



Research Article

An Annotated List of Planthoppers with Alternate Hosts from Kallar Tract of Punjab, Pakistan

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Authors' Contributions

MR, BA and AMS conceptualized the study. MR, BA and AMS surveyed the fields for sample collection. MR, BA, AMS and MS preserved while AMMRL and RM identified the planthoppers species. MR, BA, MT, MR and MA wrote the manuscript. AM-MRL, RM, MT, MR, MS and CMR reviewed the manuscript. The final manuscript was ultimately approved by all authors.

Keywords

Planthoppers, Alternate hosts, Fulgoromorpha, Cixiidae, Delphacidae, New record, Kallar tract

Abstract | Diversity of planthoppers and their host plants were studied in the “Kallar” tract of the Punjab, Pakistan (an important growing area of the world for producing Basmati rice). Planthoppers are considered the most important pests of rice. Delphacidae and Cixiidae are families of planthoppers with the most harmful species. Delphacids are primarily vector of the viruses, whereas Cixiids are vectors of phytoplasmas, mycoplasmas and prokaryotes-like associated to the class Mollicutes. Specimens of planthoppers were collected from the rice fields and surrounding weeds. A list of Fulgoromorpha is provided, with distributional and biological records as well. Records are extracted primarily from field data and specialized reference sources. Seven species from two different families of Fulgoromorpha were related to rice ecosystem (Cixiidae, one species and Delphacidae; six species). Three Delphacid species, whitebacked planthopper *Sogatella furcifera*, brown planthopper *Nilaparvata lugens* and small brown planthopper (SBPH) *Laodelphax striatellus* are well-known vectors of severe rice pathogenic diseases in the Oriental and Palearctic regions. *Laodelphax striatellus* was recorded on rice for the first time in Pakistan. Among alternate hosts, *Trifolium alexandrinum*, *Leptochloa chinensis*, *Helianthus allus*, *Medicago polymorpha* and *Sorghum bicolor* were recorded for *L. striatellus*, while *Leptochloa chinensis*, *Helianthus allus*, *Medicago polymorpha*, *Sorghum bicolor*, *Zea mays* and *Cynodon dactylon* were recorded for *S. furcifera* for the first time. *N. lugens* was recorded on weeds *Leptochloa chinensis* and *Medicago polymorpha*.

Novelty Statement | Out of seven species of planthoppers, *Laodelphax striatellus* Fallén is recorded for the first time in Pakistan, while 30 new host plants are recorded for first time the world over.

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Introduction

Family Delphacidae includes the notorious rice planthoppers i.e., whitebacked planthopper (WBPH)

Sogatella furcifera Horvath and brown planthopper (BPH) *Nilaparvata lugens* Stål. Rice planthoppers are considered as severe and notorious insect pests of rice crop (Sabir *et al.*, 2016). These planthoppers have also achieved the status of most destructive pests in rice crop (Akhter *et al.*, 2017; Sabir *et al.*, 2017a, 2017b, 2019; Rizwan *et al.*, 2019a,

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2019b; Shah *et al.*, 2019; Atta *et al.*, 2020). Since 2013, rice crop in Pakistan has been witnessing the regular incidence of planthoppers (Akhter *et al.*, 2017). Brown planthopper is a new issue for rice crop in Pakistan.

All the rice planthoppers are not serious pests of this economic crop throughout the world neither each rice cultivating area is species richer. Previously *Pentastiridius* sp., *Metadelphax propinqua* Fieber, *S. furcifera*, *Sogatella vibix*, *Sogatella kolophoni*, *Nilaparvata lugens* and *Tagosodes pusanus* were reported on rice crop in Pakistan (Qadri and Mirza, 1960; Dlabola, 1971; Mahar *et al.*, 1978; Yang, 1989; Akhter *et al.*, 2017). However, besides the economic threat, diversity and relevancy of Delphacids to alternate hosts have not been studied in Pakistan.

Various phytophagous pests limited to infest and survive on a single plant species (known as monophagous pests) (Cates, 1980), whereas other pests have a broader choice of host plants (known as polyphagous pests) which includes cultivated plants as well as species which are not under the consideration of agricultural production (Rivnay, 1962). It is essential to find out the importance and range of alternate host plants to manage the population of polyphagous pests on main agricultural crops (Tabashnik *et al.*, 1991). For example, alternate host plants may support pest reservoirs during seasonal unavailability of main host plants which become a source for pests to migrate back to the main economic plants (Clementine *et al.*, 2005). Meanwhile, alternative host plants also play a vital part to harbor the population of natural enemies (Saeed *et al.*, 2015). Therefore, the main factors that affect the losses caused by insect pests to the main crops includes the availability, density and category of alternate host plants (Pan *et al.*, 2015) and the occurrence of natural enemies (Saeed *et al.*, 2015).

The purposes of the present studies were to explore the species of planthoppers and their alternate hosts in the Kallar tract of the Punjab, Pakistan.

Materials and Methods

Collection of planthoppers

A net sweeping (net size: 30cm in diameter, 80cm in depth) was carried throughout the year in 2018 from different plant species to search out the different alternate host plants of planthoppers. Planthoppers collected from each alternate host were brought to the laboratory and were separated based on morphological appearances under a stereoscope (Cole-Parmer 625 East Bunker Court Vernon Hills, IL, 60061, USA). The separated samples were preserved in plastic vials (5g capacity) containing absolute alcohol with the proper labeling encompassing the collection place, alternate hosts, date of collection, and collector's name.

Identification of planthoppers

The collected samples were examined by the well-known Delphacid taxonomists. Standard taxonomic techniques were used to examine the male genitalia under the microscope (de Remes Lenicov and Virla, 1993) for Planthoppers' identification associated with each alternate host.

Identification of alternate hosts

Host plants were identified with the available botanical literature, while unidentified host plants were brought to the botanist and weed experts for their identification. Only those plant species were considered as alternate host plants on which planthoppers population were found from more than five different localities.

Results and Discussion

Cixiidae

Pentastiridius sp.

Distribution: Widespread, except for Neotropical and Australian biogeographic realm (relatively rare in Nearctic) (Bourgoin, 2016).

Host plant: Most species are associated with Poaceae and Cyperaceae; two of them, *P. apicalis* (Uhler) and *P. leporinus* L. are registered on rice.

Host plant records from Pakistan: *Cynodon dactylon* L. (Poaceae), *Trifolium alexandrinum* L. (Fabaceae).

Economic importance: *P. apicalis* is recognized to occur on rice but maybe a vector of Strawberry Marginal Chlorosis (SMC) (Aoki *et al.*, 2011). *P. leporinus* is known for their ability to transmit phloem-restricted prokaryotes (Bressan *et al.*, 2011).

Material studied: 6 ♂♂ (Figure 1).



Figure 1: *Pentastiridius* sp. habitus, dorsal view (originals).

Delphacidae*Metadelphax propinqua* (Fieber)

Distribution: Pantropical. Worldwide widespread is found on every continent except Antarctica (Fennah, 1965).

Host plants: This species mostly feeds on a great number of species of cultivated and wild Poaceae, including barley, maize, oat, rice, sorghum, sugarcane (de Remes Lenicov and Tesón, 1978; Wilson and O'Brien, 1987; de Remes Lenicov and Rioja, 2007; de Remes Lenicov *et al.*, 2006, 2014; Bourgoïn, 2016).

Host plant records from Pakistan: This species showed higher density in areas with a prevalence of *Leptochloa chinensis* L.*. It is also captured on *Cynodon dactylon* L., *Helianthus allus* L.*, *Medicago polymorpha* L.*, *Trifolium alexandrinum* L.*, *Sorghum bicolor* L.* and *Zea mays* L.

Economic importance: It is a known vector of Cynodon Chlorotic Streak Nucleorhabdovirus (CCSV), Barley Yellow Striate Mosaic Cytorhabdovirus (BYSMV) and Maize Rough Dwarf Virus (MRDV) (Harpaz, 1972; Wilson, 2005; Bartlett, 2013). In Argentina, it is a vector of Mal de Rio Cuarto Virus (MRCV) which affect wheat and maize (Velázquez *et al.*, 2017).

Material examined: 91 ♂♂ and 43 ♀♀.

Diagnostic features: Small-sized: 2.5-3.7mm. General body color yellowish. Carinae of head and frons considerably paler than the body, intercardinal regions of head narrowly to broadly infuscate; area posterior to M-shaped carina slightly paler to slightly darker than the body. Short vertex, rounded toward frons. Wings glassy in appearance to weakly sombre in color; veins darker in apical 1/3 of the forewing. Short-winged forms are also common. Male: pygofer medium to dark brown, the expanded posterior portion in caudal view with apices inflected; genital diaphragm elongate, apically bilobed or trilobed; parameres apically truncate (Figure 2).

Sogatella furcifera (Horvath)

Distribution: Wide-ranging and common in the Old World tropics and contiguous temperate zones. Eastern Palaearctic and Oriental regions, Western Pacific and Australia. Reports from New World, Europe and parts of Africa were based on misidentifications (Asche and Wilson, 1990; Bellis *et al.*, 2014).

Host plant: *Oryza sativa* L., *Paspalum* sp., *Zea mays* L. (Bartlett, 2013), *Trifolium alexandrinum* L. (Sabir *et al.*, 2017c).

Host plant records from Pakistan: This species

showed higher density in areas with a prevalence of *Oryza sativa* L. and *Medicago polymorpha* L.*. It is also captured on *Cynodon dactylon* L.*, *Helianthus allus* L.*, *Leptochloa chinensis* L.*, *Sorghum bicolor* L.* and *Zea mays* L.

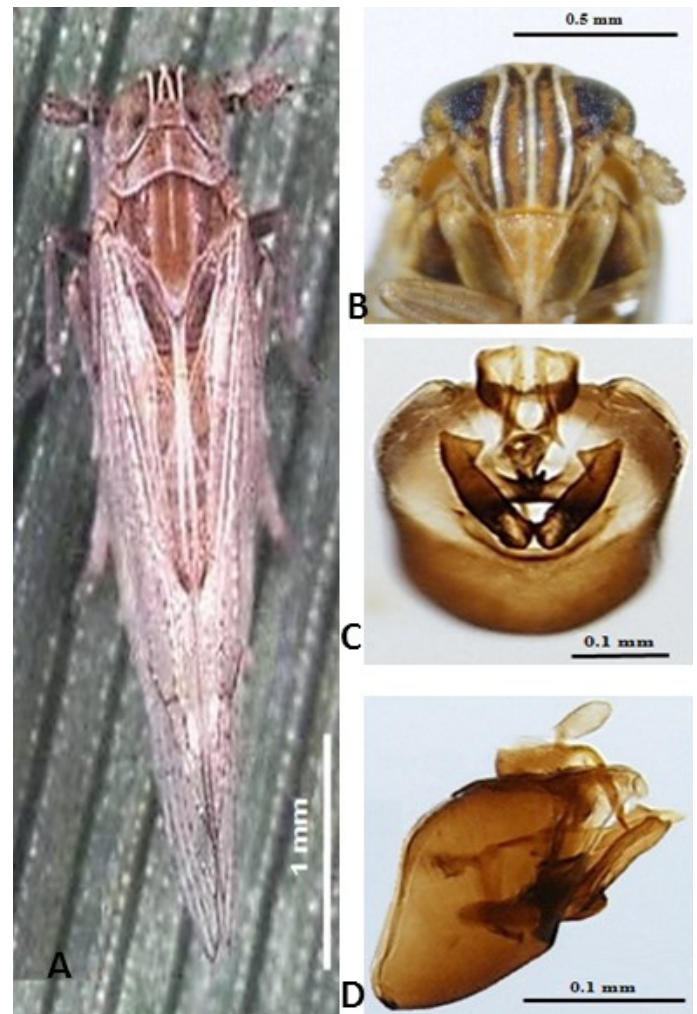


Figure 2: *Metadelphax propinqua* (Fieber), (A) habitus dorsal view; (B) head (originals); (C, D) genital segments (Bartlett, 2020).

Economic importance: It is a serious rice pest, vector of the Southern Rice Black Streak Dwarf Virus (SRBSDV) and Pangola Stunt Virus (PSV) (Harpaz, 1972; Xu *et al.*, 2014).

Material examined: 22 ♂♂ and 42 ♀♀; 1♂ and 1♀ parasitoidized by Strepsiptera, Elenchidae.

Diagnostic features: Small and slender: 2.5-3.3mm. General body color castaneus with a whitish vertical stripe at the vertex and middle portion of the pro- and mesonotum; gena, clypeus and frons black excluding whitish carina in clypeus and frons; pterostigma distinct; apicobasal half of forewing and apex of clavus with a dark brown band. Male: parameres powerfully expanded at base, apex comparatively small equally bifurcate; aedeagus compacted and twisted narrowing to the apex (Figure 3).

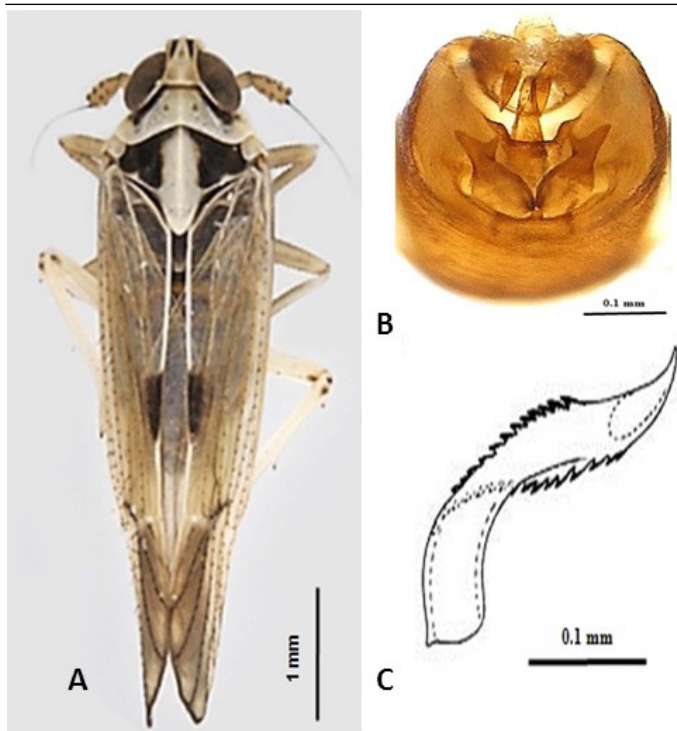


Figure 3: *Sogatella furcifera* (Horvath), (A) habitus dorsal view (originals); (B) genital segments (Bartlett, 2020); (C) aedeagus (Asche and Wilson, 1990).

Sogatella vibix (Haupt)

Distribution: Palearctic, Ethiopian and Oriental regions; Australia and the Western Pacific (Asche and Wilson, 1990).

Host plant: *Echinochloa crus-galli* L., *Digitaria* sp., *Leersia* sp., *Oryza sativa* L., *Phalacris* sp., *Setaria* sp., *Triticum* sp., *Zea mays* L. (Bartlett, 2013).

Host plant records from Pakistan: *Oryza sativa* L., *Medicago polymorpha* L.*, *Trifolium alexandrinum* L.*

Economic importance: Currently, it is not considered an important rice pest (Wilson and Claridge, 1991). It is a vector of Maize Rough Dwarf Virus (MRDV), Maize Sterile Stunt Virus (MSSV), and Finger Millet Mosaic Virus (FMMV) (Harpaz, 1972; Greber, 1982).

Material examined: 24 ♂♂ and 17 ♀♀.

Diagnostic features: Small and slender: 2.5-3.3mm. General body color stramineous or pale yellow, with a whitish vertical stripe at the vertex and middle portion of the pro- and mesonotum. Face whitish with dark brown genae. Forewings transparent, unmarked. Male: parameres with thin and petiolated base, apex powerfully bifurcate, outer process expanding from the base to middle then narrowing to the apex that is obliquely truncate (Figure 4).

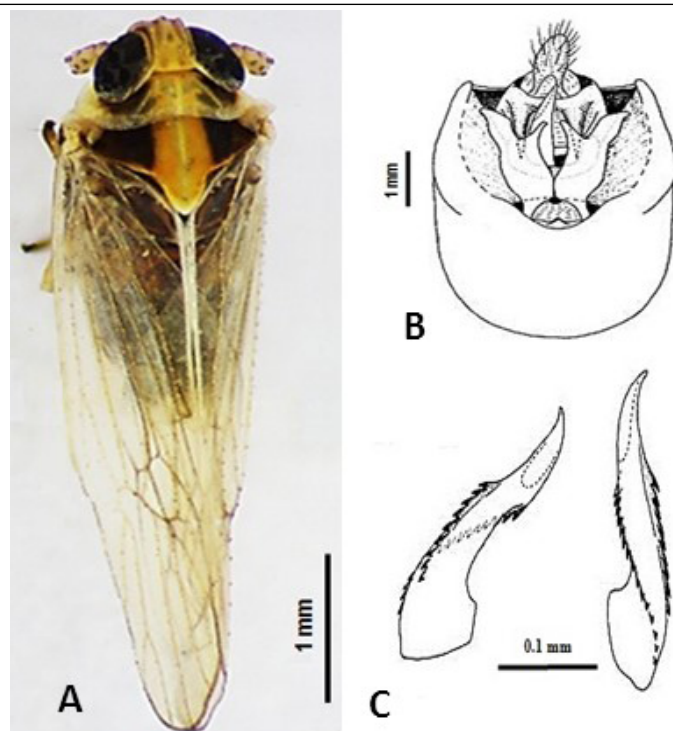


Figure 4: *Sogatella vibix* (Haupt), (A) habitus dorsal view (originals); (B) genital segments; (C) aedeagus (Asche and Wilson, 1990).

Nilaparvata lugens (Stål)

Distribution: Southeast Asia, parts of the Pacific and Australia (Wilson and Claridge 1991).

Host plant: *Leersia hexandra* Sw., *Oryza sativa* L., *Saccharum officinarum* L., *Zizania* sp. (Hasegawa, 1955; Sigsgaard, 2007), *Trifolium alexandrinum* L.* (Sabir *et al.*, 2017c).

Host plant records from Pakistan: This species showed higher density in *Oryza sativa* L. crops associated with *Leptochloa chinensis* L.* and *Medicago polymorpha* L.*.

Economic importance: It is a vector of Rice Ragged Stunt Virus (RRSV) and Rice Grassy Stunt Virus (RGSV) (Cabauatan *et al.*, 2009).

Material examined: 35 ♂♂ and 32 ♀♀.

Diagnostic features: Medium-sized: 3.7-5mm. General body yellowish-brown to dark brown; pronotum, vertex, mesonotum and tip of scutellum, uniformly brown. Basal part of tarsi III with one or more spines horizontally. Forewings glassy in appearance, with the apex of claval part black. Vertex quadrate. Short-winged forms are also common. Male: pygofer without processes from ventral margin; aedeagus slender and upturned parameres relatively long, prominently concave at the mid-inner margin with converging apices, subapically moderately swollen (Figure 5).

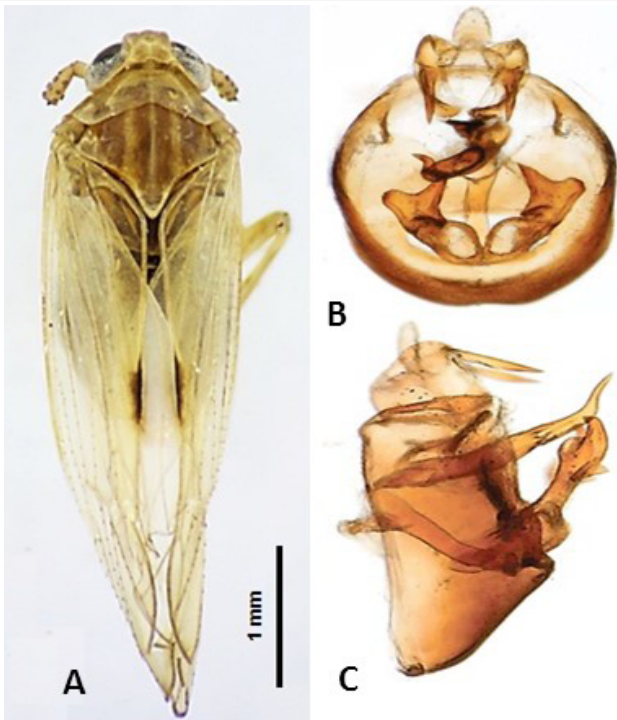


Figure 5: *Nilaparvata lugens* (Stål), (A) habitus dorsal view (originals); (B, C) genital segments (Bartlett, 2020).

Laodelphax striatellus (Fallén)

Distribution: Widespread in Palaearctic and Oriental regions and Oceania (Bellis *et al.*, 2014). The new record from Pakistan.

Host plant: It is polyphagous on many different species of Poaceae (grasses), with economically important host plants including *Oryza sativa* L., *Andropogon* sp., *Hordeum vulgare* L., *Arrhenatherum elatius* L., *Saccharum officinarum* L., *Zea mays* L., *Avena sativa* L. and *Triticum* sp. (Bartlett, 2013).

Host plant records from Pakistan: It was more frequently captured on *Leptochloa chinensis* L.*, *Medicago polymorpha* L.* and *Oryza sativa* L.. It is also collected on *Cynodon dactylon* L.*, *Helianthus allus* L.*, *Sorghum bicolor* L.*, *Trifolium alexandrinum* L.* and *Zea mays* L.

Economic importance: It is one of the most destructive Delphacid pests. It is a vector of Maize Rough Dwarf Virus (MRDC), Barley Yellow Striate Mosaic Virus (BYSMV) (Harpaz, 1972), Rice Stripe Tenuivirus (RSV), Northern Cereal Mosaic Virus (NCMV), Wheat Rosette Stunt Virus (WRSV), Rice Black-Streaked Dwarf Virus (RBSDV) and Wheat Chlorotic Streak Virus (WCSV) (Bartlett, 2013).

Material examined: 42 ♂♂ and 15 ♀♀.

Diagnostic features: Medium-sized: 3.33-4mm. General body blackish; carinae of frons, vertex, the tip of mesoscutellum, antennae and legs, yellowish-white;

pronotum white with parts behind eyes black, mesonotum shiny black in males, forewings hyaline, yellowish-brown, with notorious dark brown pterostigma. Vertex is as long submedially as wide at the base, obtusely curved close to frons, as wide at the apex as at base, lateral carinae straight, submedian carinae not amalgamation at the apex of vertex, basal section wider at the base than maximum length around 1.4:1. Male: pygofer oblongata and apparently bilobed; parameres widely deviating from the base; short anal spines (Figure 6).

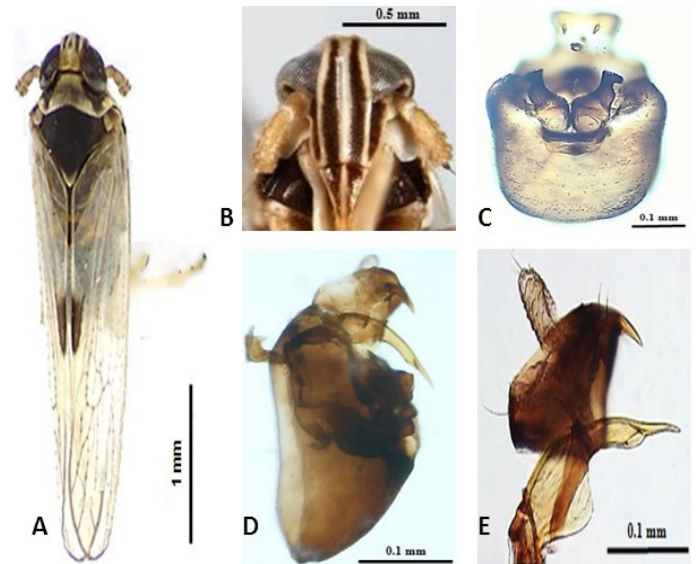


Figure 6: *Laodelphax striatellus* (Fallén), (A) habitus, dorsal view; (B) head (Bartlett, 2020 and updates); (C, D, E) genital segments (originals).

Tagosodes pusanus (Distant)

Distribution: South of the Oriental region and Australia (Bellis *et al.*, 2014).

Host plant: *Oryza sativa* L. (Wilson and Claridge, 1991).

Host plant records from Pakistan: One female was found from a sample on rice associated to *Cynodon dactylon* L.*, *Helianthus allus* L.*, *Leptochloa chinensis* L.*, *Sorghum bicolor* L.*, *Trifolium alexandrinum* L.* and *Zea mays* L.*.

Economic importance: Not considered to be a pest. Vector: Unknown.

Material examined: 1 ♀.

Diagnostic features: Medium to large-sized: 7mm. Resembles to *S. furcifera* but it is distinguished by the patterns of the dark markings of the forewings. Pterostigma distinct; forewings blatantly banded laterally apicobasal half and claval suture stretched to pterostigma, bands form four apparent spots among veins on the apical margins. Male: parameres nearly equally broad, widely concave apex slightly thinner than subbase, outer tip higher than inner spine; aedeagus not twisted (Figure 7).

Table 1: List of examined planthoppers collected from different hosts from the “Kallar” tract of the Punjab, Pakistan.

Sam- ple #	Hosts	Species and abundance
1.	<i>Leptochloa chinensis</i> L.	<i>Metadelphax propinqua</i> [21♀♀]
2.	<i>Oryza sativa</i> L.; <i>Medicago polymorpha</i> L.	<i>Sogatella furcifera</i> [21♂♂, 18♀♀, 1♂ and 1♀ with <i>Strepsiptera</i>]
3.	<i>Medicago polymorpha</i> L.	<i>Sogatella vibix</i> [14♂♂]; <i>Laodelphax striatellus</i> [1♂]
4.	<i>Medicago polymorpha</i> L.	<i>Laodelphax striatellus</i> [28♂♂]
5.	<i>Leptochloa chinensis</i> L.	<i>Metadelphax propinqua</i> [87♂♂]
6.	<i>Leptochloa chinensis</i> L.	<i>Metadelphax propinqua</i> [1♂, 19♀♀]
7.	<i>Oryza sativa</i> L.; <i>Medicago polymorpha</i> L.; <i>Trifolium alexandrinum</i> L.; <i>Zea mays</i> L.; <i>Sorghum bicolor</i> L.; <i>Helianthus allus</i> ; <i>Cynodon dactylon</i> L.	<i>Sogatella furcifera</i> [1♂, 24♀♀]; <i>Metadelphax propinqua</i> [1♂, 1♀]
8.	<i>Cynodon dactylon</i> L.; <i>Trifolium alexandrinum</i> L.	<i>Pentastiridius</i> sp. [6♂♂]
9.	<i>Oryza sativa</i> L.; <i>Medicago polymorpha</i> L.; <i>Trifolium alexandrinum</i> L.	<i>Sogatella vibix</i> [10♂♂, 17♀♀]
10.	<i>Medicago polymorpha</i> L.; <i>Oryza sativa</i> L.; <i>Trifolium alexandrinum</i> L.	<i>Nilaparvata lugens</i> [25♀♀]
11.	<i>Leptochloa chinensis</i> L.; <i>Oryza sativa</i> L.; <i>Trifolium alexandrinum</i> L.; <i>Zea mays</i> L.; <i>Sorghum bicolor</i> L.; <i>Helianthus allus</i> L.; <i>Cynodon dactylon</i> L.	<i>Laodelphax striatellus</i> [13♀♀]; <i>Tagosodes pusanus</i> [1♀]; <i>Sogatella furcifera</i> [14♀♀]
12.	<i>Leptochloa chinensis</i> L.; <i>Oryza sativa</i> L.	<i>Metadelphax propinqua</i> [2♂♂, 2♀♀]
13.	<i>Leptochloa chinensis</i> L.; <i>Oryza sativa</i> L.; <i>Medicago polymorpha</i> L.	<i>Laodelphax striatellus</i> [13♂♂, 2♀♀, with fungal infection]
14.	<i>Leptochloa chinensis</i> L.; <i>Oryza sativa</i> L.	<i>Nilaparvata lugens</i> [35♂♂, 7♀♀]

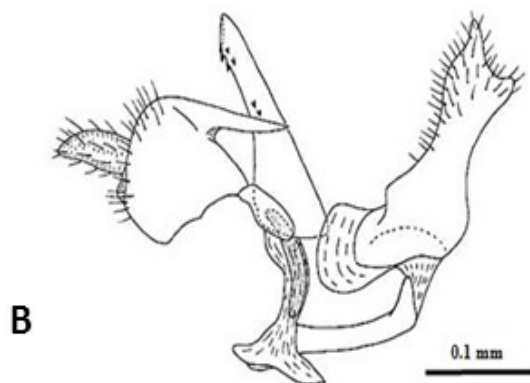
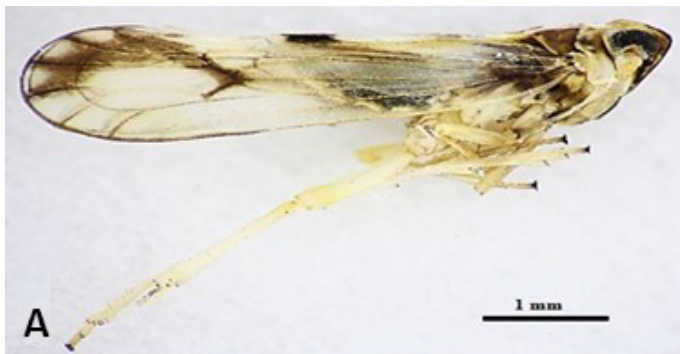


Figure 7: *Tagosodes pusanus* (Distant), (A) habitus lateral view (originals); (B) genital structures (Asche and Wilson, 1990).

Material examined collected from different hosts from famous basmati area “Kallar Tract”

Planthopper species were reported earlier but small

brown planthopper is being reported for the first time from Pakistan. Some new hosts were also listed along with already identified hosts of each planthopper (Table 1).

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Conflict of interest

The authors have declared no conflict of interest.

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