Biochemical Systematics and Ecology 46 (2013) 73–78

Contents lists available at SciVerse ScienceDirect

Biochemical Systematics and Ecology

journal homepage: www.elsevier.com/locate/biochemsyseco

Differences in chemical composition between browsed and non-browsed *Juniperus ashei* Buch. Trees

Robert P. Adams [a,*], James P. Muir [b], Charles A. Taylor [c], Travis R. Whitney [d]

[a] *Biology Dept., Baylor University, Waco, TX 76798, USA*
[b] *Texas AgriLife Research, Stephenville 76401, USA*
[c] *Texas AgriLife Research, Sonora 76950, USA*
[d] *Texas AgriLife Research, San Angelo 76901, USA*

ARTICLE INFO

Article history:
Received 17 August 2011
Accepted 8 September 2012
Available online xxx

Keywords:
Juniperus ashei
Terpenoids
Deer and goat browse
Condensed tannins
Diet selection

ABSTRACT

Leaf secondary compounds were examined in browsed and non-browsed *Juniperus ashei* trees to identify selective browsing patterns by goats and deer. Analysis of volatile leaf oils (terpenoids) revealed that the browsed trees were lower in total oil than non-browsed trees (2.18 vs. 3.46%, DW basis). Extractable and fiber-bound condensed tannins (CT) were not different but protein-bound CT concentrations were greater in browsed trees. Among digestibility measures (NDF, ADF, IVDMD), IVDMD was greater in non-browsed leaves. Terpene components analyzed on a percent total oil basis had 3 differences versus 12 significant differences on a mg/g DW basis. The terpenoid components profile differed little between browsed and non-browsed trees. Total CT are negatively associated with oil yields. No association was found between crude protein and oil yields or between digestibility (IVDMD, NDF, ADF) and oil yields. The question of whether individual plants or populations may invest less in CT when greater amounts of terpenes are produced (or vice-versa) may have evolutionary implications since individual browsers or populations may adapt to consuming or avoiding either CT or terpenes. The fact that browsed tree leaves were less digestible than non-browsed tree leaves may be a result of complex interactions between CT, terpenes, fiber, and nutrients.

1. Introduction

The genus *Juniperus* contains species with a large array of terpenoids and other secondary compounds (Adams, 2011). It is common to find trees that have been browsed by deer (as well as domestic goats and sheep). Schwartz et al. (1980a) observed browsing by deer and then tested confined deer in feeding trials using foliage of *Juniperus deppeana*, *Juniperus monosperma* and *Juniperus scopulorum*. They found the consumption of juniper foliage varied inversely with the total oil yields among these three species. Schwartz et al. (1980a) also found the levels of oxygenated terpenoids were a greater feeding deterrent than the amount of hydrocarbon terpenoids. Recently, Marko et al. (2008) reported that leaf essential oil concentrations were lowest in *Juniperus communis* heavily browsed by sheep and rabbit and highest in non-browsed plants.

Juniper foliage intake by goats has been shown to be limited by the presence of monoterpenes (Riddle et al., 1996; Pritz et al., 1997). Monoterpenes have a clearly defined ecological defensive role as feeding deterrents in a variety of mammals and

* Corresponding author. Tel.: +1 806 733 2633.
E-mail address: Robert_Adams@baylor.edu (R.P. Adams).

0305-1978/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.bse.2012.09.020

insects (Gershenzon et al., 1992). Negative post-ingestive consequences experienced by large ungulates following consumption of high levels of monoterpenes include rumen microbial inhibition (Oh et al., 1967; Schwartz et al., 1980b), hepatic pathogenesis (Straka, 1993; Bisson et al., 2001; Pritz et al., 1997), and feeding cessation (Dziba et al., 2006). Furthermore, the presence of condensed tannins (CT) in plant leaves has long been associated with protection against herbivory (Feeny, 1976) by inducing post-ingestive feedback (Provenza, 1995). The strength or direction of this feedback depends on individual plant-herbivore characteristics and therefore requires individual situation testing (Stamp, 2003).

The objective of the present study was to correlate plant chemical and nutritive values in *Juniperus ashei* leaves with the incidence of browsing by goats (and to a much lesser extent, deer).

2. Material and methods

2.1. Study site

The study was conducted at the Texas AgriLife Research Station, Sonora, located on the southwestern edge of the Edwards Plateau (30°15.747′N, 100°34.164′W, 707 m). Annual precipitation averages approximately 600 mm; it is bimodal with largest amounts occurring in spring and fall. Soils in the study pasture are Tarrant silty clays and soil depth overlaying a fractured limestone substrate ranges from about 10 to 450 mm. Dominant herbaceous species include *Hilaria belangeri* (Steud.) Nash and *Bouteloua curtipendula* (Michx.) Torr. Dominant woody species include *Quercus fusiformis* Mill, *Q. pungens* Liebm var. *vaseyana*, *J. ashei* and *Juniperus pinchotii*. Fires within the area have not occurred for at least 100 years before data collection. From 1983 to 1993, stocking rates in the study pasture were maintained at a moderate level (i.e., 11.3 ha/animal). From 1994, stocking rates in the study pasture have varied from 18 to 10.4 ha/animal. A combination of cattle, sheep, and goats were grazed on the pasture until 2003 when all cattle were removed from the study area. The area is now grazed by goats and deer.

2.2. Plant material

Nine browsed *J. ashei* trees were randomly selected along a serpentine transect line of approximately 200 m. Trees showing severe browsing (e.g., all lower branches up to approximately 1 m were essentially defoliated) and had new, immature growth on the browsed branches were sampled as "browsed trees". This corresponds to the 'heavily browsed' category of Marko et al. (2008, Fig. 2, right). Nine trees with no evidence of browsing were sampled along the transect as 'non-browsed' trees, corresponding to the 'non-browsed' category of Marko et al. (2008, Fig. 2, left). Trees with other levels of browsing were excluded from sampling. *J. ashei* has two kinds of leaves: whip- (decurrent) and scale-like leaves that remain functional for 4–6 years. The whip leaves are only found on the new growth (leaders). At the study site, due to drought, very

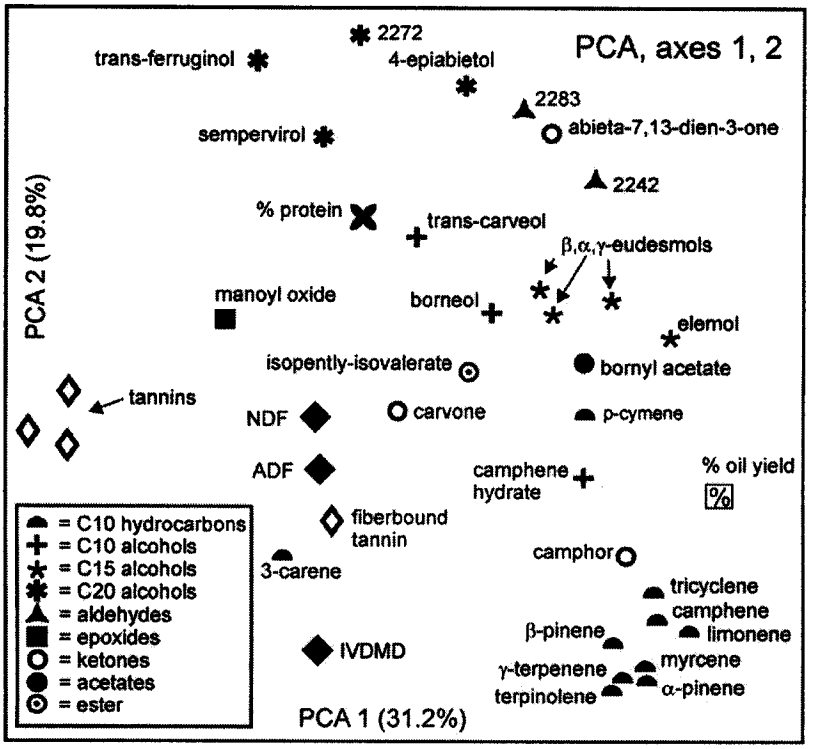

Fig. 1. Principal components analysis (PCA) of terpenoids, condensed tannins, and crude protein concentrations. Variance explained by a component is indicated in parenthesis.

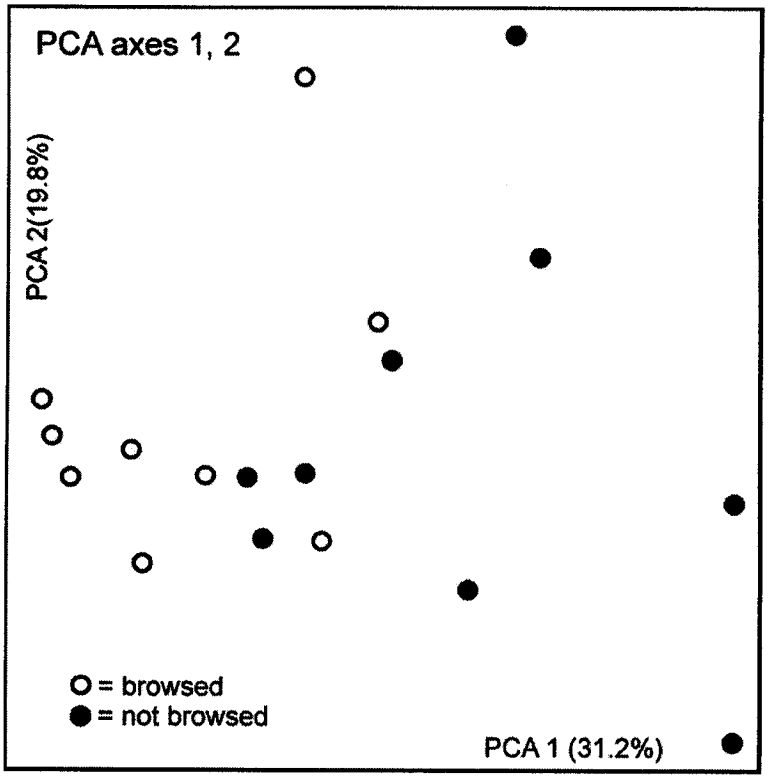

Fig. 2. Principal components analysis (PCA) ordination of browsed and not-browsed *J. ashei* trees.

few whip-leaves were observed and the occasional branch with whip-leaves was excluded from sampling as Adams and Hagerman (1976) found significant differences in the oils from whip- and scale-like leaves of *Juniperus*. No samples were taken from the branches with new, immature whip-leaves. Careful attention was given to sample at least 1 m above the browse line. As the browse line was up to 1 m above the ground, samples were taken at 2–2.5 m heights from both non-browsed and browsed trees from the south side of all trees. All trees were similar in size and height (3–6 m). Foliage was collected on May 14, 2010. Browsing occurred during the winter of 2010. Specimens collected: *J. ashei*, browsed trees: *Adams 12251–12259* and non-browsed trees: *Adams 12260–12268*; herbarium vouchers are deposited in the herbarium, Baylor University (BAYLU).

2.3. Volatile oil analysis

A portion (200 g FW) of the fresh foliage was kept cool (20 °C) and in the dark, then, within 24 h, exhaustively steam-distilled for 24 h using a modified circulatory Clevenger-type apparatus (Adams, 1991). The oil samples were concentrated (diethyl ether trap-removed) with nitrogen and stored at −20 °C until analyzed. The steam distilled leaves were oven dried to a constant weight (48 h, 100 °C) for the determination of oil yield as (oil wt./(oil wt. + oven dried extracted foliage wt.).

Extracted oils were analyzed on an HP5971 MSD mass spectrometer: 0.2 ul of a 10% solution (in diethyl ether) oil injected, split, 1:10, temperature programmed, linear, 60°–246 °C at 3 °C/min(62 min), carrier gas He, flow 34.96 cm/s or 1.02 ml/min, injector 220 °C, detector 240 °C, scan time 1/second, directly coupled to an HP 5890 gas chromatograph, using a J & W DB-5, 0.26 mm × 30 m, 0.25-micron coating thickness, fused silica capillary column (see Adams, 2007, p. 4, for detailed operating conditions).Identifications were made by searches of our volatile oil library (Adams, 2007) using HP Chemstation library search routines, coupled with retention time data of authentic reference compounds. Quantification was by flame ionization detector on an HP 5890 gas chromatograph operated under the same conditions as the GCMS (above) using the HP Chemstation software.

2.4. Condensed tannin analysis

Condensed tannins in air dried (48 h, 42 °C) leaves were assayed for soluble, protein-bound, and fiber-bound fractions by methods described by Terrill et al. (1992). Samples were oven-dried and standards prepared from Ashe juniper as recommended by Wolfe et al. (2008).

2.5. Crude protein and in vitro dry matter digestibility analyses

A portion of each foliage sample was also air dried (48 h, 60 °C), ground in a Wiley Mill (Arthur H. Thomas Co., Philadelphia, PA) to pass a 1-mm screen, and analyzed for N (AOAC, 2006); crude protein (CP) was calculated as 6.25 × N. An additional 0.35 g of the ground sample material was placed into separate F57 digestion bags and analyzed for 48-hr true in vitro dry matter digestibility (IVDMD) using an Ankom Daisy II incubator (Ankom Technol. Corp., Fairport, NY). Bags were placed into an incubation jar containing 400 mL of goat rumen fluid (donors fed Tifton 85 hay) and 1600 mL of McDougal's buffer solution (1.064 g urea L^{-1}). After anaerobic incubation at 39 °C, all bags were gently rinsed under cold water and washed by hand until water was clear. Bags were subjected to the neutral detergent fiber procedure according to Van Soest et al. (1991), modified for an Ankom 2000 Fiber Analyzer (Ankom Technol. Corp., Fairport, NY) without correcting for residual ash and using α-amylase and Na sulfite. Bags were then rinsed in acetone and dried at 55 °C in a forced-air oven for 48 h and weighed.

2.6. Statistical analyses

Terpenoids (as percentage of total oil and as mg per g dry foliage weight) compared among the samples by ANOVA and SNK (Student-Newman-Keuls) analyses as described by Steele and Torrie (1960). Gower or Manhattan metric (Gower, 1971; Adams, 1975) were computed among all populations using character weighting of F-1 (F from ANOVA). Principal Component Analysis (PCA) was performed to examine the patterns of association among individual terpenes, oil yield, crude tannins, ADF, NDF, CP and digestibility (formulation of Gower, 1966 and Veldman, 1967).

3. Results and discussion

A comprehensive analysis of the leaf oil of *J. ashei* is shown in Table 1. The most principal result was that percentage of total volatile leaf oil yields were greater ($F = 19.4^{***}$) in non-browsed trees (3.47%, DM-basis) than browsed trees (2.18%, DM-basis; Table 1). This result parallels the findings of Marko et al. (2008) who found that sheep and rabbit-browsed *J. communis* trees in Hungary had lower total volatile leaf oils than non-browsed trees.

Table 1
Comparison of leaf oils, condensed tannins (CT), neutral detergent fiber (NDF), acid detergent fiber (ADF), in vitro dry matter digestibility (IVDMD), and crude protein (CP) on a dry weight (DW) basis from browsed- and non-browsed *Juniperus ashei*. Terpenoid data were analyzed on both a mg/g DM-basis and on a percentage of total oil basis.

	Variable	Browsed	Not browsed	F signif.	Browsed	Not browsed	F signif.
	% yield (g/100 g DW)	2.18	3.47	19.4 $P < 0.001$			
	% extractable CT	6.31	6.18	0.69 ns			
	% protein bound CT	2.54	2.20	6.20 $P < 0.05$			
	% fiber bound CT	0.21	0.22	0.88 ns			
	% total CT	9.06	8.61	0.65 ns			
	% CP	6.49	6.25	0.42 ns			
	% NDF	34.30	33.65	1.52 ns			
	% ADF	23.99	23.50	1.22 ns			
	% IVDMD	71.56	74.32	12.62 $P < 0.01$			
KI	Compound	Dry Matter basis, mg/g DW			Percentage total oil basis		
921	Tricyclene (mg/g DW extracted)	0.76	1.33	10.8 $P < 0.01$	3.47	3.76	0.7 ns
932	α-pinene	0.32	0.59	7.4 $P < 0.05$	1.46	1.66	0.9 ns
946	Camphene	0.69	1.24	14.7 $P < 0.01$	3.21	3.53	1.3 ns
969	Sabinene	*t*	*t*	nt	*t*	*t*	nt
974	β-pinene	0.02	0.04	nt	0.09	0.12	nt
988	Myrcene	0.42	0.93	7.9 $P < 0.05$	1.87	2.60	3.1 ns
997	Ethyl hexanoate	*t*	*t*	nt	*t*	*t*	nt
1001	δ-2-carene	*t*	*t*	nt	*t*	*t*	nt
1002	α-phellandrene	*t*	*t*	nt	*t*	*t*	nt
1008	δ-3-carene	0.10	0.04	1.4 ns	0.64	0.12	3.4 ns
1014	α-terpinene	*t*	*t*	nt	*t*	*t*	nt
1020	p-cymene	0.57	0.75	7.7 $P < 0.05$	2.66	2.18	7.1, $P < 0.05$
1024	Limonene	1.84	3.59	11.2 $P < 0.01$	8.31	10.41	5.8 $P < 0.05$
1025	β-phellandrene	*t*	*t*	nt	*t*	*t*	nt
1054	γ-terpinene	0.14	0.30	5.4 $P < 0.05$	0.59	0.84	2.4 ns
1067	Cis-linalool oxide (furanoid)	*t*	*t*	nt	*t*	*t*	nt
1078	Camphenilone	*t*	*t*	nt	*t*	*t*	nt
1083	Fenchone	*t*	*t*	nt	*t*	*t*	nt
1084	Trans-linalool oxide (furanoid)	*t*	*t*	nt	*t*	*t*	nt
1086	Terpinolene	0.13	0.21	4.7 $P < 0.05$	0.59	0.60	0.02 ns
1089	p-cymenene	*t*	*t*	nt	*t*	*t*	nt
1095	Linalool	*t*	*t*	nt	*t*	*t*	nt
1102	Isopentyl-isovalerate	0.08	0.12	1.4 ns	0.34	0.32	0.04 ns
1112	3-methyl-3-butenyl butanoate, 3-methyl-	*t*	*t*	nt	*t*	*t*	nt
1136	Trans-p-menth-2-en-1-ol	*t*	*t*	nt	*t*	*t*	nt

Table 1 (*continued*)

	Variable	Browsed	Not browsed	F signif.	Browsed	Not browsed	F signif.
1141	Camphor	10.07	15.77	15.3 $P < 0.01$	46.79	45.49	0.2 ns
1145	Camphene hydrate	0.24	0.43	11.1 $P < 0.01$	1.30	1.26	0.6 ns
1155	Isoborneol	*t*	*t*	nt	*t*	*t*	nt
1165	Borneol	0.39	0.51	1.6 ns	1.72	1.52	0.5 ns
1174	Terpinen-4-ol	*t*	*t*	nt	*t*	*t*	nt
1176	m-cymen-8-ol	*t*	*t*	nt	*t*	*t*	nt
1179	p-cymen-8-ol	*t*	*t*	nt	*t*	*t*	nt
1186	α-terpineol	*t*	*t*	nt	*t*	*t*	nt
1187	Trans-p-mentha-1(7),8-dien-2-ol	*t*	*t*	nt	*t*	*t*	nt
1191	Cis-dihydrocarvone	*t*	*t*	nt	*t*	*t*	nt
1204	Verbenone	*t*	*t*	nt	*t*	*t*	nt
1215	Trans-carveol	0.10	0.11	0.5 ns	0.51	0.43	0.2 ns
1218	Endo-fenchyl acetate	*t*	*t*	nt	*t*	*t*	nt
1225	Cis-p-mentha-1(7),8-dien-2-ol	*t*	*t*	nt	*t*	*t*	nt
1226	Cis-carveol	*t*	*t*	nt	*t*	*t*	nt
1239	Carvone	0.12	0.15	1.5 ns	0.65	0.52	1.0 ns
1246	Isoamyl hexanoate	*t*	*t*	nt	*t*	*t*	nt
1260	3-methyl-3-butenol hexanoate	*t*	*t*	nt	*t*	*t*	nt
1275	Isopulegyl acetate	*t*	*t*	nt	*t*	*t*	nt
1287	Bornyl acetate	2.74	4.19	3.9 ns	11.87	12.33	0.4 ns
1298	Carvacrol	*t*	*t*	nt	*t*	*t*	nt
1312	Citronellic acid	*t*	*t*	nt	*t*	*t*	nt
1339	Trans-carvyl acetate	*t*	*t*	nt	*t*	*t*	nt
1340	Piperitenone	*t*	*t*	nt	*t*	*t*	nt
1417	(E)-caryophyllene	*t*	*t*	nt	*t*	*t*	nt
1452	α-humulene	*t*	*t*	nt	*t*	*t*	nt
1496	Valencene	*t*	*t*	nt	*t*	*t*	nt
1521	Isobornyl isovalerate	*t*	*t*	nt	*t*	*t*	nt
1522	δ-cadinene	*t*	*t*	nt	*t*	*t*	nt
1548	Elemol	0.16	0.36	12.9 $P < 0.01$	0.73	1.03	3.3 ns
1559	Germacrene B	*t*	*t*	nt	*t*	*t*	nt
1565	Decanoic acid	*t*	*t*	nt	*t*	*t*	nt
1582	Caryophyllene oxide	*t*	*t*	nt	*t*	*t*	nt
1630	γ-eudesmol	0.07	0.12	3.7 ns	0.33	0.34	0.01 ns
1649	β -eudesmol	0.06	0.09	1.2 ns	0.28	0.24	0.3 ns
1652	α-eudesmol	0.09	0.14	2.1 ns	0.39	0.41	0.02 ns
1792	8-α-acetoxyelemol	*t*	*t*	nt	*t*	*t*	nt
1806	Nootkatone	*t*	*t*	nt	*t*	*t*	nt
1933	Cyclohexadecanolide	*t*	*t*	nt	*t*	*t*	nt
1959	Hexadecanoic acid	*t*	*t*	nt	*t*	*t*	nt
1959	Iso-pimara-8(14),15-diene	*t*	*t*	nt	*t*	*t*	nt
1978	Manoyl oxide	0.27	0.28	0.01 ns	1.34	83	3.3 ns
2055	Abietatriene	*t*	*t*	nt	*t*	*t*	nt
2087	Abietadiene	*t*	*t*	nt	*t*	*t*	nt
2242	Diterpene,43,91,135,286	0.09	0.16	6.6 $P < 0.05$	0.47	0.46	0.01 s
2272	Diterpene,227,269,43,284	0.09	0.09	0.01 ns	0.46	0.28	2.6 ns
2282	Sempervirol	0.34	0.32	0.7 ns	1.66	1.03	7.8 $P < 0.05$
2312	Abieta-7,13-dien-3-one	0.90	1.33	3.0 ns	3.91	3.82	0.02 ns
2314	Trans-totarol	*t*	*t*	nt	*t*	*t*	nt
2331	Trans-ferruginol	0.06	0.06	0.02 ns	0.30	0.19	3.8 ns
2343	4-epi-abietol	0.10	0.12	0.3 ns	0.41	0.36	0.2 ns
2383	Diterpene,135,148,91,286	0.06	0.09	2.7 ns	0.26	0.27	0.01 ns

KI = Kovats Index on DB-5 column. Compositional values less than 0.1% are denoted as traces (*t*). The four most prevalent ions are listed for each unknown compound. The base ion (100%) is underlined. Unidentified components less than 0.5% are not reported.

Protein-bound CT concentrations differed ($F = 6.2^*$, Table 1) between browsed and non-browsed trees. Crude protein, ADF, and NDF were similar between browsed and non-browsed trees. However, browsed trees had lower IVDMD (71.56%) than non-browsed trees (74.32%; $F = 12.62^{**}$, Table 1).

Components computed on a dry matter basis (mg/g DW) varied more between browsed and non-browsed trees (Table 1) than components computed on a percentage of total oil basis. In fact, for components computed on a percentage of total oil basis, there were only three components with significant differences ($P = 0.05$) between browsed and non-browsed trees. In contrast, there are 12 components that differed (6 at $P = 0.05$, 6 at $P = 0.01$) when analyzed on a mg/g DW basis. Marko et al. (2008) found the percentage of α-pinene and γ-terpinene were larger in browsed *J. communis* trees, whereas the percentage of δ-3-carene, myrcene, and unknown (RT12.22) were larger in non-browsed trees. Marko et al. (2008) did not analyze their oil components on a mg/g basis. Estell et al. (2008) found that the addition of sesquiterpenes to alfalfa pellets tended to decrease the intake of feed, but cis-β-ocimene and cis-sabinene hydrate did not appear to effect feed consumption.

Principal Components Analysis (PCA) revealed (Fig. 1) that the percentage of oil yield was loaded to the far right on the PCA 1 (31.2% of the variance) and CT, in general, loaded very low on PCA 1, far from percentage of oil yield. In general, CT were grouped (except percent fiber-bound, which had very small values, and often zero). Monoterpene hydrocarbons were tightly grouped (Fig. 1) except for 3-carene and p-cymene. Likewise, the sesquiterpene and diterpene alcohols showed patterns that are related to their structural similarities. However, it should be noted that compressing the variables into two dimensions only gives the major trends, and individual associations may appear quite distorted. It would be of agronomic interest to closely examine statistical correlations between percentage of oil yield, CT, CP, and IVDMD but that was beyond the scope of this study.

Ordination of browsed and non-browsed trees on the basis of CT and leaf essential oils (mg/g DM-basis data), showed a slight separation (Fig. 2). Because PCA 1 is associated with the percentage of oil yield, it is apparent that there is some overlap in browsing among the intermediate oil-yielding trees (Fig. 2). It is possible that a few trees were avoided (non-browsed) for completely unrelated reasons. An observational or feeding trial would give an even more clear-cut classification.

The examination of the negative correlation between crude tannins (CT) and oil yields in *J. ashei* merits further study. The question of whether individual plants or populations may invest less in CT when terpenes are produced (or vice-versa) may have management implications since individual browsers or populations may adapt to consuming or avoiding either CT or terpenes. If this occurs, it begs the question whether plants then reverse their investment in CT or terpenes to adjust to the additional browsing pressure. Browsed tree leaves being less digestible than non-browsed tree leaves may be a result of complex interactions between CT, terpenes, fiber, and nutrients, and warrants further investigation.

Acknowledgments

This research was supported in part with funds from Baylor University and Texas AgriLife Research.

References

Adams, R.P., 1975. Statistical character weighting and similarity stability. Brittonia 27, 305–316.
Adams, R.P., 1991. Cedarwood oil – Analysis and properties. In: Linskens, H.-F., Jackson, J.F. (Eds.), Modern Methods of Plant Analysis, New Series: Oil and Waxes. Springler-Verlag, Berlin, pp. 159–173.
Adams, R.P., 2007. Identification of Essential Oil Components by Gas Chromatography/Mass Spectrometry, fourth ed. Allured Publishing, Carol Stream, IL.
Adams, R.P., 2011. The junipers of the world: The genus Juniperus, third ed. Trafford Publishing, Victoria, Canada.
Adams, R.P., Hagerman, A., 1976. A comparison of the volatile oils of mature versus young leaves of *Juniperus scopulorum*: chemosystematic significance. Biochem. Syst. Ecol. 4, 75–79.
AOAC, 2006. Official Methods of Analysis, eighteenth ed. Assoc. Off. Anal. Chem., Arlington, VA.
Bisson, M.G., Scott, C.B., Taylor Jr., C.A., 2001. Activated charcoal and experience affect intake of juniper by goats. J. Range Manage. 54, 274–278.
Dziba, L.E., Hall, J.O., Provenza, F.D., 2006. Feeding behavior of lambs in relation to kinetics of 1,8-cineole dosed intravenously or into the rumen. J. Chem. Ecol. 32, 391–408.
Estell, R.E., Fredrickson, E.L., Anderson, D.M., Remmenga, M.D., 2008. Effects of cis-β-ocimene, cis-sabinene hydrate, and monoterpene and sesquiterpene mixtures on alfalfa pellet intake by lambs. Am. Soc. Animal Sci. 86, 1478–1484.
Feeny, P., 1976. Plant apparency and chemical defense. Recent Adv. Phytochem. 10, 1–40.
Gershenzon, J., McCaskill, D., Rajaonarivony, J., Mihaliak, C., Karp, F., Croteau, R., 1992. Isolation of secretory cells from plant glandular trichomes and their use in biosynthetic studies of monoterpenes and other gland products. Anal. Biochem. 200, 130–138.
Gower, J.C., 1966. Some distance properties of latent root and vector methods used in multivariate analysis. Biometrika 53, 326–338.
Gower, J.C., 1971. A general coefficient of similarity and some of its properties. Biometrics 27, 857–874.
Marko, G., Gyuricza, V., Bernath, J., Altbacker, V., 2008. Essential oil yield and composition reflect browsing damage of junipers. J. Chem. Ecol. 34, 1545–1552.
Oh, H.K., Sakai, T., Jones, M.B., Longhurst, W.M., 1967. Effect of various essential oils isolated from Douglas Fir needles upon sheep and deer rumen microbial activity. Appl. Microbiol. 15, 777–784.
Pritz, R.K., Launchbaugh, K.L., Taylor Jr., C.A., 1997. Effects of breed and dietary experience on juniper consumption by goats. J. Range Manage. 50, 600–606.
Provenza, F.D., 1995. Postingestive feedback as an elementary determinant of food preference and intake in ruminants. J. Range Manage. 48, 2–17.
Riddle, R.R., Taylor Jr., C.A., Kothmann Jr., M.M., Huston, J.E., 1996. Volatile oil contents of Ashe and redberry juniper and its relationship to preference by Angora and Spanish goats. J. Range Manage. 49, 35–41.
Schwartz, C.C., Regelin, W.L., Nagy, J.G., 1980a. Deer preference for juniper forage and volatile oil treated foods. J. Wildl. Manage. 44, 114–120.
Schwartz, C.C., Nagy, J.G., Regelin, W.L., 1980b. Juniper oil yield, terpenoid concentration, and antimicrobial effects on deer. J. Wildl. Manage. 44, 107–113.
Stamp, N., 2003. Theory of plant defensive level: example of process and pitfalls in development of ecological theory. Oikos 102, 672–678.
Steele, R.G.D., Torrie, J.H., 1960. Principles and Procedures of Statistics. McGraw-Hill Book Co., NY.
Straka, E.J., 1993. Preferences for redberry and blueberry juniper exhibited by cattle, sheep, and goats. Thesis, Texas A&M University, College Station.
Terrill, T.H., Rowan, A.M., Douglas, G.B., Barry, T.N., 1992. Determination of extractable and bound condensed tannin concentrations in forage plants, protein concentrate meals, and cereal grains. J. Sci. Food Agric. 58, 321–329.
Van Soest, P.J., Robertson, J.B., Lewis, B.A., 1991. Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal production. J. Dairy Sci. 74, 3583–3597.
Veldman, D.J., 1967. Fortran Programming for the Behavioral Sciences. Holt, Rinehart and Winston Publ, NY.
Wolfe, R.M., Terrill, T.H., Muir, J.P., 2008. Drying method and origin of standard affect condensed tannin (CT) concentrations in perennial herbaceous legumes using simplified butanol-HCl CT analysis. J. Sci. Food Agric. 2008, 1060–1067.