EFFECTS AND CONTROL OF PERIODICAL CICADA *MAGICICADA SEPTENDECIM* AND *MAGICICADA CASSINI* OVIPOSITION INJURY ON URBAN FOREST TREES

by Fredric D. Miller

Abstract. The long-term effect of oviposition by the female periodical cicadas, *Magicicada septendecim* and *M. cassini* (Homoptera: Cicadidae) was examined on shade trees at two urban forest sites in northeastern Illinois following the 1991-1993 growing seasons. Minimum branch diameter appears to be a critical factor in ovipositional activity. Plants with stout branching habits do not appear to be suitable for oviposition. Percent canopy flagging, as a function of the number of wounds per branch, may not be an accurate measurement of ovipositional damage. Young trees with stem diameters or main scaffold branches with diameters between 5 and 10 mm may experience significant damage to the main trunk resulting in breakage and significant growth loss. Larger plant material does not appear to be significantly affected by ovipositional damage, which results only in a minor natural pruning event. Chemical control for the prevention of ovipositional wound damage by the female periodical cicada does not appear to be a practical and effective pest management option. Even severe and heavy ovipositional damage does not appear to predispose urban forest trees to attack by secondary insects or pathogens.

During late May and early June of 1990, the northern one-third of Illinois experienced the emergence of the Northern Illinois Brood (Marlatt's XIII) of the 17-year periodical cicadas, *Magicicada septendecim* and *M. cassini* (8,11). Periodical cicadas are found only in the deciduous forest areas of the eastern one-third of the United States and extensions into the plain states (2). After developing for almost 17 years underground, the nymphs emerge, shed their skin, and become adults. After mating, the female begins depositing eggs in the woody tissue of shrubs and trees (Figure 1) which may result in plant damage (Figure 2). The eggs hatch and the tiny nymphs crawl or drop to the base of the plant, enter the soil to feed on plant roots, and proceed to develop for the next 17 years. The ovipositional wound appears as a slit in the bark tissue, but may widen to form a rather large wound (Figure 3). Twigs that are weakened by these wounds are more likely to die later in the summer and break during wind storms, littering the ground. Older, well established trees exhibit branch flagging, but the damage is not considered serious. Serious damage to branch terminals and/or the trunk may occur on very young trees and nursery stock (1, 3, 4, 5, 6, 7) (Figure 4).

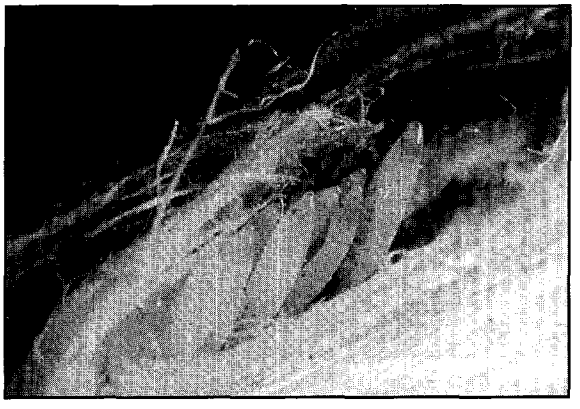

Figure 1. Eggs of the periodical cicada laid in the branch of an urban forest tree (June, 1990).

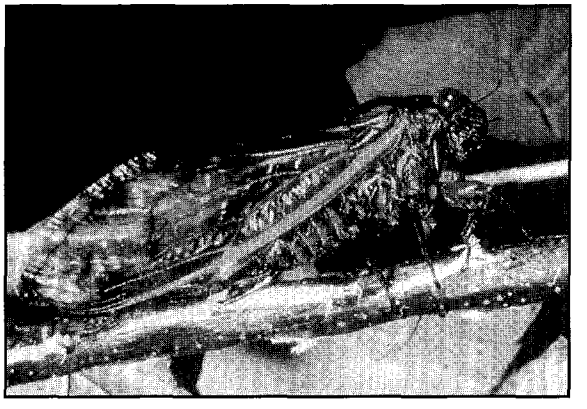

Figure 2. Adult female periodical cicada laying eggs in the branch of an urban forest tree (June, 1990).

Few studies have been conducted on the impact of periodical cicada ovipositional damage on the urban forest with most previous studies having focused on fruit and orchard trees. Smith and Linderman (10) rated deciduous and evergreen ornamental trees and shrubs in Maryland attacked by brood X of the periodical cicada. They found that wound closure varied depending on the species or cultivar involved, from none to rough partial closure with stunted growth and reduced flowering, to rapid closure and complete recovery.

Due to extensive landscaped areas adjoining natural woodlands with a history of periodical cicada emergence in northeastern Illinois concern was expressed by homeowners and members of the green industry as to the potential immediate and long-term impact of ovipositional damage to the growing stems of young woody plants, the twigs and branches of shade trees, and the possible long-term effects of such "natural pruning" by the periodical cicada. Therefore, a study was initiated to determine: 1) which species of urban forest shade trees were attacked by the periodical cicada; 2) basic ovipositional wound characteristics such as maximum branch diameter, minimum branch diameter, wound width, wound length, number of wounds per branch and percent canopy flagging; 3) plant response to wounding and rate of wound closure; and 4) the effect of selected pyrethroid, carbamate and organophosphate class insecticides for prevention of ovipositional damage by the periodical cicadas; and 5) long-term effects, if any, of ovipositional damage on overall plant health including predisposition to wound-invading insects and pathogens.

Materials and Methods

Urban forest study. Two urban forest sites in Downers Grove and LaGrange, Illinois, containing a total of 14 different shade tree species (Table 1) served as the study area. Ten single tree replicates were examined for each shade tree species. Both study sites had a history of heavy cicada attack events and contained shade tree species representative of the northern Illinois urban forest.

On each shade tree, one branch from each of four quadrants (N, S, E, W) was randomly selected. On each branch selected, the maximum branch diameter (MXBD) where wounding began, minimum branch diameter (MNBD) where wounding ceased, wound length (WL), wound width (WW), and total number of wounds per branch (WPB) was recorded. The MXBD and MNBD were measured using a hand-held vernier caliper. Wound width (WW) and WL were measured by randomly selecting one wound on each branch. Measurements were taken at the longest point of the wound length (nearest cm) and the widest point of the wound (nearest

Figure 3. Ovipositional wound damage due to egg laying by adult female periodical cicadas (August, 1990).

Figure 4. Twig breakage on young mountain ash (*Sorbus* spp.) trees due to ovipositional wound injury by the adult female periodical cicada (August, 1990).

Table 1. Ovipositional wound width reduction (WWR) expressed as a cumulative percentage for urban forest tree species following the 1991-1993 growing seasons.

TREE SPECIES	WW (mm)	Cumulative % WWR (mm)[1]		
	1990	1991	1992	1993
Gleditsia triacanthos	3.95	36.7	49.4	100.0(C)
Quercus rubra	4.80	62.1	72.9	100.0(C)
Fraxinus pennyslvanica	4.95	90.9	100.0 (C)	----
Celtis occidentalis	5.05	69.9	74.5	100.0(C)
Malus spp.	6.03	86.7	100.0 (C)	----
Acer platanoides	6.15	96.7	100.0 (C)	----
Acer saccharum	6.28	90.1	100.0 (C)	----
Acer rubrum	6.35	99.2	100.0 (C)	----
Quercus bicolor	6.43	82.9	100.0 (C)	----
Pyrus calleryana 'Bradford'	6.50	93.8	100.0 (C)	----
Liriodendron tulipifera	6.73	97.0	100.0 (C)	----
Quercus macrocarpa	6.81	86.0	100.0 (C)	----
Tilia americana 'Redmond'	7.30	57.3	72.6	74.0
Tilia cordata	8.02	55.5	60.1	76.9
Mean	**5.94**	**80.9**	**87.8**	**90.2**

[1]Percent Wound Width Reduction (WWR) is the percent reduction in width as compared to the wound width of the previous growing season. (C)=Wound had closed.

mm). Percent canopy flagging (PCF) was evaluated visually by two independent estimates and averaged using a scale of 0 to 10 at 10% increments with 0 = no apparent flagging and 10 = 100% canopy flagging. No attempt was made to distinguish between ovipositional damage caused by the two cicada species.

Nursery study. In August, 1990 twenty 1-1.5 m (3-5 ft) tall sugar maple (*Acer saccharum*) trees growing in a nursery at The Morton Arboretum were selected for study that had been heavily attacked by the periodical cicada. The maximum stem diameter where wounding began, minimum diameter where wounding ended, wound length, wound width, and the total number of wounds per stem were measured as described above. Additional field evaluations of wound closure were conducted on these seedlings following the 1991 and 1992 growing seasons.

Wound closure studies. To evaluate long-term woody plant response to wounding and subsequent wound closure, WW measurements, as described above, were taken following the 1991, 1992, and 1993 growing seasons for the 14 species of shade trees. Wounds that had completely callused over were considered closed.

Prevention of ovipositional wound damage. A planting of 30 mountain ash (*Sorbus* spp.) trees 2-3 m (6-8 ft) tall adjoining a heavy emergence area of the periodical cicada was used for study. Insecticide treatments of Talstar 10WP (bifenthrin), Tempo 2E (cyfluthrin), Sevin 50WP (carbaryl), Dursban 4E (chlorpyrifos), Mavrik 2E (fluvalinate), and Empire 20E (chlorpyrifos) were applied to each of five single tree replicates per treatment at the onset of egg laying and repeated twice at seven day intervals for a total of three sprays. Sprays were applied to the trunk, foliage, and all branches of each tree until runoff using a

Solo, 8 liter hand held pressure sprayer. Weather conditions at the initial time of spraying were: temperature = 27° C, relative humidity = 60%, wind speed = less than 5 mph. with overcast skies. Field evaluation of insecticidal efficacy was conducted 14 days after the last treatment when all cicada activity had ceased.

Because no two individual trees contain the same number of branches or have identical branching habits, a standard insecticidal efficacy variable of mean number of wounds per branch (WPB) was identified and defined as the quotient of the total number of ovipositional wounds per tree over the total number of branches per tree greater than 4 mm (1/6 in.) in diameter for all five single tree replicate per treatment.

Table 2. Summary of multivariate analysis of variance (MANOVA) and multivariate test statistics for dependent variables for urban forest tree species.

Variable	df	F	P
Maximum branch diameter	13,125	10.3	0.0001
Minimum branch diameter	13,125	11.6	0.0001
Wound length	13,125	12.2	0.0001
Wound width	13,125	10.3	0.0001
Wounds per branch	13,125	11.5	0.0001
Percent canopy flagging	13,125	12.0	0.0001
Multivariate Test Statistic			
Roy's Greatest Root: Theta=0.740, P=0.00001			

Statistical Analysis. Wound data were subjected to a multivariate analysis of variance (MANOVA) for species for all dependent variables. Individual trees were identified as the experimental unit and were considered replicates. Data were analyzed using Systat 5.0 for Windows (1992) and Statistix 4.0 Analytical Software (1992).

Insecticide efficacy data were subjected to an analysis of variance (ANOVA). Means of significant effect were compared with a Student-Neuman-Keuls (SNK) multiple comparison test. Data were analyzed using the Sigma Stat Statistical Software for Windows (Jandel Scientific 1994).

Results

Multivariate analysis of variance (MANOVA) suggested that shade tree species were affected significantly by the dependent variables of MXBD, MNBD, WL, WW, and WPB and PCF (Table 2).

Wounding: urban forest study. As the results show in Table 3, *Liriodendron tulipifera* had the smallest MXBD (9.50 mm) (0.37 in) while *Acer platanoides* had the highest MXBD of 13.84 mm (0.54 in). *Gleditsia triacanthos* had the lowest MNBD (3.39 mm) (0.13 in) and *A. platanoides* had the highest MNBD (5.88 mm) (0.27 in) where oviposition ceased. Wound length varied significantly from 3.53 cm (1.4 in) (*Quercus bicolor*) to 8.19 cm (3.2 in) for sugar maple, *Acer saccharum*. As with WL, WW also had a wide range. Honeylocust had the narrowest WW (3.95 mm) (0.16 in) while *Tilia americana* 'Redmond' and *T. cordata* had the widest wound widths (7-8 mm) (0.28 - 0.31 in).

Acer saccharum had the greatest number of wounds per branch (15) and yellow poplar, *L. tulipifera* had the fewest number of wounds per branch (5). Percent of the canopy flagging (PCF) due to ovipositional wounding varied significantly from no wounding for honeylocust, *G. triacanthos* and yellow poplar, *L. tulipifera* to between 20% and 24% for sugar maple, *A. saccharum* and northern red oak, *Q. rubra*, respectively.

Wounding: nursery study. *Acer saccharum* trees, 1-1.5 m (3.5 ft) tall and growing in a nursery at The Morton Arboretum were heavily damaged by the periodical cicada. These trees exhibited a mean maximum stem diameter (MXSD) where wounding began of 8.17 mm (0.32 in) and a mean minimum stem diameter (MNSD) where wounding

Table 3. Summary of ranges of ovipositional wound characteristics for 14 urban forest trees (August, 1990).

WOUND CHARACTERSTIC	RANGE
Maximum branch diameter (MXBD)	9.50-13.84 mm
Minimum branch diameter (MNBD)	3.39-5.88 mm
Wound length (WL)	3.53-8.19 mm
Wound width (WW)	3.95-8.02 mm
Wounds per branch (WPB)	5-15
Percent canopy flagging (PCF)	0-24%

ceased, of 6.08 mm. Mean WL on the main stem was 7.4 cm and the mean WW was 8.9 mm. The wound length was comparable with ovipositional wounds observed on other Arboretum plants, but the wound width of 8.9 mm (0.35 in) was nearly twice as wide as compared to WW's (5.25 mm) of other woody plant material. A mean of approximately three wounds per growing stem was observed.

Eighty newly transplanted elm hybrid grafts of *Ulmus japonica-wilsoniana* x *U. pumila* ('Danada') (0.6 cm in diameter) and approximately 6 cm tall were also heavily attacked. Even though damage measurements were not taken, field observations revealed severe damage along the main growing stems with the main stem breaking off in some cases.

Because the initial wound damage was so severe, the grafts were pruned to a point below the last wound. In many cases, this resulted in grafts approximately 2.5-3.0 cm tall with a loss of 50-60% of plant height or one season's growth. In spite of this radical event, none of the eighty elm grafts died.

Wound closure: urban forest study. As shown in Table 1, following the 1991 growing season, 9 of the 14 shadetree species exhibited mean WWR's of at least 80%. *Gleditsia triacanthos*, *Q. rubra*, *Celtis occidentalis*, and *Tilia* spp. had mean percent WWR's of less than 70%.

Mean WW measurements taken following the 1992 growing season revealed that all 9 of the tree species with WWR's of 80% or greater had wounds that closed. Additional wound width reductions of 5-15% were observed for *G. triacanthos*, *Q. rubra*, *C. occidentalis*, and *Tilia* spp. Following the 1993 growing season, only the lindens (*Tilia* spp.) had failed to close their wounds completely and still had mean WW's = 2.0 mm.

No visual deformation or dieback of branches or growing tips were observed throughout the study nor was there evidence of any predisposition of the trees to secondary insect pests or pathogens. Field observations did show that concentrations of lecanium scale (*Lecanium* sp.) were found in and along the wounds on hackberry, *C. occidentalis* trees during the 1991 and 1992 growing seasons, but no twig or branch dieback was observed on any of these trees. The lecanium scale (*Lecanium* sp.) populations subsided by the end of the 1993 growing season.

Prevention of ovipositional wound damage. Statistically, there was no significant difference in mean number of ovipositional wounds per branch (WPB) for all treatments and the untreated trees control (Table 4). However, trees treated with Talstar 10W (bifenthrin) exhibited fewer ovipositional wounds per branch as compared to the other treatments and the untreated trees (Table 4). Field observations, at the time of spraying, revealed that the cicadas were not deterred from landing on treated branches and did not appear to be affected by direct sprays of the chemical. No phytotoxicity was observed on any of the treated plants.

Discussion

Wounding: urban forest study. Taken together, a comparison of five plant genera common both to this study and a related study at The Morton Arboretum (Miller and Webb, unpublished) revealed that *Acer*, *Quercus*, *Fraxinus*, *Malus*, and *Tilia* had similar initial MXBD, MNBD, WL, WW, WPB, and PCF values. In our study, sugar maple (*A. saccharum*) and northern red oak (*Q. rubra*) had the highest PCF values of 20-24%, respectively. In Maryland, Smith and Linderman (10) found that Norway maple, (*A. platanoides*), red maple, (*A. rubrum*), sugar maple, (*A. saccharum*), and *Quercus* spp. had significant twig breakage.

Table 4. Oviposition response by periodical cicadas to contact insecticide application on mountain ash (*Sorbus* spp.) (June, 1990).

TREATMENTS	RATE LBS. A.I./110 GAL.	MEAN NUMBER OF WOUNDS/BRANCH[1,2]
Dursban 4E	8.0 fl. oz.	4.9a
Sevin 50W	2.0 lbs.	4.1a
Empire 20	0.3 gal.	5.1a
Mavrik	10.0 fl. oz.	4.7a
Tempo 2E	1.5 fl. oz.	5.1a
Talstar 10W	2.0 lbs.	2.3a
Control	----------	4.7a

[1]MEAN # OF WOUNDS PER BRANCH = Total number of wounds/tree / Total number of branches/tree

[2]Values within each column followed by the same letter are not significantly different ($P < 0.05$; Student-Newman-Keuls multiple comparison test)

Wounding: nursery study. Young nursery stock seedlings appeared to suffer the most damage from ovipositional activity as evidenced by the extensive wounding and breakage of the young elm (*Ulmus* sp.) and sugar maple (*A. saccharum*) trees. Skeels (9) observed that many young trees were so badly riddled, that they lost three years' growth, dying down to within a foot of the ground. Hogmire *et al.* (7) and others had observed that cicadas can inflict severe damage to young fruit trees. Small diameter branches are most often attacked with 95% of the terminals of the fruit trees destroyed. In contrast to fruit trees, elm (*Ulmus* sp.) and sugar maples (*A. saccharum*) recovered rather quickly with minimal long-term damage.

Wound closure: urban forest study. Trees growing in this study appeared to respond similarly to those growing in a related study in a landscaped area at The Morton Arboretum (Miller and Webb, unpublished). A majority of the plant species at both sites had at least 50% WWR after just two growing seasons. In addition, *Acer*, *Fraxinus*, *Malus* spp., and *Quercus*, common to both sites, responded very similarly to ovipositional damage and subsequent wound closure. Smith and Linderman (10) reported that *Quercus* spp. and *Acer* spp. sealed rapidly within two growing seasons after cicada emergence. Basswood (*Tilia* spp.) wounds slowly closed at both the urban forest and The Morton Arboretum sites which is consistent with the fact that basswoods are poor wound sealers.

Prevention of ovipositional wound damage. Chemical control for the prevention of ovipositional wound damage by the female periodical cicada does not appear to be a practical and effective measure of control. In New York, Weires and Straub (12) found that the pyrethroid insecticide fenvalerate was more effective than carbaryl, but both were only effective for 3-4 days when under heavy pressure from ovipositing female cicadas. Under severe migration pressure, neither of these materials provided adequate protection within reasonable application periods. Biweekly sprays over a three week

period would not be practical or economical for protection of urban forest tree species examined in this study.

Other than natural pruning, no significant long-term effects were observed due to ovipositional wounding. The periodical cicada does not appear to be a major threat to the health and vitality of urban forest tree species.

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Résumé. L'effet à long terme de l'oviposition par la femelle de la cicadelle, Magicada septendecim et M. cassini (homoptère: Cicadidae) a été étudié sur les arbres ornementaux de deux forêts urbaines du Nord de l'Illinois après la saison végétative des années 1991 à 1993. Le diamètre minimal des branches apparaît être un facteur critique dans le choix pour l'oviposition. Les arbres avec de grosses branches vigoureuses n'ont pas apparu être favorables pour l'oviposition. Le pourcentage de cime dépérissante, fonction du nombre de blessures par branche, ne semblerait pas constituer une mesure précise des dommages causés par l'oviposition. Les jeunes arbres avec des tiges ou des branches principales de diamètres entre 5 et 10 mm pourraient subir des dommages significatifs jusqu'au tronc, entraînant des bris et des pertes de croissance. Les arbres de plus grosses dimensions ne semblent pas être affectés significativement par les dommages associés à l'oviposition qui ne produisent alors qu'un effet peu important d'élagage naturel. Le contrôle chimique pour prévenir les dommages suite à l'oviposition par la cicadelle femelle n'apparaît pas être une solution pratique et efficace pour gérer ce problème. Même les dommages sévères causés par une oviposition massive ne semblent pas prédisposer plus les arbres à une attaque par des insectes ou des maladies secondaires.

Zussammenfassung. 1991 bis 1993 wurde während der Wachstumsperiode der Langszeiterffekt der Eiablage durch die weiblichen Zikaden *Magicicada septendecim* und *M. ccassini* (Homoptera: Cicadidae) auf Schattenbäumen in urbanen Wäldern im nordöstlichen

Illinois untersucht. Der minimale Stammdurchmesser während der Eiablage schien ein kritischer Faktor für die Aktivität zu sein. Pflanzen mit einem gedrungenen Verzweigungsmuster schinen für die Eiablage nicht geeignet. Das Erschlaffen von Kronenteilen als Reaktion auf die Anzahl der Wunden pro Ast kann keine akurate Messung der durch Eiablage entstandenen Schäden sein. Junge Bäume mit einem Stammdurchmesser oder Kronenleitäste mit Durchmessern zwischen 5 und 10 mm können zu deutlichen Schäden am Hauptstamm führen und dabei Stammbruch und Wachstumsverluste verursachen. Größere Pflanzen werden nicht besonders durch die Eiabligeschäden betroffen, was nur einen geringen Pflegeschnittaufwand bedeutet. Der Einsatz von Chemikalien zur Kontrolle von eiablegenden Zikaden erwies sich als nicht praktikable und effektive Lösung sur Krankheitsbekämpfung. Selbst heftiger Schaden durch die Eiablage schien die betroffenen Bäume in den urbanen Wäldern nicht für andere Schadensfaktoren anfällig zu machen.