Seasonal Variation of Monoterpenoids in Big Sagebrush [Artemisia tridentata]

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Abstract

Monthly monoterpenoid content was determined for 16 big sagebrush (Artemisia tridentata) plants grown on a uniform garden. These 16 plants were selected at random from 4 accessions of basin big sagebrush (A.t. ssp. tridentata)—4 plants per accession. A composite sample was taken for a fifth accession of mountain big sagebrush (A.t. vaseyana). Monoterpenoid content varied seasonally with the lowest content occurring during May (0.97% of dry matter). Highest monoterpenoid content occurred during July (4.18%) followed by August (3.36%) and September (2.73%). Dove Creek (2.61% of dry matter) and Marysvale (2.64%) basin big sagebrush accessions contained significantly higher pooled levels of monoterpenoids than the Indiana (1.73%) and Loa (1.55%) big sagebrush accessions. The composite samples of the Indian Peaks mountain big sagebrush accession, an accession significantly preferred over the Marysvale and Loa accessions, contained an overall monoterpenoid level of 2.82%. Adverse relationships between monoterpenoid content and the consumption of big sagebrush by wintering mule deer seem weak.

Monoterpenoids, also called “volatile or essential oils,” have been implicated as having an adverse effect on the preference of wintering mule deer (Odocoileus hemionus) for accessions of big sagebrush (Artemisia tridentata) (Nagy and Regelin 1977, Nagy 1979). This means that wintering mule deer would prefer accessions or plants of big sagebrush with the lowest monoterpenoid content. In general, wintering mule deer in Utah and Oregon prefer subspecies vaseyana over subspecies tridentata and wyomingensis (Hanks et al. 1973, McArthur et al. 1979, Sheehy and Winward 1981, Welch et al. 1981). Welch and McArthur (1981) reported that in a uniform garden the preferred subspecies vaseyana contained significantly higher winter levels of monoterpenoids than subspecies tridentata and wyomingensis. This conflicts with the idea that monoterpenoids have an adverse effect on the preference of wintering mule deer for big sagebrush.

The use of big sagebrush by mule deer is cyclic. Mule deer start consuming significant levels of big sagebrush in the mid to late fall period. Peak big sagebrush consumption occurs during winter and then declines to almost zero in mid to late spring (Leach 1956, Kutfeld et al. 1973, Tueller 1979, Medin 1980, Welch et al. 1981). Leach (1956), Welch and Andrus (1977), Medin (1980), and Medin and Anderson (1979) noted that other types of forages were almost continuously available for wintering mule deer consumption. Deer did not have to consume big sagebrush. Tueller (1979), however, reported a lack of choice among forages for the deer units he studied. If monoterpenoids negatively influence big sagebrush consumption, then it would be expected that maximum consumption (winter) should occur during periods of lowest monoterpenoid content. Also, among accessions of known preferences (Welch et al. 1981), the most preferred accessions should contain the least amount of monoterpenoids. Therefore, we undertook this study to determine the seasonal variation of monoterpenoid content in big sagebrush in an attempt to determine influence of monoterpenoids on the cyclic use of big sagebrush. We used accessions of known preference to mule deer to facilitate interpretations.

Materials and Methods

From a uniform shrub garden near Helper, Utah, 4 accessions of basin big sagebrush (A. tridentata ssp. tridentata) were chosen to determine the seasonal variation of monoterpenoids. These 4 accessions were Dove Creek, Marysvale, Indiana, and Loa. Each accession was represented by 4 plants selected at random. The same 4 plants per accession were used throughout the study. An accession of mountain big sagebrush (A. tridentata ssp. vaseyana) from the Indian Peaks area of Utah was selected because of the higher preference that deer have for this accession. Because of smaller plant size and higher utilization, composite samples of the Indian Peaks accession were taken to ensure enough tissue for the study. Wild mule deer feed in this garden from about November to April. The preference for these 5 accessions is known (Scholl et al. 1977, Welch and McArthur 1979, Welch et al. 1981).

Vegetative samples of current-year leaves and stems were collected randomly over the entire crown of each ssp. tridentata plant. Collections were made during the middle of each month (January through November 1980). After the November collection, some of the plants lacked terminal buds; therefore, further sampling would not have been the same as in the preceding sampling periods. All samples were collected within a 90-minute period (10:00-11:30 a.m.) (Nicholas 1973). Tissue (leaves and stems) collected from a given ssp. tridentata plant was placed in a paper bag and frozen on site with dry ice. For mountain big sagebrush, the Indian Peaks accession, 4 vegetative shoots of current year’s growth were removed from each of the plants in the Indian Peaks row, pooled in a paper bag, and frozen. Samples were transported in a cooler to the laboratory. At the laboratory the samples were placed in plastic bags, tied, and stored in a freezer (−35°C) until needed for grinding and extraction.

Samples were ground with liquid nitrogen using a motorized steel mortar and pestle. Extracting and analyzing for monoterpenoids has been described by Welch and McArthur (1981).

The data for this study are expressed on a percent dry matter basis. A randomized analysis of variance was used to detect significance among accessions of big sagebrush and among months. Tukey’s multiple-range test (a=0.05%) was used to detect significance among treatment means. Data were transformed to arcsin. (The Indian Peak accession of mountain big sagebrush was not included in the analysis of variance.)

Results

The overall mean monoterpenoid content for all accessions and dates was 2.2%. Analysis of variance detected significant effects due to accessions and dates. Monoterpenoid production in big sagebrush is cyclic (Fig. 1). Monoterpenoid content reaches a low level during the spring months of April and May. Maximum content is reached in the summer months of July and August.
Table 1. Seasonal variation of big sagebrush monoterpenoids (Tukey's B range test*) from plants were grown in a uniform garden. Data expressed as percent of dry matter.

<table>
<thead>
<tr>
<th>Month</th>
<th>May</th>
<th>April</th>
<th>March</th>
<th>February</th>
<th>June</th>
<th>July</th>
<th>August</th>
<th>September</th>
<th>October</th>
<th>November</th>
<th>December</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value</td>
<td>0.97</td>
<td>1.36</td>
<td>1.43</td>
<td>1.53</td>
<td>1.73</td>
<td>1.97</td>
<td>2.03</td>
<td>2.43</td>
<td>2.73</td>
<td>3.36</td>
<td>4.18</td>
</tr>
</tbody>
</table>

*Values not connected by a common line are significantly different. (α=0.05 percent).


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Impact of Feral Herbivores on Mamane Forests of Mauna Kea, Hawaii: Bark Stripping and Diameter Class Structure

PAUL G. SCOWCROFT AND HOWARD F. SAKAI

Abstract

Management of feral and Mouflon sheep and feral goats within the Mauna Kea Forest Reserve/Game Management area has been criticized as inadequate to prevent the adverse environmental impact which these introduced herbivores have on native components of the scrub forest ecosystem. This study determined the intensity of bark stripping of mamane (Sophora chrysophylla), a small endemic leguminous tree, by these animals and assessed the impact of their browsing on the size class structure of mamane stands. In all but one of the 4 areas sampled, a high proportion of mamane trees bore bark stripping wounds. Differences in the amount of stripping between elevations in a given area, and between areas, were attributed to differences in browsing pressure, which in turn was dependent on the frequency of human disturbance and the behavioral traits of the herbivores. Tree size class distributions revealed that browsing has suppressed mamane reproduction in some areas. Suppression appeared to be the greatest in the most heavily browsed areas.

Mamane (Sophora chrysophylla), an endemic leguminous tree (< 12 m tall), is a principal component of the scrub forest ecosystems found on Mauna Kea, on the island of Hawaii, at 1800 to 2900 m (6000 to 9500 ft) elevation. The species plays a vital role in the survival of the Palilia (Psirtirostra bailleui), an endangered endemic bird found only in the scrub forests on Mauna Kea. The Palilia depends on mamane for food, shelter, and nest sites (Berger et al. 1977). To the best of our knowledge, the species could not survive without mamane.

Mamane is also a preferred browse species for three introduced herbivores (Griffin 1976): feral sheep (Ovis aries), feral goats (Capra hircus), and Mouflon sheep (Ovis musimons). These animals not only eat shoots, leaves, and flowers, but bark as well, particularly the thin bark of young trees. Such wounds increase the likelihood of invasion by harmful insects and disease organisms that could kill trees or reduce their vigor.

Bark stripping by deer is a recognized problem in the forests of Europe, England, and parts of North America (Chard 1970, Murie 1951, Szczersinski 1966, Ueckermann 1960). McIntyre (1972), summarizing the more plausible hypotheses to explain why animals strip bark, included these:

a. Bark is high in lignin, a good source of necessary roughage.

b. Fresh bark, during droughts, can be a source of moisture.

c. Interaction of animal density and habitat quality is such that as animal density increases or habitat quality decreases, bark stripping increases.

Any or all of these reasons may apply to bark stripping on Mauna Kea.

This study was conducted to determine the intensity of bark stripping of mamane within the Mauna Kea Forest Reserve/Game Management Area and to describe the diameter class structure of mamane in areas sampled.

Study Areas

Four study areas (Fig. 1) were selected: Puu Laau, Kaluamakani, Hale Pohaku, and Pohakuloa. Browsing pressures differed among these areas, as did the vegetation.

The Puu Laau area, on the west side of the mountain, has open stands of pure mamane, ranging from 2 to 12 m (6 to 40 ft) tall. At lower elevations, the relatively dense ground cover consists primarily of introduced grasses, including Kentucky bluegrass (Poa pratensis), Yorkshire fog (Holcus lanatus), and sweet vernal-grass (Anthoxanthum odoratum). These species gradually become less common with increasing elevation, giving way to native grasses, principally Trisetum glomeratum and Agrostis sandwicense. The soil is medium over cindery, isomesic, typic vitrandept (Soil Conserv. Serv. 1973, 1975). Permeability is rapid and runoff slow. Rainfall averages 508 mm (20 inches) per year (State of Hawaii 1970). Daytime temperatures rarely exceed 24°C (75°F).

In the Kaluamakani area, on the north side of the mountain, mamane is the only tree species. Grasses are less abundant than at Puu Laau, and pukiawe bushes (Styphelia tameiameiae) are common in the understory. Climatic and edaphic features are similar to those at Puu Laau.

The Hale Pohaku area is adjacent to the paved Mauna Kea summit road on the south side of the mountain. Again, mamane is the only tree species in the area, and grows to an average canopy height of about 5 m (15 ft). The understory is composed mostly of...