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Ctenocallis setosa (Kaltenbach, 1846) (Hemiptera, Aphididae), a new adventive species in Japan

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Abstract

Numerous species of adventive aphids in Japan exhibit a strong association with naturalized plants, making the aphid studies on such plants crucial for the early detection of newly introduced species. During 2017–2018 and 2023–2024, we examined the aphids occurring on a naturalized plant, *Cytisus scoparius* (L.) Link (Fabaceae) in Japan, documenting the occurrence of a new adventive species, *Ctenocallis setosa* (Kaltenbach, 1846) in the country. This represents the first record of this species also from Asia, as it is native to Europe and had previously been adventive only in North America. This paper provides the photographs and morphological redescriptions of its viviparae (apterous and alate) and sexuals (oviparae and alate males). The findings from this field study suggest that this species exhibits a monoecious holocyclic life cycle in Japan, characterized by the sexual morph production for laying overwintering eggs in fall and the absence of host alternation during summer.

Key words: alien species, cyclical parthenogenesis, distribution, exotic species, herbivorous insects, host plant, scotch broom

Introduction

Aphids (Hemiptera: Aphididae), a group of phloem sap-feeding insects, encompass over 5,000 species globally (Blackman & Eastop 2017). The phenomenon of biological invasions poses no exception for aphids, as adventive species continue to be documented worldwide (e.g., Coeur d'Acier 2010; Kök & Özdemir 2022; Skvarla *et al.* 2017). In Japan, approximately 750 aphid species are known (Miyazaki *et al.* 2016) and 33 adventive species had already been reported in 2023 (Sasaki 2023a). In the latter literature, *Pemphigus bursarius* (Linnaeus, 1758) reported by Lee & Akimoto (2013) is overlooked. More recently, *Drepanaphis acerifoliae* (Thomas, 1878) has been reported by Sugimoto (2024). In conclusion, 35 adventive species have been currently known in Japan.

Most aphid species are highly specialized in their feeding preferences, utilizing only one or a few closely related plant species as hosts (Powell *et al.* 2006). Consequently, numerous adventive aphids in Japan are closely associated with naturalized plants that share their geographic origin: e.g. *Aphis hypochoeridis* (Börner, 1940) and *Hypochaeris radicata* L., both native to Europe (Sugimoto 2020); *Periphyllus acerihabitans* Zhang, 1982 and *Acer buergerianum* Miq., native to China (Wieczorek *et al.* 2016); and *Uroleucon nigrotuberculatum* (Olive, 1963) and *Solidago altissima* L., native to North America (Sugimoto & Matsumoto 2000). Thus, the investigation of aphids on naturalized plants is important for the early detection of new adventive species.

Scotch broom, *Cytisus scoparius* (L.) Link (Fabaceae), native to Europe and North Africa, has been introduced into numerous regions worldwide, including Australia, Canada, Chile, India, Iran, New Zealand, South Africa, the United States, and Japan (Zouhar 2005). In Japan, this plant, commonly known as "Enishida", is already widely naturalized (Koide 2019). Several mono- or oligophagous aphid species, non-native to Japan, have been reported on scotch broom in other parts of the world (Blackman & Eastop 2006; Holman 2009). This plant could therefore be the

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habitat for new adventive aphids in Japan. However, no prior studies have examined the aphids associated with this plant within the country.

In 2017, the first author found a yellow-colored aphid species on this plant in Japan, prompting a detailed investigation into its identity. Morphological identification of the specimens collected from Yamanashi and Hokkaido Prefectures during 2017–2018 and 2023–2024 identified this species as *Ctenocallis setosa* (Kaltenbach, 1846). The present paper provides the photographs and morphological redescriptions of its viviparae (apterous and alate) and sexuals (oviparae and alate males). Furthermore, we present information on the life cycle of this species in Japan.

Material and methods

Field studies on scotch broom were conducted in Yamanashi Prefecture, Honshu Island, central Japan during 2017–2018 by the first author and in 2023 by the second author. Additionally, the first author carried out similar studies in Hokkaido Prefecture, Hokkaido Island, northern Japan during 2023–2024. The scotch broom shrubs examined in these studies predominantly ranged in height from one to two meters. The aphid body colors, the host plant parts where aphids lived, and the presence of attending ants within aphid colonies were recorded.

Photographs of the field studies by the first author were taken by a digital camera (Stylus TG-4 or TG-6, Olympus) with a flash diffuser (FD-1, Olympus). Aphid samples were collected and preserved in 70 % ethanol or AGA solution (Mound & Kibby 1998) for subsequent identification. The aphid samples were mounted on microscope-slides in Canada balsam following the method by Sasaki (2022). Digital images of slide-mounted specimens were taken by a digital microscope camera (DP-28, Olympus) attached to a differential interference contrast microscope (BX-53, Olympus). Measurements of each specimen were obtained from the digital images by an imaging software (cellSens, Olympus).

Results

***Ctenocallis setosa* (Kaltenbach, 1846)**
Aphis setosa: Kaltenbach, 1846: 172–173.
Oniscomyzus setosus: Börner, 1950.
Gentnera oregona: Essig, 1952: 215–219.
Ctenocallis setosa: Quednau, 1954: 30, 44.
[Japanese name: Enishida-toge-madara-aburamushi (new proposal)]

Morphological redescription

Biometric data and abbreviations are presented in Table 2. Adult apterous viviparous females (Figs. 1B, C, 2A, 3A, B) —*Color*: body pale yellow including spinal and marginal tubercles (processes), but with dark brown dorsal sclerites. Antennae pale yellow with darker on distal segments, their pigmentation varies individually but approximately as follows: Ant I–II entirely pale; Ant III–IV pale with darker apex; Ant V–VI (base) pale with darker on apical half; Ant PT entirely dark. Legs pale yellow with darker on tarsus. Cauda and anal plate pale yellow. *Morphology*: Body spindle-shaped; Head: Dorsum surface with weakly sclerotized and rugose on median longitudinal part, with two spinal wart-like tubercle pairs on anterior half and with one spinal plus one marginal wart-like tubercle pairs on posterior half. Antennal tubercle not developed. Frontal tubercle slightly developed. Antenna six-segmented. Ant I–II smooth, Ant III–VI covered with transverse rows of fine spinules. Ant III with transverse-oval to oval shaped 3–6 secondary rhinaria. URS usually with one secondary hair pairs; Thorax: Dorsal surface with narrow intersegmental transverse brown sclerites and with large segmentally divided transverse brown sclerites, the later strongly rugose and those on metanotum sometimes divided in the middle. Pro- and mesonotum with one spinal wart-like processes pairs on anterior half, with one spinal and marginal finger-like processes pairs on posterior half. Metanotum with one spinal and marginal finger-like processes pairs on each segment. Coxa smooth dorsally and weakly spinulose ventrally. Trochanter smooth. Femur smooth dorsally and weakly spinulose ventrally. Tibia smooth proximally and spinulose distally. First tarsal segment smooth proximally and spinulose distally. Second tarsal segment spinulose entirely. Abdomen: Dorsal surface with narrow intersegmental transverse brown dorsal sclerites and with large segmentally divided transverse brown dorsal sclerites, those on abdominal tergites I–VII divided in the middle. Tergites I to VI with one spinal and marginal finger-like processes pairs. Siphuncular pores placed on basal half of marginal processes on tergite VI. Tergite VII without spinal process and with two marginal finger-like processes pairs. Tergite VIII with one spinal finger-like processes pair. Anal plate bilobed, covered with transverse rows of fine spinules, with hairs comprised very short and long one. Cauda knobbed, covered with transverse rows of fine spinules, with hairs comprised short and long one.

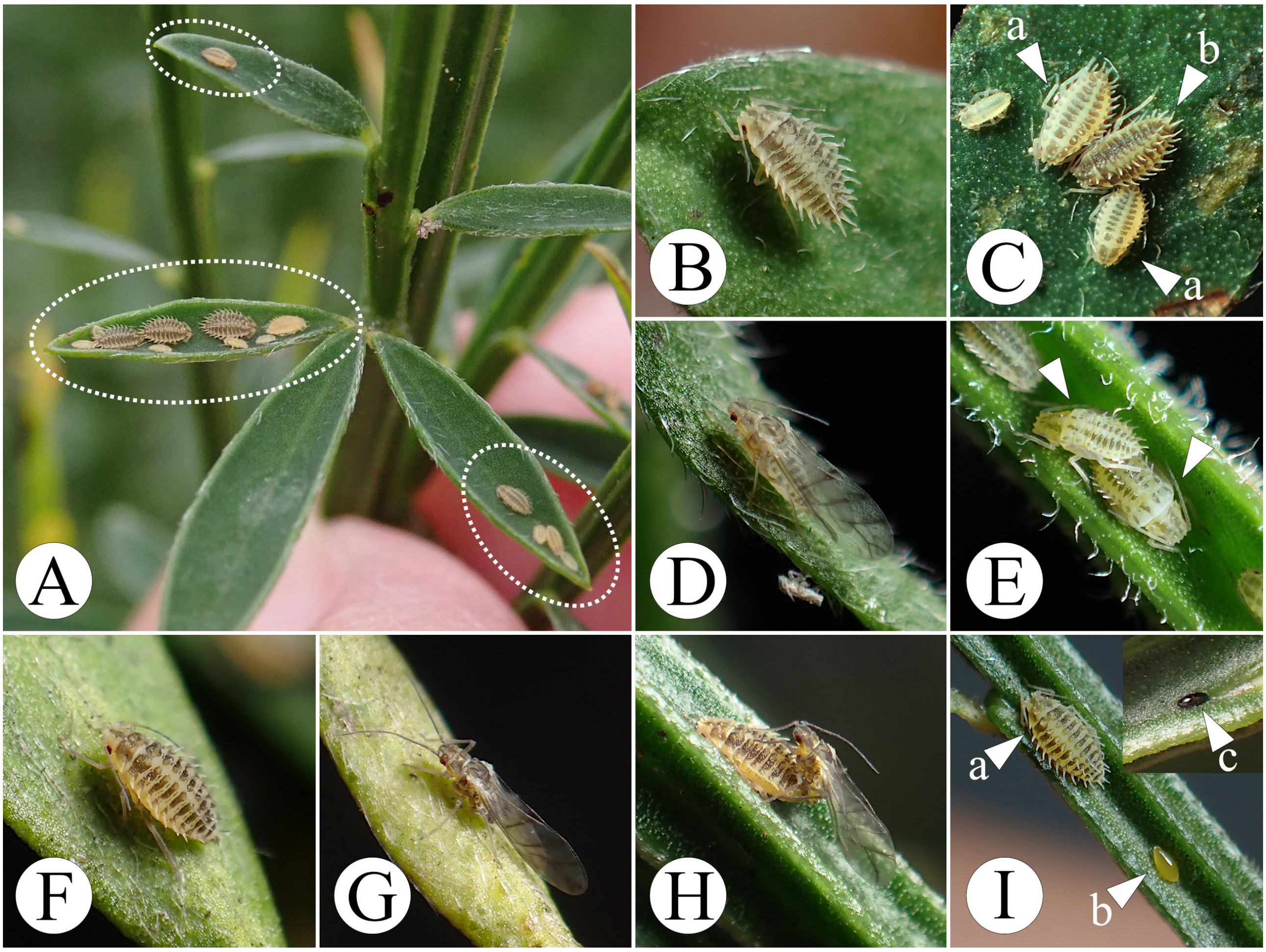

Figure 1. *Ctenocallis setosa* occurring on scotch broom in Japan. **A,** Colonies on the upper surface of matured leaves in Yamanashi on July 9, 2023; **B,** Adult apterous viviparous female in Hokkaido on July 2, 2023; **C,** Apteroid nymphs (a) and adult apterous viviparous female (b) in Yamanashi on July 30, 2017; **D,** Adult alate viviparous female in Hokkaido on July 2, 2023; **E,** Alatoid nymphs (arrows) in Yamanashi on September 10, 2017; **F,** Adult oviparous female in Hokkaido on September 28, 2024; **G,** Adult alate male in Hokkaido on September 28, 2024; **H,** Mating of ovipara and male in Hokkaido on October 20, 2024; **I,** Adult oviparous female (a) and newly-laid egg (b) in Hokkaido on September 28, 2024, and matured egg (c) in Hokkaido on October 20, 2024; **A**, photographed by Akihide KOGUCHI; **B–I**, by Daisuke SASAKI.

Adult alate viviparous females (Figs. 1D, 2C, 3C, D)—*Color*: Head and thorax dark brown, abdomen pale yellow with dark brown dorsal and marginal markings. Appendages almost the same as apterous viviparae. *Morphology*: Body spindle-shaped; Head: Dorsal surface entirely sclerotized with hardly developed tubercles located as apterous viviparae. Ant III with 9–10 secondary rhinaria. Thorax: Dorsal surface entirely sclerotized and finely imbricated. Fore wing with two unbranched cubitus veins separated widely each other, with one media vein branched twice, and without a radial sector. Hind wing with one or two oblique veins. Abdomen: Dorsal surface with narrow intersegmental transverse dark dorsal sclerites, and with large segmentally divided transverse dark dorsal sclerites, those on abdominal tergites I–VII (sometimes also VIII) divided in the middle, and with dark marginal sclerites on abdominal tergites I–V (those on V sometime fused to large dorsal sclerites). These sclerites finely imbricated on their surfaces. Tergites with hardly developed tubercles located as apterous viviparae. Other features almost the same as apterous viviparous females. As described above, this morph without finger-like dorsal processes, whereas its immatures, alatoid nymphs (Figs. 1E, 2D) with spinal and marginal finger-like dorsal processes as apteroid nymphs (Figs. 1C, 2B) and adult apterous viviparous females.

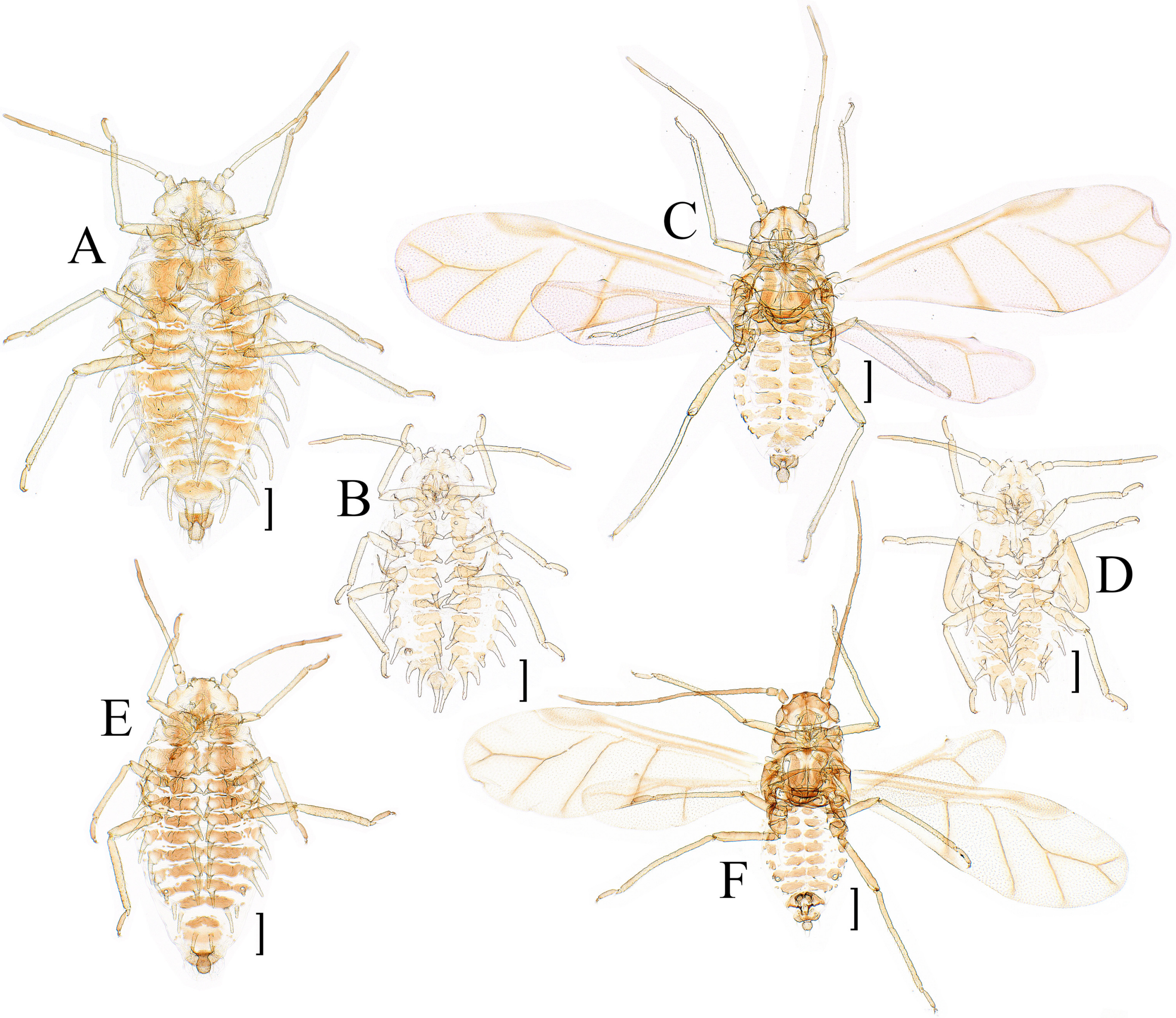

Figure 2. Slide-mounted specimens of *Ctenocallis setosa*. **A,** Adult apterous viviparous female (Specimen number: 64004); **B,** Apteroid nymph, most likely fourth-instar (64025); **C,** Adult alate viviparous female (64014); **D,** Alatoid nymph, most likely fourth-instar (64028); **E,** Adult oviparous female (68064); **F,** Adult alate male (68072); All scale bars are 200 µm.

Adult oviparous females (Figs. 1F, H, Ia, 2E, 3E)—*Color*: Almost the same as apterous viviparae. *Morphology*: Hind tibia with scent glands on swollen part. Tubercles on abdominal tergites relatively shorter on posterior segments than apterous viviparae, spinal tubercles on abdominal tergites VIII usually shorter than the posterior end of anal plate and cauda. Abdominal tergites VIII with acute marginal hairs on each side. Anal plate not bilobed. Caudal hairs as apterous viviparae (but the number was not able to measure because cauda and anal plate were overlapped each other). Other features almost the same as apterous viviparous females.

Adult alate males (Figs. 1G, H, 2F, 3F)—*Color*: Almost the same as alate viviparae except for antennae entirely dark. *Morphology*: Ant III, IV, V, and VI (base) with secondary rhinaria. Anal plate weakly bilobed. Other features almost the same as alate viviparous females.

Diagnosis

The genus *Ctenocallis* Klodnitsky, 1924 includes the following three species: *Ct. setosa* (Kaltenbach, 1846), *Ct. dobrovljanskyi* Klodnitsky, 1924, and *Ct. israelica* Hille Ris Lambers, 1954 (Blackman & Eastop 2006; Quednau 2003). According to the identification key to species of the genus by Quednau (2003), the apterous vivipara of *Ct. setosa* has elongate finger-like spinal tubercles from pronotum to abdominal tergite VI "as long as" marginal ones of respective tergites. In contrast, *Ct. dobrovljanskyi* has spinal tubercles hardly raised above surface and *Ct. israelica* has short finger-like spinal ones much shorter than marginal ones. In the key by Halaj & Osiadacz (2014), the apterous vivipara of *Ct. setosa* has spinal tubercles on abdominal tergites nearly equal to marginal ones, whereas *Ct. dobrovljanskyi* has no spinal ones, if present they are shaped like tiny projections of a height equal at the most to 0.5–0.75 times as long as their diameter at the base and *Ct. israelica* has spinal ones which never exceeds half the length of marginal ones and are never smaller than their diameter at the base.

In the present specimens of apterous vivipara, the spinal tubercles on abdominal tergites were shorter than the marginal ones but averagely longer than half the length of those (Fig. 3A, B; Table 2). Although, in a few specimens, a spinal tubercle was shorter than half the length of marginal one, other spinal tubercles in the same specimens were relatively longer. For example, in the No. 1017 specimen was 1.24, 0.92, 0.43, 0.56, 0.67, 0.65, 0.73, 0.76, and 1.65, the No. 14007 specimen was 1.00, 0.75, 0.74, 0.48, 0.61, 0.68, 0.76, 0.62, 2.31 on thorax I, II, III, abdomen I, II, III, IV, V, and VI, respectively. Furthermore, in all examined specimens, spinal tubercles were never smaller than their diameter at the base (Fig. 3A, B). Based on these morphological features, the present first author identified all the specimens collected from Japan as *Ct. setosa*.

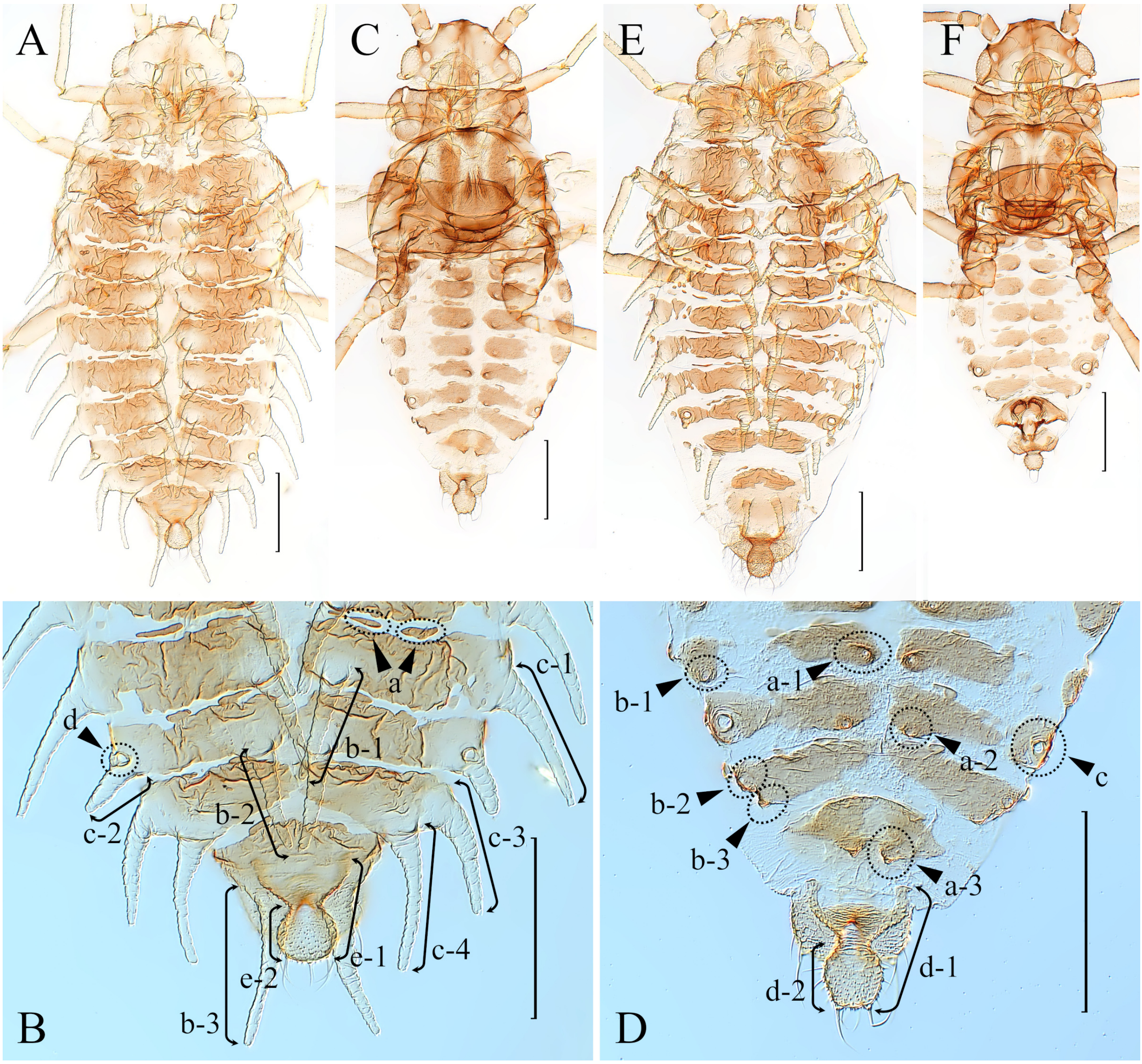

Figure 3. Dorsal views of slide-mounted specimens of *Ctenocallis setosa*. **A–B,** Adult apterous viviparous female (Specimen number: 1022)—a, intersegmental sclerites; b, spinal tubercles on abdominal tergites V (-1), VI (-2), and VIII (-3); c, marginal tubercles on abdominal tergites V (-1), VI (-2), and VII (-3, -4); d, siphuncular pore; e, cauda (-1) and its knob (-2); **C–D,** Adult alate viviparous female (2086)—a, spinal tubercles on abdominal tergites V (-1), VI (-2), and VIII (-3); b, marginal tubercles on abdominal tergites V (-1) and VII (-2, -3); c, siphuncular pore; d, cauda (-1) and its knob (-2); **E,** Adult oviparous female (68064); **F,** Adult alate male (68072); All scale bars are 200 µm.

Field observation

In Yamanashi, *Ct. setosa* was found on the scotch broom shrubs, which were planted in gardens, in 2017, 2018, and 2023 (Table 1; Fig. 1A, C, E). The colonies included apterous viviparous females and apteroid nymphs (Fig. 1A, C), and the colony in September 2017 also included alate viviparous females, alate males, and alatoid nymphs (Fig. 1E). In Hokkaido, the same aphid species was also found on the same plant shrubs, which grew on a road slope and were likely planted in the past for slope revegetation, in 2023 and 2024 (Table 1; Fig. 1B, D, F–I). The colonies consisted of apterous viviparous females (Fig. 1B) and apteroid nymphs; the colony in July 2023 also included alate viviparous females (Fig. 1D) and alatoid nymphs; the colonies in September–October 2024 also included oviparous females (Fig. 1F, H, Ia) and alate males (Fig. 1G, H). The colony had transitioned completely from viviparae to sexuals in late October (Table 1). Eggs were predominantly laid on the recessed parts between the ridges of the stems (Fig. 1Ib, c). Newly laid eggs were yellow (Fig. 1Ib), while the mature eggs turned black (Fig. 1Ic).

Table 1. Collecting records of *Ctenocallis setosa* occurring on scotch broom, *Cytisus scoparius* in Japan. Apt.—adult apterous viviparous female(s), Alt.—adult alate viviparous female(s), Ovi.—adult oviparous female(s), M.—adult alate male(s), Apt-N.—apteroid nymph(s), Alt-N.—alatoid nymph(s). The present first author's aphid specimen numbers show in parentheses of the rightmost column. All specimens were collected by Daisuke SASAKI, except for the specimens in Yamanashi Pref. in 2023 by Akihide KOGUCHI.

Site	Date	Aphid specimens
Shibokusa, Oshino-mura, Minamitsuru-gun, Yamanashi Pref. [山梨県 南都留郡 忍野村 忍草] 35°27'N, 138°49'E	Jul. 30, 2017	11 Apt. (1015–1025)
	Sep. 10, 2017	3 Apt., 2 Alt., 4 M., 3 Alt-N. (2083–2094)
	Sep. 17, 2018	3 Apt. (14006–14008)
Nishikagura 4 sen, Asahikawa City, Hokkaidô Pref. [北海道 旭川市 西神楽4線] 43°39'N, 142°27'E	Jul. 2, 2023	19 Apt., 14 Alt., 7 Apt-N., 7 Alt-N. (64003–64030)
	August 12, 2024	8 Apt., 2 Apt-N (67038–67047)
	September 14, 2024	2 Apt. (68059–68060)
	September 28, 2024	3 Apt., 8 Ovi, 7 M, 1 Apt-N, 1 Alt-N (68061–68080)
	October 20, 2024	9 Ovi, 1 M (68081–68090)
Kamisasao, Kobuchisawa-chô, Hokuto City, Yamanashi Pref. [山梨県 北杜市 小淵沢町 上笹尾] 35°51'N, 138°20'E	Jul. 9, 2023	3 Apt. (64063–64065)

In both Yamanashi and Hokkaido, the aphids sparsely colonized the upper surface of mature leaves mostly along the midrib (Fig. 1A) and on the recessed parts between the ridges of the stems (Fig. 1E). Colonization on the under surface of leaves and on the young shoots was infrequent. This distributional pattern was consistent with previous reports (e.g., Heie 1982; Nieto Nafría & Mier Durante 1998; Stroyan 1977). Ant attendance was not observed, supporting earlier statements (e.g., Heie 1982; Lampel & Meier 2003). No obvious damage to host plants was observed during the surveys.

Additionally, the present first author found an unidentified species of the genus *Aphis* Linnaeus, 1758 belonging to "black-backed" species group (Stroyan 1984) on the young shoots and the bean pods of scotch broom shrubs in Japan. This species resembled *Aphis craccivora* Koch, 1854 but differed in some morphological features. The author was not able to identify this species at present; therefore, the detail of this species was not reported in the present paper. Only *Ct. setosa* and *Aphis* sp. were found in this study.

Table 2. Biometric data of *Ctenocallis setosa* specimens collected in this study. Examined specimen number (see Table 1) are 1015–1025, 2083–2085, 14006–14008, 64003–64008 in apterous viviparae; 2086–2087, 64014–64016 in alate viviparae; 68064–68068 in oviparae; and 2088–2091, 68072–68074 in alate male.

	Part	Apterous viviparae				Alate viviparae				Oviparae				Alate males			
		n	Ave.	Min.	Max.	n	Ave.	Min.	Max.	n	Ave.	Min.	Max.	n	Ave.	Min.	Max.
Length (µm)	Body (from the middle of the frons on the head to the end of the anal plate)	23	1350.0	1157.6	1634.5	5	1209.9	1161.0	1238.4	5	1437.2	1324.2	1533.6	7	1163.1	1064.0	1259.7
	Body (to the end of the cauda)	23	1389.8	1209.7	1685.6	5	1260.4	1209.3	1301.3	5	1474.9	1336.6	1580.8	7	1203.8	1116.1	1299.0
	Body (to the end of the spinal tubercle)	23	1445.7	1237.4	1702.9	-	-	-	-	-	-	-	-	-	-	-	-
	Antennal segment (=ANT) I	23	58.9	50.8	67.1	5	54.4	52.4	55.4	5	62.1	57.4	67.0	7	55.9	53.9	61.3
	ANT II	23	47.3	40.1	52.0	5	49.5	46.8	52.0	5	47.8	44.6	50.3	7	52.5	48.3	55.8
	ANT III	23	224.6	187.3	288.2	5	313.5	293.5	328.3	5	217.6	191.2	235.6	7	349.1	326.8	370.7
	ANT IV	23	90.8	65.7	109.1	5	145.2	139.7	149.3	5	80.3	67.7	96.8	7	168.8	148.7	183.7
	ANT V	23	128.1	103.6	168.1	5	173.2	153.0	191.6	5	118.9	105.2	125.3	7	183.1	148.6	194.2
	ANT VI Processus terminalis (=PT)	23	70.2	59.6	83.8	5	77.3	74.2	80.5	5	67.1	59.8	77.2	7	86.5	75.5	104.6
	ANT VI Base (=Base)	23	129.0	115.5	151.3	5	161.1	151.5	168.3	5	126.2	114.9	131.0	7	168.4	156.5	178.8
	Whole antenna	23	748.9	651.6	916.6	5	974.1	934.8	1025.4	5	719.9	641.0	783.3	7	1064.3	1015.1	1105.0
	Barsal width (=BW) of ANT III	23	11.1	9.3	13.6	5	11.4	9.5	12.7	5	14.1	12.5	15.0	7	11.7	11.0	12.5
	Ultimate rostral segments (=URS)	23	76.6	70.1	84.4	5	74.2	71.1	78.0	5	78.0	74.7	83.4	7	67.4	62.3	70.5
	URS BW	21	44.6	35.9	56.1	5	36.8	33.4	40.6	5	52.8	45.2	60.5	7	44.1	32.8	53.3
	Spinal tubercle (=ST) on pronotum	23	60.4	31.3	92.7	-	-	-	-	5	67.3	42.8	85.0	-	-	-	-
	ST on mesonotum	23	75.3	33.6	110.9	-	-	-	-	5	73.5	53.5	83.4	-	-	-	-
	ST on metanotum	23	70.9	38.5	100.2	-	-	-	-	5	79.2	60.4	94.4	-	-	-	-
	MT on pronotum	23	61.1	31.2	98.2	-	-	-	-	5	58.8	44.2	67.0	-	-	-	-
	MT on mesonotum	23	86.5	41.3	135.7	-	-	-	-	5	102.5	86.6	129.4	-	-	-	-
	MT on metanotum	23	107.3	60.5	153.6	-	-	-	-	5	118.0	100.1	130.0	-	-	-	-
	Hind femur	23	256.4	65.2	306.2	5	282.7	276.2	288.4	5	253.7	227.6	273.5	7	287.0	271.9	301.2
	Hind tibia	23	430.6	107.6	501.0	5	560.6	551.6	573.9	5	418.1	361.0	445.3	7	543.3	516.8	579.5
	Longest hair on hind tibia	23	27.5	23.7	34.9	5	25.5	23.4	29.4	5	32.1	28.6	34.4	7	23.5	20.6	25.6
	Hind tarsal segment II (=HT II)	23	108.6	100.3	119.1	5	106.1	97.5	111.1	5	108.6	101.9	112.5	7	105.1	100.9	111.6
	ST on abdominal tergite (=AT) I	23	91.4	46.6	123.6	-	-	-	-	5	103.0	78.5	124.1	-	-	-	-
	ST on AT II	23	111.9	56.5	150.7	-	-	-	-	5	114.9	90.4	145.5	-	-	-	-

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Table 2. (Continued)

	Part	Apterous viviparae				Alate viviparae				Oviparae				Alate males			
		n	Ave.	Min.	Max.	n	Ave.	Min.	Max.	n	Ave.	Min.	Max.	n	Ave.	Min.	Max.
	ST on AT III	23	121.0	83.1	174.1	-	-	-	-	5	117.1	105.4	128.3	-	-	-	-
	ST on AT IV	23	121.7	89.8	156.2	-	-	-	-	5	112.6	99.9	121.0	-	-	-	-
	ST on AT V	23	116.3	81.7	161.0	-	-	-	-	5	102.7	84.9	116.3	-	-	-	-
	ST on AT VI	23	114.3	70.6	147.6	-	-	-	-	5	94.3	72.8	107.3	-	-	-	-
	ST on AT VIII	23	159.5	83.9	199.8	-	-	-	-	5	114.7	111.5	118.4	-	-	-	-
	MT on AT I	23	143.5	66.2	187.8	-	-	-	-	5	131.0	112.6	161.4	-	-	-	-
	MT on AT II	23	161.7	102.6	208.2	-	-	-	-	5	145.2	127.3	168.8	-	-	-	-
	MT on AT III	23	165.3	103.5	233.7	-	-	-	-	5	138.7	121.6	148.3	-	-	-	-
	MT on AT IV	23	169.8	101.7	237.3	-	-	-	-	5	131.6	122.2	143.1	-	-	-	-
	MT on AT V	23	168.7	123.2	231.4	-	-	-	-	5	118.6	96.6	128.9	-	-	-	-
	MT on AT VI	23	69.0	45.8	100.8	-	-	-	-	5	42.6	39.1	50.6	-	-	-	-
	MT on AT VII (anterior)	23	131.0	100.8	179.4	-	-	-	-	5	113.2	93.9	130.1	-	-	-	-
	MT on AT VII (posterior)	23	158.3	122.4	203.2	-	-	-	-	5	81.5	65.2	102.4	-	-	-	-
	Cauda	23	119.3	82.9	148.1	5	121.9	102.4	132.1	5	135.4	124.6	143.3	7	82.9	61.7	98.1
	Cauda BW	23	106.2	75.5	131.5	5	106.9	98.9	112.1	5	124.1	114.4	129.0	7	84.2	63.8	94.7
	Cauda-knob	23	65.4	55.7	77.8	5	65.3	62.3	71.7	5	79.0	73.7	83.6	7	44.3	40.2	47.2
	Cauda-knob BW	23	37.2	31.7	43.9	5	33.0	30.7	35.8	5	43.4	40.1	46.8	7	37.4	33.4	42.6
	Maximum width of cauda-knob	23	68.2	57.6	78.3	5	60.3	57.0	63.0	5	72.5	68.1	77.9	7	56.0	48.5	62.9
Number	Hairs on fore tarsal segment I	22	6.1	6	7	5	7.0	7	7	5	6.2	6	7	7	6.7	6	7
	Hairs on mid tarsal segment I	22	6.4	6	7	5	6.8	6	7	5	6.2	6	7	7	6.9	6	7
	Hairs on hind tarsal segment I	22	7.0	6	7	5	6.8	6	7	5	6.4	6	7	7	6.9	6	7
	Hairs on cauda	23	15.8	13	20	5	18.4	17	20	0	-	-	-	7	17.7	15	20
	Secondary hairs on URS	23	2.2	2	3	5	2.2	2	3	5	2.2	2	3	6	2.0	2	2
	Secondary rhinaria on ANT III	23	4.3	3	6	5	9.2	9	10	5	3.2	1	5	7	10.4	9	12
	Secondary rhinaria on ANT IV	23	0.0	0	0	5	0.0	0	0	5	0.0	0	0	7	1.3	1	2
	Secondary rhinaria on ANT V	23	0.0	0	0	5	0.0	0	0	5	0.0	0	0	7	2.7	2	4
	Secondary rhinaria on ANT VI	23	0.0	0	0	5	0.0	0	0	5	0.0	0	0	7	2.1	1	3

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Table 2. (Continued)

	Part	Apterous viviparae				Alate viviparae				Oviparae				Alate males			
		n	Ave.	Min.	Max.	n	Ave.	Min.	Max.	n	Ave.	Min.	Max.	n	Ave.	Min.	Max.
Ratio	Body / Whole antenna	23	1.80	1.60	1.97	5	1.24	1.21	1.32	5	2.00	1.84	2.12	7	1.09	0.96	1.19
	PT / Base	23	0.54	0.49	0.63	5	0.48	0.45	0.52	5	0.53	0.46	0.59	7	0.51	0.46	0.61
	URS / HT II	23	0.71	0.63	0.75	5	0.70	0.67	0.80	5	0.72	0.69	0.74	7	0.64	0.58	0.68
	URS / URS BW	21	1.75	1.25	2.11	5	2.02	1.82	2.13	5	1.50	1.26	1.68	7	1.58	1.18	2.03
	ST / MT on pronotum	23	1.00	0.64	1.40	-	-	-	-	5	1.17	0.68	1.56	-	-	-	-
	ST / MT on mesonotum	23	0.88	0.52	1.23	-	-	-	-	5	0.73	0.59	0.93	-	-	-	-
	ST / MT on metanotum	23	0.67	0.43	1.05	-	-	-	-	5	0.67	0.54	0.81	-	-	-	-
	ST / MT on AT I	23	0.65	0.48	0.78	-	-	-	-	5	0.78	0.70	0.86	-	-	-	-
	ST / MT on AT II	23	0.69	0.50	0.89	-	-	-	-	5	0.79	0.66	0.86	-	-	-	-
	ST / MT on AT III	23	0.73	0.60	0.85	-	-	-	-	5	0.84	0.80	0.88	-	-	-	-
	ST / MT on AT IV	23	0.73	0.57	0.93	-	-	-	-	5	0.86	0.82	0.91	-	-	-	-
	ST / MT on AT V	23	0.69	0.55	0.87	-	-	-	-	5	0.87	0.82	0.95	-	-	-	-
	ST / MT on AT VI	23	1.70	1.09	2.35	-	-	-	-	5	2.23	1.84	2.58	-	-	-	-

Discussion

The present paper documented the first distribution record of *Ctenocallis setosa* from Japan. This species feeds exclusively on *Cytisus scoparius* and *Cy*. *villosus* (Blackman & Eastop 2006; Holman 2009), neither of which is native to Japan (POWO 2025; Yonekura and Kajita 2003-), indicating that *Ct*. *setosa* is undoubtedly a new adventive species in the country. This species is assumed to have become established in Japan because it was found across multiple years and regions. This species is native in Europe and has been previously adventive only in North America (Essig 1952, as *Gentnera oregona*; Foottit *et al.* 2006; Quednau 2003); therefore, its occurrence in Japan represents the first record in Asia. Considering that scotch broom had been introduced into Japan as early as the 17th century (Isono 2007), the arrival of *Ct*. *setosa* into this country may not be a recent event. If this hypothesis is correct, its distribution within Japan could be more extensive than presently recognized. The present study was conducted in two geographically limited regions; thus, its distribution needs to be further investigated in future studies. In North America, this species has been recorded exclusively on *Cytisus* plants (Essig 1952), non-native in the continent like in Japan. This parallel suggests that the distribution of this species potentially expands to other countries or regions where *Cytisus* plants have become established as adventive species.

All species of the genus *Ctenocallis* are monoecious and holocyclic (Halaj & Osiadacz 2014; Lampel & Meier 2003), meaning their life cycles characterized by the sexual morph production for laying overwintering eggs in fall and the absence of host alternation during summer. Sexual morphs of *Ct*. *setosa*, both oviparae and alate males, have been recorded in both its native and non-native ranges (e.g. Essig 1952; Heie 1982; Nieto Nafría & Mier Durante 1998; Stroyan 1977). In the present field study, its viviparae were collected during the summer and fall months (July to September), indicating that this species is monoecious in Japan. Furthermore, its oviparae and males were collected from the Hokkaido population during late September and subsequently the population switched completely from viviparae to sexuals in late October, indicating that the population is holocyclic. Conversely, only males were recorded in the Yamanashi population in mid-September. While this result raises the possibility that the Yamanashi population could be androcyclic or intermediate (Blackman 1971; Dedryver *et al.* 1998), it does not conclusively exclude holocycly. This uncertainty arises because the study in Yamanashi was not extended beyond mid-September, during which time oviparae may have emerged. In addition, androcyclic or intermediate types have not been observed in either the native or the previous non-native ranges of this species. The present authors, thus, conclude that *Ct*. *setosa* populations in Japan, including the Yamanashi population, are exclusively monoecious holocyclic.

Nonetheless, it is important to note that variations in life cycles between native and non-native ranges have been reported in other adventive aphids. For example, *Uroleucon nigrotuberculatum* (Olive, 1963) is holocyclic or anholocyclic in its non-native range (Japan) (Sugimoto & Matsumoto 2000), despite no reports of such variation in its native range (North America). Similarly, *Illinoia* (*Masonaphis*) *lambersi* (MacGillivray, 1960) is holocyclic in both its native (North America) and non-native (Japan) ranges, while anholocyclic in another non-native range (Europe) (Sasaki 2023b). Given these precedents, further investigations into the life cycle of *Ct*. *setosa* in other regions of Japan are needed, particularly in southern regions where this species may potentially overwinter parthenogenetically.

Whether *Ct*. *setosa* poses a threat as a pest species to scotch broom is a significant concern, given that the plant is cultivated in Japan for gardening and revegetation (Koide 2019). Alford (2012) regards *Aphis cytisorum* ssp. *sarothamni* as a pest of broom (*Cytisus*), while not considering *Ct*. *setosa* as such. Furthermore, there is no literature documenting the plant damage by *Ct*. *setosa* within its native range (e.g. Nieto Nafría & Mier Durante 1998; Stroyan 1957). In the present study, the colonies of *Ct*. *setosa* were sparse and no obvious damage to the host plants was observed. Given the above, the potential for this species as a pest in Japan appears to be low. However, contrasting evidence from North America highlights the potential risk. Essig (1952) reported that *Ct*. *setosa* caused significant damage to scotch broom in North America, stating that "young plants were practically defoliated" and "These seedlings were about 18 inches high and were considerably injured by the aphids". Similarly, for the related species, *Ct*. *israelica*, Broza *et al.* (1992) noted that young scotch broom shrubs, mostly two years old and regenerating after a forest fire, were killed by aphid infestations. These accounts suggest that the damage risk by *Ctenocallis* is particularly high for young scotch broom shrubs. The absence of observable damage in the present study may be attributed to the fact that the examinations were conducted on mature shrubs measuring one to two meters in height. Consequently, attention should be directed towards *Ct*. *setosa* infestations on seedlings and younger shrubs in Japan.

The impact of this species must be assessed not only in relation to its host plants but also concerning other plants and the broader ecosystem. The study in Hawaii (Messing *et al.* 2007) indicates that invasive aphids feed on native plants, warning of profound impacts on the island's flora. However, given the host plant range of this species is limited only to *Cytisus* plants and the absence of closely related native plants in Japan, the direct effect on native flora is presumed to be minimal. Conversely, its influence on the broader ecosystem remains entirely unpredictable. Sakata & Ueyama (2022)'s research in Japan highlights that *U. nigrotuberculatum*, which is a non-native specialist herbivore of a naturalized plant, negatively affects a native plant through indirect interactions mediated by a naturalized plant and pollinators. In North America, a non-native soybean aphid, *Aphis glycines* Matsumura, 1917, is positioned as one of the potential components of an extensive invasional meltdown (Heimpel *et al.* 2010). As mentioned above, the ecological impacts of non-native aphids are highly intricate. Moreover, the invasion of non-native aphids may alter the ecological functions of naturalized plants within ecosystems. To accurately predict the ecological impact of *Ct. setosa*, it is imperative to first elucidate its direct effect on host plants or associated organisms such as predators.

The present study examined the aphids associated with scotch broom in Japan, for the first time, revealing a limited diversity of only two species, *Ct. setosa* and an unidentified *Aphis* species. Notably, it is intriguing that *Acyrthosiphon pisum* (Harris, 1776), which has been frequently recorded on scotch broom in the plant's native (Holman 2009) and non-native range (Syrett 1993; Syrett *et al.* 1999), was not observed. This aphid is also common in Japan. Molecular study has indicated that this species complex comprises eight host races and three possible species, each specialized for different host plants (*Cy. scoparius*, *Lathyrus pratensis*, and *Ononis* spp.) (Peccoud *et al.* 2009). Therefore, the absence of *Ac. pisum* on *Cy. scoparius* in Japan may be attributed to the absence of a specialized strain adapted to this host plant in the country. The unidentified *Aphis* species found on scotch broom in the present study could also be a similar lineage, underscoring the need for a detailed investigation into its taxonomic identity.

The present study revealed that the number of adventive aphid species in Japan has reached 36. This number is expected to increase further, as several species have been reported even in the 2020s (e.g. Sugimoto 2020; Nozaki *et al.* 2022; Sasaki 2023a; Sugimoto 2024). Numerous adventive aphid species probably remain unfound or unreported in Japan. We hope that future research will promptly report these species or any newly introduced ones. For this to happen, aphid faunistic studies are crucial, as they provide valuable opportunities to find adventive aphid species (e.g. Adachi *et al.* 2017).

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