

EFFECTS OF TEMPERATURE AND MULCH DEPTH ON
CHINESE TALLOW TREE (*SAPIUM SEBIFERUM*)
SEED GERMINATION

Candice Donahue*, William E. Rogers
and Evan Siemann

Department of Ecology and Evolutionary Biology
Rice University, Houston, Texas 77005

*Current address:

Armand Bayou Nature Center
PO Box 58828
Houston, Texas 77258

Abstract.—Shredding mowers can be used in prairie and savannah restoration to quickly eliminate trees, such as the invasive Chinese tallow tree (*Sapium sebiferum*), and leave a layer of mulch on the ground. *Sapium* has shown highest germination rates in fluctuating daily temperatures, and mulch has been shown to damp those fluctuations in the field. A lab study was conducted to separate direct effects of mulch depth and indirect effects from changes in soil temperatures on *Sapium* seed germination. *Sapium* seeds were exposed to different combinations of mulch depth and temperature oscillations. *Sapium* seeds showed highest germination in large temperature oscillation treatments regardless of the depth of the mulch. Seedlings were able to emerge through mulch up to 10 cm deep, the maximum used in this study. While herbicide use appears to be necessary because of resprouting from stumps, this study indicates that mulching *Sapium* trees shows promise as a restoration tool by removing existing trees as well as by reducing *Sapium* regeneration from seed through the indirect effects of mulch on seed germination. The lower subsequent seedling numbers might reduce the frequency and intensity of future herbicide treatments.

The invasive Chinese tallow tree (*Sapium sebiferum* (L.) Roxb.), Euphorbiaceae, was introduced to the United States from Asia in 1772 and has spread across the southeastern states (Barrilleaux & Grace 2000; Bruce et al. 1997). Grasslands have always been subject to woody encroachment, but the great seed output, bird dispersal, rapid growth, and adaptation to wide environmental conditions of *Sapium* (Renne & Gauthreaux 2000; Rogers et al. 2000; Siemann & Rogers 2003a) have allowed it to become the most serious threat to endangered prairies along the upper coast of the Gulf of Mexico (Grace 1998). Once *Sapium* becomes established, it shades out the native herbaceous vegetation and forms a monospecific forest (Bruce et al. 1997; Siemann & Rogers 2003b). This also displaces native animal species, such as several federally endangered grassland birds (Herkert et al. 2003; Perkins et al. 2003). The loss of prairie bunchgrasses and rapid decomposition of *Sapium* litter (Cameron & Spencer 1989) leave the soil bare beneath the trees; such a condition may reduce bioremediation of anthropogenic

pollutants and speed the flow of water and sediments to rivers (Fajardo et al. 2001; Harbor et al. 1995; Liaghat & Prasher 1996).

Sapium invasion is not limited to prairies. A 20-yr forest dynamic study (Harcombe et al. 1999) revealed that *Sapium* had increased dramatically in the Neches Bottom Unit of the Big Thicket National Preserve between 1981 and 1995. Among small saplings, *Sapium* growth was three times the median of all species studied during that period, and among large saplings, *Sapium* growth significantly exceeded that of all other species. In another study of the area, Hall & Harcombe (1998) documented an interaction of shade tolerance and flood tolerance among the species present. For example, species often were found in higher light conditions than would be expected from their known tolerance for shade, apparently having to make environmental trade-offs to survive both stresses of shade and flooding. Since *Sapium* is known to perform well in shade (Jones & McLeod 1989; Rogers 2002) and withstand flooding (Conner 1994; Grace 1998), it may become a serious threat to native tree species in the Big Thicket.

Effective control for *Sapium* has been elusive, and a great percentage of coastal prairie has been displaced by this exotic species. A promising new technique for prairie restoration uses shredding mowers to mulch stands of *Sapium*. This method employs a large shredding mower to chip entire trees at ground level. Herbicide is manually applied to the cut surface of the stumps to reduce resprouting. For restoration to be successful, *Sapium* regeneration needs to be controlled while simultaneously promoting native prairie plant regeneration. Mulch from *Sapium* trees may contribute to successful prairie restoration by limiting *Sapium* regeneration from seed. However, mulch depths necessary for suppression of *Sapium* seed germination and the mechanisms that contribute to suppression are not known.

Armand Bayou Nature Center, located 44 km southeast of Houston, Texas, has twice mulched *Sapium* trees on invaded prairie with a shredding mower, once in summer of 2000 and again in fall 2002/spring 2003. In the 2000 restoration, the stand was more mature and resulting mulch depths ranged up to 15 cm. In the younger stand mulched in 2002/2003, average mulch depths were approximately 5 cm. The subsequent emergence of *Sapium* seedlings in the area mulched in 2000 appeared lower than in the area where *Sapium* trees were killed with herbicide and left standing.

The mulch layer might have reduced germination by limiting day/night variation in surface soil temperatures. Experimental studies have shown highly variable germination rates for *Sapium*, depending on the geographic source of the seeds (Cameron et al. 2000) and the germination protocols. Conway et al. (2000) only achieved 0-10% germination on filter paper in petri dishes under an oscillating light and temperature regime, but Cameron et al. (2000) and Renne et al. (2001) achieved 26% and 22.5% germination rates, respectively, for seeds planted in soil in greenhouses under natural temperatures and light. Seeds under these conditions would be expected to experience natural daily fluctuations in soil temperatures. In another study, highest germination rates were obtained for seeds planted in soil under experimentally controlled fluctuating daily temperatures (Nijjer et al. 2002).

The objective of this lab study was to separate direct effects of mulch and indirect effects by changes in soil temperatures on *Sapium* seed germination by maintaining constant temperature regimes under varying mulch depths. If direct effects of mulch on seed germination are the primary cause of lower germination rates, then germination should decrease as mulch depth increases for all temperature treatments. However, if indirect effects *via* changes in soil temperatures are more important, germination should be greatest in high oscillating temperatures regardless of the mulch depth.

MATERIALS AND METHODS

Seeds of *Sapium* were collected from trees at the University of Houston Coastal Center in Galveston County, Texas, from August to September, 2002 and stored at room temperature. On 16 July 2003, 50 seeds were planted in each of 48 plastic bins (16 by 30 by 10 cm deep) on a 2.5 cm layer of commercially available topsoil and covered with another 2.5 cm layer of topsoil. Bins were randomly assigned to a temperature treatment (high oscillation, low oscillation, warm, and cool) and a mulch treatment (bare soil, 5 cm *Sapium* mulch, and 10 cm *Sapium* mulch) in a full-factorial design. Temperature treatments were chosen based on field soil temperatures measured during spring 2003 in the field that was mulched in late 2002 (Fig. 1). Bins were in a temperature controlled room (21°C) without windows or artificial light for the duration of the experiment. *Sapium* germination is independent of light conditions (Nijjer et al. 2002).

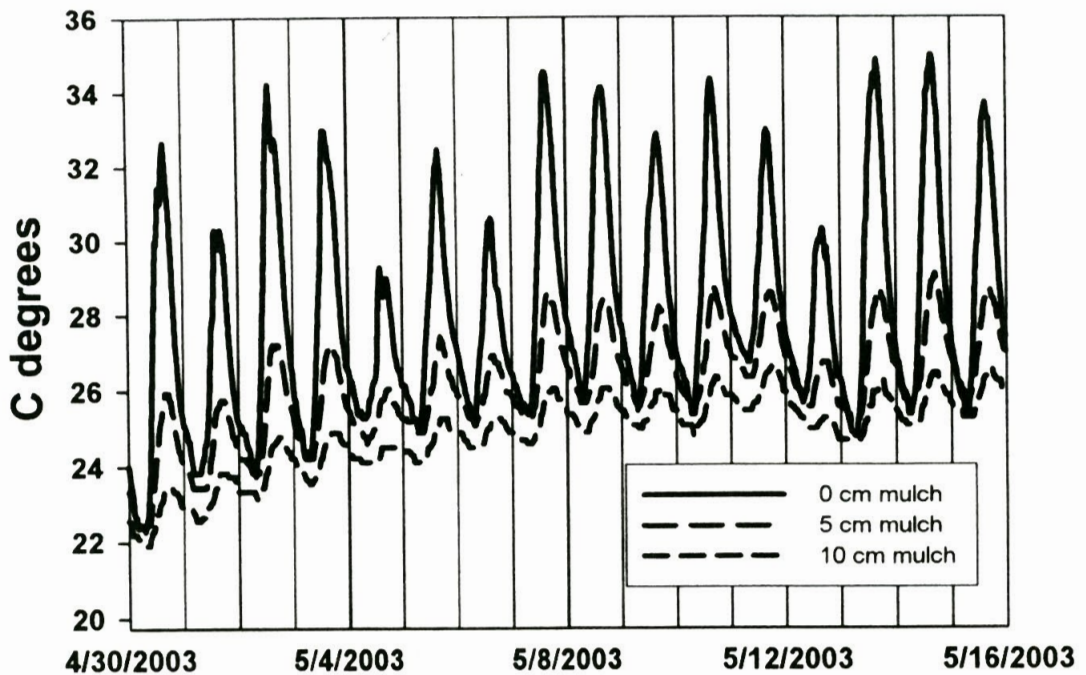


Figure 1. Sample of field soil temperatures recorded every 30 minutes, by mulch depth, in a field that had *Sapium* trees removed with a shredding mower in late 2002. Vertical bars indicate midnight on successive days.

Electric roof de-icing cables (EASYHEAT, New Carlisle, IN) laid in the bottoms of the bins raised the soil temperatures. Cables passed once through low-oscillation bins and twice through high-oscillation and warm bins. Oscillation treatments were warmed for 16 hours and allowed to return to room temperature over eight hours. The high oscillation temperature maximum was 33°C, and the low oscillation temperature maximum was 27°C. The warm treatment was a constant 33°C, and the cool treatment was constant room temperature (21°C).

Fresh *Sapium* mulch was collected from a recently mulched *Sapium* restoration area at Armand Bayou Nature Center. Mulch was spread evenly across the soil in the 5 cm and 10 cm mulch treatment bins. Plastic baffles were used to support the mulch layer at the edges of the 10 cm treatment bins. Because the 0 cm and 5 cm mulch treatments lost more heat to the air than the 10 cm mulch treatment and did not maintain the desired soil temperatures, heavy-duty plastic sheeting was cut slightly larger than each bin and laid over the tops of the bins for these two treatments. The plastic was neither sealed to the bins nor in contact with the soil or mulch layers.

Table 1. Dependence of *Sapium* germination on experimental temperature and mulch depth treatments in an ANOVA.

Factor	df	SS	F-value	P-value
Temperature	3	112.2	123.5	<0.0001
Mulch Depth	2	2.0	3.4	<0.05
Temperature*Mulch	6	3.5	1.9	0.11
Error	36	10.9		

All treatments were thoroughly watered three times each week until water drained from the bins, and newly germinated seeds were counted and removed from the bins during these periods. The experiment was conducted for 125 days, but no seeds germinated after 110 days.

ANOVA was used to compare the different experimental treatments and Fisher's LSD tests were used for post-hoc means contrasts (Statview 5.0, SAS Institute, 1998, Cary, North Carolina). Data were checked for normality and square root transformed to meet the assumptions of ANOVA. Data were back-transformed for presentation.

RESULTS

Temperature treatment and mulch depth treatment, but not their interaction, had significant effects on seed germination; however, temperature alone explained 87% of the variation in germination (Table 1). All pairwise comparisons among temperature treatments were significantly different (P ranging from <0.0001 to 0.0152) with the greatest germination in the high oscillation (217 germinants from 600 seeds total) followed by low oscillation (34 germinants), warm (18 germinants) and cool (1 germinant) treatments (Fig. 2). The only significant difference among mulch treatments was the lower germination rate under 5 cm of mulch compared to bare soil (Fig. 2).

DISCUSSION

Germination success for *Sapium* clearly depends on daily fluctuations in temperature, and the amplitude of the fluctuation is critical, as evidenced by the magnitude of the difference between germinants in the high-oscillation treatment and the low-oscillation treatment (Fig. 2). Pioneer species and wetland species commonly use diurnal temperature fluctuations as an indicator of canopy gaps (Fenner 1985; Baskin & Baskin 1989), proximity to the soil surface (Thompson & Grime 1983;

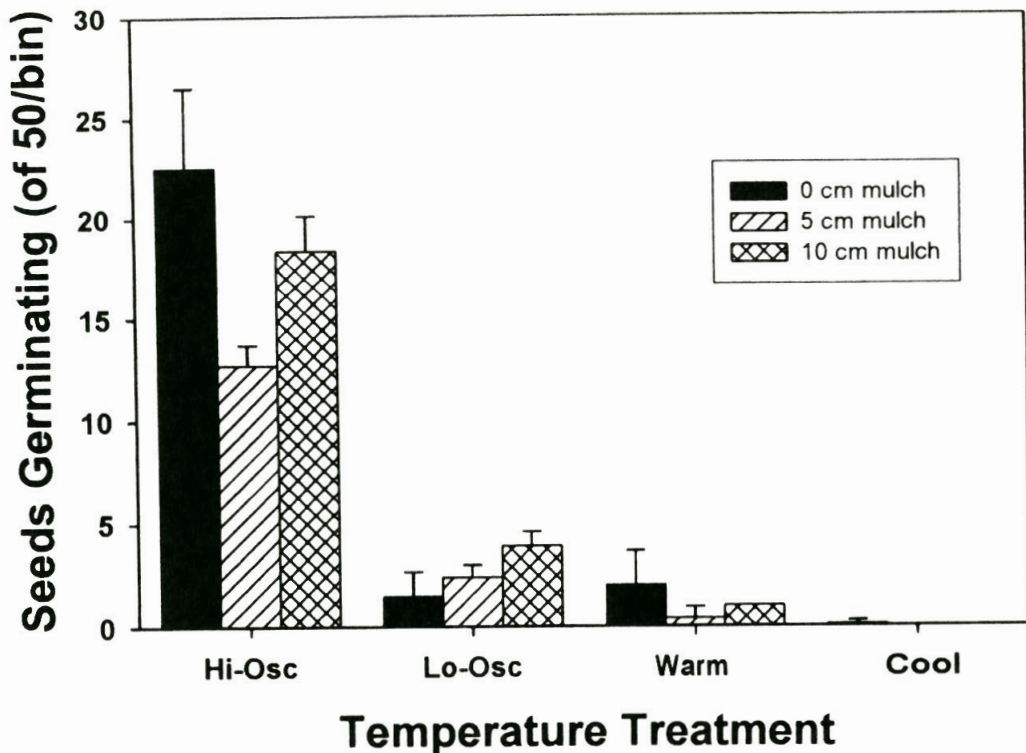


Figure 2. Number of *Sapium* seeds germinating in each bin (means + 1 SE) for each combination of temperature treatment (Hi-Osc = 21-33°C, Lo-Osc = 21-27°C, Warm = constant 33°C, Cool = constant ambient 21°C) and mulch depth (0 cm, 5 cm, 10 cm).

Ghera et al. 1992), or recession of standing water (Fenner 1985). These environmental conditions are often critical to subsequent seedling success (Thompson & Grime 1983; Fenner 1985; Vleeshouwers et al. 1995).

Several studies of invasive species have shown dependence on temperature fluctuations for successful germination (Ghera et al. 1992; Lonsdale 1993; Young & Clements 2001). Also, several threatening invasives are woody invaders of wetland areas, including *Sapium* (Davis et al. 1946; Bruce et al. 1997), *Schinus terebenthifolius* Raddi, or Brazilian peppertree (Wheeler et al. 2001; Hight et al. 2003), and *Melaleuca quinquenervia* (Cav.) Blake, or punktree (Costello et al. 2003; Johnston et al. 2003). Mulching might be an effective control method for other invasive woody species as well.

Germination and emergence from under 10 cm of mulch was not significantly different from that from bare soil ($P = 0.6575$), and there was no consistent trend in germination rates as mulch depth increased. This supports a conclusion that the indirect effect of mulch on soil

temperature oscillations is more important than mulch depth alone for *Sapium* seed germination. It is encouraging for the potential success of this restoration method that only 5 cm of mulch in the field was required to damp the soil temperature oscillations sufficiently (Fig. 1) to achieve the germination suppression evidenced by the low oscillation treatment in Figure 2.

The cotyledons of the seedlings in 10 cm of mulch were on long attenuated stems. The large *Sapium* seed (0.16 g/seed, Bonner 1989) apparently provides adequate resources for the seedling to emerge through deep mulch before reaching light where it can begin to photosynthesize. Several studies in different environments have shown a positive correlation between seed mass and ability for seedlings to become established (Dzwonko & Gawronski 2002; Christie & Armesto 2003). When they modeled the emergence response of weed seeds to burial depth, Grundy et al. (2003) also found that some species had adequate reserves to emerge from a wider range of depths than might be expected in the field, as *Sapium* demonstrated in the present study. This may contribute to *Sapium*'s ability to invade and exploit many different environmental conditions.

To be useful, the mulching treatment should have minimal effects on native prairie species. Foster & Gross (1998) found that prairie forbs and the prairie grass, *Andropogon gerardi*, were able to establish a significant number of seedlings in intact plant litter, even though the densities in litter were significantly lower than where litter was removed. In multiple-site studies, Foster & Gross (1997) and Foster (1999) found that accumulated litter affected *Andropogon gerardi* seedling establishment in some sites but not in others. Also, when examining tallgrass prairie recolonization mechanisms after soil disturbance by pocket gophers, Rogers & Hartnett (2001) found that vegetative regrowth after burial under soil was the dominant recolonization mechanism. Therefore, possible mulch-induced seed germination suppression could be expected to have little impact on native vegetation. Finally, the high flotation rubber tires of the mulching equipment limit damage to the root structure of existing perennial vegetation.

Techniques for control of invasive vegetation include biological, herbicidal, mechanical, or some combination of these. While herbicide use appears to be necessary because of resprouting from stumps (Jubinsky & Anderson 1996), this study indicates that mulching live

trees can be an effective initial mechanical treatment that reduces subsequent seedling numbers, and thereby reduces the frequency and intensity of herbicide treatments.

ACKNOWLEDGMENTS

The authors would like to thank Armand Bayou Nature Center for mulch, the University of Houston Coastal Center for permission to collect seeds, Brad Butterfield, Summer Nijjer, and Rachel Tardiff for assistance in the lab, and Wray-Todd Fellowship, US EPA (R82-8903), and US NSF (DEB-9981654) for financial support.

LITERATURE CITED

- Barrilleaux, T. C. & J. B. Grace. 2000. Growth and invasive potential of *Sapium sebiferum* (Euphorbiaceae) within the coastal prairie region: the effects of soil and moisture regime. *Am. J. Bot.*, 87:1099-1106.
- Baskin, J. M. & C. C. Baskin. 1989. Physiology of dormancy and germination in relation to seed bank ecology. Pp. 53-66, in *Ecology of soil seed banks* (M. A. Leck, V. T. Parker & R. L. Simpson, eds.). Academic Press, Inc., San Diego, CA, 462 pp.
- Bonner, F. T. 1989. *Sapium sebiferum* (L.) Roxb. Chinese tallow tree. Pp. 760, in *Seeds of woody plants in the United States* (C. S. Schopmeyer, ed.). USDA, Forest Service, Washington, DC, 883 pp.
- Bruce, K. A., G. N. Cameron, P. A. Harcombe & G. Jubinsky. 1997. Introduction, impact on native habitats, and management of a woody invader, the Chinese tallow tree, *Sapium sebiferum* (L.) Roxb. *Nat. Areas J.*, 17:255-260.
- Cameron, G. N. & S. R. Spencer. 1989. Rapid leaf decay and nutrient release in a Chinese tallow forest. *Oecologia*, 80:222-228.
- Cameron, G. N., E. G. Glumac & B. D. Eshelman. 2000. Germination and dormancy in seeds of *Sapium sebiferum* (Chinese tallow tree). *J. of Coastal Research*, 16:391-395.
- Christie, D. A. & J. J. Armesto. 2003. Regeneration microsites and tree species coexistence in temperate rain forests of Chiloe Island, Chile. *J. Ecol.*, 91:776-784.
- Conner, W. H. 1994. The effect of salinity and waterlogging on growth and survival of baldcypress and Chinese tallow seedlings. *J. of Coastal Research*, 10:1045-1049.
- Conway, W. C., L. M. Smith & J. F. Bergan. 2000. Evaluating germination protocols for Chinese tallow (*Sapium sebiferum*) seeds. *Tex. J. Sci.*, 52(3):267-270.
- Costello, S. L., P. D. Pratt, M. B. Rayamajhi & T. D. Center. 2003. Arthropods associated with above-ground portions of the invasive tree, *Melaleuca quinquenervia*, in South Florida, USA. *Fla. Entomol.*, 86:300-322.
- Davis, W. S., R. Stanger, W. L. Nash, J. Kucera & A. Surface. 1946. District Program: Brazoria-Galveston Soil Conservation District No. 318, Texas. US Department of Agriculture, Soil Conservation Service, Washington, DC.
- Dzwonko, Z. & S. Gawronski. 2002. Influence of litter and weather on seedling recruitment in a mixed oak-pine woodland. *Ann. Bot.*, 90:245-251.
- Fajardo, J. J., J. W. Bauder & S. D. Cash. 2001. Managing nitrate and bacteria in runoff from livestock confinement areas with vegetative filter strips. *J. Soil Water Conserv.*, 56:185-191.
- Fenner, M. 1985. *Seed Ecology*. Chapman & Hall Ltd., London, 151 pp.

- Foster, B. L. 1999. Establishment, competition and the distribution of native grasses among Michigan old-fields. *J. Ecol.*, 87:476-489.
- Foster, B. L. & K. L. Gross. 1997. Partitioning the effects of plant biomass and litter on *Andropogon gerardi* in old-field vegetation. *Ecology*, 78:2091-2104.
- Foster, B. L. & K. L. Gross. 1998. Species richness in a successional grassland: effects of nitrogen enrichment and plant litter. *Ecology*, 79:2593-2602.
- Ghersa, C. M., R. L. Benech & M. A. Martinez. 1992. The role of fluctuating temperatures in germination and establishment of *Sorghum halepense*. Regulation of germination at increasing depths. *Funct. Ecol.*, 6:460-468.
- Grace, J. B. 1998. Can prescribed fire save the endangered coastal prairie ecosystem from Chinese tallow invasion? *Endangered Species Update*, 15:70-76.
- Grundy, A. C., A. Mead & S. Burston. 2003. Modelling the emergence response of weed seeds to burial depth: interactions with seed density, weight and shape. *J. Appl. Ecol.*, 40:757-770.
- Harcombe, P. A., R. B. W. Hall, J. S. Glitzenstein, E. S. Cook, P. Krusic, M. Fulton. 1999. Sensitivity of Gulf Coast forests to climate change. Vulnerability of coastal wetlands in the Southeastern United States: climate change research results. Pp. 45-66 in *Biology Science Report USGS/BRD/BSR -1998-0002* (G. Gunterspergen & B. A. Varain, eds.). United States Geological Survey, Washington, DC, 101 pp.
- Hall, R. B. W. & P. A. Harcombe. 1998. Flooding alters apparent position of floodplain saplings on a light gradient. *Ecology*, 79:847-855.
- Harbor, J. M., J. Synder & J. Storer. 1995. Reducing nonpoint source pollution from construction sites using rapid seeding and mulching. *Phys. Geogr.*, 16:371-388.
- Herkert, J. R., D. L. Reinking, D. A. Wiedenfeld, M. Winter, J. L. Zimmerman, W. E. Jensen, E. J. Finck, R. R. Koford, D. H. Wolfe, S. K. Sherrrod, M. A. Jenkins, J. Faaborg & S. K. Robinson. 2003. Effects of prairie fragmentation on the nest success of breeding birds in the midcontinental United States. *Conserv. Biol.*, 17:587-594.
- Hight, S. D., I. Horiuchi, M. D. Vitorino, C. Wikler & J. H. Pedrosa-Macedo. 2003. Biology, host specificity tests, and risk assessment of the sawfly *Heteroperreyia hubrichi*, a potential biological control agent of *Schinus terebinthifolius* in Hawaii. *Biocontrol*, 48:461-476.
- Johnston, S. G., P. G. Slavich & P. Hirst. 2003. Alteration of groundwater and sediment geochemistry in a sulfidic backswamp due to *Melaleuca quinquenervia* encroachment. *Aust. J. Soil Res.*, 41:1343-1367.
- Jones, R. H. & K. W. McLeod. 1989. Shade tolerance in seedlings of Chinese tallow tree, American sycamore, and cherrybark oak. *Bull. Torrey Bot. Club*, 116:371-377.
- Jubinsky, G. & L. C. Anderson. 1996. The invasive potential of Chinese tallow-tree (*Sapium sebiferum* Roxb.) in the southeast. *Castanea*, 61:226-231.
- Liaghat, A. & S. O. Prasher. 1996. A lysimeter study of grass cover and water table depth effects on pesticide residues in drainage water. *Trans. ASAE*, 39:1731-1738.
- Lonsdale, W. M. 1993. Losses from the seed bank of *Mimosa pigra*: soil micro-organisms vs. temperature fluctuations. *J. Appl. Ecol.*, 30:654-660.
- Nijjer, S., R. A. Lankau, W. E. Rogers & E. Siemann. 2002. Effects of temperature and light on Chinese tallow (*Sapium sebiferum*) and Texas sugarberry (*Celtis laevigata*) seed germination. *Tex. J. Sci.*, 54(1):63-68.
- Perkins, D. W., P. D. Vickery & W. G. Shriver. 2003. Spatial dynamics of source-sink habitats: effects on rare grassland birds. *J. Wildl. Manage.*, 67:588-599.
- Renne, I. J. & S. A. Gauthreaux Jr. 2000. Seed dispersal of the Chinese tallow tree (*Sapium sebiferum* (L.) Roxb.) by birds in coastal South Carolina. *Am. Midl. Nat.*, 144:202-215.
- Renne, I. J., T. P. Spira & W. C. Bridges, Jr. 2001. Effects of habitat, burial, age and

- passage through birds on germination and establishment of Chinese tallow tree in coastal South Carolina. *J. Torrey Bot. Soc.*, 128:109-119.
- Rogers, W. E., S. Nijjer, C. L. Smith & E. Siemann. 2000. Effects of resources and herbivory on leaf morphology and physiology of Chinese tallow (*Sapium sebiferum*) tree seedlings. *Tex. J. Sci.*, 52(4)Supplement:43-56.
- Rogers, W. E. & D. C. Hartnett. 2001. Temporal vegetation dynamics and recolonization mechanisms on different-sized soil disturbances in tallgrass prairie. *Am. J. Bot.*, 88:1634-1642.
- Rogers W. E. & E. Siemann. 2002. Effects of simulated herbivory and resource availability on native and invasive exotic tree seedlings. *Basic Appl. Ecol.*, 3:297-307.
- Siemann, E. & W. E. Rogers. 2003a. Herbivory, disease, recruitment limitation and success of alien and native tree species. *Ecology*, 84:1489-1505.
- Siemann, E. & W. E. Rogers. 2003b. Changes in light and nitrogen under pioneer trees may facilitate tree invasions of grasslands. *J. Ecol.*, 91:923-931.
- Thompson, K. & J. P. Grime. 1983. A comparative study of germination responses to diurnally fluctuating temperatures. *J. Appl. Ecol.*, 20:141-156.
- Vleeshouwers, L. M., H. J. Bouwmeesterl & C. M. Karssen. 1995. Redefining seed dormancy: an attempt to integrate physiology and ecology. *J. Ecol.* 83:1031-1037.
- Wheeler, G. S., L. M. Massey & M. Endries. 2001. The Brazilian peppertree drupe feeder *Megastigmus transvaalensis* (Hymenoptera : Torymidae): Florida distribution and impact. *Biol. Control*, 22:139-148.
- Young, J. A. & C. D. Clements. 2001. Purple loosestrife (*Lythrum salicaria*) seed germination. *Weed Technol.*, 15:337-342.

CD at: candy@abnc.org