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Germination of Overcup Oak and Bur Oak Following Inundation

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ABSTRACT

Cosgriff, R.J. and P.M. Brown. (Great Rivers Field Station, Illinois Natural History Survey, 8450 Montclair Avenue, Brighton, IL 62012). Germination of overcup oak and bur oak following inundation. Hard mast species have experienced a lack of regeneration over the past seventy years on the Upper Mississippi River System (UMRS). This has been attributed to anthropogenic alterations to floodplain hydrology. The focus of this study is to determine to what extent do overcup oak (*Quercus lyrata*) and bur oak (*Quercus macrocarpa*) have the ability to survive flooding as a seed and to determine whether the bur oak floodplain genotype has adapted to a flood regime through increased survivorship as a seed. Overcup oak and bur oak have the ability to survive inundation up to 60 days with no decrease in germination rates. We found no differences in germination rates between sites and between upland and floodplain genotypes. However, seed mass, site and treatment were significant predictors in the number of days to germination. Days to germination decreased as seed mass increased. Overcup oak seed mass was not significantly different between sites, whereas, seed mass of bur oak was different at all sites.

Key Words: *Quercus lyrata*, *Quercus macrocarpa*, overcup oak, bur oak, white oaks, hydrochory, seed survivorship, Upper Mississippi River System.

INTRODUCTION

Periodic flooding is the most common disturbance event on floodplains and often determines the distribution of forest species and communities (Illichevsky 1933; Bedringer 1978; Streng et al. 1989). Floodplain trees are most susceptible to flood disturbance as a seed or recently germinated seedling and establishment is dictated by an individuals capability to be dispersed to an elevation suitable to its physiological tolerance or avoidance of inundation (Briscoe 1961; Streng et al. 1989; Lopez 2001). Recent anthropogenic alterations in river hydrology of the Upper Mississippi River System (UMRS) has raised the floodplain water table and decreased fall drought, placing many species (oak, *Quercus spp*.; hickory/pecan, *Carya spp*.) that rely on higher elevations for regeneration in peril (Yeager 1949; Yin and Nelson 1995; Yin et al. 1997; Knutson and Klaas 1998). Consequently, there has been little regeneration into seedling and sapling cohorts by these important hard mast species since lock and dam construction in the 1930's (Yeager 1949; Knutson and Klaas 1998; Cosgriff unpublished data). Fall flooding can potentially reduce regeneration of oak by inducing high mortality in seeds (Briscoe 1961).

Natural re-establishment of oak forest communities is problematic because of short dispersal distances and short seed viability. However, observations of recruitment of oak species in debris zones on the floodplain and at heads of islands, many kilometers away from the nearest parent tree, suggest that flooding maybe a possible source of dispersal. Many floodplain species have developed means for seed dispersal by water (hydrochory) and to survive inundation through air pockets and impermeable seed coats (Lopez 2001). Several floodplain species have been described as not being affected by seed inundation (Briscoe 1961; Guo et al. 1998). Overcup oak (*Quercus lyrata* Walt.) is a floodplain oak species described as using hydrochory, and is common in many oak-hickory forests of the UMRS (Burns and Honkala 1990; McCarthy and Evans 2000). However, information on seed survivorship following fall inundation is lacking.

Floodplain oaks often have better survival following long-term seed inundation compared to upland oaks (Briscoe 1961; Guo et al. 1998). Bur oak (*Quercus macrocarpa* Michx.) is associated with upland savanna, however, it is a common species on the floodplains of the UMRS and has the ability to survive the most extreme flood events as a mature tree (Cosgriff unpublished data). A hypothesis for the success of this species in a floodplain environment is evolved means of seed survivorship in flooded regimes. The focus of this study is to determine the extent that seeds of two white oak species (overcup and bur oak) have the ability to survive flooding and to determine the extent to which bur oak has adapted to a flood regime.

MATERIALS AND METHODS

Seed collection of overcup oak and bur oak occurred from September 1 to October 15, 2001 (Mohlenbrock 1986). These seeds were collected from a minimum of five adult trees at each site. Special care was taken to not select seeds that appeared non-viable (small size or deformed) or browsed. Seeds of overcup oak were collected from three floodplain forest sites (Stump Lake 1, Stump Lake 2, and Silver Lake) near the confluence of the Mississippi and Illinois Rivers (Fig. 1). Bur oak seeds were collected from three floodplain forest sites (Silver Lake, Royal Landing, and Calhoun Point) near the confluence of the Mississippi and Illinois Rivers and one upland site ten miles west of Carlinville, Illinois (Fig. 1). Seeds were stored in a refrigerator at a constant temperature of 5°C for a 30 days. Seed mass was measured to the nearest 1 mg and volume was calculated using seed length and width (mm).

Linear regression of mass compared to calculated volume was used by species to identify soundness of seeds. Residuals were utilized and a proportion of the seeds dissected to determine model effectiveness. Seeds of overcup oak with a residual less than –0.7 were identified as being nonviable and were removed from the study (mass=0.105+0.015*volume; r=0.81). Seeds of bur oak with a residual less than –0.5 were identified as being unviable and were removed from the study (mass=-2.336+0.027*volume; r=0.93).

Seeds were randomly subjected to five treatments within five replicates. The treatments included 0 days (control), 7 days, 14 days, 30 days and 60 days of inundation and were subjected to inundation from Dec. 1 to Feb. 1 (2001-02). Seeds were placed in burlap bags by treatment and replicate and submersed in weighted, five gallon buckets. The location of inundation was Chickahominy Slough, an isolated backwater located near the confluence of the Mississippi and Illinois Rivers (Fig. 1). The seeds were then collected at proper intervals in time and placed on moist crepe-cellulose paper and covered with a moist soil/sand mixture (1 part potting soil/2 parts sand). The seeds were stored at room temperature (70° C) and inspected weekly for germination. A seed was classified as successfully germinated when the radicle emerged from the seed. Inspections started Dec. 1 and continued to March 31.

To test for differences in seed germination by site and treatment, a linear logistic regression model for binary response data was utilized for each species (SAS 1990). Proportion germinated was calculated by dividing the number of germinants in each site, replicate and treatment by the total number planted at each site, replicate and treatment. Wald chi-square tests were used to test for significant differences between individual sites and treatments. General linear models (SAS 1990) were utilized to identify the effects of seed mass, site, and treatment on days to germination. Seeds that did not germinate were removed from the data set prior to analysis. General linear models and Tukey's Honestly Significant Difference (SAS 1990) were utilized to identify any differences in seed size between sites.

RESULTS

Our results indicate that seeds of overcup oak and bur oak have the ability to survive long term flooding. No statistical differences were found in germination by site or treatment for the two species (Table 1). Variation in percent germination was large and inspection of mean percent germination by site and treatment reveals that overcup oak at Silver Lake had greater mean germination rates compared to the two Stump Lake sites (Table 2). However, Wald chi-square tests failed to indicate any significant differences between individual sites or treatments (p-value <0.0001). Bur oak seeds from Silver Lake and Calhoun Point had germination rates similar to those of the Royal Lake and upland sites. However, this was not significant (Wald chi square =0.0049, df=1, P=0.9443). Likewise, there were no differences between the upland site and the floodplain sites (Wald chi square =0.0004, df=1, P=0.9843) indicating that over time, bur oak has not developed, within species, physiological adaptations to flooding.

Mass, site, treatment, mass*site, and mass*treatment were significant predictors of days to germination for overcup oak (F=4.16, P<0.0001, R=0.64), whereas, mass, site, treatment, mass*site, and mass*site*treatment were significant predictors of days to germination for bur oak (F=5.34, P<0.0001, R=0.72)(Table 3).

There was no significant differences in overcup oak seed size by site (F=0.30, P=0.7389, R=0.03) (Table 4). However, seed size was significantly different in bur oak between all sites (F=462.06, P<0.0001, R=0.85).

DISCUSSION

Overcup oak and bur oak seeds have the ability to survive inundation up to 60 days with no significant differences between control and treatments. Germination rates for these two species are similar to rates found for two red oak species (Nuttall's oak, *Q. nuttallii* E.J.Palmer, and Spanish oak, *Q. falcata* Michx.) following a similar inundation study (Briscoe 1961). However, Briscoe (1961) indicated that seed germination decreased after 18 and 34 days (Spanish oak and Nuttall's oak, respectively). Survivorship of long-term flooding may indicate that these species do have the ability to utilize hydrochory. This finding is very important when trying to determine the length of time for forest re-establishment following catastrophic disturbance events (man-made and natural) where the entire parent community has been removed. However, most viable oak seeds do not stay afloat for very long (Young and Young 1992). McCarthy and Evans (2000) indicate that overcup oak possess a thick corky seed coat that promotes hydrochory. However, we found no quantifiable evidence in the literature to support this. Being carried away in a debris pile or rolling along the river bottom with the current may be a means of periodic dispersal, but it is unlikely that it would constitute a means of reliable seed dispersion. The main river channel, secondary channels and backwaters are likely to act as sinks for oak seeds rather than reliable means of dispersal. A short-term seed bank may be a means of regeneration. However, Young and Young (1992) indicated that viability in the white oak group is very short. Contrary to their findings, personal observations in the field indicate that overcup oak seeds will germinate after three years of dormancy. Likewise, Schroeder and Walker (1987) indicated that viability of bur oak acorns increases with seed moisture content. Floodplain environments may be suitable to promote viability in the white oak group by maintaining high seed moisture content.

Floodplain plant species have developed means to survive or avoid flood disturbance events. One adaptation includes seeds that have air pockets and impermeable seed coats, which would seemingly give these species an advantage over upland species (Kubitzki and Ziburski 1994; Lopez 2001). There may also be genotypic variations where individual populations have developed a means to survive a particular stress. Keeley (1979) identified differences in seedling survivorship within sour gum (*Nyssa sylvatica* Marsh.) related to the moisture regime of the parent tree. In this study, seedlings from parent trees in a swampy environment had better survivorship within that environment than in an upland environment and seedlings from the uplands had better survivorship within the drier environment than the in the swampy environment. Floodplain seedlings, in between the swamp and upland moisture regime, had survivorship in between the swampy and upland seedlings in the corresponding environments. We found no differences in germination between seeds of upland and floodplain sites. This would indicate that bur oak, generally considered an upland species, has not developed adaptations in seed survivorship due to inundation within the floodplain genotype.

We determined that seed size was a significant predictor of days to germination in both species. Streng et al. (1989) also indicated that larger seed size translates into increased germination. Differences in seed size identified in this study were related to site location for bur oak but not for overcup oak. These differences can be attributed to environmental, biotic, and genotypic differences. Seed size may influence germination rates, but may not be related to seedling survivorship (Jones et al. 1994; Long and Jones 1996).

SUMMARY

The ability of overcup oak and bur oak seeds to survive long-term flooding is critical with the current altered hydrologic regime that exposes these two species to increased flooding. For the past 70 years, these species have experienced a lack of regeneration with the current hydrologic regime. The altered hydrologic regime, however, is not affecting the ability of the seed to germinate. We found no evidence that bur oak has adapted to a floodplain environment through physiological or morphological adaptations in the seed. Upland and floodplain genotypes within this species experience the same germination rates. The number of days to germination decreased as seed mass increased.

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Figure 1. Location of study sites at the confluence of the Mississippi and Illinois Rivers and the upland site near Carlinville, IL.

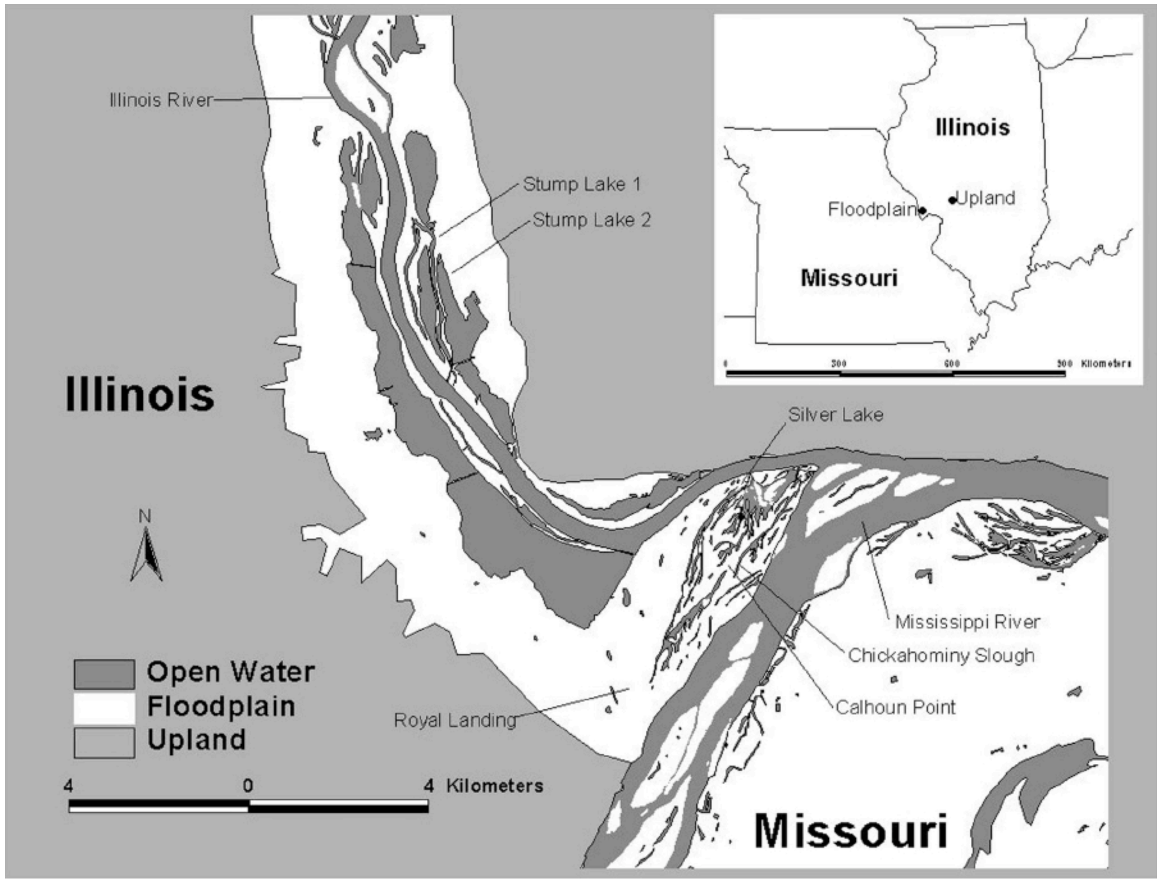

Table 1. Site and treatment effects on proportion germinated for *Q. lyrata* (Wald chi square=121.41, df=74, P=0.0004) and *Q. macrocarpa* (Wald chi square=72.93, df=99, P=0.9771).

Species	Effect	df	Wald Chi-Square	Pr > Chi-Square
Quercus lyrata	Site	2	0.0072	0.9964
	Treatment	4	0.0056	1.0000
	Site*Trt	8	8.1407	0.4198
	Replicate	60	63.0322	0.3696
Quercus macrocarpa	Site	3	0.0129	0.9996
	Treatment	4	0.0029	1.0000
	Site*Trt	12	0.0076	1.0000
	Replicate	74	31.7460	1.0000

Table 2. Mean percent germination by site, treatment and species.

Species	Site	Treatment	N	Percent Germination	Std.
Quercus lyrata	Stump Lake 1	0 Days	5	18.00	8.37
		7 Days	5	26.00	8.94
		14 Days	5	22.00	13.04
		30 Days	5	18.00	16.43
		60 Days	5	42.00	14.83
	Stump Lake 2	0 Days	5	48.89	27.89
		7 Days	5	22.22	28.33
		14 Days	5	13.33	24.09
		30 Days	5	33.33	22.22
		60 Days	5	37.78	26.76
	Silver Lake	0 Days	5	90.00	16.30
		7 Days	5	77.50	5.59
		14 Days	5	55.00	20.92
		30 Days	5	55.00	24.37
		60 Days	5	75.00	12.50
Quercus macrocarpa	Calhoun Point	0 Days	5	60.00	43.46
		7 Days	5	46.67	18.26
		14 Days	5	26.67	14.91
		30 Days	5	40.00	27.89
		60 Days	5	40.00	14.91
	Royal Landing	0 Days	5	100.00	0.00
		7 Days	5	93.33	14.91
		14 Days	5	46.67	38.01
		30 Days	5	66.67	33.33
		60 Days	5	60.00	36.51
	Silver Lake	0 Days	5	64.00	8.94
		7 Days	5	28.00	17.89
		14 Days	5	44.00	21.91
		30 Days	5	40.00	14.14
		60 Days	5	64.00	21.91
	Upland	0 Days	5	90.00	12.25
		7 Days	5	80.00	18.71
		14 Days	5	60.00	30.82
		30 Days	5	80.00	15.81
		60 Days	5	88.00	4.47

Table 3. Site, treatment, and seed mass effects on days till germination.

Species	Effect	df	F-Value	Pr>F
Quercus lyrata	Seed Mass	1	20.28	<0.0001
	Site	2	7.59	0.0007
	Mass*Site	2	5.11	0.0069
	Treatment	4	38.99	<0.0001
	Mass*Trt	4	2.82	0.0263
	Site*Trt	8	1.76	0.0863
	Mass*Site*Trt	8	1.56	0.1393
	Rep(Site*Trt)	54	1.95	0.0005
Quercus macrocarpa	Seed Mass	1	32.61	<0.0001
	Site	3	35.70	<0.0001
	Mass*Site	3	7.48	<0.0001
	Treatment	4	68.54	<0.0001
	Mass*Trt	4	0.46	0.7644
	Site*Trt	12	1.57	0.1015
	Mass*Site*Trt	12	1.98	0.0267
	Rep(Site*Trt)	73	1.60	0.0044

Table 4. Mean seed mass by site.

Species	Site	N	Mean Mass (g)	std
Quercus lyrata	Stump Lake 1	250	4.63	0.86
	Stump Lake 2	225	4.55	1.55
	Silver Lake	200	4.61	0.88
Quercus macrocarpa	Calhoun Point	75	18.13	3.34
	Royal Landing	75	21.32	5.41
	Silver Lake	125	5.81	1.79
	Upland	250	13.81	2.64