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Systematics, Nymphal Characteristics and Food Plants of Sitobion (Sitobion) Miscanthi (Takahashi) (Homoptera: Aphididae)

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Abstract: *The wheat aphid,* Sitobion miscanthi *(Takahashi) (Aphididae: Hemiptera) is a destructive aphid, native to Formosa but now distributed in many wheat growing countries of the world. It is a small (apterae 3.05-3.45 mm, alatae 2.35–2.92 mm) greenish to brownish aphid with dark siphunculi and light coloured cauda. Young ones are yellowish green in colour while grown-ups are light brownish to blackish brown. In India, it is reported on 84 plant species belonging to 13 plant families. It infests especially plant families Poaceae (Graminae). In northeastern Uttar Pradesh it was observed on feeding five host plants:* Avena sativa *L.,* Hordeum vulgare *L.,* Pennisetum glaucum *(L.) R. Br.,* Phalaris minor *Retz, and* Triticum aestivum *L. In this article the taxonomic status, synonymy, economic importance, distribution, life history, and food plants of S. miscanthi were described. The adult parthenogenetic viviparous apterae and alatae as well as alate male (sexual morph, not recorded in the study area) were morphologically described giving the morphometry of all taxonomic characters along with illustrations. Several taxonomic characters of the first to fourth instar nymphs of apterous morph of* S. miscanthi *were measured. Interestingly, significant positive correlations were observed between the length of antennae, processus terminalis, siphunculus, cauda, and the body size from first instar to adult stage. A key was also prepared for easy identification of the nymphal stages. It caused crop loss by direct feeding by which nutrients, amino acids and carbohydrates are extracted from leaves and earheads, while some plant physiological processes may be disrupted. Honeydew and sooty moulds interfere with light capturing by green tissues and reduce photosynthetic efficiency. Damage is dependent on the number of tillers infested, the number of aphids per tiller and the duration of infestation. The resulting yield loss can be quantified in terms of a reduced number of earheads, reduced number of grains per head or reduced seed weight. Maximum yield losses in cereals are most likely to occur because of attack between ear emergence and flowering.* S. miscanthi *feed on leaves, moving to the earheads as they develop. The* S. miscanthi *also transmit a number of plant viruses like barley yellow mosaic viruses (BYMV), millet red leaf persistent luteovirus (MRLV) and yellow dwarf virus (CYDV).*

Keywords: *Sitobion (Sitobion) miscanthi, systematics, food plants, nymphal characteristics.*

1. INTRODUCTION

The wheat aphid, *Sitobion (Sitobion) miscanthi* (Takahashi) (Aphididae: Hemiptera) is a tiny, soft-bodied, pear shaped insect and is comparatively large species. The length of apterae varies between 3.05-3.45 mm while of alatae 2.35 – 2.92 mm. It is a destructive aphid native to Formosa that is now found in many other areas of the world. This is a small greenish to brownish aphid with dark siphunculi and light coloured cauda. Young ones are yellowish green in colour while grown-ups are light brownish to blackish brown, however, a great variation in the colour of *S. miscanthi* was observed in field population [1]. It is an important polyphagous species and sometimes attains pest status on wheat, oat, and barley in India. In India, it was reported on 84 plant species belonging to 13 plant families. It infests especially plant families Asteraceae, Poaceae, and Polygonaceae [2]. Considering the vast geo-climatic variations within the states of India, it is expected that life cycle exhibited by this insect might show some interesting variations as photoperiod and temperature are known to influence the life cycle patterns of aphids [3].

S. miscanthi was reported as early as 1921 in Formosa on *Miscanthus* sp. by Takahashi [4]. In India, it was probably first reported on finger millet, *Eleusine coracana* (L.) Gaertn. (Family : Poaceae) as *Macrosiphum (Sitobion) eleusinae* (Theobald, 1929) [5]. In China, it is a serious pest of the cereal crop, wheat infesting heavily on the tender earheads of the plant [6]. In 2007, it was reported as major pest of wheat in Punjab [7]. It is also the main aphid pest of wheat in China, Australia and other tropical countries [8]. *S. miscanthi* is believed to be an anholocyclic and polyphagous species, migration during the winter months is observed to take place to the warmer plains to escape the harshness of the approaching winter and depleting food sources. Transmission of virus disease is the primary damage caused by aphids and the potential for this varies significantly from year-to-year and area-to-area. Only on occasions do aphids reach damaging populations [9].

For aphid identification, still taxonomists rely upon morphometric characters. Many species-level aphid dichotomous keys require a significant amount of measuring and computing of ratios [10, 11, 12]. Much insect morphometrics was pioneered using aphid models [13, 14] and numerous aphid species have been described based on morphometry [12, 15, 16, 17, 18]. Biometrical studies are an important aspect of and a reliable criterion for age grading aphids. Morphometrical data play a critical role in studying the population of the any species in the field. Despite studies on several aphids, very little information is available on *S. miscanthi.* This species is characterised by a high rate of fecundity, due to its parthenogenetic phase which occurs during the summer, when it attacks several plants. Indeed, this remarkable multiplication capacity is one of the reasons why it is a dangerous pest. The aim of this study is to contribute to the knowledge of the biosystematics of *S. miscanthi,* so as to evaluate the potential of quantitative measures of this aphid for population.

2. MATERIALS AND METHODS

2.1. Geography of the Study Area: North Eastern Uttar Pradesh (NEUP)

The NEUP includes following districts, Gorakhpur, Basti, Sant Kabir Nagar, Maharajganj, Kushinagar, Deoria and Siddharthnagar. These areas extend between 27.5’ N, 26.2’S, 82.5’W and 84.5’E. The area is a terai belt and has fertile land. The climate of the area is very much influenced by the proximity of Himalayas. It has subtropical monsoon type climate. On the basis of climatic conditions, the whole year is divided into 3 climatic seasons: (i) summer - March to mid June, (ii) rainy - mid June to September, and (iii) winter - from October till February. The maximum temperature is recorded during the months of May and June. The maximum temperature raises upto 45°C to 50°C sometimes. Heavy rainfall is recorded during the month of mid June till mid September. The annual rainfall is about 125 cm of which about 86% is received during the rainy seasons. About 70% of the annual rainfall is concentrated in July and August and that too only in 40 days of the rainy season. A high degree of uncertainty and variability is exhibited by the monsoon rainfall and so the agriculture is greatly dependent on the irrigation. The relative humidity increases from 56% RH in May to 85% in July. The rainfall in the winter seasons is very beneficial for the *rabi* or winter crops. The crops like paddy, maize, wheat, sugarcane, vegetables, shrubs, weeds and many other plants of medicinal importance are grown successfully. The crop of wheat sometimes is heavily infested by the wheat aphid, *S. miscanthi*.

2.2. Collection of the Aphids

The aphids were collected either directly from leaves, flowers, stem, buds and inflorescence bearing aphids by cutting that part of the plant. The infested part is then kept in plastic bags. Within 24 hours these plastic bags were brought to the laboratory. Among the collected aphids some of them were preserved in a preservative (a mixture of 70% ethyl alcohol and glycerin in the ratio of 5:1) for taxonomical studies. The remaining aphids were kept into a translucent plastic vials with moist cotton at the bottom. The open ends were covered with muslin cloth and tightened with rubber bands to get alate forms of the aphids, if any. The extensive field notes on the colour of the specimen, food plants, intensity of infestation, locality and date of collection etc. were recorded.

2.3. Rearing of the Aphid

Stock culture. Cohorts of I instar nymphs of *S. miscanthi* obtained from field collected apterous parthenogenetic viviparous female and alate parthenogenetic viviparous female were maintained separately on potted seedlings of wheat (*Triticum aestivum* L.) and placed in insectaries (30x30x45 cm) placed in an open-air field. Temperature varied between 21-30°C and RH between 40-70%.

Rearing of the aphid to know age-structure. Adult aphids, originated from stock culture, were put on leaf clip on the first and second leaf of potted wheat seedlings and were kept in a growth chamber at 25˚C, 60-80% R.H. and 10 hour photoperiod. Aphids were allowed to reproduce. New born aphids were reared individually on leaf clip and inspected at 6 hour intervals (from 08.00-20.00 hours) to record the time of their moult to their next instar. First instar aphids were collected very soon after their birth and well before their first moult, whilst for each of the successive instar aphids were collected after the moult and at various stages towards the end of the instar but before the next ecdysis. This was an attempt to obtain and examine different size aphids within each instar.

Ten first instar nymphs were slide mounted for morphometrical examinations. Rests of the nymphs were allowed to develop further and successively 10 nymphs were mounted after each moult. The lengths and width of the body (nearest to 0.025 mm; magnification – 40X: 10X eyepiece, 4X objective lens) and various parts (antennae, a.s. III, b.d. of III, p.t.; U.r.s.; h.t.2; siphunculus; cauda etc.; nearest to 0.0025 mm; magnification – 400X: 10X eyepiece, 40X objective lens) were measured using an ocular micrometer and an stereomicroscope.

2.4. Clearing of the Material

The aphids were first gently boiled in 95% ethanol for 5 to 10 minutes in water bath. Thereafter, the alcohol is decanted off and the aphids were gently boiled again in 10% KOH solution until the specimen appeared somewhat transparent. KOH solution is decanted off after cooling and the specimens were again rinsed in 95% ethyl alcohol. The specimens were again put in saturated mixture of chloral hydrate and phenol and were heated for 10-15 minutes in water bath.

2.5. Mounting of the Aphids

For mounting the aphid specimens, the mounting medium is prepared by mixing chloral hydrate (20 g), powered gum acacia (12 g), glycerin (6.25 ml) and distilled water (20 ml). For this, firstly the gum was dissolved in distilled water. The chloral hydrate and glycerin were then dissolved in this solution. The solution was filtered twice through glass wool for removing impurities. The cleared specimens were mounted in the mounting medium on micro-slides. After mounting the specimens, the slides were properly labeled and left in the trays in horizontal position, and then placed in an incubator at 50-60°C for slow drying. The dried slides were stored in the horizontal slide cabinets.

2.6. Measurement of the Aphids

The following measurements were taken by occular micrometer corroborated with stage micrometer and have expressed in mm.

- *Body length*: Distance from middle of frons to tip to cauda.
- *Body width*: Maximum width of body.
- *Antenna*: Length of ultimate segment from its base of segment I to the tip of flagellum.
- *Base of ultimate segment of antenna*: Length of the ultimate segment from basal articulation to distal end of primary rhinaria.
- *Processus terminalis (p.t.)*: Length of ultimate segment between apical end of primary rhinarium and tip of the segment.
- *Basal diameter of antennal segment (b.d.)*: Diameter of the segment just following basal articulation of the segment.

- *Ultimate rostral segment (u.r.s.)*: Length of the portion of rostrum between basal articulations of segment IV to the tip of rostrum.
- *Secondry segment of hind tarsus (h.t.2)*: Length of segment of hind tarsus from basal articulation to the tip.
- *Length of siphunculus*: Length from its base to apex.
- *Length of cauda***:** Length from middle of its very base to apex.

For instar identification, following characters of each instar of the aphid were examined in addition to the above-mentioned characters: number of antennal segments, length of antenna with length of individual segments, number of primary and secondary rhinaria, existence of setae on a.s.iii, number of primary and secondary hairs on u.r.s., existence of wing pads, length of hindtibia and second hind tarsus (h.t.2), number of hairs on cauda, etc.

3. RESULTS AND DISCUSSION

3.1. Historical Account of *S. Miscanthi*

The genus *Sitobion* was erected in 1914 with *Aphis granaria* Kirby, 1798 (= *Aphis avenae* Fabricius, 1775) designated as type by Mordvilko [19]. After Mordvilko erected the name *Sitobion*, it remained unused until Hille Ris Lambers [20] placed it as a subgenus of *Macrosiphum* Passerini, 1860 and included three European species. Following Hille Ris Lambers, Eastop [21, 22, 23] described many African species of *Sitobion*, considering *Sitobion* as a genus or a subgenus of *Macrosiphum.* Many other species were described in *Sitobion* from Africa and the Indian sub-continent, and other African, European, and Asian species were transferred to *Sitobion.* Richards [24] and Hille Ris Lambers [25] were first to mention *Sitobion* in north America, each describing new species and providing a key to species within a limited region (Canada and California, respectively). Hille Ris Lambers [25] also transferred one endemic fern feeding species from *Macrosiphum* to *Sitobion.* Robinson [26] described a single species in *Macrosiphum (Sitobion)*, but provided neither key nor discussion of the group. Eastop & Hille Ris Lambers [27] transferred 9 northern American species from various genera to *Sitobion* but provided no explanation. Robinson [28] accepted his classification and described four new species and provided a key to all the fern feeding species. This, and the discovery of *S. equiseti* Holeman, 1961 in British Columbia [29], resulted in *Sitobion* containing 22 species in North America, and caused many problems because there was no clear definition of boundaries of *Sitobion.* North American *Sitobion* had such disparate morphologies and differed so much from European, African and Asian species that *Sitobion* was nearly impossible to distinguish from similar genera. Jensen [30] redefine the genus *Sitobion* Mordvilko, 1914 and separated it from *Macrosiphum* Passerini, 1860 on the basis of presence of only four setae on the abdominal tergite VIII, frequent presence of rounded base of the u.r.s., head usually completely lacking spinules and first instar nymphs with 2 setae on tarsal segment I. The genus *Sitobion* is divided into 3 subgenera, *Sitobion* (s.s.) and *Metobion* Heikinheimo, 1990 [31]. Presently, two genera, *Bromaphis* Amyot, 1847 and *Anameson* Mordvilko, 1914, *Aphidiella* Theobald, 1923 and subgenus *Neomacrosiphum* Basu, Ghosh & Raychaudhury, 1976 of the genus *Macrosiphum* are considered as synonym of the subgenous *Sitobion* [27, 31, 32].

S. miscanthi was described by Takahashi [4] under the genus *Macrosiphum* Passerini, 1860 from Formosa. Later on, Theobald [33] described a species *M. elusinae* from south India infesting *E. coracana*. Krishnamurti [5] reported the species from south India from the same host plant and put the species under subgenus *Sitobion* as *M. (S.) elusinae* Theobald. David [34, 35, 36] considered the species as subspecies of *M. (S.) avenae* as *M. (S.) avenae elusinae* (Theobold). Later, *M. (S.) africanum* Hille Ris Lambers, 1954 and *M. (S.) fragariae* (Walker, 1848) reported from South India [36] and *M. (S.) avenae miscanthi* (Takahashi) reported from north India [37, 38] have been considered synonym of *M. (S.) miscanthi* Takahashi, 1921 [39, 40]. Later, several species of *Macrosiphum* Passerini, 1860 were transferred to the genus *Sitobion* Mordvilko, 1919 under the subgenus *Sitobion* (s.s.) as *S. (S.) miscanthi* (Takahashi) [30, 31, 41].

3.2. Description of Sitobion Miscanthi

Type: *Macrosiphum miscanthi* Takahashi, 1921. *Aphididae of Formosa***,** 1: 8-9

3.2.1. Synonymy

= *Macrosiphum (Sitobion) eleusinae* Theobald, *Entomologis*t, 62: 177-181, 196-201.

= *Macrosiphum (Sitobion) avenae elusinae* Theobald : David, 1975. *Orient. Ins*., 9: 461-493

= *Macrosiphum (Sitobion) avenae miscanthi* (Takahashi): Ghosh & Raychaudhuri, 1963. *Sci. Cult*., 29: 104.

= *Uroleucon yiliense* Zhang, Chen, Zhong & Li, 1999: Eastop & Blackman, 2005. *Zootaxa*, 1089:25.

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3.2.3. Common Names

Wheat aphid, oat aphid, grain aphid, barley aphid, Indian grain aphid.

3.2.4. Materials Examined

Several apterous viviparous and alate viviparous adults and nymphs were observed collected from the following host plants at different places and date in different districts of eastern Uttar Pradesh, India: *Avena sativa* L., 16.ii.2003 [Ramkola (Kushinagar)], 25.ii.2004 [Partawal (Maharajganj)], 20.ii.2008 [Gorakhpur]; *Hordeum vulgare* L., 11.iii.2007 [Jagdishpur (Gorakhpur)], 27.ii.2008 [Balapar (Gorakhpur)], 11.iii.2008 [Chaurichaura (Gorakhpur)]; *Pennisetum glaucum* (L.) R. Br., 11.vii.2004 [Padrauna (Kushinagar)]; *Phalaris minor* Retz., 25.ii.2007 [Kusumhi (Gorakhpur)], 26.ii.2008 [Kusumhi (Gorakhpur)]; *Triticum aestivum* L., 20.ii.2004 [Naugarh (Siddharthnagar)], 12.i.2005 [Nautanawa (Maharajganj)], 25.ii.2007 [Kusumhi (Gorakhpur)], 30.iii.2007 [Pipiganj (Gorakhpur)], 26.ii.2008 [Kusumhi (Gorakhpur)], 05.iii.2008 [Maharajganj],.

3.2.5. Morphological Description

i. Apterous parthenogenetic viviparous female (Fig. 1). It infests the leaves, both basal and aerial portion of the shoots. The species exhibits colour variations, brown to blackish–brown, aphids; brown to light yellow aphid infests leaves.

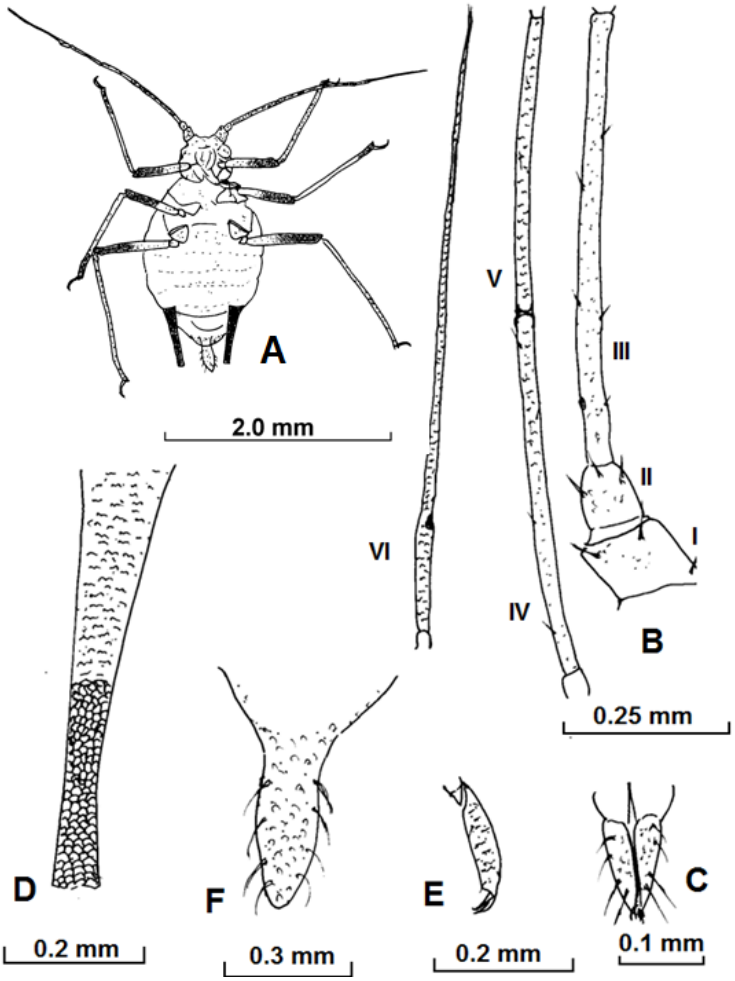

Figure 1. *Apterae viviparous female, A. Adult, B. Antenna, C. U.r.s., D. Siphunculus, E. H.t.2, F . Cauda.*

Body dark, 2.0 - 3.00 mm (mean 2.85 mm) long 0.8 - 1.5 mm (mean 1.27 mm) as maximum width. Head usually completely smooth, diverging smooth lateral frontal tubercle and indistinct to

distinct median frontal prominence; dorsal cephalic hairs shorter than b.d.III with acute apices. Antennae 6-segmented, shorter to longer than body but always more than 0.75x body length; basal 2 segments either smooth or scabrous; antennal tubercles rather weakly developed; flagellum imbricated; a.s. III with 1-4 circular non-protuberant secondary rhinaria in a row either restricted to a very base of segment III; longest hairs on a.s. III 0.45–0.8x b.d. III., more than 20μm long; primary rhinaria ciliated; p.t. much longer than base (4.6- 6.6x base, mean 5.6x) of last segment; flagellar hairs like dorsal cephalic hairs, shorter than 0.50x b.d. III. Rostrum reaches beyond midcoxae, u.r.s. with bulbous sides and blunt apex, 0.68–0.80x h.t.2 and bearing 6 accessory hairs. Midthoracic furca with a narrow base. Legs smooth; second tarsal segments with normal imbrications, F.T.C. 3,3,3. Dorsal abdomen sclerotic but with any pigmentation rather ill defined, not concentrated at hair-bases; abdominal tergite 2–5 with 0–8 marginal tubercles in total, but mostly (67%) with 2–6; h.t.2 1.24–1.45x u.r.s. Siphunculi cylindrical, wholly dark with a distinct flange, faintly to distinctly imbricate, imbrications passing on to a distinct apical reticulated area about 0.15 - 0.40 portion of siphunculi, reticulations in the form of isodiametrical cells, 1.41–2.27x cauda and 0.79–1.05x a.s.III. Cauda elongated, pale or dark, with a basal constriction. Subanal plate somewhat emarginate on posterior margin. Subgenital plate with 7-12 hairs in 2 groups on posterior margin and 2 long fine hairs on anterior 0.50 portion and has a rather pointed apex. Venter of abdomen with spinulose striae; ventral abdominal hairs long with fine to acuminate apices.

The above mentioned characters observed in the local population of *S. miscanthi* on *T. aestivum* only varied with other populations on the same host plant in the following aspects: antennal length all segments), siphunculi and cauda were little shorter than the specimen measured by Ghosh *et al.* [1] (Table 1).

Table 1. *Measurements (in mm) of randomly selected 5 individuals of apteraous viviparous females of S. miscanthi reared on T. aestivum.*

Particulars		Specimens					Mean ± SD	After Ghosh, L.K., 19
		1	2	3	4	5		
Body	Length	2.050	2.250	3.425	3.250	3.250	2.845±0.642	3.00
	Width	0.800	1.125	1.500	1.500	1.425	1.270±0.305	1.25
Antenna	Length	2.000	2.350	3.250	2.750	2.750	2.620±0.471	3.50
	Length III	0.500	0.588	0.675	0.763	0.775	0.660±0.117	0.84
	b.d. III	0038	0.033	0.050	0.038	0.048	0.041±0.007	-
	Length IV	0.425	0.470	0.525	0.600	0.513	0.507±0.065	0.65
	Length V	0.338	0.353	0.438	0.475	0.425	0.406±0.058	0.55
	Base VI	0.135	0.103	0.150	0.125	0.145	0.132±0.019	0.15
	p.t.	0.625	0.675	0.725	0.825	0.750	0.720±0.076	1.10
U.r.s.	Length	0.098	0.103	0.120	0.113	0.118	0.110±0.010	0.11
	Width	0.080	0.063	0.075	0.105	0.100	0.085±0.018	-
h.t.2	Length	0.125	0.128	0.175	0.160	0.170	0.152±0.024	0.14
Siphun-culus	Length	0.525	0.575	0.600	0.625	0.613	0.588±0.040	0.75
	Width	0.115	0.135	0.150	0.138	0.143	0.136±0.013	-
Cauda	Length	0.338	0.350	0.425	0.275	0.400	0.358±0.058	0.50
	Width	0.115	0.135	0.083	0.113	0.163	0.122±0.030	-
	No. of hairs	11	8	7	6	7	7-11	-

ii. Alate parthenogenetic viviparous female (Fig. 2, Plate 2). Head minutely spinulose, lateral frontal tuberacles rather low and without any spinules ventrally. Antennae 6-segmented, flagellum imbricated and secondary rhinaria on segment III fewer (10-17) and arranged nearly in a row; distributed at most over basal 0.75 portion, p.t. longer than a.s. III (1.11 – 1.42x); and much longer than base of last segment (4.6 – 6.8x), longest hair on a.s. III never more than 0.55x basal diameter of segment. U.r.s. is shorter than h.t.2 (0.69 – 0.75x). First tarsal segments with 3,3,3 hairs; hindtibiae lacking spine-like hairs, 8th tergite with 4 hairs which are up to about 0.80 x b.d. III. Siphunculi cylindrical, longer than cauda (1.3 – 2.5), wholly dark with a distinct flange, faintly to distinctly imbricate, imbrications passing on to a distinct apical reticulated area about

0.15 - 0.40 portion of siphunculi, reticulations in the form of isodiametrical cells. Cauda elongated and dark with 6-9 hairs, all caudal hairs more or less of similar length. Subanal plate with 6-15 hairs. Venter of abdomen with spinules. Rest of the characters similar to those of apterous viviparous adults. Measurements of 5 individuals of alate adults are given in Table 2.

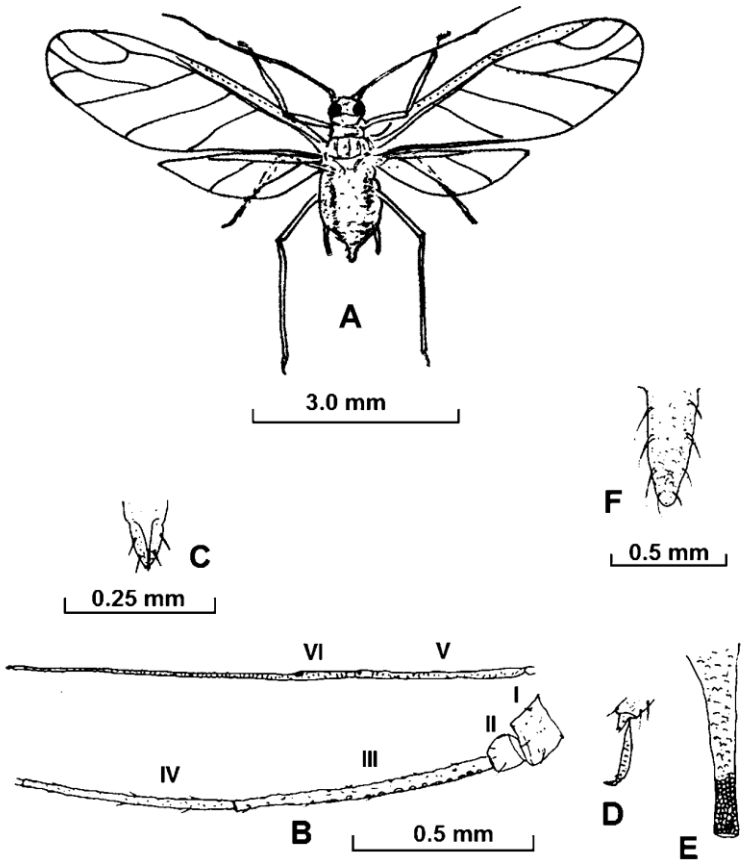

Figure 2. *Alate female : A. Adult, B. Antennal segmets I-VI, C. U.r.s., D. Hind tarsi and distal part of tibia, E. Siphunculus, F. Cauda.*

Table 2. *Measurements (in mm) of 5 randomly selected individuals of alate viviparous females of S. miscanthi reared on T. aestivum.*

Particulars		Specimens					Mean ± SD
		1	2	3	4	5	
Body	Length	3.000	2.875	3.000	3.000	3.125	3.000±0.088
	Width	1.250	1.000	1.000	1.200	1.250	1.140±0.129
Antenna	Total length	2.750	2.625	2.750	2.750	2.750	2.725±0.056
	Length III	0.700	0.638	0.650	0.763	0.663	0.683±0.050
	b.d. III	0.028	0.025	0.023	0.028	0.023	0.025±0.003
	Length IV	0.563	0.538	0.575	0.625	0.563	0.573±0.032
	Length V	0.450	0.425	0.425	0.438	0.450	0.438±0.013
	Base VI	0.163	0.138	0.138	0.125	0.170	0.147±0.019
	p.t.	0.838	0.750	0.925	0.850	0.775	0.828±0.069
U.r.s.	Length	0.113	0.100	0.113	0.118	0.113	0.111±0.007
	Width	0.075	0.063	0.088	0.063	0.095	0.077±0.015
h.t.2	Length	0.163	0.138	0.150	0.158	0.150	0.152±0.009
Siphunculus	Length	0.488	0.500	0.500	0.500	0.525	0.503±0.014
	Width	0.113	0.138	0.118	0.125	0.125	0.124±0.009
Cauda	Length	0.375	0.313	0.200	0.325	0.313	0.305±0.064
	Width	0.138	0.125	0.050	0.150	0.150	0.123±0.042
	No. of hairs	6	7	7	7	9	6-9

iii. Sexual morphs. No sexual morph was observed in this area throughout the year. However, Ghosh [42] collected alate males from Shimla (on 6.i.1970) and Nainital (on 6.iii.1998) (Himachal Pradesh) on unidentified fern described by Ghosh [43]. This indicates that the *S. miscanthi* may enjoy monoecious holocyclic life at least in the altitudinal areas of north India. Following is the description of male alate of *S. miscanthi.*

Alate male (Fig. 3). Body elongated, dark brown, 2.10 mm long with 1.02 mm as maximum width near the middle of the abdomen. Head diverging with lateral frontal tubercles, brownish, antennae 6-segmented, much longer (2.90 mm) than body, flagellum dark brown, a.s. III (0.75 mm) with many round secondary rhinaria; p.t. 7.2 times as long as base of segment VI. Rostrum reaches midcoxae, u.r.s. (0.11 mm) a little longer than h.t.2 (0.09 mm). Abdominal dorsum with pleural and marginal sclerotic paches. Dorsal hairs long and fine. p.t. 1.20x a.s.III; a.s. III with 48-62 sensoria, a.s.IV with 32-41 and a.s. V with 24-25. Siphunculi cylindrical (0.36 mm), about 0.18 times as long as body and 2.3x cauda. Otherwise, as in alate viviparae. Hales *et al.* [18] described the morphology of male *S. miscanthi* from Australia as follows: Antennae 1.92-2.96x of hindtibia, p.t. 1.43-1.73x a.s.III; a.s. III with 41-62 sensoria, a.s.IV with 17-23 and a.s. V with 11-20. Unlike Indian specimen, u.r.s. was equal or shorter (0.74-1.0x) than h.t.2. Siphunculi 0.23-0.33 mm, 2.1-2.8 x cauda.

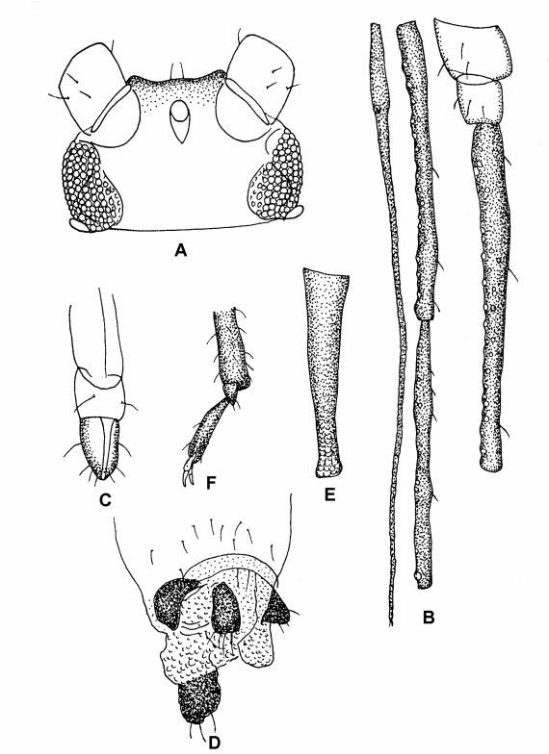

Figure 3. *Alate male: A. Head; B. Antenna; C. U.r.s.; D. Posterior portion of abdomen showing male genitalia; E. Siphunculus; F. Portion of hind tibia and tarsus.*

Ovipara. No Indian specimen of *S. miscanthi* ovipara was so far collected. However, Hales *et al.* [46] described the morphology of ovipara from Australia as: body straw-coloured: older specimens greenish to dark green; eggs appear green through body wall; eyes dark red-brown. antennae black; coxae and trochanters pale, femora dark pigmented for approximately distal two-thirds; tibiae dark at femoral joint and distal quarter; tarsi black; siphunculi black; cauda pale; anal plate and anterior third of genital plate lightly pigmented. Body length 1.57-1.88 mm; antennae 1.36-2.02 mm; p.t. 1.2-1.7x a.s. III, A3 and 4.5-6.0x base of a.s.VI, a.s. III with 0-1 medium to small rounded sensorium on the lateral surface; u.r.s. reaching mesothoracic, 0.84-1.01x h.t.2; hindtibiae swollen with numerous pseudosensoria; siphunculi 0.3-0.48 mm in length, with reticulations on the terminal 13-22% and imbrications on the remainder; siphunculi 1.5-2.5x

cauda and 0.21-0.29x body length; cauda tapering to rounded tip, usually without evident constriction.

3.3. Instar Characteristics and their Identification

Aphid populations are characterised by facultative polymorphism and the existence of overlapping generations, features which complicate the study of their population dynamics [45]. Hughes [44, 45, 46] developed a method for time-specific analysis of populations which overcame these problems. This technique has since been used in the study of the population dynamics of *Myzus persicae* (Sulzer) in the International Biological Programme [47]. Since *S. miscanthi* co-exists simultaneously with *Rhopalosiphum maidis* (Fitch) on cereal crops particularly wheat, barley and oat, their identification along with diagnostic characters for separation of the various nymphal instars are prepared. The biological control of the aphids also needs a full understanding of the population dynamics of the target pest(s) so that biocontrol agents (parasitoids/predators) can be used against them at proper time. Timing is an important consideration since the parasitoids are only able to attack and successfully develop in aphids of a certain stage of development [48]. In this study, the reliable characters for identifying nymphal instars of *S. miscanthi* was explored that will be helpful in estimating the stage structures of field populations adopting earlier works [49, 50, 51, 52, 53, 54].

Earlier, key using morphological characters for the identification of nymphal instar of *S. avenae*, a closely related species, was prepared [51], but till now, no key was available for the identification of different instars of *S. miscanthi*. In the present study, help of morphometry was taken to identify the instars of *S. miscanthi* reared on leaf discs to a known instar and taken from non-clonal populations.

3.3.1. Characteristics of Apterous Morph

First instar apterous nymphs (Fig. 4). First instar nymphs of *S. miscanthi* were very small and were 0.84 ± 0.09 SD mm long. The apices of the segments of all the tibae, all tarsi, u.r.s. and siphunculi are darker. Head smooth with 4 spinules and bears 5 segmented antennae. Antennal segment III smooth without setae while IV and V imbricated entirely with few setae. U.r.s. darker and measures 0.088 ± 0.004 mm and bears 4 primary and 2 secondary hairs and almost equal to length of siphunculi and a little smaller than h.t.2 (0.94x). Tibial spinules vary in number and size among pro-, meso- and metathoracic legs. Foretibiae bear 17-19 small spinules arranged throughout the length but more densely distally. Midtibiae bear 17-20 small spinules, almost equal to that of foretibiae. Hindtibiae bear 10-12 large (subequal to the maximum width of tibia) spines outwardly while 4-6 smaller, about half the size of the larger ones.

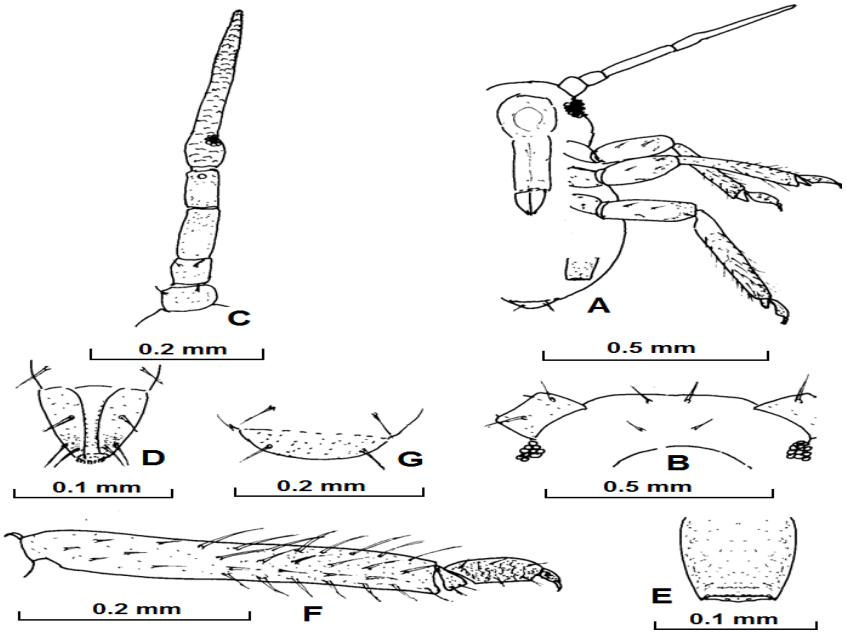

Figure 4. *First instar nymph of apterous viviparous female S. miscanthi : A. Body, B. Head, C. Antenna, D. U.r.s, E. Siphunculus, F. Hind tibia with tarsi, G. Cauda.*

Hindtibiae almost 4x u.r.s. and subequal to the last antennal segment. Siphunculus small but twice the length of cauda. The cauda bears 2 hairs. Measurements of various body parts are given in Table 3.

Table 3. *Measurements (in mm) of 5 randomly selected individuals of I Instar nymph of viviparous females of S. miscanthi reared on T. aestivum.*

Particulars		Specimens					Mean ± SD
		1	2	3	4	5	
Body	Length	0.725	0.825	0.825	0.825	1.000	0.840±0.099
	Width	0.250	0.300	0.375	0.350	0.375	0.330±0.054
Antenna	Total length	0.500	0.575	0.550	0.650	0.650	0.585±0.065
	Length III	0.100	0.125	0.113	0.130	0.125	0.119±0.012
	b.d. III	0.035	0.050	0.040	0.050	0.050	0.045±0.007
	Length IV	0.075	0.075	0.083	0.088	0.088	0.082±0.006
	Base V	0.050	0.060	0.055	0.055	0.063	0.057±0.005
	p.t.	0.263	0.275	0.280	0.338	0.325	0.296±0.033
U.r.s.	Length	0.083	0.088	0.088	0.088	0.093	0.088±0.004
	Width	0.053	0.050	0.075	0.068	0.070	0.063±0.011
h.t.2	Length	0.075	0.088	0.098	0.103	0.105	0.094±0.012
Siphunculus	Length	0.088	0.095	0.088	0.090	0.088	0.090±0.003
	Width	0.063	0.045	0.058	0.055	0.063	0.057±0.007
Cauda	Length	0.038	0.050	0.045	0.038	0.050	0.044±0.006
	No. of hairs	2	2	2	2	2	2

Second instar apterous nymphs (Fig. 5). Head smooth with 4 spinules and bears 5 segmented antennae. Antennal segment III smooth with few very small setae, while IV and V imbricated entirely. The third segment in second instar is more elongated and significantly longer than the first instar. There is no overlap in the range of lengths of the third and fourth antennal segments, hindtibiae and siphunculi in the first and second instars, the most convenient feature for separation of these instars. The measurements are similar to that of an allied species *S. avenae* [51] but unlike *S. avenae*, the ratio of length of a.s III to a.s. IV is insignificant. U.r.s. blunt, darker and measures 0.094 ± 0.006 mm and bears 4 primary and 4-6 secondary hairs and almost half of the length of siphunculi and 0.83x of h.t.2.

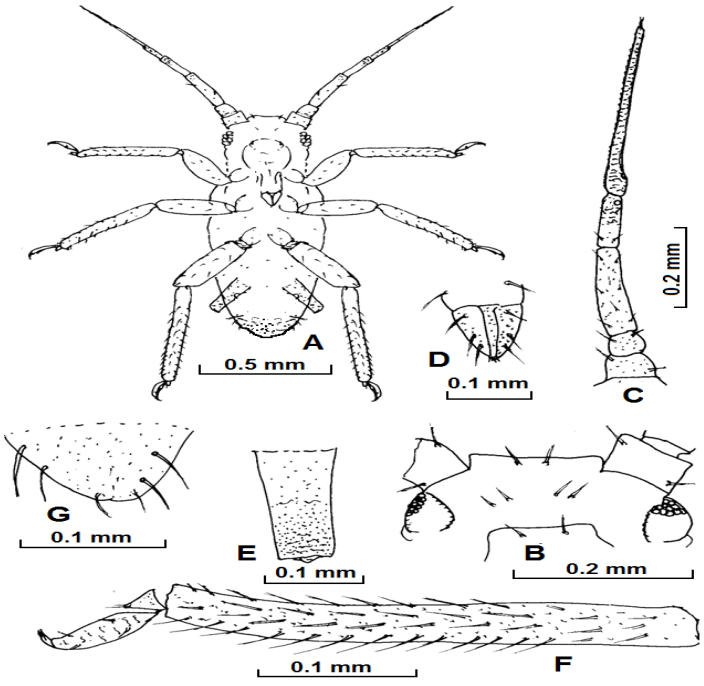

Figure 5. *Second instar nymph of apterous viviparous female S. miscanthi. A. Body, B. Head, C. Antenna, D. U.r.s, E. Siphunculus, F. Hind tibia with tarsi, G. Cauda.*

Tibial spinules vary in number and size among pro-, meso- and metathoracic legs. Foretibiae bear 17-19 small spinules arranged throughout the length but more densely distally. Midtibiae bear 25-40 small spinules, almost equal to that of foretibiae. Hindtibiae bear 12-18 large (subequal to the maximum width of tibia) spines outwardly while 12-18 smaller, about half the size of the larger ones. Hindtibiae almost 6x u.r.s. and 1.22x last antennal segment. Siphunculus small but more than twice the length of cauda. The cauda bears 4 hairs. Measurements of various body parts are given in Table 4.

Table 4. *Measurements (in mm) of 5 randomly selected individuals of II Instar nymph of females of S. miscanthi reared on T. aestivum.*

Particulars		Specimens					Mean ± SD
		1	2	3	4	5	
Body	Length	1.175	1.200	1.250	1.250	1.250	1.225±0.035
	Width	0.525	0.550	0.500	0.525	0.500	0.520±0.021
Antenna	Total length	0.900	0.850	0.875	0.950	0.900	0.895±0.037
	Length III	0.218	0.225	0.225	0.235	0.240	0.229±0.009
	b.d. III	0.050	0.050	0.045	0.050	0.050	0.049±0.002
	Length IV	0.125	0.133	0.138	0.145	0.148	0.138±0.009
	Base V	0.075	0.073	0.068	0.088	0.073	0.075±0.008
	p.t.	0.375	0.388	0.375	0.363	0.413	0.383±0.019
U.r.s.	Length	0.095	0.088	0.100	0.100	0.088	0.094±0.006
	Width	0.075	0.063	0.088	0.075	0.068	0.074±0.009
h.t.2	Length	0.113	0.110	0.120	0.113	0.113	0.114±0.004
Siphunculus	Length	0.175	0.188	0.150	0.163	0.205	0.176±0.021
	Width	0.075	0.075	0.063	0.080	0.073	0.073±0.006
Cauda	Length	0.075	0.068	0.083	0.088	0.078	0.078±0.008
	No. of hairs	4	4	4	4	4	4

Third instar apterous nymphs (Fig. 6). Head smooth with 4 spinules and bears 6 segmented antennae, this being the most obvious morphological difference between third instar and ealier two instars. The additional antennal segment arises from the division into two parts of a.s. III of the second instar. Antennal segment III smooth with few very small spines, while IV, V and VI imbricated entirely. U.r.s. blunt, darker and measures 0.10±0.004 mm and bears 4-6 primary and 2-4 secondary hairs and about 0.41x to length of siphunculi and 0.87x of h.t.2. Tibial spinules vary in number and size among pro-, meso- and metathoracic legs.

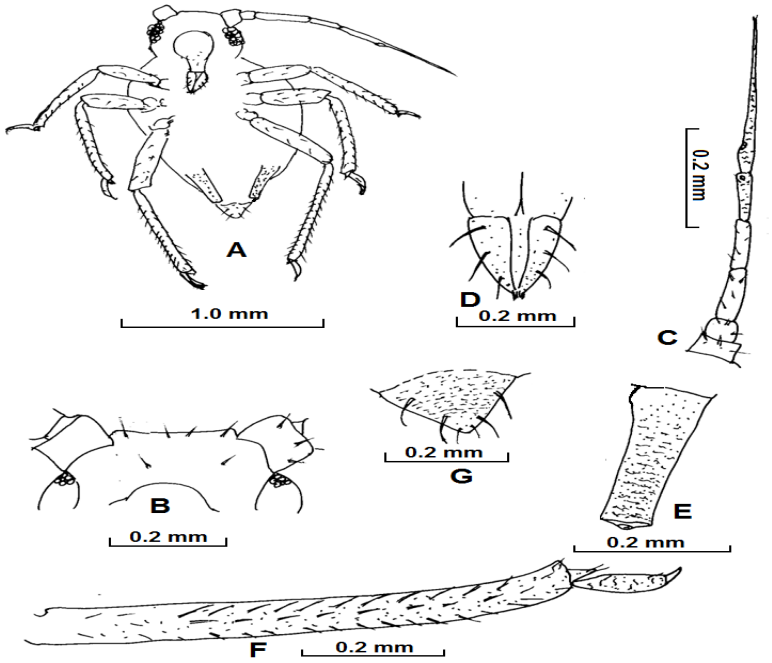

Figure 6. *Third instar nymph of apterous S. miscanthi : A. Body, B. Head, C. Antenna, D. U.r.s, E. Siphunculus, F. Hind tibia with tarsi, G. Cauda*

Fore- and midtibiae bear several small spinules arranged throughout the length but more densely distally. Hindtibiae bear several large spines (more than to the maximum width of tibia) outwardly. Hindtibiae almost 7x u.r.s. and 1.27x last antennal segment. Siphunculus 2x of cauda. The cauda bears 4-7 hairs. Measurements of various body parts are given in Table 5.

Table 5. *Measurements (in mm) of 5 randomly selected individuals of III Instar apterae nymph of females of S. miscanthi reared on T. aestivum.*

Particulars		Specimens					Mean ± SD
		1	2	3	4	5	
Body	Length	1.375	1.900	1.375	1.325	1.575	1.510±0.238
	Width	0.500	0.700	0.650	0.750	0.650	0.650±0.094
Antenna	Total length	0.875	1.225	1.125	1.125	1.200	1.110±0.139
	Length III	0.195	0.188	0.180	0.183	0.168	0.183±0.010
	b.d. III	0.038	0.050	0.038	0.043	0.035	0.041±0.006
	Length IV	0.125	0.168	0.193	0.183	0.195	0.173±0.029
	Length V	0.128	0.153	0.175	0.175	0.190	0.164±0.024
	Base VI	0.075	0.088	0.088	0.100	0.100	0.090±0.010
	p.t.	0.448	0.450	0.460	0.463	0.480	0.460±0.013
U.r.s.	Length	0.093	0.105	0.100	0.100	0.100	0.100±0.004
	Width	0.085	0.100	0.095	0.090	0.090	0.092±0.006
h.t.2	Length	0.100	0.138	0.115	0.113	0.110	0.115±0.014
Siphunculus	Length	0.188	0.238	0.258	0.263	0.275	0.244±0.034
Cauda	Length	0.125	0.125	0.100	0.113	0.153	0.123±0.019
	No. of hairs	5	7	6	7	4	4-7

Fourth instar apterous nymphs (Fig.7). Head smooth with 6 spinules and bears 6 segmented antennae. Antennal segment III that bears 1-2 circular and non-protuberant rhinaria and IV smooth with few very small spines (less than half of the cephalic hairs), V and VI imbricated entirely. U.r.s. blunt, darker and measures 0.103±0.006 mm and bears 4-8 primary and 2-4 secondary hairs and about 0.19x to length of siphunculi. Tibial spinules vary in number and size among pro-, meso- and metathoracic legs. Fore- and midtibiae bear several small spinules arranged throughout the length but more densely distally. Hindtibiae bear several large spines (more than to the maximum width of tibia) outwardly. Hindtibiae almost 7x u.r.s. and 1.27x last antennal segment. Siphunculus twice the length of cauda. The cauda bears 5-7 hairs. Measurements of various body parts are given in Table 6.

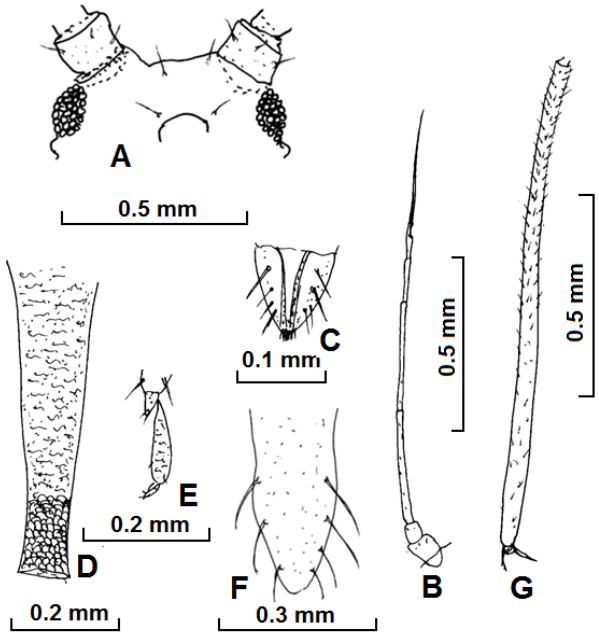

Figure 7. *Fourth instar nymph of apterous S miscanthi. A. Head, B. Antenna, C. U.r.s, D. Siphunculus, E. H.t.2, F. Cauda, G. Hind tarsi.*

Table 6. *Measurements (in mm) of 5 randomly selected individuals of IV Instar apterae nymph of females of S. miscanthi reared on T. aestivum.*

Particulars		Specimens					Mean ± SD
		1	2	3	4	5	
Body	Length	2.750	2.750	2.550	2.500	2.625	2.635±0.114
	Width	1.000	0.875	0.750	1.000	1.025	0.930±0.116
Antenna	Total length	2.125	2.325	2.125	2.375	2.750	2.340±0.256
	Length III	0.550	0.563	0.550	0.555	0.575	0.559±0.011
	b.d. III	0.033	0.038	0.038	0.045	0.033	0.037±0.005
	Length IV	0.400	0.450	0.450	0.425	0.538	0.453±0.052
	Length V	0.288	0.350	0.375	0.338	0.338	0.338±0.032
	Base VI	0.125	0.138	0.138	0.150	0.150	0.140±0.010
	p.t.	0.625	0.650	0.675	0.575	0.600	0.625±0.040
U.r.s.	Length	0.100	0.100	0.100	0.100	0.113	0.103±0.006
	Width	0.088	0.088	0.085	0.085	0.093	0.088±0.003
h.t.2	Length	0.125	0.138	0.125	0.150	0.150	0.138±0.013
Siphunculus	Length	0.500	0.513	0.550	0.575	0.625	0.553±0.050
Cauda	Length	0.300	0.363	0.350	0.325	0.375	0.343±0.030
	No. of hairs	6	7	5	5	5	5-7

Third and fourth apterous instars are easily separated from each other by the length of a.s. III and IV which do not overlap in the two instars. A highly significant difference ($P< 0.001$) was found in the ratio of the length of the a.s. III and a.s. IV. The a.s. III in the third instar has almost the same length as the a.s. IV but it is distinctly longer in the fourth instar. These characters agree with that of *S. avenae* [51]. The difference was found to be a very useful character when large numbers of aphids had to be shorted out into instars.

Table 7 display the measurements of various parts of first to fourth instar nymphs of apterous morph of *S. miscanthi*. Interestingly, the length of antennae, p.t., siphunculus and cauda increase linearly with increase in body size (i.e., from first instar to adult stage). The correlation coefficients of all regressions are significant at $P < 0.001$ (Fig. 8, 9).

Table 7. *Comparative length (in mm) of various parts of the body of different instars of apterous morphs of S. miscanthi reared on T. aestivum. Values are expressed as mean±SD.*

Characters		Developmental stages (Instars)			
		I	II	III	IV
Body	Length	0.840±0.099a	1.225±0.035b	1.510±0.238c	2.635±0.114d
	Width	0.330±0.054a	0.520±0.021b	0.650±0.094c	0.930±0.116d
Antenna	Total	0.585±0.065a	0.895±0.037b	1.110±0.139c	2.340±0.256d
	a.s. III	0.119±0.012a	0.229±0.009c	0.183±0.010b	0.559±0.011d
	b.d. III	0.045±0.007a	0.049±0.002a	0.041±0.006a	0.037±0.005a
	IV	0.082±0.006a	0.138±0.009b	0.173±0.029c	0.453±0.052d
	V/base	0.057±0.005a	0.075±0.008b	0.164±0.024c	0.338±0.032d
	VI base	-	-	0.090±0.010a	0.140±0.010b
	p.t.	0.296±0.033a	0.383±0.019b	0.460±0.013c	0.625±0.040d
U.r.s.	Length	0.088±0.004a	0.094±0.006a	0.100±0.004a	0.103±0.006a
	No. primary hairs	4	4-6	4-6	4-8
	No. Secondary hairs	2	2-4	2-4	2-4
H.t.2	Length	0.094±0.012a	0.114±0.004b	0.115±0.014b	0.138±0.013b
Siphunculus	Length	0.090±0.003a	0.176±0.021b	0.244±0.034c	0.553±0.050d
Cauda	Length	0.044±0.006a	0.078±0.008b	0.123±0.019c	0.343±0.030d
	No. hairs	2	4	4-7	5-7

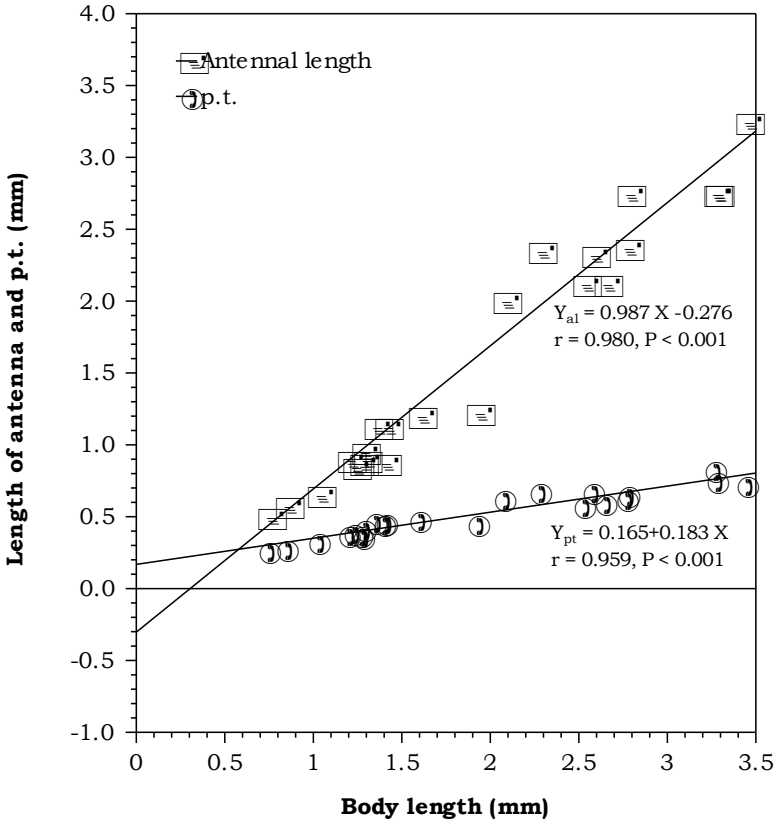

Figure 8. *Relationship between body length (in mm) with length of antenna and p.t. of developing stages (I instar to adult) of apterous morph of S. miscanthi.*

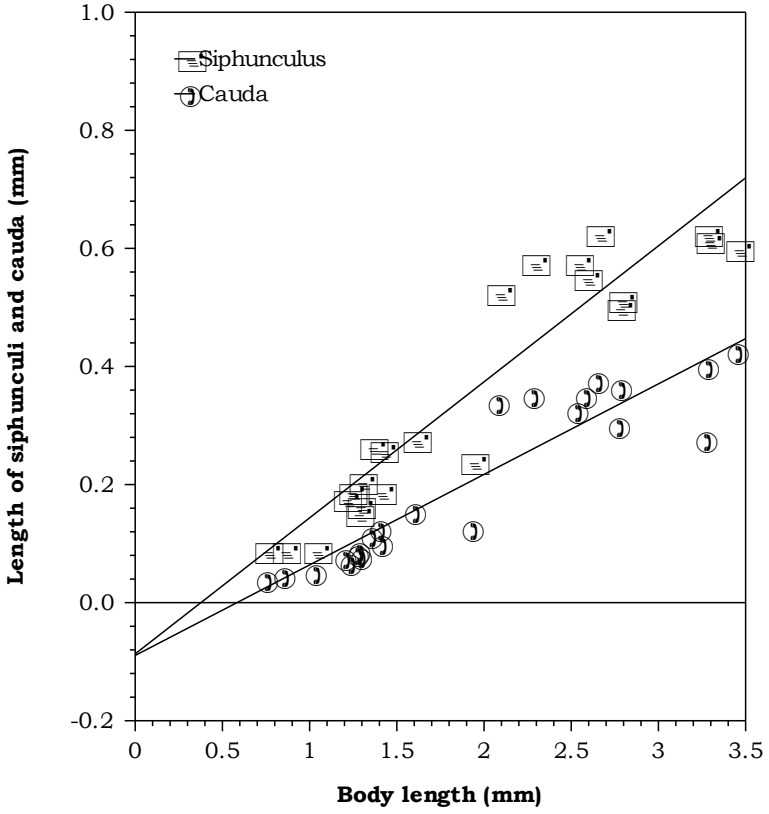

Figure 9. *Relationship between body length (in mm) with length of siphunculi and cauda of developing stages (I instar to adult) of apterous morph of S. miscanthi.*

3.3.2. Characteristics of Alate Morph

First and II instar nymphs of apterous and alate morphs cannot be segregated either taken from the field collected samples or from clones of the aphids reared in the laboratory that develop into alate morphs. Therefore, the measurements of these instars given in the Table 10 are taken from the apterous morphs (Table 7)

Third and IV instar alate nymphs of *S. miscanthi* can easily be identified from apterous morphs by having wing pads. The wing pad of III instar nymph are much smaller (Fig. 10) and do not overlap each other while in IV instar (Fig. 11) the wing pads are comparatively larger than III instar and overlap each other. Head of the both instars bears 6 segmented antennae like apterous morphs. The measurements of other body parts of III (Table 8) and IV (Table 9) instars do not vary significantly from apterous morphs. Cauda bears same number of hairs as in apterous morphs. Table 10 display the measurements of various parts of first to fourth instar nymphs of alate morph of *S. miscanthi.*

Table 8. *Measurements (in mm) of 5 randomly selected individuals of III Instar alatae nymph of females of S. miscanthi reared on T. aestivum.*

Particulars		Specimens					Mean ± SD
		1	2	3	4	5	
Body	Length	1.425	1.375	1.425	1.300	1.325	1.370±0.057
	Width	0.500	0.450	0.525	0.500	0.525	0.500±0.031
Antenna	Total length	1.000	1.050	1.125	1.050	1.125	1.070±0.054
	Length III	0.180	0.183	0.185	0.188	0.200	0.187±0.008
	b.d. III	0.028	0.028	0.030	0.030	0.038	0.031±0.004
	Length IV	0.138	0.138	0.150	0.143	0.140	0.142±0.005
	Length V	0.163	0.143	0.163	0.150	0.138	0.151±0.011
	Base VI	0.095	0.088	0.093	0.088	0.083	0.089±0.005
	p.t.	0.400	0.400	0.425	0.425	0.425	0.415±0.014
U.r.s.	Length	0.075	0.063	0.075	0.075	0.070	0.072±0.005
	Width	0.055	0.063	0.068	0.065	0.070	0.064±0.006
H.t.2	Length	0.095	0.093	0.100	0.098	0.093	0.096±0.003
Siphunculus	Length	0.210	0.213	0.213	0.228	0.213	0.215±0.007
	Width	0.060	0.063	0.063	0.063	0.063	0.062±0.001
Cauda	Length	0.075	0.088	0.075	0.075	0.125	0.088±0.022
	No. of hairs	5	4	5	7	5	4-7

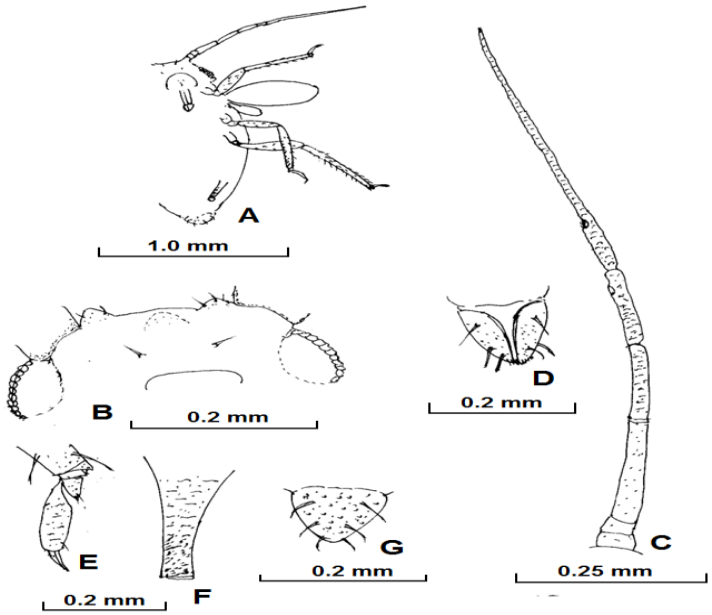

Figure 10. *Third instar nymph of alate S. miscanthi. A. Body, B. Head, C. Antenna, D. U.r.s, E. H.t.2, F. Siphunculus, G. Cauda.*

Table 9. *Measurements (in mm) of 5 randomly selected individuals of IV Instar alatae nymph of females of S. miscanthi reared on T. aestivum.*

Particulars		Specimens					Mean ± SD
		1	2	3	4	5	
Body	Length	2.375	2.750	2.750	2.875	2.875	2.725±0.205
	Width	1.200	1.000	0.750	1.000	1.000	0.990±0.160
Antenna	Total length	1.875	2.050	2.000	2.000	2.200	2.025±0.117
	Length III	0.363	0.388	0.400	0.405	0.450	0.401±0.032
	b.d. III	0.045	0.055	0.045	0.055	0.050	0.050±0.005
	Length IV	0.325	0.363	0.363	0.375	0.375	0.360±0.021
	Length V	0.313	0.310	0.288	0.325	0.350	0.317±0.023
	Base VI	0.125	0.125	0.125	0.125	0.125	0.125±0.000
	p.t.	0.600	0.675	0.643	0.700	0.750	0.674±0.057
U.r.s.	Length	0.113	0.113	0.113	0.113	0.113	0.113±0.000
	Width	0.075	0.088	0.075	0.083	0.080	0.080±0.005
H.t.2	Length	0.138	0.138	0.138	0.150	0.163	0.145±0.011
Siphunculus	Length	0.355	0.425	0.413	0.413	0.425	0.406±0.029
	Width	0.118	0.120	0.113	0.110	0.100	0.112±0.008
Cauda	Length	0.188	0.163	0.175	0.200	0.213	0.188±0.020
	No. of hairs	9	6	9	11	11	6-11

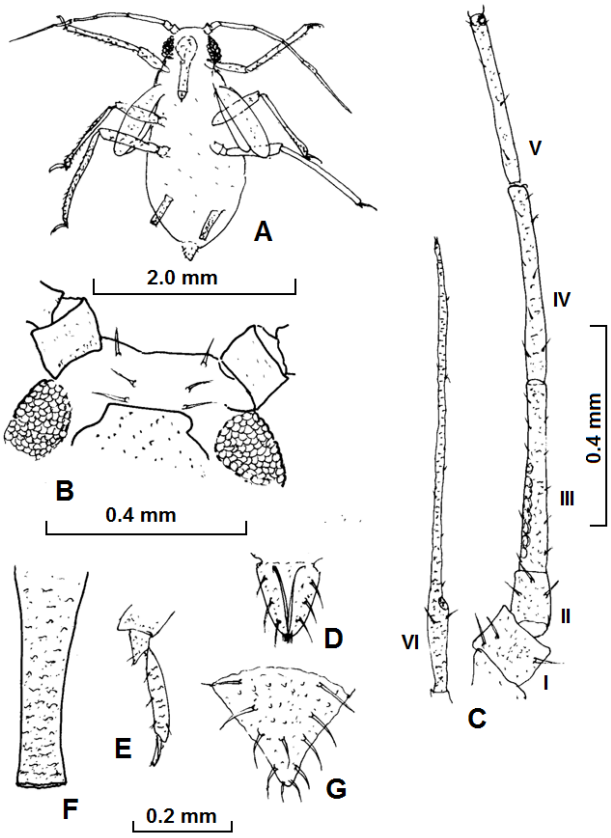

Figure 11. *Fourth instar nymph of alate S. miscanthi. A. Body, B. Head, C. Antenna, D. U.r.s, E. H.t.2, F. Siphunculus, G. Cauda.*

Table 10. *Measurement of length (in mm) of various parts of the body of alate morphs of S. miscanthi. Values are expressed as mean±SD.*

Morphological characters		Developmental stages (Instars)			
		I	II	III	IV
Body	Length	0.840±0.099	1.225±0.035	1.370±0.057	2.725±0.205
	Width	0.330±0.054	0.520±0.021	0.500±0.031	0.990±0.160
Antenna	Total	0.585±0.065	0.895±0.037	1.070±0.054	2.025±0.117
	a.s. III	0.119±0.012	0.229±0.009	0.187±0.008	0.401±0.032
	b.d. III	0.045±0.007	0.049±0.002	0.031±0.004	0.050±0.005
	IV/base	0.082±0.006	0.138±0.009	0.142±0.005	0.360±0.021
	V/base	0.057±0.005	0.075±0.008	0.151±0.011	0.317±0.023
	VI base	-	-	0.089±0.005	0.125±0.000
	p.t.	0.296±0.033	0.383±0.019	0.415±0.014	0.674±0.057
U.r.s.	Length	0.088±0.004	0.094±0.006	0.072±0.005	0.113±0.000
	No. primary hairs	4	4-6	4-6	4-8
H.t.2	Length	0.094±0.012	0.114±0.004	0.215±0.007	0.406±0.029
Siphunculus	Length	0.090±0.003	0.176±0.021	0.062±0.001	0.112±0.008
Cauda	Length	0.044±0.006	0.078±0.008	0.088±0.022	0.188±0.020
	No. hairs	2	4	4-7	6-11

The number of setae on the cauda and sub-anal plate on the third and fourth instars showed some overlap in their ranges.

3.4. Key for Identification of Instars of *S. Miscanthi*

The key constructed on the basis of the data given above enables immature stages of *S. miscanthi* to be identified to instars with certainty under a binocular dissecting microscope at 40 x magnification.

1. Antennae 5 segmented, cauda with 2 hairs…..…… ……..**2**
- Antennae 6 segmented, cauda with more than 2 hairs ……..…...**3**
2. Cauda with only 2 hairs, third antennal segment without setae; length of siphunculi ranges from 0.088-0.095 mm (0.090 ± 0.003 mm)……...……..…… **I instar**
- Cauda with 4 hairs, third antennal segment with setae; length of siphunculi ranges from 0.150-0.205 mm (0.176 ± 0.021 mm)….... ……..…….. **II instar**
3. Wing pad absent…….……...….**4**
- Wing pad present ..……...……..**6**
4. Antennal segment III small, measures 0.168 to 0.195 mm (0.183±0.010 mm), length of p.t. less than 12.0 times to that of b.d. III, length of siphunculi ranges 0.188-0.275 mm (0.244±0.034 mm) ……..…….**Apterous III instar**
- Antennal segment III large, more than 0.5 mm, length of p.t. more than 15 times to that of b.d. III, length of siphunculi more than 0.5 mm ……**5**
5. Cauda less than 0.20 mm (0.188±0.020 mm) …..…..……..**Apterous IV instar**
- Cauda more than 0.27 mm (0.358±0.058 mm) ……..……..…….…....**Apterous adult**
6. Wing pads small and do not completely overlap…….. ..… …….**Alate III instar**
- Wing pads large and completely overlap or fully developed ……...….**7**
7. Wing pads large and completely overlap, siphunculi more than 2.0x of cauda..**Alate IV instar**
- Wing pads fully developed, siphunculi less than 2x of cauda …….**Alate adult**

3.5. Economic Importance

The *S. miscanthi* is a pest of wheat, barley, corn and millets in eastern Uttar Pradesh. The damage of the crop is caused by both nymphs and adults (wingless and winged forms). Direct feeding damage occur on stems, leaves and earheads, usually in the tillering. During later stages of crop growth, *S. miscanthi* usually colonise on the earhead of the wheat, barley and oat, however, it may

be observed on tender apical shoot of the food plant. They suck the sap by slender mouthparts, the stylets into plant cells. The stylets bundle consists of an outer pair of mandibular stylets and an inner pair of maxillary stylets. The maxillary stylets are held together by interlocking grooves and ridges and in channels between them run the food and salivary canals. After penetrating into the tissue of a plant the stylets go between the cells and rarely pass through a cell, until they reach the sieve tubes within the veins of the host plants. The stylets then pierce the cell and the feeding commences. The enzyme pectinase in the saliva breaks down the bonding between the cell and stylets while moving between cells often change direction.

Both the nymphs and adults feed by sucking the cell sap from the host plants. They suck the sap from leaves and earheads of the crops. Due to high population the whole plant becomes devitalized. In addition to direct damage the aphids also excrete a large amount of honeydew, on which black fungus called sooty mould develops, which interfere in the normal functioning of photosynthetic activity of the plant. Aphid infestation causes a marked disturbance in the concentration of plant growth hormones. There is a pronounced increase in the level of the plant growth inhibitors and a decrease in the growth promoters [55]. This imbalance could be due to plant growth inhibitor introduced into the plant through the saliva of the aphid. Damage is further aggravated when the aphid removes large quantities of plant growth promoters and essential food materials from the plants [56]. By aphid infestation, the leaves turn yellow and become dry. As soon as earhead matured in the early summer the number of aphid population becomes greatly reduced.

S. miscanthi infest heavily the wheat crop in Delhi [57] and Punjab [58]. Singh [59] extensively surveyed Punjab state from 2004 to 2007 and observed that aphid incidence was present in all the districts of the state. In 2008, a severe attack of the wheat aphid was noticed in Ludhiana, Moga, Muktsar, Bathinda, Barnala, Jalandhar, Gurdaspur, Amritsar and Hoshairpur districts (Punjab) causing heavy yield loss of wheat [60]. In north eastern Uttar Pradesh, *S. miscanthi* cause severe damage to wheat and barley [61]. The *S. miscanthi* also transmit a number of plant viruses like barley yellow mosaic viruses (BYMV) [62], millet red leaf persistent luteovirus (MRLV) [41] and yellow dwarf virus (CYDV) [63].

The economic threshold levels (ETL) for wheat variety PBW 343 and WH 542 were estimated 4.69 and 5.10 aphids per earhead, respectively and the economic injury level (EIL) at 7.18 and 7.62 aphids per tiller for WH 542 and PBW 343, respectively [64].

3.6. Life History

Aphids are remarkable on account of their peculiar mode of development and the polymorphism exhibited in different generations. Life cycle of *S. miscanthi* is anholocyclic in India and many parts of the world. It reproduced by viviparous parthenogenesis throughout the year on one or the other food plants, mostly belonging to Poaceae. Newly laid nymphs usually undergo four moults to reach adulthood. In Delhi, *S. miscanthi* complete five successive generations. The duration of nymphal instars did not differ much among the five generations. An additional fifth instar was observed in some of the individuals during first, second and fourth generations [65]. The occurrence of fifth instar has been reported to be a rare phenomenon in aphids. The total nymphal period ranged from 6.0 to 7.6 days in different generations with over all mean of 7.16 days. It was interesting to note that there was no marked variation in total nymphal period whether the individual went four or five instars. However, it was observed that wherever five instars were involved, the emerging adults were always alate [66], while in cases were four instars were involved the emerging adults could be either apterous or alate. The adult longevity varied between 7.6 to 9.33 days in different generations with over all mean of 8.68 days. The pre-reproductive, reproductive and post reproductive periods showed generation means of 1.01, 6.63 and 1.04 days, respectively. The total life cycle in different generations varied between 13.4-16.0 days with mean value of 15.18 days. The total fecundity per female exhibited a gradual decline in successive generations from 31.2 to 13.0 nymphs with overall mean value of 21.91 nymphs. Mean fecundity per female per day also showed a gradual decline from 4.26 to 1.88 nymphs and recorded an overall mean of 3.26 nymphs. Wingless aphids produce more offspring than alates like other aphid species. There are several generations, depending on whether first or last young of each generation are considered. In winter, they are found almost exclusively on wheat, barley and millets water.

3.7. Geographic Distribution

In India, *S. miscanthi* has been reported from most of the states such as Arunachal Pradesh, Assam, Bihar, Delhi, Himachal Pradesh, Manipur, Meghalaya, Nagaland, Orissa, Punjab, Sikkim, Tamil Nadu, Tripura, Uttar Pradesh, West Bengal [40, 67, 68, 69]. Outside India, *S. miscanthi* is reported from most of the countries, viz., Australia, Bangladesh, China, Fiji, Hawaii, Indonesia, Japan, Korea, Malaya, Nepal, New Zealand, Pakistan, Philippines, Tonga, Turkey, South Africa, Sri Lanka, etc. [70, 71].

3.8. Food Plants

In India, *S. miscanthi* feed on 84 plant species belonging to 13 plant families given below. It infests especially Asteraceae, Poaceae, and Polygonaceae.

1. Asteraceae : *Cineraria* sp. [72], *Erigeron* sp. [73], *Granotia* sp. [74], *Helianthus annuus* L. [75], *Lactuca sativa* L. [76], *Youngia japonica* (L.) DC. (=*Crepis japonica* (L.) Benth.) [75].

2. Brassicaceae : *Brassica napus* L. [77], *Brassica oleracea* L. [78].

3. Cannaceae : *Canna* sp. [79].

4. Cyperaceae : *Cyperus rotundus* L. [75], *Cyperus* sp. [75]

5. Chenopodiaceae : *Spinacia oleracea* L. [80].

6. Euphorbiaceae : *Bridelia* sp. [81].

7. Lamiaceae [=Labiatae] : *Elsholtzia blanda* (Benth.) Benth. [39].

8. Poaceae : *Agropyron* sp. [74], *Agrostis* sp. [82], *Andropogon* sp. [39], *Andropogon vulgaris* Raspail [83], *Anthoxanthum odoratum* L. [84], *Apluda mutica* L. [79], *Aristida* sp. [39], *Avena sativa* L. [85], *Bothriochloa bladhii* (Retz.) S.T. Blake (=*Bothriochloa intermedia* (R. Br.) A. Camus) [79], *Bothriochloa insculpta* (Hochst. ex A. Rich) A. Camus [39], *Bothriochloa pertusa* (L.) A. Camus [82], *Bothriochloa* sp. [79], *Brachypodium sylvaticum* (Huds.) P. Beauv. [39], *Bromus catharticus* var. *catharticus* Vahl. (=*Bromus uniloides* Kunth) [76], *Bromus hordeaceus* ssp. *hordeaceus* L. (=*Bromus mollis* L.), [86], *Capillipedium parviflorum* (R. Br.) Stapf. [39], *Chloris barbata* Sw. (=*Chloris inflata* Link) [36, 82], *Chrysopogon nodulibarbis* (Steud.) Henr. (=*Chrysopogon zylanicus* (Nees ex Steud.) Thwaites) [36,82], *Cymbopogon martini* (Roxb.) Watson [39], *Cymbopogon nardus* (L.) Rendle [39], *Cymbopogon* sp. [79], *Cynodon dactylon* (L.) Pers. [39], *Dactyloctenium aegypticum* (L.) Willd. [34], *Dichanthium* sp. [79], *Digitaria* sp. [39], *Echinochloa colona* (L.) Link [79], *Echinochloa* sp. [87], *Eleusine coracana* (L.) Gaertn. [33], *Eleusine indica* (L.) Gaertn. [75], *Eleusine* sp. [88], *Enteropogon* sp. [82], *Eragrostis gangetica* (Roxb.) Steud. [89], *Eragrostis* sp. [39], *Eragrostis superba* Peyr. [34], *Heteropogon contortus* (L.) P. Beauk ex Roem & Schult. (= *Andropogon contortus* L.) [90], *Hordeum vulgare* L. [76], *Ischaemum rugosum* Salisb. [36], *Ischaemum* sp. [39], *Koeleria macrantha* (Ledeb.) Schul. (=*Koeleria cristata* auct.) [76], *Oplismenus compositus* (L.) P. Beauv. [79], *Oplismenus* sp. [39], *Oryza sativa* L. [91], *Panicum* sp. [92], *Paspalum conjugatum* Bergius [74], *Paspalum dialatum* Poir. [75], *Paspalum* sp. [39], *Pennisetum flaccidum* Griseb. [39], *Pennisetum glaucum* (L.) R. Br. (=*Setaria glauca* (L.) P. Beauv.) [69], *Phalaris minor* Retz. [99], *Poa annua* L. [76], *Poa pratensis* L. [39], *Poa* sp. [93], *Polypogon littoralis* J.C. Sm. [76], *Saccharum officinarum* L. [39], *Secale cereale* L. [73], *Setaria palmifolia* (J. Koeing) Stapf [78], *Thysanolaena latifolia* (Roxb. ex Hornem.) Honda (=*Thysanolaena agrostris* Nees) [75], *Triticum aestivum* L. [87], *Triticum aestivum* ssp. *aestivum* L. (=*Triticum vulgare* Vill., *Triticum sativum* Lam.) [73], *Triticum* sp. [94], *Zea mays* L. [87].

9. Polygonaceae : *Persicaria capitata* (Buch.-Ham. ex D. Don) H. Gross (=*Polygonum capitatum* Buch.-Ham. ex D. Don) [95], *Persicaria chinensis* (L.) H. Gross (=*Polygonum chinense* L.) [38].

10. Rubiaceae : *Galium mollugo* L. [76].

11. Ranunculaceae : *Ranunculus arvensis* L. [76], *Ranunculus* sp. [92].

12. Rosaceae : *Rosa indica* Linn. [96], *Rosa* sp. [96].

13. Smilacaceae : *Smilax parvifolia* Wall. ex Hook.f. [79], *Smilax* sp. [92].

4. CONCLUSION

The Indian grain aphid, *S. miscanthi* is a destructive aphid pest in many wheat growing countries of the world. It is a small (apterae 3.05-3.45 mm, alatae 2.35–2.92 mm) greenish to brownish aphid with dark siphunculi and light coloured cauda. Young ones are yellowish green in colour while grown-ups are light brownish to blackish brown. In India, it is reported on 84 plant species belonging to 13 plant families, most suffered family is Poaceae (Graminae). In northeastern Uttar Pradesh it was observed on feeding 5 food plants, viz. oat (*Avena sativa* L.), barley (*Hordeum vulgare* L.), pearl-millet (*Pennisetum glaucum* (L.) R. Br.), bunchgrass (*Phalaris minor* Retz.), and wheat (*Triticum aestivum* L.). The adult parthenogenetic viviparous apterae and alatae as well as alate male (sexual morph, not recorded in the study area) were re-described. A key was prepared for easy identification of the nymphal stages.

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