THE ALLELOPATHIC INFLUENCE OF POST OAK (*QUERCUS STELLATA*) ON PLANT SPECIES IN SOUTHERN U.S. FORESTS

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Abstract—Post oak (*Quercus stellata*) is a commonly occurring tree in the southeastern United States, offering forage and shelter for a variety of wildlife as well as having commercial uses. This species is often planted in parks and urban green-spaces for the shade it offers. Previous studies have found that parts of the plant can be toxic to livestock and that it can inhibit the germination and/or growth of plant species in its vicinity. This study focuses on the allelopathic potential of post oak in an urban, old growth forest. Post oak was selected subsequent to an understory inventory of plant species on a plot established in Marshall Forest in Rome, GA. White oak (*Quercus alba*) and chestnut oak (*Quercus montana*) seeds, and muscadine (*Vitis rotundifolia)* were used to determine if leachates prepared from leaves collected from Post oak inhibit germination and/or growth. Radish (*Raphanus sativus)* was also used, as it was previously found to be impacted by post oak. Two different concentrations of leachate were prepared and tested on the selected species. The results revealed significant differences in both germination rates and mean sprout lengths between the control (distilled water) and both concentration groups. No significant difference was found between the two concentrations of leaf leachate during the experiment. These results suggest that post oak inhibits the germination rate and sprout length of the tested species. It is important that resource managers understand these relationships in managed landscapes (e.g., parks). In the future, it may be possible to utilize allelochemicals from post oak as a biocontrol agent.

INTRODUCTION

Allelopathy is the process by which an organism produces biochemicals that have a potentially detrimental impact on the survival, growth, and/or reproduction of another organism (Pérez and others 2013). While the mechanism of allelopathy is not entirely known, it has been found that some biochemicals interfere with plant physiological processes through disrupting the cell membrane, target energy producing, and energy consuming steps (Rietveld 1983). Interfering with these processes in plants will result in impacts on growth and/or survivability of seedlings. This phenomenon has not been thoroughly explored and the effects that certain plants (e.g., trees) have on their surrounding environment (i.e., the understory) warrants further investigation.

Allelochemicals can be introduced into the environment by two methods. The first is via living plant matter where rainfall washes allelochemicals off the leaves and into the soil. The second method is leaf litter, which occurs when leaves senesce, fall to the ground, and decompose on the forest floor. The decomposition of leaves allows the allelochemicals to leach into the soil. Determining the strength of the allelopathic chemicals present in plants is important for determining the impacts to surrounding plant species and may be useful for producing natural, targeted, herbicides allowing for more efficient crop production by killing specific weeds and not harming crop plants. Understanding allelopathic processes is also important when dealing with invasive species, as many are known to produce biochemicals that inhibit surrounding plants, allowing the invasive plant to outcompete them for resources (Pérez and others 2013).

Post oak (*Quercus stellata)* has not been widely explored as a potential allelopathic species and has been classified as a moderate allelopathic species (Coder 1999). This species occupies rocky/sandy ridges and dry woodlands, is native to the eastern U.S., and is considered drought resistant (Starskey 1990). Post Oak is also commonly planted in parks for use as shade trees because of the large, lobed leaves. Buehler (2010) used post oak as a control to compare a known allelopathic species *Casuarinas* on radish and beans because Post Oak was not previously documented as an allelopathic species. The results demonstrated that post oak significantly inhibited germination of radish and beans.

The objective of this study was to determine the allelopathic effects of post oak leachates on reduction

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of germination and sprout lengths in white oak (*Quercus alba*), chestnut oak (*Quercus montana*), muscadine (*Vitis rotundifolia*), and radish (*Raphanus sativus*). The selected species were chosen because of an initial understory survey. Muscadine was the most prevalent species found under post oak. The second objective was to determine if there was a significant difference between two concentrations of the allelopathic leachates.

MATERIALS AND METHODS

Plant Collection and Leachate Preparation

A half-acre plot was established in Marshall Forest, an urban, old-growth forest in Rome, GA, in September 2014. An inventory of understory species was recorded for post oaks as well as several associated species from study plots. Species diversity under post oak, chestnut oak (*Quercus montana)*, white oak (*Quercus alba)*, loblolly pine (*Pinus taeda)*, and pignut hickory (*Carya glabra)* were assessed, and post oak was found to have a lower species diversity (table 1). Fresh leaves were then collected from post oak trees and were immediately transported to a laboratory at Shorter University where they were weighed to make two different concentrations of leachate. Two hundred fifty-six grams of fresh green leaves were weighed for concentration one and placed in a large basin to prepare for leachate extraction. Five hundred twelve grams of fresh green leaves were weighed for concentration two and placed in another large basin for preparation of leachates. The leaves were covered with 1L of distilled water and allowed to soak for seven days to extract allelochemicals. Once the allelochemicals had been extracted, leachate was vacuum filtered through Whatman #1 filter paper and stored at 4 degrees Celsius. The pH was measured and recorded as 5.7.

Preparation of Selected Species and Recording Data

The study design consisted of four species (radish, chestnut oak, white oak, and muscadine), a post oak leachate control and two leachate concentrations (C1 and C2), and three study replicates (R1, R2, and R3) of each concentration and species. Laboratory temperature and humidity conditions were kept at approximately 25 degrees Celsius and 60 percent relative humidity. A grow lamp was suspended approximately 3 feet above Petri dishes used for seed germination to ensure equal distribution of light. Light was turned on for 12 hours and off for 12 hours for one month to allow the selected species to sprout and grow. Controls were moistened with 3mL of distilled water, and replicates were moistened with 3 mL of the leachates. Radish seed were germinated by placing Whatman #1 filter paper in the bottom of Petri dishes and placing 20 radish seeds in each plate, moistened with either distilled water (controls) or leachates (replicates), and covered with Parafilm. Thirty chestnut oak and white oak acorns were placed in each bin (plastic container) on top of sterilized sand and moistened with the distilled water for controls and leachates for the replicates. Ten Muscadine seeds were placed in Petri dishes on Whatman #1 filter paper and moistened with distilled water (controls) and leachates (replicates). The germination rates were counted and sprout lengths measured using a micrometer and recorded at regular intervals (time periods T1, T2, T3, and T4). The effects of the leachates on percent germination and sprout length were analyzed using ANOVA, and the Tukey post-hoc analysis with a confidence level of 95 percent was used to test differences between individual time periods.

RESULTS AND DISCUSSION

Radish Sprouting Percentage and Mean Sprout Length

Radish germination varied between controls and leachates (fig. 1a) with a 95 percent germination rate (control) at time period T1 which slightly increased throughout the measurement period. Germination rates for C1 start at 75 percent at time period T1 measurement and increase to about 81 percent through time period T3 measurement. C2 starts 68 percent sprouting percentage at T1 and increases to about 71 percent through T3. These decreases demonstrate that radish sprouting percentage was inhibited by both leachate concentrations and that C2 inhibited the radish sprouting percentage more than C1.

Radish sprout length (fig. 1b) was measured through three time periods. The control was measured at 8mm in T1 and increased significantly to 35mm through T3. C1 started near 5mm at T1 and increased slowly to 20mm through T3. C2 also started at 5mm at T1 and increased to 19mm through T3. This indicates that C1 and C2 leachates inhibited radish sprout length as mean sprout length for the control was higher and increased more rapidly than the C1 and C2 radish seeds. If sprout lengths are inhibited in natural conditions, ability to compete and survive may be diminished. C2 inhibited the mean sprout length of radish the greatest.

ANOVA results were used to determine if a significant difference between the control and concentrations C1 and C2 during the same period (table 2). For control versus C1 at time period T2, the p-value was less than 0.05, indicating that at time period T2, a significant difference exists between the mean sprout lengths of the control and C1. For control versus C1 at time period T3, there was a significant difference between the mean sprout lengths of the control and C1. For control versus C2 at time periods T2 and T3 a significant difference occurs between mean sprout lengths between the control and C2 for time periods T2 and T3. There was no significant difference between C1 and C2 in sprouting percentage or mean sprout length growth.

Table 1—Results of understory species inventory for species on study plot in Marshall Forest

Species	Muscadine	%	Red Maple	%	Chestnut Oak	%	Pignut Hickory	%	Spotted Wintergreen	%	White Oak	%
Post Oak	30	67	3	7	1	2	6	13	5	11	0	0
Loblolly Pine	12	40	11	37	0	0	6	20	1	3	0	0
Chestnut Oak	12	24	6	12	8	16	3	6	21	42	0	0
White Oak	7	16	9	20	1	2	5	11	17	39	5	11

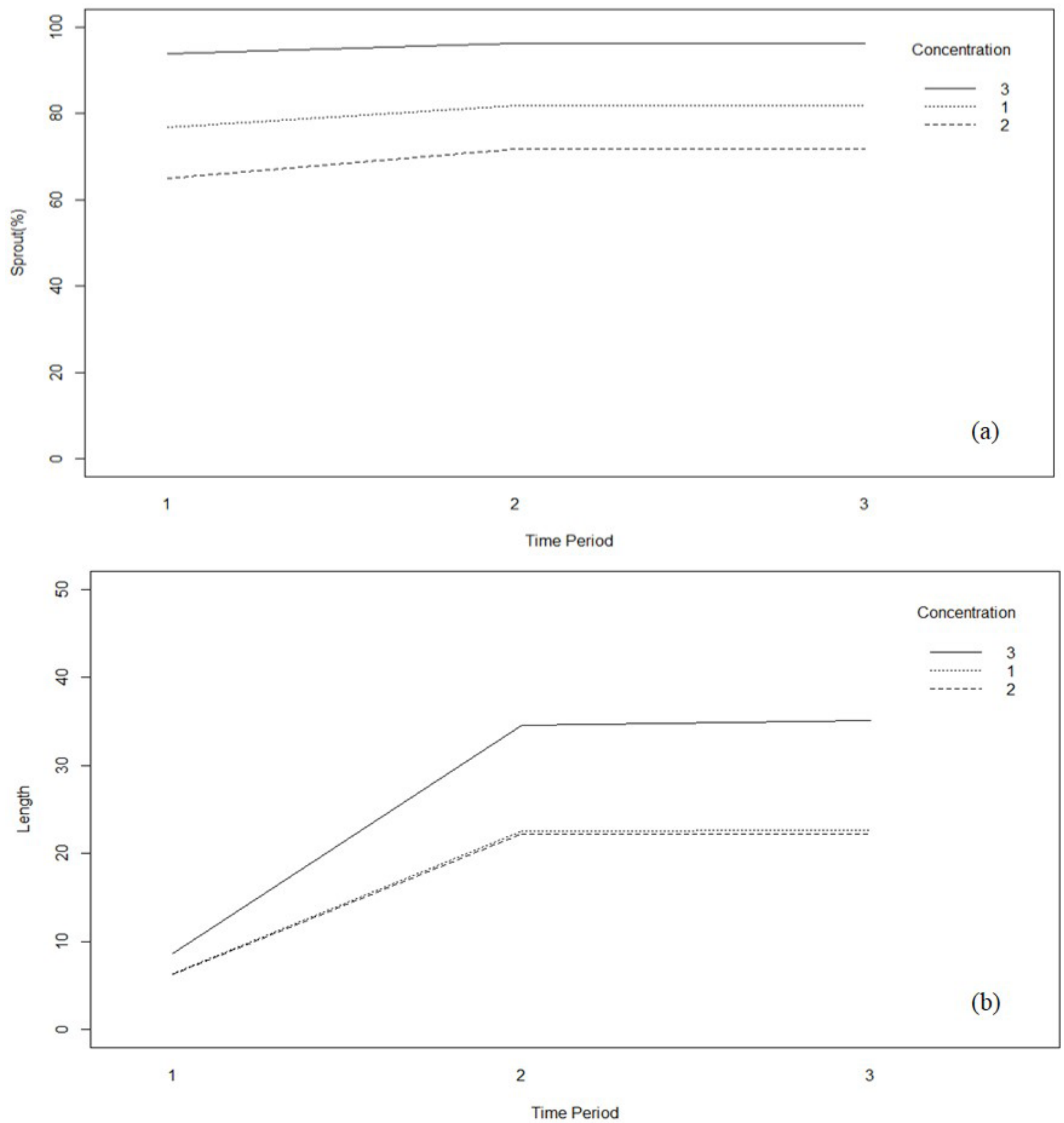

Figure 1—Radish germination (a) and sprout length (b). The start date was September 17, 2014; time period 1(T1) = September 19, 2014; time period 2 (T2) = September 24, 2014; time period 3 (T3) = September 30, 2014.

Table 2—ANOVA results for radish

Concentration	Time Period	P-value
Control	1 vs. 2	<0.05
Control	1 vs. 3	<0.05
C2	1 vs. 2	<0.05
C2	1 vs. 3	<0.05
Control vs. C1	2	<0.05
Control vs. C2	2	<0.05
Control vs. C1	3	<0.05
Control vs. C2	3	<0.05

Both germination and sprout length were inhibited by post oak leachate. This is not surprising, as germination inhibition was noted by Buehler (2010). Given that post oak is commonly planted for shade, these results may be of interest to those with vegetable gardens near post oak trees. Additional tests with other vegetable species (e.g., corn, beans, etc.) would be required.

Chestnut Oak Sprouting Percentage and Mean Sprout Lengths

The chestnut oak control was measured at 37 percent sprouting percentage at T1 and increased to 88 percent through T4. C1 was measured at 25 percent at time period T1 and increased slowly to 47 percent through T4. C2 was measured at 25 percent at time period T1 and increased to 61 percent through T4. These results indicate that C1 and C2 inhibited the sprouting percentage of chestnut oak, but C1 inhibited the sprouting percentage the greatest (fig. 2a).

The mean sprout length of chestnut oak was measured through four time periods (fig. 2b). The control measured 9mm at T1 and increased significantly 50mm through T4. C1 started at 11mm and increased to 31mm through T4. C2 started at 5mm and increased to 36mm through T4. This indicates that C1 inhibited the mean sprout length of chestnut oak greater than C2.

White Oak Sprouting Percentage and Mean Sprout Lengths

White oak controls started at 55 percent sprouting percentage in T1 and increased to 95 percent through T4 (fig. 3a). C1 started at 36 percent and increased to 55 percent throughout the measuring periods to T4. C2 started at 44 percent and increased to 77 percent through T4. These results indicate that C1 inhibited the sprouting percentage greater than C2. These results can also suggest that there is possibly a threshold of how much post oak allelochemicals can inhibit the selected species because doubling the concentration (C2) seems to not inhibit the sprouting percentage or mean sprout lengths more than C1.

The mean sprout lengths for the control started at 5mm at T1 and increased to 33mm through T4. C1 started at 10mm and increased to 21mm though T4. C2 started at 6mm and increased to 15mm through T4. This indicates that C2 inhibited the mean sprout lengths greater than C1 (fig. 3b).

For the ANOVA test, chestnut oak and white oak numbers were combined for mean sprout lengths (table 3). These results showed that there was a significant difference between control and C1 at T3 (p-value 0.0163) and T4 (p-value 0.0172). There was also a significant difference between the control and C2 at time periods T3 (p-value 0.0149) and T4 (p-value 0.0016). There was no significant difference between C1 and C2. It is worth noting that the differences in sprout length are not immediate. Figures 2b and 3b show that it takes approximately two weeks for significant differences between leachates to occur. Where these species (i.e., post oak and white oak) occur together, post oak allelopathic inhibition of germination or sprout length, could lead to a reduction of these species in forests.

Muscadine Sprouting Percentage

Muscadine germination rates for control seeds begin at 35 percent in T1 and slightly increased to 36 percent over the two measuring periods, T1 and T2 (fig. 4). C1 started at 35 percent in T1 and increased to 39 percent at T2. C2 started at 10 percent at T1 and increased to 18 percent at T2. These results are not consistent with the results of other species tested (white oak and chestnut oak), but could possibly be a result of the short measuring period. Mean sprout length could not be graphically displayed due to the small number of germinated seeds.

Overall, species (other than muscadine) exhibit a reduction in germination rates and sprout lengths when leachates were applied. It is also worth noting that in a cursory survey of Marshall Forest, where post oak occurs, there are several trees in relatively close proximity. Other associated species (e.g., hickories and red maple (*Acer rubrum*)) should be tested to see if this relationship holds for such species. The understory plant inventory indicates that red maple may be susceptible to post oak leachate. This would be useful as red maple is increasing in abundance throughout the forest, which is altering the forest composition on Marshall Forest as fire is suppressed.

CONCLUSION

A significant difference was observed for germination and sprout length between the post oak leachate

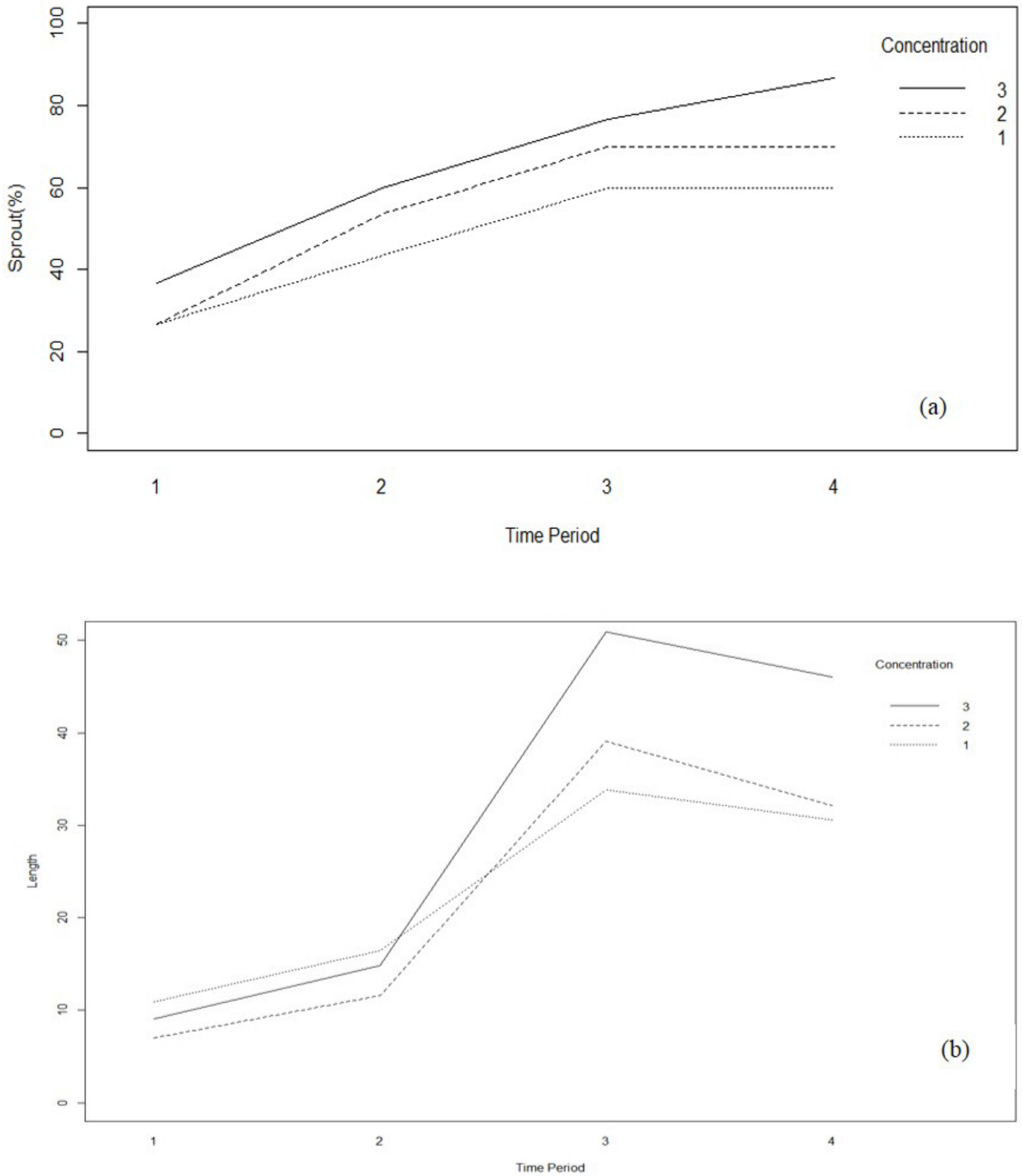

Figure 2—Chestnut oak germination (a) and sprout length (b). The start date was October 31, 2014; time period 1(T1) = November 3, 2014; time period 2 (T2) = November 5, 2014; time period 3(T3) = November 14, 2014; time period 4 (T4) = November 20, 2014.

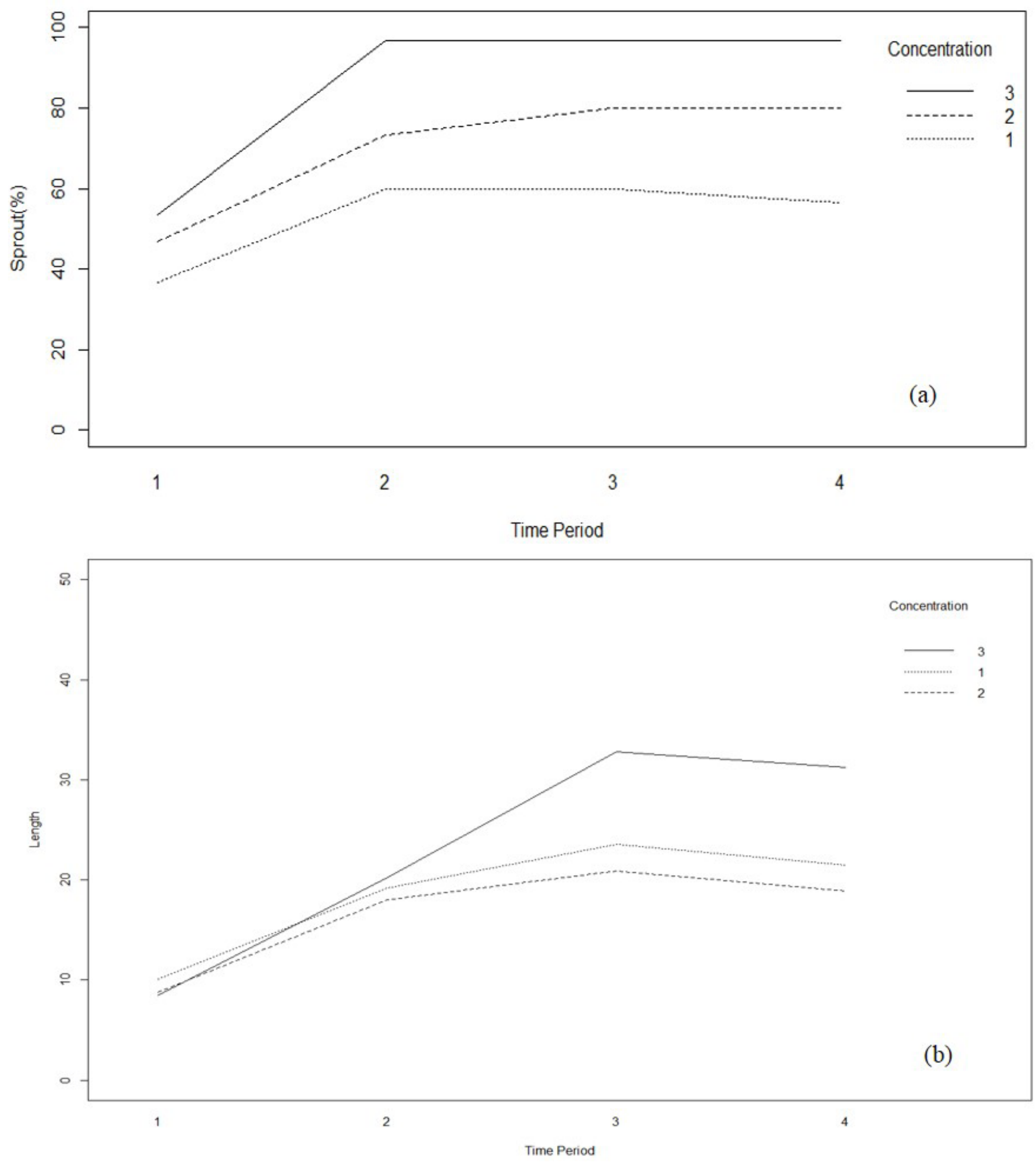

Figure 3—White oak germination (a) and sprout length (b). The start date was October 31, 2014; time period 1 (T1) = November 3, 2014; time period 2 (T2) = November 5, 2014; time period 3 (T3) = November 14, 2014; time period 4 (T4) = November 20, 2014.

Table 3—ANOVA results for oak species (Chestnut oak and white oak combined)

Concentration	Time Period	P-value
Control	1 vs. 3	<0.05
Control	1 vs. 4	<0.05
Control	2 vs. 3	<0.05
Control	2 vs. 4	<0.05
C1	1 vs. 3	<0.05
C1	1 vs. 4	<0.05
C2	1 vs. 3	<0.05
C2	1 vs. 4	<0.05
Control vs. C1	3	<0.05
Control vs. C2	3	<0.05
Control vs. C1	4	<0.05
Control vs. C2	4	<0.05

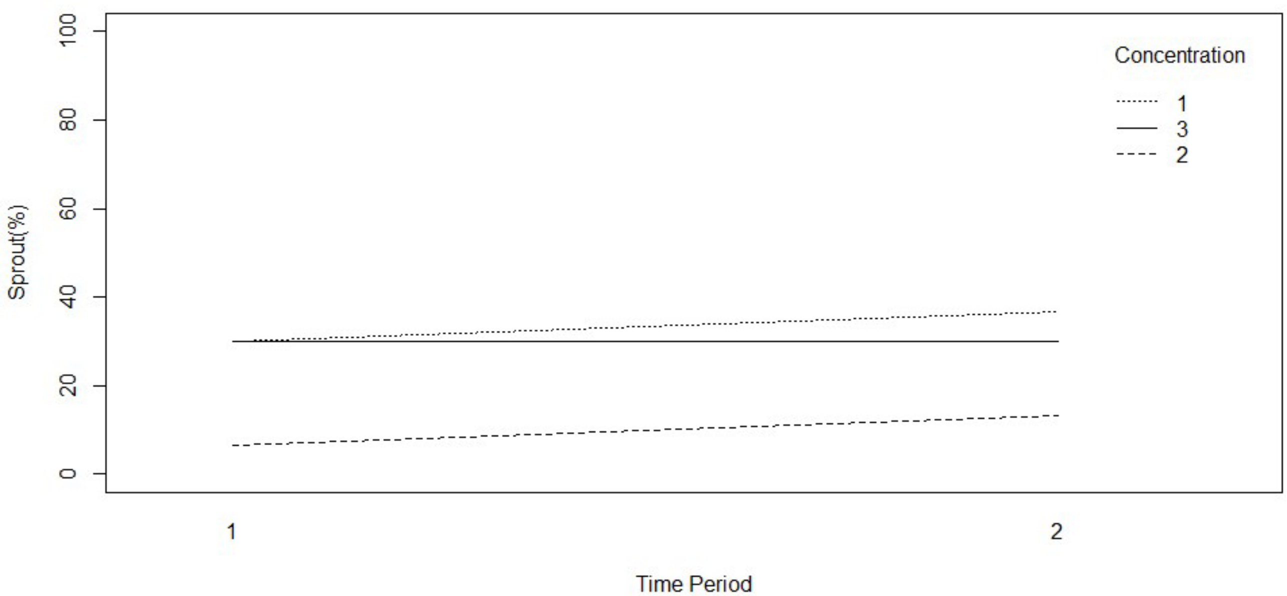

Figure 4—Muscadine germination. The start date was January 21, 2015; time period 1 (T1) = January 29, 2015; time period 2 (T2) = February 5, 2015.

control and different concentration levels (C1 and C2). There was no significant difference between leachate C1 and C2; that is, doubling the concentration of leaves in the leachate had no significant effect. Germination rates for C2 were only slightly higher than for C1. This suggests a fine balance where plants are sensitive to a threshold level of allelochemicals from leaves and increased levels have no additional effect. Marshall Forest is an old-growth forest and serves as a model for natural forest ecosystems in the southeastern United States. Additional species warrant study and may be useful for determining the influence of allelochemicals on forest compositional changes. These results demonstrate that post oak does exhibit allelopathic effects on the selected species by reducing germination rates and inhibiting mean sprout growth. Additional study will elucidate the allelochemical involved and its potential pathway for inhibiting plant germination and sprout growth.

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