SURVIVAL OF HARDWOOD SEEDLINGS AND SAPLINGS FOLLOWING OVERSTORY THINNING AND PRESCRIBED FIRES IN MIXED-OAK FORESTS OF SOUTHERN OHIO

Joanne Rebbeck, Robert Long, and Daniel Yaussy[1]

Abstract—Prescribed fires in combination with thinning are being investigated as silvicultural tools in the regeneration of mixed-oak forests in central Appalachia. Burns were conducted in spring 2001 within three forests in southern Ohio. Each site was divided into four treatments of roughly 20 ha each: control (C), burn only (B), thin only (T), or thin plus burn (TB). The basal area of T and TB stands was thinned from about 28 to 20 m^2 ha^{-1} in the 4 months prior to the burns. Ten seedlings ($\leq$140 cm tall) and 10 saplings [stems >140 cm tall and <10 cm in diameter at breast height (d.b.h.)] within each of nine 1,000-m^2 plots in a treatment area at each site were evaluated before (2000) and after (2001) treatment. Oak and hickory species were targeted for seedling evaluations. Dominant sapling species evaluated were red and sugar maple, blackgum, hickory, and beech (oak was sparse or absence). At 4 months postburn, 0, 13, 62, and 80 percent of the pretreatment seedlings were dead with living sprouts on the C, T, TB, and B plots, respectively. Nearly half of the 10 original saplings per plot were dead with sprouts in the TB and B plots (4.9 and 4.2). Sapling mortality (dead with no live sprouts) was highest in TB plots (1.6 of original 10 per plot) compared with T (0.6), B (0.2), and C (0.07) plots. Seedling mortality was highest in TB plots (3.4 seedlings of original 10 per plot), followed by T (2.2), B (1.6), and C (0.7) plots. We anticipate that resprouting seedlings in the TB plots will respond vigorously to increased light conditions if maintained by subsequent fires.

INTRODUCTION

In many Midwestern and Eastern States, oak-hickory forests, e.g., black (*Quercus velutina*), chestnut (*Q. prinus*), scarlet (*Q. coccinea*), northern red (*Q. rubra*), white oak (*Q. alba*), and shagbark (*Carya ovata*) and mockernut hickory (*C. tomentosa*) are converting to forests dominated by maples (e.g., red (*Acer rubrum*) and sugar (*A. saccharum*)), beech (*Fagus grandifolia*), and tulip-poplar (*Liriodendron tulipifera*). In Ohio, USDA Forest Service inventory data indicate that the annual removal of white and red oaks (8 billion board feet of sawtimber) equals or exceeds annual growth, while the growth of maples and tulip-poplar, far exceeds removal (~56 to 74 percent) (Griffith and others 1993). Currently, oak regeneration on xeric sites is successful, but failures are common on high-quality mesic sites (Abrams and Downs 1990). Fire suppression, deer browsing, pathogens, insect herbivory, acorn predation, and inadequate competition for limited resources such as light, soil nutrients, and moisture contribute to the poor regeneration of oak (Johnson and others 2002, Loftis and McGee 1993).

Fire has been a component of oak-hickory forests in central Appalachian mixed-oak forests since pre-European settlement (Brose and others 2001). Since the 1930's, fire has been actively suppressed concurrent with a shift in the composition of the understory and subcanopy to more shade-tolerant and fire-intolerant species, e.g., maples.

In 1994, a large study was initiated in southern Ohio to assess the use of low-intensity prescribed fires as a management tool to regenerate oaks, and to examine the effects of fire at an ecosystem level (Sutherland and Hutchinson 2003). Preliminary findings indicate that despite annual and infrequent burns, the canopy did not open sufficiently to promote adequate oak regeneration (Personal communication. Daniel Yaussy. 2002. Research Forester, USDA Forest Service, Northeastern Research Station, 359 Main Road, Delaware, OH 43015). Consequently, a new study was initiated in 2000 to assess the effects of overstory thinning and fire on regenerating mixed-oak forests in southern Ohio. It is one of 13 sites participating in the national Fire and Fire Surrogates (FFS) Project, which has incorporated a common "core" design to quantify the ecological and economic impacts of prescribed fire and thinning. A multidisciplinary cooperative research team is studying how fire and/or thinning treatments promote the sustainability of mixed-oak ecosystems in central hardwood forests. In this paper, we present the first-season posttreatment effects of prescribed fires and thinning on the survival and health of hardwood seedlings and saplings.

STUDY AREA

The Ohio Hills site of the FFS Project is replicated on three study areas in southeastern Ohio: Zaleski State Forest (ZAL), Tar Hollow State Forest (TAR), and Raccoon Ecological Management Area (REMA). These sites have a highly dissected topography with elevations ranging from 200 to 300 m, and slopes of 10 to 40 percent. Located within the unglaciated Allegheny Plateau, the study area compromises a variety of sandstones, shales, and clays. Each study area is about 80 ha and is divided into four 20-ha treatment units: thin only (T), burn only (B), thin+burn (TB) and control (C). Within each treatment area, ten 50- by 20-m plots were established across a range of moisture conditions (three

[1] Plant Physiologist, Research Plant Pathologist, and Research Forester, USDA Forest Service, Northeastern Research Station, Delaware, OH 43015, respectively.

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xeric, four intermediate, three mesic) determined by the Integrated Moisture Index (IMI) (Iverson and others 1997). Within each 50- by 20-m plot, ten 10- by 10-m subplots were identified.

Due to logistical and personnel limitations, only 9 of the 10 plots in each treatment area were used. A plot was eliminated if its IMI value was redundant or nearly redundant with another plot in the same treatment area; 108 plots were used for the pathology and health evaluations of seedlings and saplings.

THINNING AND PRESCRIBED FIRES

The initial basal area (BA) averaged 28.8 m^2 ha^{-1} across all areas. T and TB treatment areas were commercially thinned from below to a BA of 20 m^2 ha^{-1} during the fall and winter of 2000. Low-intensity surface burns were conducted on 28 March and 4-5 April 2001 at the TAR, ZAL, and REMA study sites. Air temperature was measured at 25 cm from the forest floor with stainless steel temperature probes and logged every 2 seconds with buried data loggers. Fires at TAR were the least intense with maximum air temperatures ranging from 21 to 226 °C in TB units and 21 to 293 °C in B units. At ZAL, maximum air temperatures during fires ranged from 42.2 to 414.6 °C in the TB unit and 63.8 to 397 °C in the B unit. At REMA, maximum air temperatures ranged from 50 to 354 °C in the B unit and 36.2 to 496 °C in the TB unit. Details of the prescribed fires are reported elsewhere (Iverson and others 2004).

PROCEDURES

Health Evaluations

In May and June 2000, 10 seedlings and 10 saplings were identified in each plot. Seedlings were defined as woody stems <140 cm tall and were further divided into three height-based size classes: small (<10 cm), medium (10 to 50 cm), and large (50.1 to 140 cm). Saplings were defined as >140 cm tall and <10 cm in diameter at breast height (d.b.h.) and were divided into three d.b.h. classes: small (<3 cm), medium (3 to 6 cm), and large (6.1 to 10 cm). Attempts were made to ensure that individuals were distributed across the range of size classes for both seedlings and saplings, and that they were distributed evenly across the 50- by 20-m plot. For evaluations of seedling health, tree species were selected in the following order of preference: *Quercus spp.*, *Carya spp.*, and others. Oaks and hickories were preferred for saplings, but generally were infrequent. As a result, health evaluations for saplings focused on stems likely to be killed by fire, e.g., such as red and sugar maple, blackgum (*Nyssa sylvatica*), and beech.

For seedlings, initial measurements included height to terminal bud, basal diameter, and stem origin. If seedlings were of sprout origin, the diameter of the root collar was measured also. Since stems would be reevaluated numerous times over several years, seedlings were flagged and locations were recorded on a plot map. Saplings were similarly identified and mapped but only d.b.h. was measured. In all, 1080 seedlings and 1080 saplings were identified (360 each within a study area).

Pretreatment health evaluations were conducted in June and July 2000. For seedlings, number of leaves, leaf color and size, crown shape, percent herbivory/disease/injury, and percent fine twig dieback were determined using a rating system adapted after Carvell (1967) and Gottschalk (Personal communication. Kurt W. Gottschalk. 2000. Research Forester, USDA Forest Service, Northeastern Research Station, 180 Canfield St., Morgantown, WV 26505) (see table 1). If problems related to pathogens or insects were obvious during evaluations, seedlings with similar symptoms from off-plot locations were sampled destructively to determine probable causal agents. Small saplings were evaluated with the health protocols for seedlings. For medium and large saplings, evaluations of overstory health included crown vigor, percent dieback of fine twig, percent herbivory/disease/injury, and presence or absence of any stem injury (wounds and defects) (table 1). Sapling protocols (stem injury, crown vigor, and dieback) were adapted from methods developed for the North American Maple Project (Cooke and others 1997). All stems were reevaluated in June and again in late August/September 2001 to determine postthinning and postfire impacts.

RESULTS AND DISCUSSION

Pretreatment Evaluations

Shagbark, mockernut, bitternut [*Carya cordiformis*], and pignut [*C. glabra*] hickory, represented ~35 percent of the seedlings evaluated at each of three study sites (fig. 1a). Oak (black, chestnut, red, scarlet, and white) represented ~64 percent of the seedlings evaluated at each site. Tulip-poplar, white ash [*Fraxinus americana*], and American chestnut [*Castanea dentata*]) represented 0 to 4 percent. Eighty-four percent of the seedling stems originated from seedlings with the remainder 16 percent originating from sprouts.

Saplings evaluated were represented primarily by shade-tolerant and fire-intolerant species. Red and sugar maples represented 26 to 60 percent of the stems evaluated at each study site (fig. 1b). Sugar maple was the dominant species evaluated at TAR (40 percent), blackgum at ZAL (28 percent), and hickory spp. at REMA (31 percent). Nearly 75 percent of the evaluated seedlings were 10 to 50 cm tall while saplings were distributed more equally across all size classes.

Posttreatment Evaluations

Survival and mortality of seedlings—Four months after the prescribed fires (late August-early September 2001), survival of the original 10 seedlings per plot averaged 0.37 ($\pm$0.14) and 0.41 ($\pm$0.13) in the TB and B units, respectively, compared to average survival of 9.33 ($\pm$0.15) and 6.52 ($\pm$0.35) of the original 10 seedlings in the C and in the T plots, respectively (fig. 2a). Sprouting was greatest in the B plots (~80 percent), followed by the TB (~62 percent) plots (fig. 2b). This level of postfire sprouting was anticipated since oaks and hickories are fire-tolerant and readily sprout from the root collar (Brose and Van Lear 1998). Seedling mortality (dead with no live sprouts) was greatest in the TB plots (~34 percent), followed by T (~22 percent), B (~16 percent) and C (7 percent) plots (fig. 2c).

Table 1—Health evaluation criteria and classes used to assess the effects of prescribed fire, thinning, and fire plus thinning on hardwood seedlings and saplings

Seedlings and small saplings		Medium and large saplings		All saplings and seedlings	
Parameter	Class	Parameter	Class	Parameter	Class
Size	1 = Small, <10 cm tall 2 = Medium, 10 – 50 cm tall 3 = Large, 50.1 – 140 cm tall	Size	1 = Small, <3 cm d.b.h., >140 cm tall 2 = Medium, 3 – 6 cm d.b.h. 3 = Large, 6.1 – 10 cm d.b.h.	Stem injury	W = Wounds C = Cracks O = Open 1 = Closed
Origin	S = Seedling P = Sprout	Vigor[a]	1 = Healthy, <10% dieback, discolor 2 = 10 – 25% dieback, discolor 3 = 26 – 50% dieback, discolor 4 = 51 – 75% dieback, discolor 5 = 76 – 100% dieback, discolor 6 = Dead	Dieback[a]	0 = No trace or dieback 1 = <10% dieback 2 = 11 – 25% dieback 3 = 26 – 50% dieback 4 = 51 – 75% dieback 5 = 76 – 100% dieback 6 = Dead
Crown shape	1 = Normal, leader present 2 = Flat-topped, no leader 3 = Flat-topped, with major fork below crown 4 = Dead			Herbivory and disease	0 = None, trace 1 = <10% 2 = 11 – 25% 3 = 26 – 50% 4 = 51 – 75% 5 = 76 – 100% 6 = Dead
Leaf size	1 = Large, >15 cm long 2 = Medium, 10 – 15 cm long 3 = Small, <10 cm long				
Leaf color	1 = Normal, dark green 2 = Light green between veins, and dark green along veins 3 = Chlorotic, yellowish green between veins and light green along veins 4 = Brown edges and tips				
Leaf number	1 = <10 2 = 10 – 25 3 = 26 – 50 4 = 51 – 100 5 = 100+				

[a] For dieback and sapling vigor estimates, only fine twigs included in estimates if other twigs with foliage present in the same area of bole or crown. Isolated dead twigs with no foliage nearby considered dead due to shading excluded from estimates.

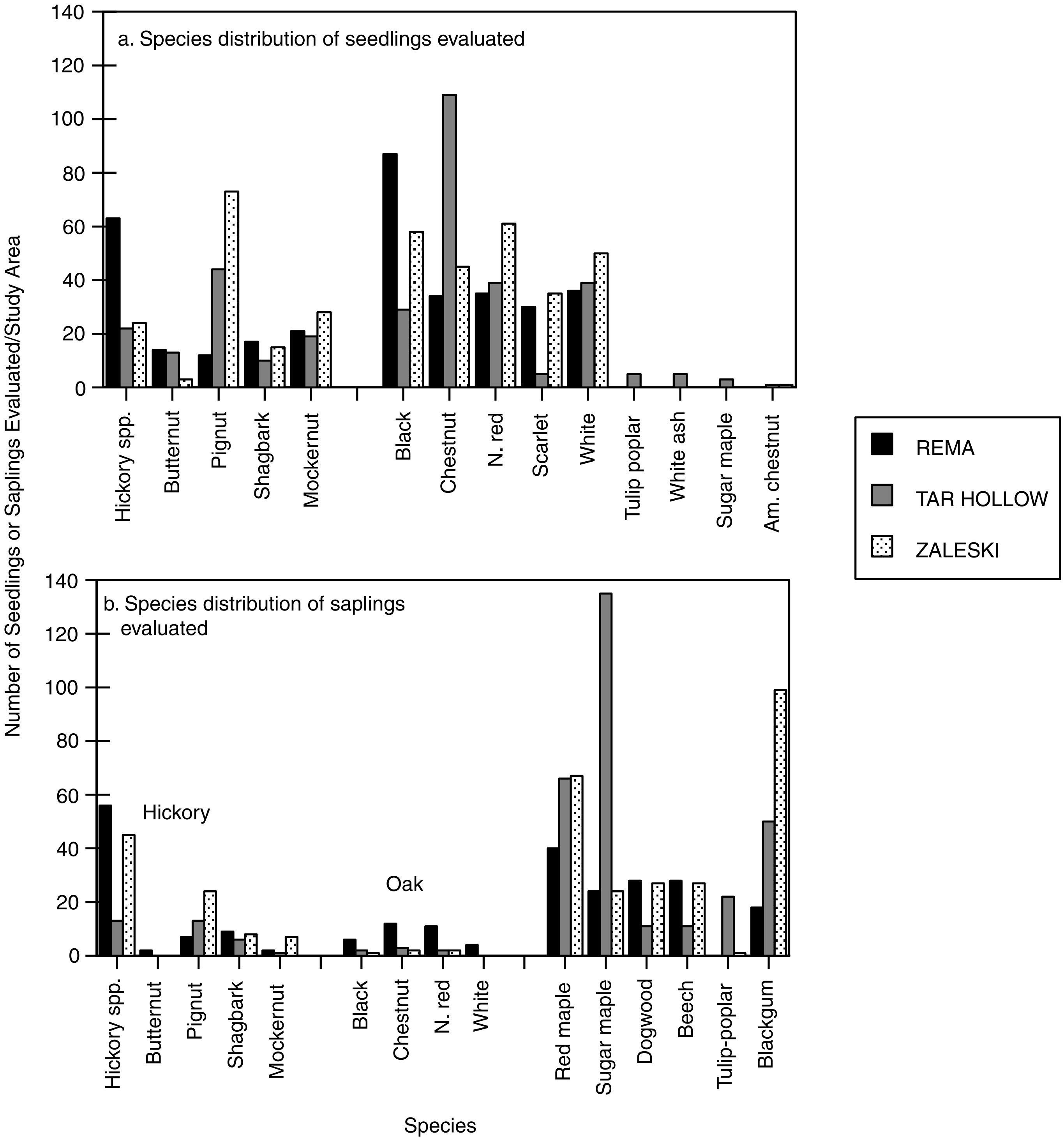

Figure 1—(a) Number of seedlings evaluated per species at REMA, Tar Hollow, and Zaleski study sites; (b) Number of saplings evaluated per species at each site.

Survival and mortality of saplings—As expected survival of original sapling stems was far greater than that observed for seedlings. C plots had the highest survival at 98.9 percent (±0.6), while TB plots had the lowest at 48.5 percent (±3.8) (fig. 3a). Survival was 90.4 percent (±1.7) in T plots and 56.7 percent (±4.8) in B-only plots. At Tar Hollow, B plots had the highest number of surviving original saplings of all B and TB units. This was not surprising since the lowest maximum air temperatures during the prescribed fires were observed at Tar Hollow. Likewise, the lowest number of dead saplings with sprouts (2.9 saplings per plot) was also observed at the TAR B-only unit (fig. 3c). Almost half of the 10 original sapling stems per plot were dead with sprouts in the TB (4.9 ±0.4) and B (4.2 ±0.5) plots (fig. 3b). Four

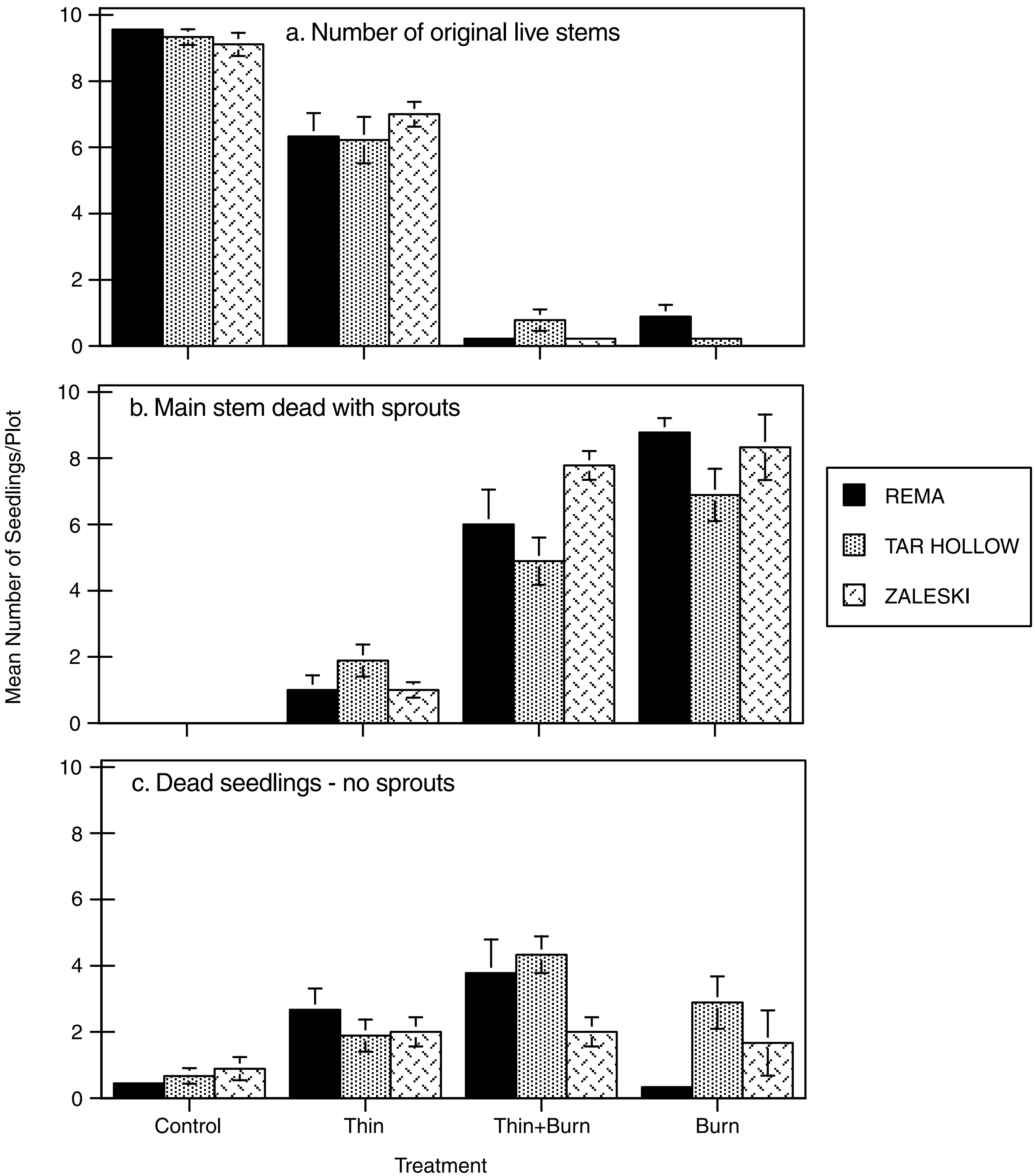

Figure 2—Survival of oak and hickory seedlings 4 months after low-intensity prescribed fires and/or overstory thinning at three sites in southern Ohio: (a) mean number of original live stems per plot; (b) mean number of dead stems with live sprouts per plot; (c) mean number of dead seedlings with no live sprouts.

months post-fire, sapling mortality (dead saplings with no live sprouts) was highest in the TB plots (~16 percent of the original saplings), compared with T alone (6.3 percent), B alone (2 percent), and C (0.7 percent). Logging injury (stem snapping, breakage, and wounding) was patchy and most prevalent closest to cutting and skidding operations. In some plots, the slash may have enhanced fuel loading or provided fire breaks, depending on slope aspect, twig/branch size and slash moisture content.

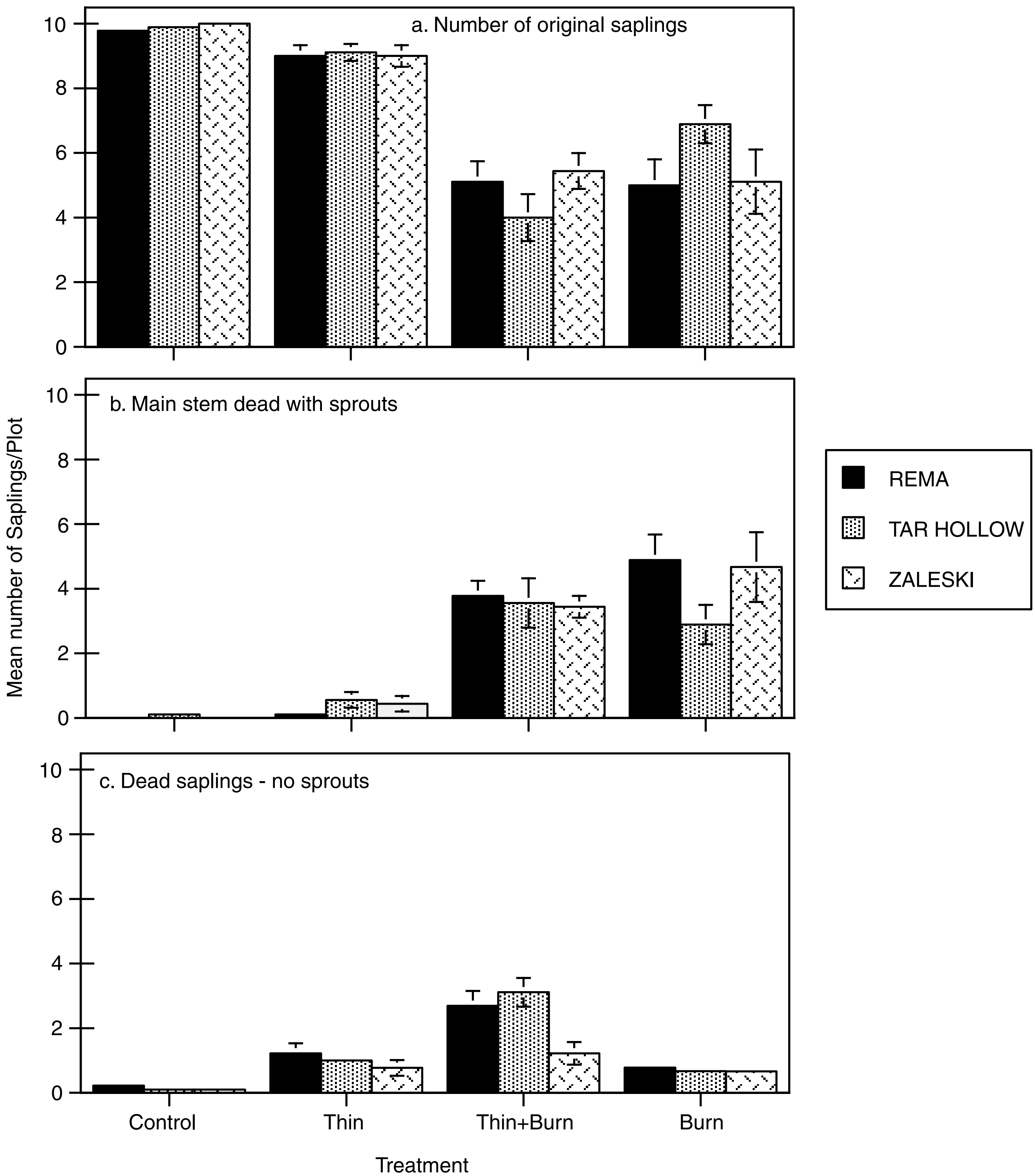

Figure 3—Survival of hardwood saplings (<3 to 10 cm in d.b.h.) 4 months after low-intensity prescribed fires and/or overstory thinning at three sites in southern Ohio: (a) mean number of original live stems per plot; (b) mean number of dead stems with live sprouts per plot; (c) mean number of dead seedlings with no live sprouts per plot.

Sapling vigor—Vigor was assessed only for medium and large saplings. The proportion of control saplings in the healthy and light decline (10 to 25 percent dieback) vigor classes did not change between 2000 and 2001 (fig 4a). The proportion of T saplings in the severe decline vigor class (76 to 100 percent) increased from 0 to 20 percent from pre- to post-treatment measurements (fig. 4b). In the B and TB plots, there were dramatic increases in the proportion of saplings with severe decline (76 to 100 percent dieback) fig. 4c and d), particularly at REMA and ZAL where fires were intense.

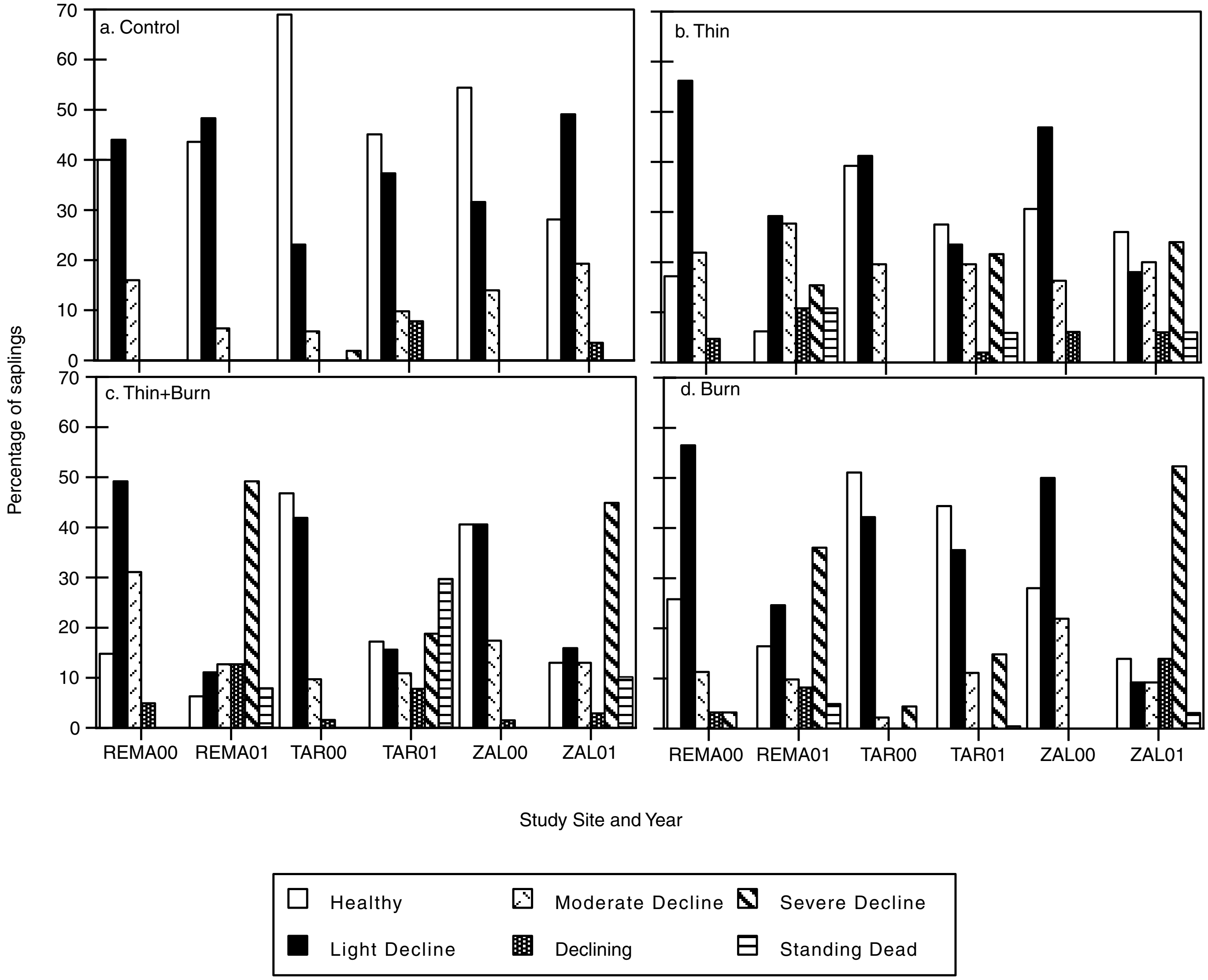

Figure 4—Percentage of hardwood saplings in vigor classes (healthy = <10 percent dieback and discolor, light decline = 10 to 25 percent, moderate decline = 26 to 50 percent, declining = 51 to 75 percent, severe declining = 76 to 100 percent, and standing dead) pretreatment (2000) and posttreatment (2001) for control, thin, thin+burn, and burn units.

Dieback—Seedling dieback in control and burn plots averaged <10 percent (fig. 5a). Dieback was higher (11 to 25 percent) in the T and TB units. Since most of the B and TB seedlings had resprouted, these evaluations indicated new current-year stems. Not surprisingly, dieback of small saplings in B and TB plots was similar to that of seedlings (fig. 5b). For larger saplings, dieback was highest in the T and TB plots, averaging 51 to 75 percent (fig. 5c). It is likely that the position of these taller stems within the midcanopy made them more prone to logging damage, as evidenced by stem bending, breakage, and wounding, and thus more vulnerable to fire-related injuries.

Incidence of foliar herbivory and disease—At 4 months following the prescribed fires, there were no changes in damage by foliar insects or diseases associated with thinning or burning among seedlings or small saplings (fig. 6). Mean herbivory-disease index values were similar across treatments. Damage associated with foliar insects and pathogens generally was insufficient in the summer of 2001 to adversely affect seedling or sapling growth.

SUMMARY

These first-season postfire results suggest that initial seedling and sapling mortality is highest when prescribed fire is combined with overstory removal. The incidence of foliar herbivory and disease was not affected by fire or thinning treatments. Sprouting of seedlings and saplings (all size classes) was common in both the B and TB units at all 3 study sites. We anticipate that resprouting seedlings in the TB plots will respond vigorously to increased light conditions if maintained by subsequent fires. Competition from fire-intolerant species such as red maple should be minimized with a second prescribed fire (planned for spring

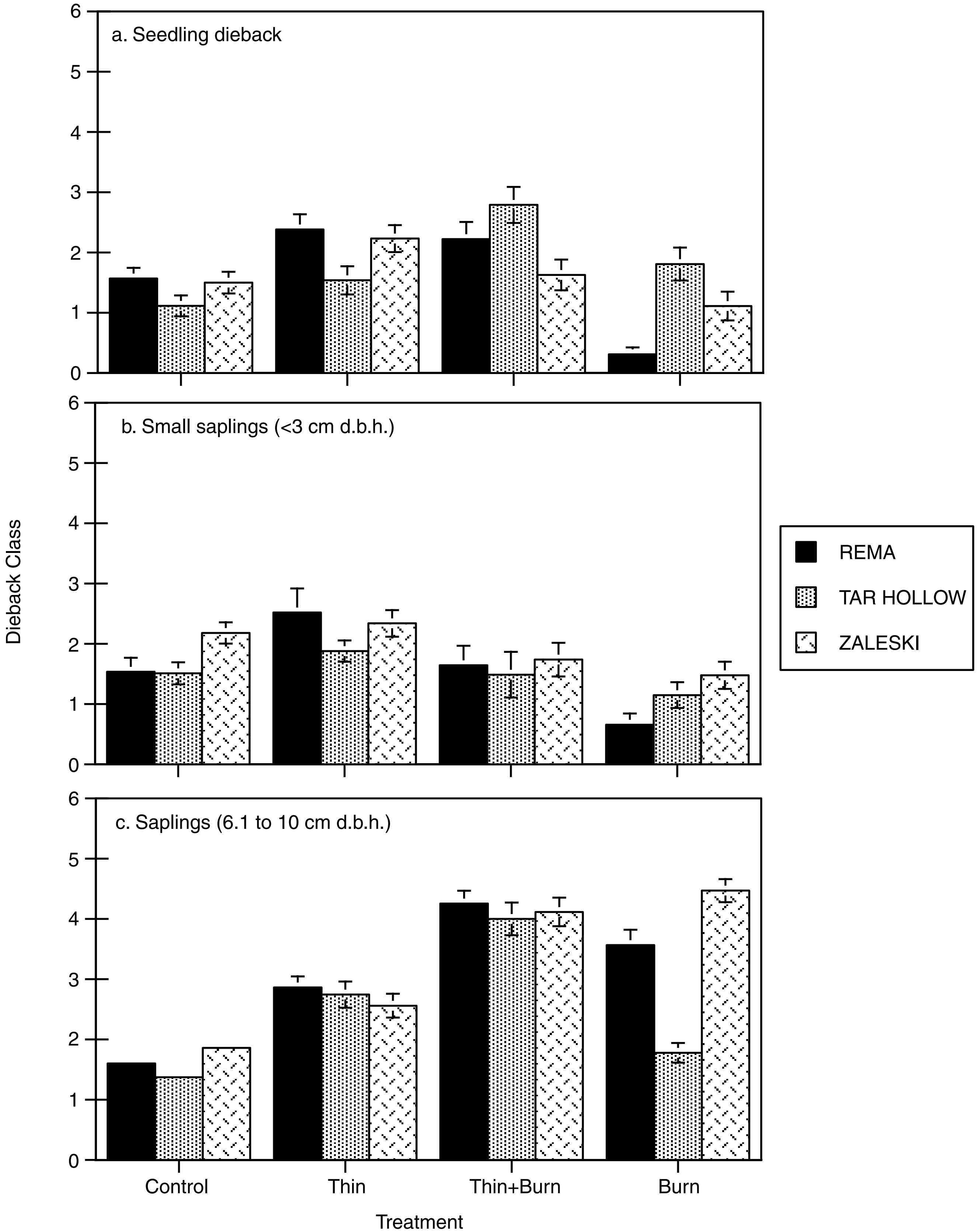

Figure 5—Late summer assessments of dieback of hardwood seedlings and saplings following prescribed fires and/or overstory thinning: (a) mean seedling dieback per plot; (b) mean small sapling dieback per plot; and (c) mean sapling dieback per plot. Rating of 1 = <10 percent dieback, while a rating of 5 = 76 to 100 percent dieback.

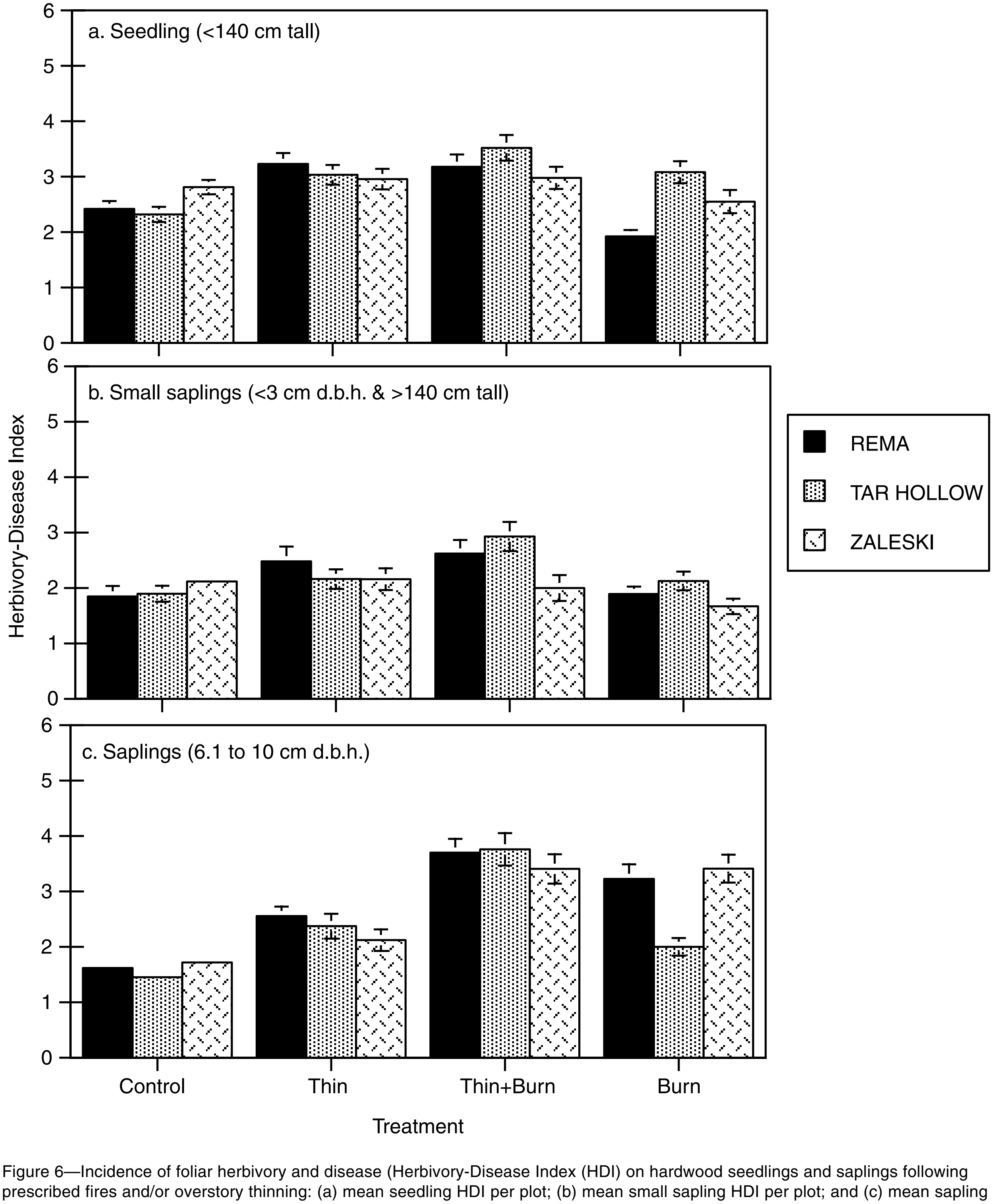

Figure 6—Incidence of foliar herbivory and disease (Herbivory-Disease Index (HDI) on hardwood seedlings and saplings following prescribed fires and/or overstory thinning: (a) mean seedling HDI per plot; (b) mean small sapling HDI per plot; and (c) mean sapling HDI per plot. Rating of 1 = <10 percent, while a rating of 5 = 76 to 100 percent.

2005). Fire improved height growth in oak and hickory and enhanced stem form in oaks (Brose and Van Lear 1998). Annual growth measurements and health evaluations of these stems will allow us to determine whether prescribed fire alone or combined with thinning results in larger and more competitive oak and hickory stems compared to unmanipulated controls in southern Ohio's mixed-hardwood forests.

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