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Leaf essential oil compositions of *Rudbeckia fulgida* Aiton, *Rudbeckia hirta* L., and *Symphyotrichum novae-angliae* (L.) G.L. Nesom (Asteraceae)

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Abstract
The leaf essential oils from three herbaceous members of the Asteraceae, *Rudbeckia fulgida*, *Rudbeckia hirta*, and *Symphyotrichum novae-angliae*, were obtained by hydrodistillation and analyzed by gas chromatography – mass spectrometry. The leaf oils were dominated by sesquiterpene hydrocarbons, mainly (*E*)-caryophyllene (10.0%, 4.7%, and 4.4%, respectively), γ-muurolene (8.9%, 8.1%, and 5.4%, respectively), germacrene D (30.1%, 23.6%, and 25.5%, respectively), and δ-cadinene (17.8%, 16.2%, and 14.3%, respectively). Additionally, (2*E*)-hexenal (6.0%, 20.2%, and 31.0%, respectively) was also abundant in the leaf oils. The essential oils were screened for antimicrobial activity, but were found to be inactive.

Keywords: Orange coneflower, Black-eyed Susan, New England aster.

1. Introduction
The genus *Rudbeckia* (Asteraceae) is made up of 23 North American species [1]. *R. fulgida*, the orange coneflower, and *R. hirta*, the black-eyed Susan, are herbaceous perennial plants native to eastern North America. Both of these species were used by Cherokee Native Americans to treat earache, sores, venereal diseases, and worms [2]. *Symphyotrichum*, represented by 91 species in eastern Asia and 76 species in North America, was formerly included in the genus *Aster* [1]. *S. novae-angliae*, the New England aster, is also an herbaceous perennial native to eastern North America. The Cherokee used this plant to relieve fever and treat pains [2]. To our knowledge, the essential oils of these three medicinal plants have not been previously investigated, and in this work we present the chemical compositions and antimicrobial screening of the leaf essential oils.

2. Materials and Methods
2.1 Plant Material
Plant materials were obtained from *R. fulgida*, *R. hirta*, and *S. novae-angliae*, grown from seeds (Prairie Moon Nursery, Winona, Minnesota), growing in Huntsville, Alabama, in June, 2014. The fresh leaves (39.20, 67.62, and 37.29 g, respectively) were each hydrodistilled for 4 h using a Likens-Nickerson apparatus with continuous extraction with $CHCl_3$ to obtain the clear colorless essential oils (857, 1294, and 1003 mg, respectively).

2.2 Gas Chromatography – Mass Spectrometry
GC-MS analyses of the three leaf essential oils were carried out using an Agilent 6890 GC with Agilent 5973 mass selective detector as previously described [3]. Identification of the oil components was achieved based on their retention indices (determined with reference to a homologous series of normal alkanes), and by comparison of their mass spectral fragmentation patterns with those reported in the literature [4] and stored on the MS library [NIST database (G1036A, revision D.01.00)/ChemStation data system (G1701CA, version C.00.01.08)].

2.3 Antimicrobial Screening
The three leaf essential oils were screened for antimicrobial activity against *Bacillus cereus*,

Staphylococcus aureus, *Escherichia coli*, *Pseudomonas aeruginosa*, and *Candida albicans* using the microbroth dilution technique as previously described [5].

3. Results and Discussion

The leaf essential oil compositions of *R. fulgida*, *R. hirta*, and *S. novae-angliae* are summarized in Table 1. The essential oil of *R. fulgida* was dominated by the sesquiterpene hydrocarbons germacrene D (30.1%), δ-cadinene (17.8%), (*E*)-caryophyllene (10.0%), and γ-muurolene (8.9%), with lesser quantities of (*E*)-β-ocimene (6.2%) and (2*E*)-hexenal (6.0%). The leaf oil of *R. hirta* was qualitatively similar with 23.6% germadrene D, 16.2% δ-cadinene, 4.7% (*E*)-caryophyllene, 8.1% γ-muurolene, 15.2% (*E*)-β-ocimene, and 20.2% (2*E*)-hexenal. *S. novae-angliae* showed a somewhat different leaf oil composition with a large concentration of (2*E*)-hexenal (31.0%) and 16.4% α-pinene (not observed in the *Rudbeckia* leaf oils), along with 25.5% germacrene D, 14.3% δ-cadinene. (*E*)-Caryophyllene, germacrene D, and δ-cadinene are, of course, common components of many essential oils, but they are especially abundant in some members of the Asteraceae [6]. Thus, for example, the essential oils of *Ageratum fastigiatum* [7], *Clibadium leiocarpum* [3], and *Vernonia scorpioides* [8], are rich in these sesquiterpenes.

Table 1: Chemical compositions of the leaf essential oils of *Rudbeckia fulgida*, *Rudbeckia hirta*, and *Symphyotrichum novae-angliae*.

RI[a]	Compound	Composition (% ± SD)[b]		
		R. fulgida	***R. hirta***	***S. novae-angliae***
863	(2*E*)-Hexenal	6.0±0.2	20.2±0.8	31.0±5.0
943	α-Pinene	---	---	16.4±2.6
995	Myrcene	1.3±0.2	3.7±0.0	---
1051	(*E*)-β-Ocimene	6.2±0.4	15.2±0.2	---
1419	(*E*)-Caryophyllene	10.0±0.1	4.7±0.8	4.4±1.0
1453	α-Humulene	2.2±0.1	0.9±0.0	0.3±0.0
1478	γ-Muurolene	8.9±1.3	8.1±0.8	5.4±2.3
1482	Germacrene D	30.1±4.4	23.6±1.8	25.5±5.9
1495	γ-Amorphene	2.5±1.0	1.7±0.5	tr[c]
1497	Bicyclogermacrene	3.2±0.7	1.5±1.2	0.2±0.1
1515	γ-Cadinene	4.9±0.4	3.4±0.1	2.0±1.2
1525	δ-Cadinene	17.8±2.1	16.2±1.4	14.3±7.4
1537	α-Cadinene	1.1±0.1	0.8±0.0	tr
1551	Elemol	3.6±2.4	---	---
1642	τ-Muurolol	0.7±0.6	---	---
1656	α-Cadinol	1.8±2.0	---	---

[a] RI = Retention Index determined with reference to a homologous series of *n*-alkanes on an HP-5ms column.
[b] Percentages are averages (± standard deviations) of three measurements and are based on total ion current without standardization.
[c] tr = "trace" (< 0.5%).

The leaf essential oils were screened for antimicrobial activity using the microbroth dilution technique (see Table 2). The essential oils were largely inactive in these assays, consistent with the relative inactivities of the major components (*E*)-caryophyllene and germacrene D [9].

Table 2: Antimicrobial activity (MIC, μg/mL) of *Rudbeckia fulgida*, *Rudbeckia hirta* and *Symphyotrichum novae-angliae* leaf essential oils.

	Rudbeckia fulgida	***Rudbeckia hirta***	***Symphyotrichum novae-angliae***
Bacillus cereus	625	312.5	625
Staphylococcus aureus	1250	1250	1250
Escherichia coli	625	625	625
Pseudomonas aeruginosa	1250	625	1250
Candida albicans	1250	1250	1250

4. Conclusions

The leaf essential oils of *Rudbeckia fulgida*, *Rudbeckia hirta*, and *Symphyotrichum novae-angliae* were obtained by hydrodistillation and analyzed by GC-MS. All three essential oils were found to be rich in the sesquiterpene hydrocarbons germacrene D, (*E*)-caryophyllene, and δ-cadinene. The leaf oils were screened for antimicrobial activity, but were found to be inactive.

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