<p>19. Somatic metaphase plate of <i>Sitobion chanikiwiti</i></p>	<p>20. Karyotype</p>	<p>21. Idiogram</p>
		
<p>22. Somatic metaphase plate of <i>Takecallis taiwanus</i></p>	<p>23. Karyotype</p>	<p>24. Idiogram</p>
		
<p>25. Somatic metaphase plate of <i>Toxoptera odinae</i></p>	<p>26. Karyotype</p>	<p>27. Idiogram</p>

Table 3: Represents aphid species along with their mean actual length, total complement length and relative length of chromosomes

Sr. No.	Aphid species	Mean actual length (MAL) in μm		Total complement length (TCL) in μm	Relative length (RL) in μm	
		Shortest chromosome	Longest chromosome		Shortest chromosome	Longest chromosome
1.	<i>Aphis craccivora</i> Koch	0.75 \pm 0.01	2.83 \pm 0.14	13.12 \pm 0.34	5.74 \pm 0.15	21.04 \pm 0.79
2.	<i>Aphis fabae solanella</i> Theobald	1.49 \pm 0.01	3.20 \pm 0.15	19.80 \pm 1.04	8.44 \pm 0.91	15.35 \pm 0.55
3.	<i>Aphis gossypii</i> Glover	1.49 \pm 0.01	4.32 \pm 0.10	19.80 \pm 1.04	8.44 \pm 0.91	15.35 \pm 0.55
4.	<i>Lipaphis erysimi</i> (Kaltenbach)	0.76 \pm 0.11	3.49 \pm 0.11	23.82 \pm 0.50	4.04 \pm 0.01	14.67 \pm 0.11
5.	<i>Macrosiphum euphorbiae</i> (Thomas)	1.63 \pm 0.09	2.23 \pm 0.01	22.72 \pm 1.32	8.16 \pm 0.30	11.22 \pm 0.20
6.	<i>Rhopalosiphum maidis</i> (Fitch)	1.11 \pm 0.24	2.98 \pm 0.01	22.32 \pm 1.25	4.43 \pm 0.88	12.43 \pm 1.19
7.	<i>Sitobion chanikiwiti</i>	1.61 \pm 0.02	3.72 \pm 0.01	47.58 \pm 0.48	1.61 \pm 0.02	8.12 \pm 0.13
8.	<i>Takecallis taiwanus</i> (Takahashi)	1.49 \pm 0.01	2.60 \pm 0.15	32.48 \pm 1.30	4.60 \pm 0.08	8.10 \pm 0.17
9.	<i>Toxoptera odinae</i> (van der Goot)	1.93 \pm 0.22	3.49 \pm 0.11	24.80 \pm 1.13	7.86 \pm 1.01	14.04 \pm 0.33

Conclusion

Aphids infesting different host plants were studied for their chromosomes in the present study. In all these aphid species, diploid chromosome number ranged from $2n=8$ to $2n=18$. In *Aphis craccivora*, *Aphis fabae*, *Aphis fabae solanella* and *Toxoptera odinae* it was determined that there were eight diploid chromosomes ($2n=8$). $2n$ for *Lipaphis erysimi*, *Macrosiphum euphorbiae*, and *Rhopalosiphum maidis* were observed to be ten ($2n=10$). $2n$ was discovered to be eighteen ($2n=18$) in *Sitobion chanikiwiti*. In *Takecallis taiwanus* the diploid chromosome number was found to be sixteen ($2n=16$). Out of these 9 species 2 species namely *Aphis fabae solanella* ($2n=7, 8$) and *Lipaphis erysimi* ($2n=9, 10$) showed karyotypic variations. Chromosomal rearrangements, due to their holocentricity, appear to be involved in causing changes in chromosome number in aphid karyotypes. This role may be explained by the higher capacity of fusions and dissociations of holocentric chromosomes to survive cell division.

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Author contribution

SK: Conceptualization; PK: Data analysis, curation and validation; KC: Data interpretation and literature review, PK: Original draft preparation; KC: Editing, final draft preparation and critical revision, KR: Data interpretation and literature review.

Conflicts of interest

The authors declare that they have no conflict of interest. The manuscript has not been submitted to any other journal.

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