

Forrest A. Sneva

USDA, Agricultural Research Service
Star Route 1—4.51 Highway 205
Burns, Oregon 97720

Al Winward

USDA, Forest Service
Ogden, Utah 84401

and

Rick G. Kelsey

Department of Chemistry
University of Montana
Missoula, Montana 59812

Nitrogen Fertilization Effects on the Essential Oils in Sagebrush¹

Abstract

Total essential oil concentrations in low sagebrush (*Artemisia arbuscula* Nutt. ssp. *arbuscula*), mountain big sagebrush (*A. tridentata* ssp. *vaseyana* (Rydb.)), and Wyoming big sagebrush (*A. tridentata* ssp. *Wyomingensis* Beetle) as influenced by N and S fertilization were examined. No significant effects were found due to large variation in oil levels between plants within a fertilizer treatment. A tendency for lower oil concentrations in fertilized mountain and Wyoming big sagebrush was evident, whereas levels of oil in low sagebrush were almost nil, regardless of treatment.

Introduction

The essential oils were the first group of secondary metabolic products in sagebrush foliage to be isolated and studied chemically (Adams and Oakberg 1934, Kinney *et al.* 1941). Monoterpenes are the major constituents in these oils, and their bacteriostatic and antibiotic effects toward rumen microbes lead investigators to suspect an ecological role for these compounds by influencing digestion and shrub consumption (Nagy *et al.* 1964; Nagy and Tengerdy 1967, 1968). In the subsequent years there has been an explosion of research (as cited by the following works) on all species of these oils: 1) their chemical makeup (Scholl 1976, Buttkus *et al.* 1977, Noble 1978, Gaudioso 1980, Welch and McArthur 1981); 2) influence on shrub palatability (Sheehy 1975, Scholl 1976) and digestion (Welch and Pederson 1981); and 3) response to environmental factors (Powell 1968).

In this article we present information on how the total concentration of essential oils in *A. arbuscula* Nutt. ssp. *arbuscula* (low sagebrush), *A. tridentata* ssp. *Wyomingensis* Beetle (Wyoming big sagebrush), and *A. tridentata* ssp. *vaseyana* (Rydb.) Beetle (mountain big sagebrush) responds to commercial fertilizer applied over a number of years.

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Methods

The Wyoming sagebrush site at 1403 m elevation was located on the Squaw Butte Experiment Station, 68 km west of Burns, Oregon. Sites supporting mountain big sagebrush at 1433 m and low sagebrush at 1403 m elevation were situated on Sagehen summit, 40 km west of Burns. Soils underlying these stands are unclassified but are sandy-loams with indurated restrictive layers cemented by siliceous materials occurring from 20-30 cm below the surface. Annual precipitation is approximately 28 cm on all sites.

The Wyoming big sagebrush site was plowed and seeded to crested wheatgrass (*Agropyron desertorum*) [Fisch] Schult.) in 1951-1952 but was rapidly reclaimed by the shrubs. In 1971, field experiments were initiated to assess the relative competition between sagebrush and crested wheatgrass when fertilized with nitrogen and sulfur.² A randomized complete block design with four replications and four treatment plots (9 x 18 m) was established. Plots were fertilized in the fall as follows:

1. Four consecutive years (1971-1974) of annual applications at 22.4 kg/ha of N.
2. A single application in 1971 at 134 kg/ha of N.
3. Applications in 1971 and 1974 at 67 kg/ha of N each.
4. No fertilizer.

From 1-7 May 1975 five plants were selected at random in each treatment plot. Approximately 20 g (oven dry) of current season's growth (twig and leaf) were plucked from each shrub, sealed in plastic storage bags, and maintained in a frozen state until analyzed. Total volatile oils of each sample (twigs and leaves) were determined by steam distillation at Oregon State University (Sheehy 1975).

The mountain big sagebrush and low sagebrush sites were studied in a different time frame. Two 0.4 ha plots were established within each species during 1975 and fertilizer applied to one plot at each site as follows:

1975:	24 N - 10P - 4S	(kg/ha)
1976:	18 N - 10P - 22S	(kg/ha)
1977:	None	
1978:	30 N	(kg/ha)
1979:	20 N	(kg/ha)

Current season's growth of twigs and leaves (100 g) was obtained from each of three randomly selected plants in each plot from 12-18 September 1980. These tissues were loosely packed in airtight plastic freezer cartons and maintained in a frozen state. Prior to analysis the material was frozen in liquid nitrogen and gently stirred to dislodge the leaves from the twigs. The woody tissue was removed and the volatile oils in the leaves only quantified by 2 hours of steam distillation on duplicate samples (Kelsey *et al.*, in press). A small sample was used for determining leaf moisture content (oven dried at 100°C). Concentrations of oils in this report are expressed as a percent of oven dry leaf weight.

Results and Discussion

The mean concentration of volatile oils in Wyoming big sagebrush was 3.7 percent \pm 1.0 percent (standard deviation) in plants from unfertilized plots and decreased to

² NH_4NO_3 + 6 percent sulfur.

2.3 ± 0.8, 2.9 ± 0.8, 2.8 ± 1.1 percent in plants from treatment 1, 2, and 3, respectively. However, due to the great variation in volatile oil concentrations between individual plants (ranges from 1.1 to 6.1 percent), significant differences could not be established for treatments at the 5 percent probability level. This finding supports the conclusions of Welch and McArthur (1981) that the quantity of oil is strongly influenced by genetic makeup.

Concentrations of essential oils in mountain big sagebrush were 5.4 ± 2.5 and 4.4 ± 1.5 percent of dry leaf tissue for unfertilized and fertilized plants, respectively. Significant differences between treatments were not established at the 5 percent level because of large variation for plants within a treatment with oil levels in the control group ranging from 3.0 to 8.1 percent. However, as observed in *wyomingensis*, there was a tendency for lower concentrations of oils in fertilized plants.

All *A. arbuscula* contained only trace quantities of volatile oils, regardless of fertilizer treatment. The laboratory apparatus and techniques used have previously determined levels as low as 0.5 percent oil successfully. Sheehy (1975) reported 0.0 to 0.5 percent oil concentrations in low sagebrush collected from three eastern Oregon sites. In Montana, Scholl (1976) reported summer concentrations in *A. arbuscula* to be much higher (1.71 percent).

No quantitative measurements of sagebrush growth were made; but, increased leader length, denser foliage, and increased numbers of reproductive stems were observed on fertilized plots. Thus, even though differences were not statistically significant, the lowest oil levels were associated with vegetation that had visually responded to N with increases in vegetative material, which possibly diluted the concentrations. Alternatively, monoterpene biosynthesis could have been reduced if the energy from available photosynthate and stored reserve compounds was channeled into primary metabolism required in the formation of the additional vegetative tissue on fertilized plants (Loomis and Croteau 1973).

Mean oil concentrations in these studies not only reflect differences among sagebrush taxa but also plant component differences. The mean concentration for Wyoming sagebrush is that representing twigs and leaves as compared with that of leaves only for mountain big sagebrush and low sagebrush. Neither the oil concentration in the two compartments nor the proportion of leaves to twig for current season growth for the different sagebrush taxa has been adequately addressed by research.

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