Anagyrine in Western American Lupines

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Abstract

The teratogenic condition known as 'crooked calf disease' occurs when pregnant cows eat certain lupines with anagyrine concentrations at or above 1.44 g kg^{-1} dry matter between the 40th and 70th day of pregnancy. Five of eight species collected in Oregon and Washington had accessions with anagyrine at or above the hazardous concentrations as determined by gas/liquid chromatography. A total of 14 species of lupine are now shown to contain accessions with potentially hazardous concentrations of anagyrine. Any range/livestock management system that will expose susceptible cattle to anagyrine-bearing lupines could result in serious calf crop losses.

Lupine species are distributed throughout the temperate regions of the world and are particularly rich in western North America. Speciation within the genus is extensive and confusing. Rydberg (1922) developed a list of 80 species in the Rocky Mountains and the adjacent plains, Tidestrom (1925) listed 53 from the Great Basin, and Hitchcock and Cronquist (1976) accepted 23 species in Washington. To further complicate species identification within the genus, Herman (1966) noted that hybridization among the species is a common occurrence.

Lupines have been considered good to poor feed, depending on their toxic principals, season of use, and class of livestock (Herman 1966). They have been shown to be a common source of the apparently teratogenic alkaloid anagyrine (Keeler 1976) and the extent of its occurrence is only partially understood. At least 9 species are reported to contain anagyrine in concentrations high enough to cause crooked calf disease (Davis 1982). The true extent of the teratogenic potential of this genus will not be known until the lupine species and ecotypes are more completely collected and analyzed. This study was undertaken to further the understanding of the distribution of the probable teratogen anagyrine in the native western American lupines.

Materials and Methods

The collection of native lupines (Tables 1 and 2) represents the native species commonly found in the rangelands of the Pacific Northwest. The procedures for field grown lupines were the same in this experiment as were employed by Davis (1982) and are not repeated here. This collection has been catalogued and entered in the USDA Plant Introduction system and seeds of all accessions that were used in this study are available for further testing, evaluation or breeding at the authors' address.

The accessions reported in Table 2 were grown in plastic greenhouse pots 9 inches in diameter and 9 inches high (22 cm × 22 cm) containing 2.2 lb (1 kg) of air-dried soil mix, 1/3 soil, (Tucannon silt loam), 1/3 commercial peat, and 1/3 riverbank sand v/v. Each pot received 15 ml of a complete nutrient solution before planting, (Hoagland) and Arnon 1950). Twelve scarified lupine seeds were uniformly disturbed in the pot in 6 evenly distributed locations. and 4 pots were seeded to each accession for a total of 156 pots in the experiment. Each pot was thinned to 6 plants per pot as soon as the seedlings were well established. At 6, 12, and 18 weeks after emergence, an additional 15 ml of the same nutrient solution as initially used was injected into the soil of each pot with a repeating syringe. When the plants were 24 weeks old, the tops were cut to ground level. The plants from each pot were analyzed for anagyrine and total alkaloids by the procedures used by Davis (1982). Anagyrine and total alkaloid concentrations reported in Table 2 are the averages of 4 pots, each with 6 plants.

Results and Discussion

Six of the eight field-grown lupine species sampled contained identifiable amounts of anagyrine (Table 1). Five had concentrations high enough to be potentially teratogenic, i.e., greater than 1.44 g kg^{-1} (Keeler 1976). The presence of anagyrine in toxic amounts was previously reported by Davis (1982) for all species in this trial except the seashore lupine[6]. Lupines contain many alkaloids in addition to anagyrine (Waller and Nowacki 1978). Anagyrine may be considered a minor alkaloid in most species when compared to the concentrations of sparteine, lupinine, and lupanine. These and other lupine alkaloids are responsible for the classic symptoms of lupine poisoning or toxicosis (Anon. 1968). The average highest total alkaloid concentration was found in silvery lupine, with a range of 11.4 to 50.2 g kg^{-1}. In contrast, the anagyrine content of spurred lupine, was only 0.1 g kg^{-1} in the 2 collections that had detectable levels, but total alkaloid varied from 8 to 25 g kg^{-1}. The dry ground lupine, a low growing, mound-like, almost stemless lupine, was low in total alkaloids with a range of 4.2 to 18 g kg^{-1} and no anagyrine was found. This species is morphologically similar to the prairie lupine, a recognized poisonous species, and is considered by some botanists to be a subspecies of the prairie lupine. Burke's lupine had anagyrine in 3 of the 4 accessions, but only 1 of these was high enough to be potentially teratogenic. Burke's lupine ranked second only to the silvery lupine in total alkaloids.

The tailcup lupine was the only species in which all of the accessions had anagyrine concentrations at or above the minimum teratogenic level of 1.44 g kg^{-1}. These concentrations verify the teratogenicity of this species as reported by Keeler (1976). Total alkaloids ranged from 6-12 g kg^{-1} with anagyrine the principal alkaloid in this species, averaging 33.5% of the total alkaloid content. Other teratogenic lupines were the silky lupine, the velvet lupine and the seashore lupine.

Lupine species collected from Montana, Idaho, California, Oregon, and Washington were grown in the greenhouse and alkaloid levels are presented in Table 2. Eleven species were found to have accessions with anagyrine levels above the critical concentration of 1.44 g kg^{-1}. None of the annual species were found to contain anagyrine at teratogenic levels.

The cultivar 'Hederma' (sickle-keeled or pine lupine) is the only developed agronomic cultivar of a native western lupine. Ornamental cultivars have been bred from the Washington lupine, (Kelsey and Dayton 1942) and have been used for green manure in Europe. 'Hederma' has been fed to cattle and sheep with no teratogenic effects (James 1976). Foliage of 'Hederma' has been analyzed by the author and no anagyrine was found, but high concentrations of total alkaloids were present. By comparison 2 of the 3 wild collected accessions of sickle-keeled or pine lupine showed concen-

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Reference samples of previously analyzed lupine tissue, as well as purified extracts of anagyrine were provided by Dr. Richard Keller, USDA Poisonous Plant Laboratory, Logan, Utah 84321. Identification and quantification of the anagyrine peak, as well as the total alkaloids, was based on those samples.

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Table 1. Anagyrine and total alkaloid concentration in field grown lupine accessions from central Oregon and central Washington.

Lupinus species	Number of accessions analyzed	Number with anagyrine	Number exceeding 1.44 g kg^{-1} anagyrine	Total alkaloids g kg^{-1}
arbustus Doug. (spurred lupine)[1]	4	2	0	17.1
argenteus Pursh (silvery lupine)	5	0	0	37.8
aridus Doug. (dry ground lupine)	6	0	0	8.0
burkei S. Wats. (Burke's lupine)	4	3	1 @ 1.59	18.1
caudatus Kell. (tailcup lupine)	4	4	4 @ 2.94	8.75
leucophyllus Doug. (velvet lupine)	13	12	11 @ 2.90	8.38
littoralis Doug. (seashore lupine)	1	1	1 @ 3.31	8.68
sericeus Pursh. (silky lupine)	5	2	1 @ 3.46	10.00

[1]Common names follow Kelsey & Dayton (1942).

Table 2. Anagyrine and total alkaloid concentration in greenhouse grown lupine accessions from western America.

Lupinus species	Number of accessions analyzed	Number with anagyrine	Number exceeding 1.44 g kg^{-1} anagyrine	Total alkaloids g kg^{-1}
albicaulis Doug (pine lupine)[1]	3	2	2 @ 2.08	11.43
albifrons Benth. (white face lupine)	2	0	0	8.48
alpestris A. Nels (mountain silvery lupine)	2	1	1 @ 3.36	14.35
andersonii S. Wats. (Anderson's lupine)	1	1	1 @ 3.15	10.20
argenteus Pursh. (silvery lupine)	5	4	3 @ 3.34	18.22
bicolor Lindl. (bicolor lupine)	1	0	0	8.19
burkei S. Wats. (Burke's lupine)	4	2	0	6.32
concinnus Agardh. (bajada lupine)	1	0	0	6.09
erectus Hend. (tall silvery lupine)	1	1	1 @ 1.59	8.72
evermannii Rydb. (Everman's lupine)	1	1	1 @ 4.62	21.52
hirsutissimus Benth. (stinging lupine)	1	0	0	2.99
humicola A. Nels. (lowland lupine)	1	1	0	18.99
latifolius Agardh. (broadleaf lupine)	1	1	1 @ 6.04	23.33
leucophyllus Dougl. (velvet lupine)	1	1	1 @ 2.05	8.44
montigenus Heller (Mt. Rose lupine)	1	1	1 @ 10.27	19.54
nootkatensis Lindl. (Nootka lupine)	2	0	0	6.14
polyphyllus Lindl. (Washington lupine)	1	1	1 @ 6.10	21.76
rivularis Doug. (stream lupine)	1	1	0	2.20
rothmalerii Klingk. (Rothmal's lupine)	1	0	0	10.00
ruber Heller. (red lupine)	1	1	0	13.59
sericeus Pursh. (silky lupine)	4	2	1 @ 6.84	18.71
species	3	0	0	12.43

[1]Common names follow Kelsey and Dayton, 1942.

trations of anagyrine in the teratogenic range. The single collection of Anderson's lupine was average in total alkaloids and had anagyrine concentrations well above the teratogenic minimum. The broadleaf lupine was above average in total alkaloids and had anagyrine concentrations similar to the Washington lupine and the silky lupine. The species with anagyrine at the highest concentration was the Mt. Rose lupine with anagyrine at 10.27 g kg^{-1} and a total alkaloid concentration of 19.14 g kg^{-1}.

Based on these and previous findings of Davis (1982), the following species have produced accessions with anagyrine levels that are potentially teratogenic; the pine or sickle-keeled lupine, the mountain silvery lupine, Anderson's lupine, the silvery lupine, Burke's lupine, the tailcup lupine, the tall silvery lupine, Everman's lupine, the broadleafed lupine, the seashore lupine, the velvet lupine, the Mt. Rose lupine, the Washington lupine, and the silvery lupine.

This brings to 14 the known species with anagyrine at teratogenic concentrations. This number is variable depending on the system of speciation used and the synonomy that is present in the literature.

With the development of 'Hederma' as an anagyrine-free cultivar of the pine or sickle-keeled lupine, it follows that anagyrine-free cultivar development in other species should be possible. Concurrently the total alkaloids could be reduced and the palatability and forage quality should be improved. With extensive screening of widely collected germplasm, followed by intensive selection and breeding, accessions and possible new cultivars free of anagyrine with low total alkaloid content could be developed. They could be valuable additions to seeding mixtures where revegetation of depleted ranges is required. They could provide both forage and a nitrogen source to the range forage plant community.

References

Anonymous. 1968. 22 plants poisonous to livestock in the Western States. USDA Informtion Bulletin 327.

Davis, A.M. 1982. The occurrence of anagyrine in a collection of western American lupines. J. Range Manage. 35:81-84.

Herman, F.J. 1966. Notes of Western Range Forbs. Agr. Handbook #293, USDA Forest Service. U.S. Gov. Print. Off., Washington D.C. 20402.

Hitchcock, C.L., and A. Cronquist. 1976. Flora of the Pacific Northwest. p. 265-269. (Washington) Univ. Washington Press.

Hoagland, D.R., and D.I. Arnon. 1950. The water-culture method of growing plants without soil. Calif. Agr. Exp. Sta. Circ. 347.

James, L.F. 1976. Letter report on file at the SCS Plant Materials Center, Rm. 255, Johnson Hall, WSU, Pullman, Wash. 99164.

Keeler, R.F. 1976. Lupine alkaloids from teratogenic and nonteratogenic lupines, III: Identification of anagyrine as the probable teratogen by feeding trials. J. Toxicol. Environ. Health 1:882-898.

Kelsey, H.P., and W.A. Dayton. 1942. Standardized Plant Names. J. Horace McFarland Company. Harrisburg, PA.

Rydberg, P.A. 1922. Flora of the Rocky Mountains and adjacent plains. Hafner Publ. Co., New York.

Tidestrom, I. 1925. Flora of Utah and Nevada. Contributions from the United States National Herbarium. Vol. 25. GPO. Washington, D.C.

Waller, G.R., and E.K. Kowacki. 1978. Alkaloid Biology and Metabolism in Plants. Plenum Press, New York.