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Tables: 3, Figs : 2

# Allelopathic potential of *Sassafras albidum* and *Pinus taeda* essential oils

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## ABSTRACT

The bark essential oil of *Sassafras albidum* was obtained by hydrodistillation and analyzed by GC-MS. The major components were α-pinene (38-62%), camphene (3-5%), β-pinene (10-13%), 1,8-cineole (7-10%), camphor (2-5%) and α-terpineol (4-12%). *Pinus taeda* leaf, bark and wood essential oils were obtained and analyzed by GC-MS. α-Pinene dominated in all three *P. taeda* essential oils (50%, 44% and 67%, respectively), however, β-pinene was also abundant (22%, 8% and 27%, respectively). *P. taeda* bark oil also had large amounts of myrcene (18%) and β-phellandrene (17%). *S. albidum* bark oil and *P. taeda* leaf oil, along with the essential oil components, [α-pinene, camphene, β-pinene, limonene, 1,8-cineole, camphor and α-terpineol] were screened for phytotoxic effects on lettuce (*Lactuca sativa*) and perennial ryegrass (*Lolium perenne*). *S. albidum* bark oil inhibited the seed germination of *L. sativa* ($IC_{50}$ = 1834 µg/mL) and *L. perenne* ($IC_{50}$ = 1848 µg/mL), while, camphor ($IC_{50}$ = 3.1 mM) and α-terpineol ($IC_{50}$ = 2.9 mM) inhibited the germination of *L. sativa*; and β-pinene ($IC_{50}$ = 6.4 mM) and limonene ($IC_{50}$ = 8.8 mM) inhibited *L. perenne* seed germination. Both *S. albidum* bark oil and *P. taeda* leaf oil, as well as all of the major essential oil components tested, but especially α-terpineol, significantly inhibited the radicle elongation of *L. sativa*. Similarly, both essential oils and all of the components except camphene significantly inhibited the radicle elongation in *L. perenne*. The phytotoxic effects of *S. albidum* bark oil and *L. perenne* leaf oil are consistent with their hypothetical allelopathy.

**Key words:** Camphor, cineole, essential oil composition, *Lactuca sativa*, limonene, *Lolium perenne*, pinene, *Pinus taeda*, *Sassafras albidum*, terpineol.

## INTRODUCTION

Numerous essential oils to exhibits the allelopathic activity e.g. *Artemisia* (7,13), *Chenopodium* (20), *Cinnamomum* (11), *Eucalyptus* (51), *Juniperus* (49), *Mentha* (6), *Minthostachys* (4), *Pictacia* (9), *Ruta* (12) and *Tagetes* (37). *Sassafras albidum* (Nutt.) Nees had previously shown allelopathic effects in old-field succession (15) and it has been hypothesized that allelopathic effects may be responsible for the negative host association of poison ivy, [*Toxicodendron radicans* (L.) Kunth.] vines with *S. albidum* (44).

Many herbaceous and woody plants interfere with loblolly pine (*Pinus taeda* L.) seedling growth (16,18,30,42,45). Conversely, allelopathic substances from *Pinus* species inhibit the germination and growth of understory plants (5,14,23,24,28,29,31,39). We have

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observed that grasses do not grow well under stands of loblolly pine (personal observations). Additionally, Spanish moss, *Tillandsia usneoides* L., has shown a negative host preference for *Pinus* species (10,36). To probe the potential allelopathic effects of volatile components in *Sassafras albidum* bark and *Pinus taeda*, we have obtained the essential oils from these plants, determined the chemical compositions and screened the essential oils and major components for phytotoxic activity against two model plants lettuce [*Lactuca sativa* L. (47)] and perennial ryegrass [*Lolium perenne* L. (8)].

## MATERIALS AND METHODS

### I. Essential Oils

The stem bark of *S. albidum* was collected on February 18, 2008, from four different mature trees growing on the campus of University of Alabama, Huntsville (34° 43.34′ N, 86° 38.30′ W, 185 m elevation). The fresh bark samples were chopped and hydrodistilled using a Likens-Nickerson apparatus for 4 h with continuous extraction with dichloromethane to give the essential oils [#1: 51.40 g bark → 0.789 g oil (1.54%); #2: 50.52 g bark → 0.540 g oil (1.07%); #3: 50.12 g bark → 1.069 g oil (2.13%); #4: 51.43 g bark → 1.178 g oil (2.29%)]. *P. taeda* leaves, bark and wood were collected on April 7, 2010, from a mature tree growing on the campus of University of Alabama, Huntsville. The fresh *P. taeda* tissue samples were chopped and hydrodistilled as above using a Likens-Nickerson apparatus to give the essential oils [needles: 200.0 g → 12.753 g oil (6.38%); bark: 46.74 g → 2.733 g oil (5.85%); wood: 77.49 g → 7.602 g oil (9.81%)].

### II. Gas Chromatographic – Mass Spectral Analyses

A gas chromatographic-mass spectral analysis was performed on each of the essential oils using an Agilent 6890 GC with Agilent 5973 mass selective detector (EIMS, electron energy = 70 eV, scan range = 45-400 amu and scan rate = 3.99 scans/s) and a fused silica capillary column (HP 5 ms, 30 m × 0.25 mm) coated with 5% phenyl-polymethylsiloxane (0.25 mm phase thickness). The carrier gas was helium with a flow rate of 1 mL/min and the injection temperature was 200°C. The oven temperature was programmed to initially hold for 10 minutes at 40°C, then ramp to 200°C at 3°C/min and finally to 220°C at 2°C/min. The interface temperature was 280°C. A 1% w/v solution of each sample in dichloromethane was prepared and 1 μL was injected using a splitless injection technique. Identification of the oil components was based on their retention indices determined by reference to a homologous series of *n*-alkanes and by comparison of their mass spectral fragmentation patterns with those reported in the literature (3) and stored on the MS library [NIST database (G1036A revision D.01.00)/ChemStation data system.

### III. Allelopathy Assays

An allelopathic bioassay based on lettuce (*Lactuca sativa*) and perennial ryegrass (*Lolium perenne*) germination and subsequent radicle and hypocotyl growth was done to examine the effects of the essential oil of *S. albidum* and *P. taeda* and the major essential oil components. Pure compounds were purchased from Sigma-Aldrich. Stock solutions of essential oils (2.0 g/L essential oil and 1.0 g/L Tween-80 in water) and the pure compounds (10 mM compound and 1.0 g/L Tween-80 in water) were used. Two-fold serial dilutions of stock test solutions were prepared to give test concentrations of 2000, 1000 and 500 µg/mL (essential oils) and 10, 5 and 2.5 mM (pure compounds). The control was 1.0 g/L aqueous Tween-80. Seeds were placed in 6-well test plates (10 seeds per well) each well lined with two layers of Whatman No. 1 filter paper moistened with test solution. The test plates were sealed with Parafilm. The test plates were incubated at room temperature in dark for 5 days. After 5 days, the number of germinated seeds was determined and the root (radicle) and shoot (hypocotyl) lengths were measured. The allelopathic assay results are summarized in Table 3.

**Statistical analysis:** Calculations were carried out using Excel. Student's *t*-test (50) was used to compare radicle and hypocotyl test means with controls. Seed germination $IC_{50}$ values were determined using the Reed-Muench method (34).

## RESULTS AND DISCUSSION

### ***Sassafras albidum*** **bark essential oil**

The hydrodistillation of bark of *S. albidum* produced pale yellow essential oils in yields ranging from 1.07% to 2.29%. The main components (Table 1) in all four essential oils were monoterpenoids, which included α-pinene (38-62%), β-pinene (10-12%), 1,8-cineole (7-10%), α-terpineol (4-12%), camphene (3-5%), camphor (2-5%) and limonene (2-3%). This was in contrast to the leaf oil compositions of *S. albidum*, which are dominated by geranial (11-27%) and neral (10-18%) (21), or the root bark essential oils, composed largely of safrole (80-85%) (22,38,46).

### ***Pinus taeda*** **essential oils**

The leaves (needles), stem bark and wood of *P. taeda* were hydrodistilled to give 6.38%, 5.85% and 9.81% yields of colourless essential oils, respectively. The leaf oil was composed predominantly of α- and β-pinenes (50.2% and 21.8%, respectively, Table 2). The wood oil was also dominated by α- and β-pinenes (67.2% and 27.2%, respectively), while the bark essential oil, in addition to α-pinene (44.3%) and β-pinene (7.8%), also contained a large concentration of myrcene (17.8%) and β-phellandrene (16.8%). Both α- and β-pinene have been reported to be abundant components of a number of *Pinus* leaf oils (27,33) and these two compounds are the abundant monoterpenes emitted from *P. taeda* pine branches (17). *P. taeda* oleoresin from north Alabama is generally comprised of high α- and β-pinenes, myrcene and β-phellandrene, but low limonene (43), consistent with the bark essential oil composition observed in this present study.

### **Allelopathic activity of essential oils and components**

*S. albidum* bark oil at concentration of 2000 µg/mL inhibited the germination of both lettuce (50% germination) and rye grass (57% inhibition). The major components of *S. albidum* bark oil that showed allelopathic activity, based on inhibition of *L. sativa* seed germination, were camphor and α-terpineol, with $IC_{50}$ values of 3.1 and 2.9 mM, respectively (see Fig. 2). The compounds that inhibited the *L. perenne* germination were α-pinene, β-pinene and limonene ($IC_{50}$ = 4.3, 6.4 and 8.8 mM, respectively).

Table 1. Chemical compositions of *Sassafras albidum* bark essential oils

| RI[a] | Compound | Composition (%) | | | |
|---|---|---|---|---|---|
| | | #1 | #2 | #3 | #4 |
| 941 | α-Pinene | 61.5 | 49.3 | 37.9 | 51.3 |
| 952 | Camphene | 5.1 | 2.9 | 3.1 | 4.1 |
| 977 | β-Pinene | 10.0 | 13.0 | 11.2 | 12.2 |
| 994 | Myrcene | 0.2 | 0.1 | 0.3 | 0.1 |
| 1025 | *p*-Cymene | 0.3 | 0.2 | 0.3 | 0.2 |
| 1029 | Limonene | 3.2 | 2.2 | 1.7 | 3.4 |
| 1033 | 1,8-Cineole | 10.0 | 8.7 | 7.8 | 7.3 |
| 1093 | Terpinolene | Tr[b] | Tr | 0.3 | Tr |
| 1108 | Unidentified | 0.9 | 0.1 | 0.3 | 0.5 |
| 1118 | Fenchol | Tr | 0.2 | 0.4 | 0.1 |
| 1142 | *Trans*-Sabinol | Tr | 1.1 | 2.0 | 0.9 |
| 1148 | Camphor | 1.7 | 4.2 | 4.6 | 2.9 |
| 1165 | Pinocarvone | ND | 0.2 | 0.5 | 0.2 |
| 1167 | Borneol | 0.6 | 1.1 | 1.7 | 1.4 |
| 1178 | Terpinen-4-ol | Tr | 0.4 | 0.8 | 0.4 |
| 1190 | α-Terpineol | 4.2 | 9.4 | 11.6 | 8.6 |
| 1193 | Myrtenol | Tr | 1.3 | 1.4 | 1.0 |
| 1201 | Verbenone | Tr | 0.5 | 1.4 | 0.5 |
| 1459 | (*E*)-β-Farnesene | ND | ND | 0.1 | ND |
| 1477 | *Trans*-Cadina-1(6),4-diene | Tr | Tr | 0.1 | Tr |
| 1501 | α-Muurolene | Tr | 0.1 | 0.3 | 0.1 |
| 1510 | β-Bisabolene | ND | Tr | 0.2 | Tr |
| 1513 | γ-Cadinene | 0.2 | 0.4 | 0.8 | 0.4 |
| 1522 | *Trans*-Calamenene | 0.3 | 0.1 | 0.2 | Tr |
| 1523 | δ-Cadinene | 0.3 | 0.8 | 1.3 | 0.7 |
| 1541 | α-Calacorene | ND[C] | Tr | 0.1 | Tr |
| 1624 | 1-*epi*-Cubenol | ND | Tr | 0.2 | Tr |
| 1639 | τ-Cadinol | 0.7 | 1.5 | 3.9 | 1.4 |
| 1644 | Torreyol | Tr | Tr | 0.8 | 0.2 |
| 1652 | α-Cadinol | 0.9 | 2.2 | 5.0 | 2.1 |

[a]RI = Retention Index determined with respect to a homologous series of normal alkanes, [b]TR = Trace (< 0.1%), [c]ND = not detected.

In addition to inhibiting the germination, *S. albidum* bark oil significantly reduced the radicle growth in *L. sativa*, but was less effective to inhibit the hypocotyl elongation. The most effective compound in inhibiting the *L. sativa* radicle and hypocotyl growth was α-terpineol, but limonene and camphor were also effective. Although not effective in germination inhibition, camphene and β-pinene did inhibit *L. sativa* radicle elongation and limonene inhibited both the radicle and hypocotyl growth. *S. albidum* bark oil significantly inhibited both *L. perenne* radicle and hypocotyl growth, with α-pinene, β-pinene, limonene, camphor and α-terpineol causing significant growth reduction.

*P. taeda* leaf essential oil, although not especially active in terms of inhibition of seed germination, did show growth inhibitory activity, notably on ryegrass (*L. perenne*).

Table 2. Chemical compositions of *Pinus taeda* essential oils

| RI[a] | Compound | Composition (%) | | |
|---|---|---|---|---|
| | | Leaf | Bark | Wood |
| 934 | Tricyclene | 0.1 | 0.2 | 0.1 |
| 945 | α-Pinene | 50.2 | 44.3 | 67.2 |
| 956 | Camphene | 0.4 | 0.5 | 0.7 |
| 979 | β-Pinene | 21.8 | 7.8 | 27.2 |
| 993 | Myrcene | 0.5 | 17.8 | 0.7 |
| 1003 | α-Phellandrene | Tr[b] | 0.3 | ND[c] |
| 1012 | δ-3-Carene | Tr | ND | ND |
| 1018 | α-Terpinene | Tr | ND | ND |
| 1024 | *p*-Cymene | Tr | TR | ND |
| 1028 | β-Phellandrene | 1.7 | 16.8 | 1.9 |
| 1040 | (*Z*)-β-Ocimene | Tr | ND | ND |
| 1050 | (*E*)-β-Ocimene | Tr | ND | ND |
| 1059 | γ-Terpinene | Tr | ND | ND |
| 1086 | Terpinolene | 0.2 | 0.1 | 0.1 |
| 1098 | Linalool | 0.1 | 0.2 | ND |
| 1112 | Phenylethyl alcohol | 0.1 | ND | ND |
| 1138 | Camphor | ND | Tr | ND |
| 1162 | Borneol | Tr | Tr | ND |
| 1171 | (6*Z*)-Nonenol | 0.1 | ND | ND |
| 1174 | Terpinen-4-ol | Tr | Tr | ND |
| 1189 | α-Terpineol | 0.8 | 0.3 | 0.3 |
| 1197 | Methyl chavicol (= Estragole) | ND | ND | 0.2 |
| 1207 | Decanal | 0.1 | ND | ND |
| 1232 | Thymol methyl ether | ND | 0.1 | ND |
| 1241 | Carvacrol methyl ether | ND | Tr | ND |
| 1257 | 2-Phenylethyl acetate | 0.1 | ND | ND |
| 1273 | 1-Decanol | Tr | ND | ND |
| 1286 | Bornyl acetate | 0.1 | ND | ND |
| 1293 | (2*E*,4*Z*)-Decadienal | Tr | ND | ND |
| 1312 | Carvacrol | ND | Tr | ND |
| 1316 | (2*E*,4*E*)-Decadienal | 0.1 | ND | ND |
| 1335 | δ-Elemene | 0.1 | ND | ND |
| 1348 | α-Terpinyl acetate | 0.1 | ND | ND |
| 1372 | α-Copaene | 0.1 | ND | ND |
| 1390 | β-Elemene | 0.7 | ND | ND |
| 1393 | Phenyl ethyl isobutanoate | 0.1 | ND | ND |
| 1403 | Methyl eugenol | 0.1 | 0.2 | 0.2 |
| 1408 | Dodecanal | 0.2 | ND | ND |
| 1417 | α-*cis*-Bergamotene | ND | 0.1 | ND |
| 1420 | (*E*)-Caryophyllene | 3.1 | 2.5 | 0.1 |
| 1428 | β-Copaene | Tr | ND | ND |
| 1436 | α-*trans*-Bergamotene | 0.1 | 0.3 | ND |
| 1438 | Aromadendrene | 0.1 | ND | ND |
| 1443 | 2-Phenylethyl butanoate | 0.3 | ND | ND |
| 1446 | 6,9-Guaiadiene | Tr | ND | ND |
| 1453 | α-Humulene | 0.6 | 0.5 | ND |
| 1458 | Sesquisabinene | ND | Tr | ND |
| 1461 | *cis*-Cadina-1(6),4-diene | 0.1 | ND | ND |
| 1465 | Ethyl cinnamate | Tr | ND | ND |

| RI[a] | Compound | Composition (%) | | |
|---|---|---|---|---|
| | | Leaf | Bark | Wood |
| 1474 | *trans*-Cadina-1(6),4-diene | 0.1 | ND | ND |
| 1477 | γ-Muurolene | 0.3 | ND | ND |
| 1482 | Germacrene D | 1.2 | ND | ND |
| 1485 | β-Selinene | 0.1 | ND | ND |
| 1490 | *trans*-Muurola-4(14),5-diene | 0.1 | ND | ND |
| 1501 | Bicyclogermacrene | 4.7 | ND | ND |
| 1503 | α-Muurolene | 0.3 | ND | ND |
| 1507 | Germacrene A | 0.2 | ND | ND |
| 1515 | γ-Cadinene | 0.7 | ND | ND |
| 1528 | δ-Cadinene | 4.0 | ND | ND |
| 1533 | *trans*-Cadina-1,4-diene | 0.1 | ND | ND |
| 1537 | α-Cadinene | 0.2 | ND | ND |
| 1541 | α-Calacorene | Tr | ND | ND |
| 1563 | (*E*)-Nerolidol | 0.2 | ND | ND |
| 1575 | Germacrene D-4-ol | 0.2 | ND | ND |
| 1577 | Spathulenol | 0.1 | ND | ND |
| 1582 | Caryophyllene oxide | 0.1 | Tr | ND |
| 1592 | Globulol | Tr | ND | ND |
| 1616 | 1,10-di-*epi*-Cubenol | Tr | ND | ND |
| 1628 | 1-*epi*-Cubenol | 0.1 | ND | ND |
| 1631 | γ-Eudesmol | Tr | ND | ND |
| 1641 | τ-Cadinol | 1.5 | ND | ND |
| 1641 | Phenylethyl hexanoate | 1.3 | ND | Tr |
| 1646 | Torreyol (= α-Muurolol) | 0.2 | ND | ND |
| 1653 | α-Cadinol | 2.1 | ND | ND |
| 1714 | (2*E*,6*Z*)-Farnesol | Tr | ND | ND |
| 1737 | Phenylethyl heptanoate | Tr | ND | ND |
| 1812 | Hexadecanal | Tr | ND | ND |
| 1844 | Phenylethyl octanoate | 0.1 | ND | ND |
| 1879 | 1-Hexadecanol | Tr | Tr | ND |
| 1931 | *ent*-Rosa-5,15-diene | Tr | Tr | Tr |
| 1942 | Pimaradiene | Tr | Tr | 0.1 |
| 1957 | (*Z*,*Z*)-Geranyl linalool | ND | 1.1 | ND |
| 1989 | Manool oxide | Tr | 0.4 | 0.1 |
| 1990 | (*E*,*Z*)-Geranyl linalool | ND | 0.4 | ND |
| 2012 | 13-*epi*-Manool oxide | Tr | 0.6 | Tr |
| 2033 | Abieta-8,12-diene | Tr | ND | ND |
| 2081 | Abietadiene | Tr | 0.1 | ND |
| 2148 | Abienol | ND | 3.0 | 0.1 |
| 2147 | Abieta-8(14),13(15)-diene | Tr | ND | ND |
| 2161 | Unidentified diterpenoid | ND | 0.4 | 0.7 |
| 2222 | 3,5-Dimethoxystilbene | ND | Tr | ND |
| 2228 | Unidentified diterpenoid | ND | 0.6 | ND |
| 2299 | 4-*epi*-Abietal | ND | 0.7 | ND |
| 2307 | Abietal | ND | ND | Tr |
| 2309 | Methyl levopimarate | Tr | ND | ND |
| 2340 | Methyl dehydroabietate | Tr | 0.1 | Tr |
| 2382 | Methyl abietate | Tr | 0.2 | ND |
| 2439 | Methyl neoabietate | Tr | 0.2 | Tr |
| 2499 | Methyl 7,13,15-abietaTrienoate | ND | 0.1 | ND |

[a]RI = Retention Index determined with respect to a homologous series of normal alkanes, [b] Tr = Trace (< 0.1%), [c]ND = not detected.

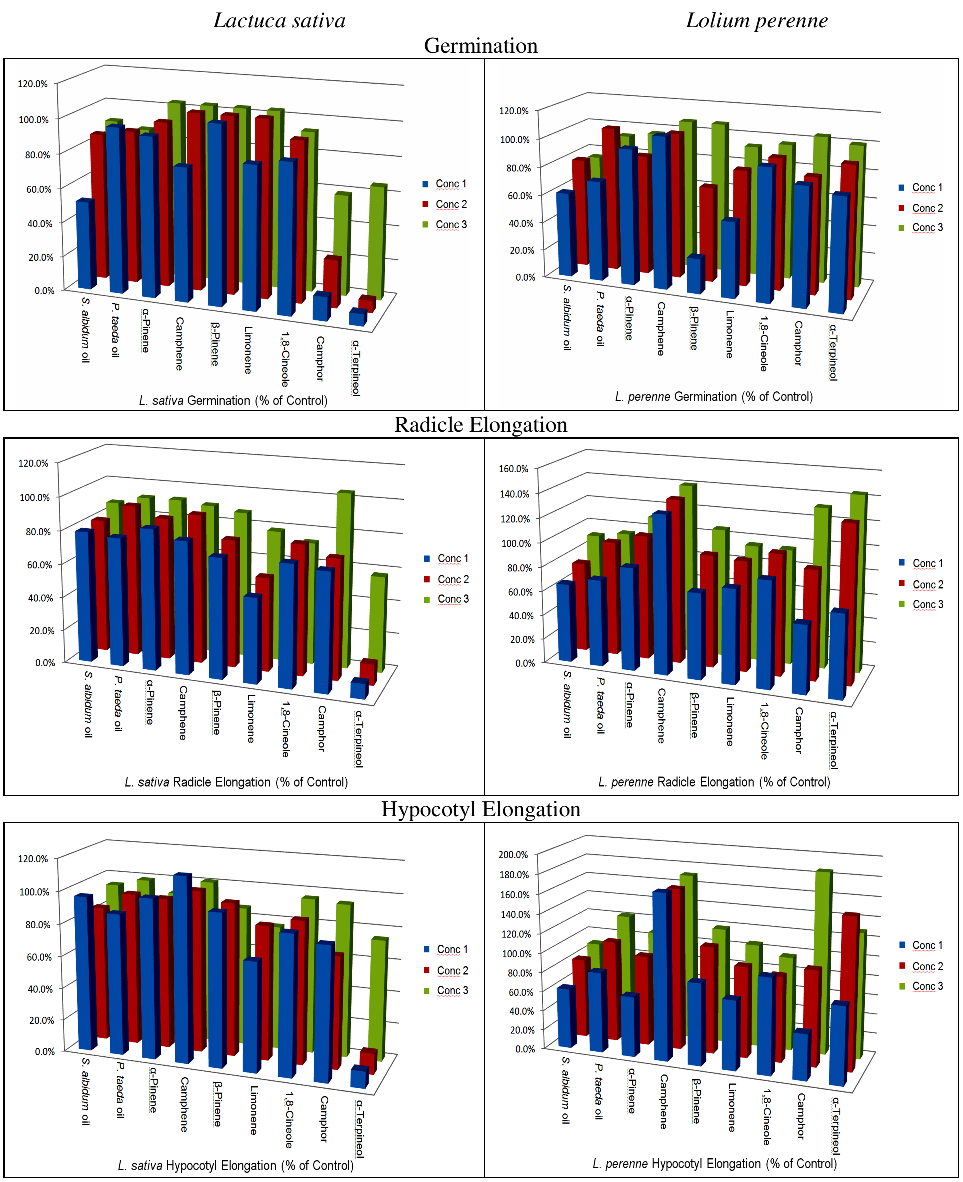


Figure 2. Inhibitory effects of essential oils of *S. albidum*, *P. taeda*, and components on germination and seedling growth of lettuce and rye grass.

Table 3. Inhibitory effects of *Sassafras albidum* and *Pinus taeda* essential oils and essential oil components on seed germination and seedling growth of *Lactuca sativa* and *Lolium perenne*

| Sample | Concentration | *Lactuca sativa* | | | *Lolium perenne* | | |
|---|---|---|---|---|---|---|---|
| | | Germination (%) | Radicle length (mm) | Hypocotyl length (mm) | Germination (%) | Radicle length (mm) | Hypocotyl length (mm) |
| Control[b] | --- | 96.7 | 27.7(6.7) | 19.4(3.5) | 93.3 | 21.4(6.8) | 13.9(4.8) |
| *Sassafras albidum* bark essential oil | 2000 µg/mL | 50.0 | 21.9(7.1)[a] | 18.7(4.3) | 56.7 | 13.9(6.2) | 8.6(4.5) |
| | 1000 µg/mL | 83.3 | 22.4(8.4) | 16.4(5.5) | 73.3 | 15.9(4.7) | 11.4(4.5) |
| | 500 µg/mL | 86.7 | 24.1(8.1) | 18.3(3.3) | 70.0 | 19.4(8.2) | 12.4(5.9) |
| *Pinus taeda* leaf essential oil | 2000 µg/mL | 93.3 | 21.4(7.7) | 17.0(3.8) | 66.7 | 15.3(8.6) | 11.5(8.0) |
| | 1000 µg/mL | 86.7 | 25.3(7.0) | 18.4(4.3) | 96.7 | 20.3(6.7) | 14.5(4.4) |
| | 500 µg/mL | 83.3 | 25.4(10.2) | 19.2(4.7) | 86.7 | 20.3(9.1) | 17.0(5.5) |
| α-Pinene | 10 mM | 90.0 | 23.4(7.9) | 19.2(3.9) | 90.0 | 18.1(7.1) | 8.6(6.5) |
| | 5 mM | 93.3 | 23.7(8.6) | 18.2(4.5) | 80.0 | 22.0(8.3) | 12.9(4.5) |
| | 2.5 mM | 100.0 | 25.5(7.8) | 17.9(3.9) | 90.0 | 23.8(7.6) | 15.0(4.9) |
| Camphene | 10 mM | 75.0 | 22.0(8.6) | 22.1(7.2) | 100.0 | 27.8(11.4) | 23.6(9.8) |
| | 5 mM | 100.0 | 24.8(8.2) | 19.5(4.3) | 96.8 | 28.9(11.0) | 23.0(10.4) |
| | 2.5 mM | 100.0 | 25.0(9.1) | 19.6(4.9) | 100.0 | 30.0(8.4) | 23.8(8.0) |
| β-Pinene | 10 mM | 100.0 | 19.9(7.8) | 18.3(4.5) | 23.3 | 15.1(6.9) | 11.7(5.2) |
| | 5 mM | 100.0 | 21.2(8.8) | 18.4(4.7) | 63.3 | 19.8(10.3) | 15.3(9.6) |
| | 2.5 mM | 100.0 | 24.3(9.2) | 16.8(4.5) | 100.0 | 22.7(8.4) | 16.5(8.2) |
| Limonene | 10 mM | 80.0 | 14.1(5.9) | 13.1(5.4) | 50.0 | 16.5(9.5) | 9.9(5.8) |
| | 5 mM | 100.0 | 15.6(5.8) | 16.1(5.1) | 76.7 | 19.4(8.3) | 13.0(6.9) |
| | 2.5 mM | 100.0 | 21.7(6.4) | 14.9(4.5) | 86.7 | 20.4(12.5) | 14.7(8.2) |
| 1,8-Cineole | 10 mM | 83.3 | 20.1(7.1) | 16.7(4.7) | 86.7 | 18.6(6.4) | 13.6(5.1) |
| | 5 mM | 90.0 | 21.6(7.3) | 17.1(5.7) | 86.7 | 21.3(6.9) | 12.2(3.9) |
| | 2.5 mM | 90.0 | 20.3(6.3) | 18.6(3.9) | 90.0 | 20.3(7.3) | 13.4(5.3) |
| Camphor | 10 mM | 13.3 | 19.5(3.9) | 15.8(8.3) | 77.4 | 11.9(7.1) | 6.5(5.2) |
| | 5 mM | 26.7 | 19.9(7.8) | 13.4(6.4) | 76.7 | 19.2(7.5) | 13.6(6.1) |
| | 2.5 mM | 56.7 | 28.9(7.3) | 18.3(7.9) | 97.0 | 28.1(10.3) | 25.8(6.9) |
| α-Terpineol | 10 mM | 6.7 | 2.5(0.7) | 2.0(0.0) | 73.3 | 14.5(9.7) | 10.9(3.9) |
| | 5 mM | 6.7 | 3.5(0.7) | 2.5(0.7) | 86.7 | 27.5(8.1) | 21.4(4.5) |
| | 2.5 mM | 63.3 | 15.9(8.0) | 14.5(5.5) | 93.3 | 30.8(12.2) | 17.9(4.0) |

[a]Values in bold are significantly different ($P < 0.05$) than controls; standard deviations are in parentheses., [b]Control = 0.1% aqueous Tween-80.

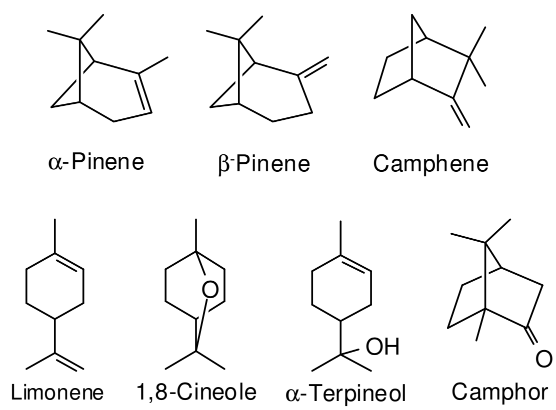


Figure 1. Chemical structures of essential oil components discussed in this manuscript.

Both α-pinene (2,12,41) and β-pinene (9), limonene (9,19,37), 1,8-cineole (26,35,40), camphor (1,7,32) and α-terpineol (24,46), have previously been shown to exhibit allelopathic activity.

Both *Sassafras albidum* bark essential oil and *Pinus taeda* leaf essential oil have shown phytotoxic effects against two model plant species, lettuce and perennial ryegrass. The allelopathic effects of *S. albidum* bark essential oil and the major components are consistent with the negative host preference of poison ivy (*Toxicodendron radicans*), an adventitious-root-climbing vine, for this tree. The growth inhibitory activities of major components of *P. taeda*, α-pinene and β-pinene, are consistent with the allelopathic activity of leaf oil and may account for the observed sparse growth of understory herbaceous plants under *P. taeda*, as well as the negative host association of Spanish moss (*Tillandsia usneoides*) for *Pinus* species.

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