

Both nymphs and adults of the maize orange leafhopper induce galls on their host plant

Keiichiro Matsukura,^{1,*} Masaya Matsumura¹ and Makoto Tokuda²

¹Research Team for Insect and Nematode Management; National Agricultural Research Center for Kyushu Okinawa Region; Koshi, Kumamoto Japan;

²Center for Research and Advancement in Higher Education; Kyushu University; Motoooka, Fukuoka Japan

The maize orange leafhopper, *Cicadulina bipunctata*, is a multivoltine insect that induces galls on various plants of the Poaceae. A previous study revealed that galls produced by this leafhopper were induced by dose-dependent stimulation on distant leaves from the feeding site, probably by chemical(s) injected from adults during feeding. In this paper, we examined the gall-inducing ability of *C. bipunctata* nymphs. The degree of gall induction gradually increased depending on the number of feeding nymphs and there were no significant differences from the positive control (feeding by five male adults) when seedlings were exposed to five or more nymphs. These results indicate that both adults and nymphs of *C. bipunctata* have the ability to induce galls on their host plants, a unique feature among gall-inducing insects. This feature may be related to the free-living, multivoltine and polyphagous habits of *C. bipunctata*.

Various herbivores such as insects and mites manipulate host plants and induce galls on them.¹⁻³ Gall induction is adaptive for inducers and gall morphology is specific to the species inducing the gall.^{4,5}

In general, only certain developmental stages or a particular generation of insect has the ability to induce galls.⁶ For example, feeding stimuli by the first instars of gall midges and gall wasps induce galls, whereas in sawflies, female adults inject chemicals responsible for gall induction during oviposition. In the case of aphids, fundatrices (stem mothers) induce initial galls on their primary hosts. Such

specificities are closely related to the life history of gall inducers⁴ and are important in elucidating their adaptive strategies.

The maize orange leafhopper *Cicadulina bipunctata* (Homoptera: Cicadellidae) is a multivoltine insect that induces galls on various plants of the Poaceae including maize, rice and wheat.⁷⁻¹⁰ Galls produced by the leafhopper are characterized by growth stunting of the host plant and swelling of leaf veins.¹¹ In a previous paper, we determined that some chemicals injected by adults during feeding are probably responsible for gall induction and galls are induced not on feeding sites but on distant leaves by dose-dependent stimulation.¹² In this paper we focus on the gall-inducing ability of leafhopper nymphs.

Using the same experimental techniques as mentioned in the previous study,¹² we exposed a 7 day-old maize seedling (variety "3081"; at the third leaf stage) to zero (negative control), two, five or ten first instar nymphs, or five male adults (positive control) of *C. bipunctata* for eight days. Then we examined the galled leaf position and degrees of gall induction and growth stunting 8 days later. We evaluated the degree of gall induction by assigning a symptom score (0: no visible symptoms, 1: leaf veins partially thickened, 2: leaf tissues heavily swollen) and by measuring plant height to assess the degree of stunted growth.

Both nymphal and adult feedings induced galls on veins of the third leaves (Fig. 1). The degrees of gall induction and growth stunting gradually increased depending on the number of feeding nymphs. The degree of gall induction and

Key words: *Cicadulina bipunctata*, gall induction, insect-plant interaction, maize, sap feeding

Submitted: 04/12/10

Accepted: 04/12/10

Previously published online:

www.landesbioscience.com/journals/cib/article/12031

*Correspondence to: Keiichiro Matsukura;
Email: mtkr@affrc.go.jp

Addendum to: Matsukura K, Matsumura M, Tokuda M. Host manipulation by the orange leafhopper *Cicadulina bipunctata*: gall induction on distant leaves by dose-dependent stimulation. *Naturwissenschaften* 2009; 96:1059-66; PMID: 19513593; DOI: 10.1007/s00114-009-0566-1.

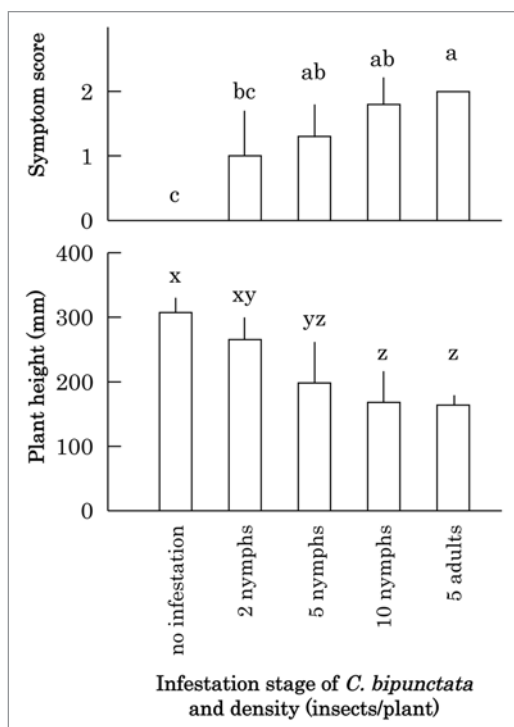


Figure 1. Degrees of gall induction (upper) and growth stunting (lower) on maize by the feeding of adults and nymphs of *C. bipunctata*. The degree of gall induction was assessed by a symptom score (0: no visible symptoms, 1: leaf veins partially thickened, 2: leaf tissues heavily swollen). Vertical bar indicates the standard deviation. Different letters above the bars indicate significant differences among treatments (a–c: Steel-Dwass test, $p = 0.05$, x–z: Tukey HSD test, $p = 0.05$).

growth stunting were not significantly different from the positive control when seedlings were exposed to five or more nymphs (Fig. 1). These results indicate that leafhopper nymphs have the ability to induce galls at a similar efficiency as adults. Gall-inducing ability of both adults and nymphs is a unique feature of *C. bipunctata*. These results also support the dose-dependent stimulation for gall induction by feeding of this leafhopper (Fig. 1), as in other gall-inducing insects.^{13–16}

Although the effect of gall induction by the leafhopper on its performance has not yet been clarified,¹² galled tissue is

well known to be nutritionally superior to ungalled parts.^{5,17} Unlike other gall-inducing insects, *C. bipunctata* has free-living, multivoltine and polyphagous habits.^{8,10,18} Gall induction by both adults and nymphs may be related to such ecological traits of this insect.

References

- Mani MS. Ecology of Plant Galls. Dr. W. Junk, Publishers. The Hague 1964.
- Yukawa J, Masuda H. Insect and Mite Galls of Japan in Colors. Zenkoku Nôson Kyôiku Kyôkai. Tokyo 1996.
- Redfern M, Shirley P. British plant galls: identification of galls on plants and fungi. Field Stud 2002; 10:207-531.

- Price PW, Fernandes GW, Waring GL. Adaptive nature of insect galls. Environ Entomol 1987; 16:15-24.
- Stone GN, Schönrogge K. The adaptive significance of insect gall morphology. Trends Ecol Evol 2003; 18:512-22.
- Raman A, Schaefer CW, Withers TM. Biology, Ecology and Evolution of Gall-inducing Arthropods. Science Publishers Inc., Enfield 2005.
- Maramorosch K, Calica CA, Agati JA, Pableo G. Further studies on the maize and rice leaf galls induced by *Cicadulina bipunctata*. Entomol Exp Appl 1961; 4:86-9.
- Tokuda M, Matsumura M. Effect of temperature on the development and reproduction of the maize orange leafhopper *Cicadulina bipunctata* (Melichar) (Homoptera: Cicadellidae). Appl Entomol Zool 2005; 40:213-20.
- Matsukura K, Matsumura M. Effect of infestation of 6 summer-seeding forage crops by the maize orange leafhopper *Cicadulina bipunctata*. Kyushu Pl Prot Res 2009; 105-10. (in Japanese with English summary).
- Matsukura K, Matsumura M, Takeuchi H, Endo N, Tokuda M. Distribution, host plants and seasonal occurrence of the maize orange leafhopper, *Cicadulina bipunctata* (Melichar) (Homoptera: Cicadellidae), in Japan. Appl Entomol Zool 2009; 44:207-14.
- Matsumura M, Tokuda M. A mass rearing method using rice seedlings for the maize orange leafhopper *Cicadulina bipunctata* (Melichar) (Homoptera: Cicadellidae) and a simple method for evaluating varietal resistance of maize to maize wallaby ear disease. Kyushu Pl Prot Res 2004; 50:35-9. (in Japanese with English summary).
- Matsukura K, Matsumura M, Tokuda M. Host manipulation by the orange leafhopper *Cicadulina bipunctata*: gall induction on distant leaves by dose-dependent stimulation. Naturwissenschaften 2009; 96:1059-66.
- Hori K. Insect secretions and their effect on plant growth, with special reference to hemipterans. In: Shorthouse JD, Rohfritsch O, eds. The biology of insect-induced galls. Cary, NC: Oxford University Press 1992; 157-70.
- Hartley SE. Are gall insects large rhizobia? Oikos 1999; 84:333-42.
- Mapes CC, Davies PJ. Cytokinins in the ball gall of *Solidago altissima* and in the gall forming larvae of *Eurosta solidaginis*. New Phytol 2001; 151:203-12.
- Sopow SL, Shorthouse JD, Strong W, Quiring DT. Evidence for long-distance, chemical gall induction by an insect. Ecol Lett 2003; 6:102-5.
- Nyman T, Julkunen-Tiitto R. Manipulation of the phenolic chemistry of willows by gall-inducing sawflies. Proc Natl Acad Sci USA 2000; 97:13184-7.
- Matsumura M, Tokuda M, Endo N. Recent outbreaks of the maize orange leafhopper *Cicadulina bipunctata* inducing gall-like structures on maize in Japan. In: Ozaki K, Yukawa J, Ohgushi T, Price PW, eds. Galling Arthropods and Their Associates: Ecology and Evolution. Tokyo, Springer-Verlag 2006; 149-58.