Notes on the Biology of *Clastoptera distincta* Doering, the Dwarf Mistletoe Spittlebug (Hemiptera: Cercopoidea: Clastopteridae)

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Abstract: Nymphs of the spittlebug *Clastoptera distincta* Doering (Hemiptera: Cercopoidea: Clastopteridae) are xylem sap hyperparasites of the mistletoe *Arceuthobium vaginatum* subsp. *cryptopodum*, a parasite of *Pinus ponderosa* in the southwestern United States. *C. distincta* adults, which live directly on *P. ponderosa*, are polymorphic for three distinct color forms. Mistletoe feeding in the nymphal stage may be an adaptation to the regional monsoon climate, permitting the spittlebugs to take advantage of high mistletoe transpiration and xylem flow rates during the early summer dry season, when transpiration in the host trees is curtailed.

Zusammenfassung: Larven der Schaumzikade *Clastoptera distincta* Doering (Hemiptera: Cercopoidea: Clastopteridae) sind Xylemsaft-Hyperparasiten an der Mistelart *Arceuthobium vaginatum* subsp. *cryptopodum*, einem Parasiten an *Pinus ponderosa* im Südwesten der Vereinigten Staaten. Die Adulten von *C. distincta*, die direct an *P. ponderosa* leben, sind polymorph bzgl. drei verschiedener Farbformen. Das Saugen an Misteln im Larvalstadium könnte eine Anpassung an das regionale Monsunklima sein, das es den Schaumzikaden ermöglicht, von der hohen Transpirationrate und Xylemsaftflüssen während der Trockenphase im Frühsommer zu profitieren, wenn die Transpiration in der eigentlichen Nahrungspflanze eingeschränkt ist.

Key words: spittlebug, *Clastoptera*, mistletoe, *Arceuthobium, Pinus ponderosa,* hyperparasite, monsoon

1. Introduction

Spittlebugs (Hemiptera: Cercopoidea) parasitize the xylem sap of living plants, a nutrient source shared with cicadas and sharpshooter leafhoppers and certain parasitic plants, including witchweeds (*Striga* spp.) and mistletoes (Parker, 1993; Press & Whittaker, 1993; Marshall *et al.*, 1994; Thompson, 2004). The spittlebug *Clastoptera distincta* Doering 1928 (Clastopteridae) has been reported on two dwarf mistletoes of conifers: *Arceuthobium vaginatum* subsp. *cryptopodum* in Arizona, New Mexico and Southwestern Colorado, and *Arceuthobium abietinum* f.sp. *concoloris* in Arizona (Stevens & Hawkesworth, 1970, 1984; Hawkesworth & Wiens, 1996). *C. distincta* causes occasional minor damage to the host mistletoes. The mistletoes cause economically important damage to their conifer hosts (Hawkesworth & Wiens, 1996).

Because the component organisms share the unusual characteristic of xylem sap parasitism, the spittlebug-dwarf mistletoe parasitic interaction is of special interest in understanding the ecology of xylem sap parasites. I undertook this study to augment the very limited published information on *C. distincta* and lay the groundwork for further investigation.

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2. Methods and Study Areas

In July 2003 I carried out field investigations at three localities in Arizona (Rustler Park, San Francisco Peaks, Jacob Lake) and one in Colorado (Laporte) (Fig. 1). The goal was to verify the presence of *C. distincta* on *Arceuthobium* mistletoes, determine the nature and frequency of *C. distincta* color forms, and elucidate relationships among the spittlebugs, the mistletoes, and the ultimate conifer hosts. The Arizona sites were chosen based on published information or specimen labels indicating that *C. distincta* could be found at those localities. The Colorado site was chosen as an accessible area well out of the summer monsoon range that had abundant *P. ponderosa* heavily infested with *A. vaginatum* subsp. *cryptopodum*. During 2003 and 2004 I also examined *C. distincta* specimens in four entomological collections: the Snow Entomological Collection of the University of Kansas Natural History Museum (Lawrence, Kansas), the American Museum of Natural History Southwestern Research Station (near Portal, Arizona), the U.S. National Museum (Washington, DC), and the Natural History Museum (London, UK).

Fig. 1: Field sites in Arizona (large grey circles) and Laporte, Colorado (grey triangle) superimposed on a distribution map of the host mistletoe *Arceuthobium vaginatum* subsp. *cryptopodum* (small black circles). The Arizona sites, from north to south, are Jacob Lake, San Francisco Peaks and Rustler Park.

3. Results

At Laporte, Colorado intensive examination of large stands of *Pinus ponderosa* heavily infested with *A. vaginatum* subsp. *cryptopodum* revealed no sign of spittle masses or adults of *C. distincta* (though many adults of another spittlebug, *Aphrophora irrorata* Ball, were swept from the pines). At Rustler Park Campground in the Chiricahua Mountains of southeastern Arizona, examination of dozens of clusters of *A. vaginatum* subsp. *cryptopodum* parasitizing *P. ponderosa* revealed a single *Clastoptera* nymph, probably *C. distincta*. The Southwestern Research Station collection includes one adult *C. distincta* specimen taken at Rustler Park in August 1968, verifying the species presence at this location.

In the San Francisco Peaks just north of Flagstaff, Arizona a large population of *C. distincta* nymphs occupied *A. vaginatum* subsp. *cryptopodum* infecting *P. ponderosa*. Spittle masses on the mistletoes of some of the older, lower, heavily infested pine branches were densely clustered and coalescing, with multiple nymphs per spittle. Sweeping of the mistletoes, their host pines and the surrounding open grassy understory yielded no adult spittlebugs, apparently because adults had not emerged at the time of observation. Twelve adults emerging from sleeved spittle masses were later recovered to verify species identity and determine sex and color form (Table 2). Ten (83%) were female.

Two miles northwest of Jacob Lake, Arizona, near the North Rim of the Grand Canyon, *C. distincta* spittles with nymphs were abundant on *A. vaginatum* subsp. *cryptopodum* parasitizing *P. ponderosa* and 26 adult individuals were swept from the host pines (Table 2). As at San Francisco Peaks, a large majority (81%) were female, suggesting female-biased sex ratios in both populations. Direct sweeping of mistletoe clumps and the pine forest understory produced no *C. distincta* adults, strongly suggesting that *P. ponderosa* was the unique adult host.

The adult *C. distincta* specimens recovered from both localities exhibit three distinct dorsal color patterns, designated here as the plain, dark and yellow-headed color forms (Table 2). The plain form (Fig. 2a) has brown markings on a light tan background and bears a general resemblance to several other North American *Clastoptera* species (*see* Plates I and II, Doering, 1928). The dark form (Fig. 2b) has similar markings obscured by a more or less uniform dark tan to brown background color. The yellow-headed form (Fig. 2c) has a greenish yellow head and pronotum, set off by dark tan to brown elytra and a scutellum of the same dark coloration. It is the only *C. distincta* color form previously illustrated (Plate I, No. 31, Doering, 1928) and is the color form of the holotype (a male in the Snow Collection).

The plain color form was most frequent in both populations, comprising 75% of the San Francisco Peaks specimens (n=12) and 54% of the Jacob Lake specimens (n=26). Every plain specimen collected was female (Table 2). Of the 7 adult males collected at both sites, 4 were yellow-headed, 3 were dark, and none plain. However, 7 males collected from the Chiricahua Mountains in Arizona in 1933 (U.S. National Museum collection) all exhibit the plain color form, demonstrating that this color form is not limited to females.

Several *Clastoptera* species in North America and the Neotropics host fly larvae of the genus *Cladochaeta* in their spittle masses (Thompson & Mohd-Saleh, 1995; Grimaldi & Nguyen, 1999). A search of several dozen *C. distincta* spittle masses at the San Francisco Peaks and Jacob Lake sites revealed no *Cladochaeta* larvae or pupae.

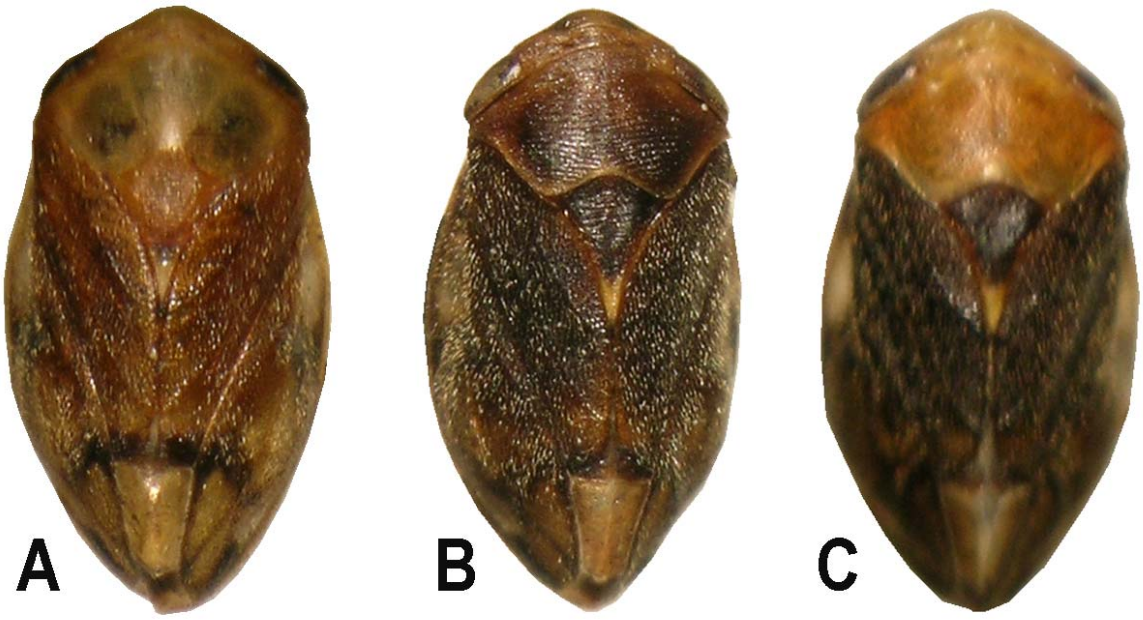

Fig. 2: *Clastoptera distincta* color forms: A plain form, B dark form, C yellow-headed form. In each case the individual illustrated is a female from the Jacob Lake population (see text for more details).

Table 1: Summer 2003 survey of 4 localities for *Clastoptera distincta*. In all 4 localities the mistletoe *Arceuthobium vaginatum* var. *cryptopodum* was locally common on *Pinus ponderosa*. See text for more details. *For nearest recording station of precipitation, in order from top: Ft. Collins CO, Chiricahua National Monument AZ, Fort Valley AZ, Jacob Lake AZ (data from Western Regional Climate Center, http://www.wrcc.dri.edu, with metric conversion).

		Clastoptera distincta		Mean monthly precip. (cm)*			
Locality	Date	Nymphs	Adults	May	June	July	Aug
Laporte, CO	7 July	Absent	Absent	7,1	4,6	4,0	3,5
Rustler Park, AZ	16 July	Rare	Absent	0,8	2,1	10,4	10,5
San Francisco Peaks, AZ	19 July	Abundant	Absent	2,0	1,4	7,3	8,1
Jacob Lake, AZ	22 July	Abundant	Abundant	3,0	2,0	6,9	6,8

4. Discussion

Adult color polymorphism is common in spittlebugs, including several North American species of *Clastoptera* (Doering, 1928; Hamilton, 1982), perhaps in part because their unusually effective jumping mechanism (Burrows, 2003) combines with apostatic selection for rarity to maintain conspicuous and cryptic color forms in balance in local populations (Thompson, 1973, 1984). In this context, the minority yellow-headed color form of *C. distincta* (Fig. 2c), perhaps the basis for the species name, is particularly striking. Broader geographical collections of longer series will be necessary to thoroughly document the distribution and frequency of color forms in *C. distincta.*

Table 2: Adult specimens of *Clastoptera distincta* collected in Arizona in Summer 2003, by sex and color form. The San Francisco Peaks specimens were collected from sleeves placed around spittle masses on *Arceuthobium vaginatum* subsp. *cryptopodum* living on *Pinus ponderosa*. The Jacob Lake specimens were swept directly from *P. ponderosa.*

	Males			Females			Males + Females			Total
Locality	Plain	Dark	Yellow-headed	Plain	Dark	Yellow-headed	Plain	Dark	Yellow-headed	
S. Francisco Peaks	-	1	1	9	-	1	9	1	2	12
Jacob Lake	-	3	2	14	3	4	14	6	6	26
Total	-	4	3	23	3	5	23	7	8	38
Proportion	0,0%	57,1%	42,9%	74,2%	9,7%	16,1%	60,5%	18,4%	21,1%	

Pines (*Pinus* spp.) are common hosts of adult spittlebugs, including at least two additional species of *Clastoptera*: *C. testacea* and *C. osborni* (Doering, 1928; Hamilton, 1982;). Mistletoes, in contrast, are not characteristic spittlebug hosts. Nymphal *C. distincta* has evidently made an unusual evolutionary host switch to dwarf mistletoes, providing evidence for the hypothesis that biological proximity facilitates insect host shifts between conifers and their mistletoe parasites (Mooney, 2003).

Whatever its origin, the *C. distincta-Arceuthobium* relationship raises a conundrum. Why, from an evolutionary point of view, should spittlebug nymphs feed on the xylem sap of a mistletoe parasitizing a pine, when they could, as the adults evidently do, feed directly on the xylem sap of the pine itself? The answer, I suggest, lies in the southwestern monsoon climate in which *C. distincta* has evolved as a mistletoe hyperparasite.

C. distincta appears to have a single generation per year. Nymphs develop in late spring and early summer. Adults emerge in July. At all three Arizona collection sites, the nymphal period coincides with a pronounced May-June pre-monsoon drought (Table 2), usually broken by monsoon rains in early July (Higgins *et al.*, 1997), before *C. distincta* adults begin to emerge. Conifers resist the effects of drought by minimizing transpiration and the flow of xylem sap during periods of water deficit. In contrast, their mistletoe parasites transpire freely during droughts to maintain water and nutrient flow, often damaging their hosts in the process (Parker & Riches, 1993; Press & Whittaker, 1993; Marshall *et al.*, 1994; Hawkesworth & Wiens, 1996). By hyperparasitizing mistletoes during the May-June dry season, *C. distincta* nymphs gain indirect but effective access to the conifer xylem stream, circumventing drought-induced reduction of conifer transpiration. In the rainy season, it appears, the adults feed directly on the xylem sap of the ultimate conifer hosts.

This hypothesis is consistent with the geographical distribution of *C. distincta*. Based on the field work reported above and a survey of museum collections, *C. distincta* is present on *Arceuthobium* in many monsoonal areas of Arizona and adjacent New Mexico and Southwestern Colorado, but absent from *Arceuthobium* in Northern and Central Colorado (Laporte, this study; Boulder and Teller Counties, K. Mooney, pers. comm.) where the monsoonal May-June drought is not pronounced (*see* climate maps in Higgins *et al.*, 1997).

Presently, *C. distincta* is the only documented mistletoe spittlebug, but there are indications that it is not unique. R. Mathiasen (pers. comm.) has observed spittle masses on *Arceuthobium apacheum* and *Arceuthobium blumeri* parasitizing *Pinus strobiformis* in Arizona, and on *A. blumeri* parasitizing *Pinus ayacahuite* var. *brachyptera* in Mexico. Gill (1935) reports an unidentified spittlebug causing heavy mortality of shoots of *Arceuthobium campylopodum* f. *typicum* in California, well outside the known geographical range of *C. distincta* (Stevens & Hawkesworth, 1970, identify this mistletoe as *A. "occidentale"* on *Pinus radiata*). D. Peck (pers. comm.) has observed nymphs of an unidentified *Clastoptera* species on an unidentified mistletoe of citrus in Dapa, Colombia. These observations suggest that closer study may reveal additional spittlebug species associated with other mistletoe hosts.

5. Summary

C. distincta nymphs, the mistletoe *A. vaginatum*, and *P. ponderosa* exhibit an unusual xylem sap-mediated, host-parasite-hyperparasite relationship that may be linked to the annual monsoon cycle of rainy and dry periods in parts of the Southwestern U.S. Further investigation is needed to determine how closely the fine scale distribution of *C. distincta* fits these climatic patterns, whether the emergence of adult *C. distincta* is tied to the onset of monsoon rains, and what, if any, biological significance attaches to the observed color polymorphism.

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