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Consumption of low larkspur (*Delphinium nuttallianum)* by cattle

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Abstract

Low larkspur (*Delphinium nuttallianum* Pritz.) is a toxic range plant that is often fatal to cattle when ingested during spring or early summer on foothill or mountain rangelands. Grazing trials near Price, Ut. during 1996 and 1997 examined toxicity and consumption of low larkspur by cow-calf pairs. Toxic alkaloid concentrations were relatively stable although larkspur plants rapidly matured. Cows and calves did not differ (P>0.1) in consumption of low larkspur (0.6 and 1.1% of bites, respectively), and calves began eating low larkspur readily (up to 21% of bites) early in the trial. Larkspur density did not affect consumption by cattle (P>0.1), but there was an interaction between density and day, as on 2 days (days 8 and 21) cattle ate more (P<0.05) low larkspur in the pastures with more larkspur. Stage of growth also affected consumption (P<0.05) with greater consumption after flowering. Increased grazing pressure caused cattle to eat more larkspur until larkspur density was reduced by grazing. Cattle apparently avoid eating low larkspurs before flowering, and cattle may eat little low larkspur if sufficient other forage is available. Losses may be reduced by ensuring that grazing pressure and/or stock density are not excessive on low larkspur-infested rangelands.

Key Words: cattle grazing, poisonous plants, alkaloids, diet selection

Resumen

"Low larkspur" (*Delphinium nuttallinum* Pritz.) es una planta tóxica que a menudo es mortal para el ganado cuando la consume en primavera o inicio del verano en pastizales de montaña o de pie de montaña. Durante 1995 y 1996 se condujeron ensayos de apacentamiento cerca de Price, Ut. en los que examinamos la toxicidad y consumo de "Low larkspur" por parejas de vaca-becerro. Las concentraciones de alcaloides tóxicos fueron relativamente estables a pesar de que las plantas de "low larkspur" maduraron rápidamente. Las vacas y los becerros no difirieron (P>0.1) en el consumo de "Low larkspur" (0.6 y 1.1% de mordidas respectivamante) y en el ensayo, los becerros comenzaron a comer "low larkspur" más temprano (hasta 21% de mordidas). La densidad de "Larkspur" no afectó el consumo por el ganado (P>0.1) pero hubo una intracción entre densidad y día, en 2 días (días 8 y 21) el ganado consumió mas "low larkspur" (P<0.05) en los potreros con mayor cantidad de "Low larkspur". La etapa de desarrollo del "Low larkspur" también afectó el consumo (P<0.05) siendo mayor después de floración. Incrementos en la presión de apacentamiento causo que el ganado consumiera mas "larkspur" hasta que la densidad de "larkspur" fue reducida por el apacentamiento. El ganado aparentemente evito el consumo de "Low larkspur" antes de la floración y puede consumir poco "low larkspur" si otros forrajes estan disponible en suficiencia. Las pérdidas pueden ser reducidas al asegurar que la presión de apacentamiento y/o la densidad de carga animal no son excesivas en pastizales infestados de "Low larkspur".

Low larkspur (*Delphinium nuttallianum* Pritz.) is a low-growing shallow-rooted perennial plant often implicated in livestock deaths during spring and summer. Low larkspurs generally occur on foothill or mountain ranges, and may initiate growth before other forage species. Availability of low larkspurs may be cyclic, as plant density and seasonal longevity are influenced by precipitation patterns and temperature (Majak and Engelsjord 1988). Inouye and McGuire (1991) reported that timing and abundance of flowering in low larkspurs depends on winter snowpack. Death losses to low larkspur are sporadic, and cattle losses can be severe at times.

The toxins in low larkspur are diterpenoid alkaloids, with most of the toxicity attributed to methyllycaconitine (Majak 1993, Bai et al. 1994, Manners et al. 1995) and nudicauline (Manners et al. 1995). Low larkspur contains other untested alkaloids that may play a role in mammalian toxicity (Gardner and Panter, unpublished data).

There is little information about cattle grazing of low larkspurs. Thus, the objectives of the present study were to determine (1) when cattle consumed low larkspur in relation to plant phenology and toxicity, (2) whether consumption by cattle is related to larkspur density, and (3) whether grazing pressure influences consumption of low larkspurs.

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Materials and Methods

Trial 1, 1996

The trial was conducted about 18 km northeast of Price, Utah on the western edge of the West Tavaputs Plateau at 2621 m elevation. The 5 ha pasture was enclosed with electric fence. Vegetation was dominated by mountain sagebrush (*Artemisia tridentata* var. *vaseyana* Nutt.), with groves of quaking aspen (*Populus tremuloides* Michx.) occurring near the study pasture. Other important vegetation included mountain dandelion (*Taraxacum officinale* Weber ex Wiggers), arrowleaf balsamroot (*Balsamorhiza sagittata* (Pursh) Nutt.), longleaf phlox (*Phlox longifolia* Nutt.), mountain brome (*Bromus carinatus* Hooker & Arn.), sedge (*Carex raynoldsii* Dewey), and low larkspur.

Five lactating, mature Hereford x Angus cows with calves were used. Calves were about 3 months old; they were still suckling, but also were fully functioning ruminants and grazed avidly at times. Cattle grazed on the pasture from 30 May to 12 June 1996. The trial ended when cattle ate nearly all the low larkspur in the pasture.

Density of low larkspur was determined at the beginning and end of the trial using 100, 0.25 m^2 plots placed every 15 m along 3 pace transects across the pasture. Forage availability was determined by clipping twenty, 0.25 m^2 plots at the beginning and end of the trial, and separating clipped material into grasses, other forbs, and low larkspur. Shrubs were ignored. Low larkspur phenology was determined weekly using pace transects to record phenology for 100 low larkspur plants. Growth stages of low larkspur were categorized as vegetative, early flower (i.e., flowers apparent but most not opened), flower (i.e., most flowers opened), late flower/pod (i.e., mix of flowers and pods on the same plant), and pod (i.e., nearly all flowers developed into pods).

Bite counts were used to determine animal diets, and categorized as low larkspur, grass and other forbs. Cattle were kept in a corral during the night, and released to graze each day about 0700 hours. Each cow was observed in a predetermined order for numerous 5 min periods; these observations continued during all active grazing periods until 1900 hours. Generally we obtained 30 to 40 min of daily observation time for each cow. Calves were also observed for 5-min periods when actively grazing but calves grazed less often than cows.

A composite sample of > 20 individual low larkspur plants was collected weekly for alkaloid analysis. Plants were collected fresh, frozen in plastic bags, freeze-dried, and ground through a 1-mm screen. Larkspur samples were analyzed for toxic alkaloids (methyllycaconitine, 14-deacetylnudicauline, barbinine, and nudicauline/geyerline) using electrospray mass spectrometry methods similar to that described by Marko and Stermitz (1997) with modifications to make the method quantitative. Ground plant material (100 mg) was extracted with 5 ml absolute methanol for 18 hours by mechanical rotation. Reserpine was added as an internal standard and mixed with the sample for an additional 15 min. A 50 µl aliquot of the sample was added to 1.5 ml of methanol/1% acetic acid (1:1) and the sample analyzed by flow injection electrospray mass spectrometry (Gardner, unpublished data).

Trial 2, 1997

We hypothesized that low larkspur is selected as encountered by cattle, and that higher densities would be reflected in higher consumption by cattle. The trial was conducted approximately 30 km southwest of Price, Ut. on Gentry Mountain on the eastern edge of the Wasatch Plateau at 2,650 m elevation. Four, 6-ha pastures were delineated based on density of low larkspur and 2 replicate pastures were designated as either high density (7–9 larkspur plants/m^2) or moderate density (3–5 larkspur plants/m^2). Initial density was determined before grazing began using 250, 0.5 m^2 plots located in each pasture along pace transects. Dominant vegetation in the area was aspen, sagebrush, mountain dandelion, mountain brome, and low larkspur. Aspen stands occurred in every pasture.

On 11 June 1997, 2 cow-calf pairs were randomly placed into each pasture. Cows were 3 to 4 yrs old, and the suckling calves were about 6 weeks old when the 21-day study began. Bite counts were done as described in the previous trial.

Standing crop was determined at the beginning of the trial by clipping, drying and weighing material from 20 plots as described above for Trial 1. Similarly, composite collections of low larkspur plants were made weekly for alkaloid analysis. Larkspur phenology was determined weekly using pace transects as described for Trial 1.

Trial 3, 1997

The cattle from Trial 2 were used at the same location in a 7-day study to determine the effect of grazing pressure on low larkspur consumption. We hypothesized that low larkspur consumption would increase over days as standing crop was reduced. A 3.5 ha pasture was delineated with electric fence, and forage availability was determined by clipping thirty, 0.25 m^2 plots, and drying and weighing the clipped material (i.e., grasses, forbs, and larkspur). All 8 cow-calf pairs were placed into the pasture on 1 July 1997, and bite counts conducted until 7 July 1997, as previously described. Low larkspur phenology and density were determined at the end of the trial using pace transects as previously described. A composite sample of > 20 low larkspur plants was also collected at the beginning and end of the trial to determine alkaloid concentration.

Statistical analysis

Consumption of low larkspur by cows and calves in Trial 1 was compared over days using the GLM procedure of SAS (1988). The repeated measures model included type of animal (i.e., cows vs. calves), individual animals nested within type (error a), with repeated measures over the 14 days of the trial. During Trial 2, calves ate no larkspur so they were not compared to cows. The repeated measures model for Trial 2 included larkspur density (high vs. moderate), pasture (i.e., replication), density x pasture, stage of growth (i.e., flower vs. pod), day nested within stage, pasture x stage, pasture x day within stage, density x stage, density x day within stage, density x pasture x stage, and density x pasture x day within stage. The pasture and density x pasture terms were added to test density effects, the pasture x stage and pasture x day within stage were added to test for stage effects, and the last 2 interaction terms were summed to test the density x stage and density x day within stage interactions. Significant interactions ($P < 0.05$) were examined using the PDIFF procedure of SAS (1988). Trial 3 was analyzed using an ANOVA model that included animals as blocks and days as the treatment effect.

Results

Toxic alkaloid concentrations

Toxic alkaloid concentrations were relatively stable (Table 1), particularly for methyllycaconitine, although larkspur plants rapidly matured during the studies (Table 2). Concentrations of nudicauline decreased as low larkspur plants matured during 1996, and after an initial reduction early in 1997, concentrations remained relatively stable after flowering even in senesced plants. Very low concentrations of 14-deacetylnudicauline and barbinine (a minor toxic alkaloid) were found in all plant samples. The dry matter content of individual low larkspur plants ranged from 21% in the early flower stage to 55% in the late pod stage; individual plants ranged in dry weight from 0.2 to 0.65 g/plant.

Trial 1, 1996

Low larkspur density was 2.5 plants/m^2 when the trial began, and forbs dominated the available forage (Table 3). Low larkspur comprised roughly 1% of the available forage; similarly cows selected 0.5 to 2% of their bites as low larkspur during the first week of the trial. The cattle consumed most of the low larkspur plants in the pasture and larkspur density was 0.3 plants/m^2 when the trial ended. Cows and calves did not differ (P>0.1) in consumption of low larkspur (0.6 and 1.1% of bites, respectively), even though some calves began eating low larkspur readily in the early days of the study (Fig. 1). Individual calves ate a maximum of 16 to 21% of their bites as low larkspur in the first 2 days of the study; during some grazing bouts larkspur consumption exceeded 50% of their bites. Overall, cows and calves selected remarkably similar (P>0.1) amounts of grass (84 and 83% for cows and calves, respectively) and forbs (15 and 14%, for cows and calves, respectively).

Trial 2, 1997

The experimental pastures were similar in available forage except for amounts of low larkspur. There was a stage of growth effect (P<0.001) for low larkspur consumption as cattle ate more larkspur after larkspur flowered. Few larkspur plants had flowered during the first week of the trial, and cattle took only a few bites of low larkspur before most plants had fully flowered (Fig. 2). Cattle ate <1% of their bites as low larkspur during the preflower and flower stages, but as low larkspur matured into the late flower/pod stage consumption increased to 2.5% of bites. There was a density x day within stage interaction (P<0.01), but the main effect of density was not significant (P>0.1). The density x day within stage interaction occurred because on day 8 during the preflower/flower period cattle in the high density pasture averaged over 5% low larkspur bites, whereas in the moderate density pasture on this day cattle ate almost no low larkspur. Furthermore, during the late flower/pod stage on day 21, cattle in the high density larkspur ate almost 10% of their bites as low larkspur, whereas cattle in the moderate density pasture ate <1% of their bites as low larkspur. Although cattle in the moderate density pasture appeared to eat more larkspur on days 15 to 19, these differences were not significant (P>0.1), and consumption of low larkspur by cattle in the moderate density treatment was near zero when the trial ended on day 21.

Table 1. Concentration (mg/g, dry weight) of toxic alkaloids in low larkspur (*Delphinium nuttallianum*) during 3 grazing trials in central Utah.

Date	Phenological Stage[2]	Toxic Alkaloid[1]			
		MLA	DAN	NUD	Barbinine
		(mg/g)			
Trial 1-1996					
21 May	Early Flower	1.9	<0.5	1.6	<0.5
30 May	Early Flower	1.2	<0.5	1.0	<0.5
6 June	Flower	1.4	<0.5	1.0	<0.5
12 June	Late Flower/Pod	1.8	<0.5	1.1	<0.5
Trial 2-1997					
20 May	Vegetative	1.6	<0.5	1.5	<0.5
12 June	Early Flower	1.0	<0.5	0.8	<0.5
19 June	Early Flower/Flower	1.1	<0.5	0.7	<0.5
26 June	Flower/Early Pod	1.3	<0.5	0.9	<0.5
Trial 3–1997					
3 July	Flower/Early Pod	1.2	<0.5	0.8	<0.5
3 July	Pod	1.3	<0.5	0.6	<0.5
7 July	Flower/Early Pod	1.6	<0.5	0.6	<0.5
7 July	Pod	1.3	<0.5	0.4	<0.5
7 July	Shattered	1.1	<0.5	0.6	<0.5

[1]N-methyl succinimido anthranoyllycoctonine (MSAL) type alkaloids that are the dominant toxic alkaloids in low larkspurs. MLA=methyllycaconitine; DAN=14-deacetylnudicauline; NUD=nudicauline and a closely related isomer, geyerline. 14-deacetylnudicauline and barbinine occurred in all samples but concentrations were very low.
[2]Early flower/flower=flowers apparent but not open; flower/early pod=mix of flower and pod on the upper and lower portion of the stem, respectively.

Table 2. Phenology of low larkspur during summer, 1996 and 1997 in central Utah. Each value is the percentage of plants in the respective growth stage on the sampling date.

Trial/Date	Growth Stage				
	Vegetative	Early Flower[1]	Flower	Late Flower/ Early Pod[2]	Pod
	(%)				
Trial 1, 1996					
5/30	0	77	20	3	0
6/6	0	7	71	13	9
6/12	0	0	0	65	35
Trials 2 & 3, 1997					
6/11	38	59	3	0	0
6/20	0	21	79	0	0
6/26	0	0	48	52	0
7/7	0	0	0	5	95

[1]Flowers apparent but not open
[2]Mix of flower and pod on the upper and lower portion of the stem, respectively

Trial 3, 1997

Cattle diets differed over time as the forage standing crop was reduced. Consumption of low larkspur peaked on day 4 (P<0.05) and was lowest on day 7 (Fig. 3) as larkspur was depleted from the pasture. Forb consumption was highest (P<0.05) during the first 2 days (7 to 9%) and then fell to <2% during the rest of the trial. Low larkspur and forb consumption both averaged about 3% during the 7-day trial, whereas grass consumption averaged 93% (range 88 to 96%, P<0.05).

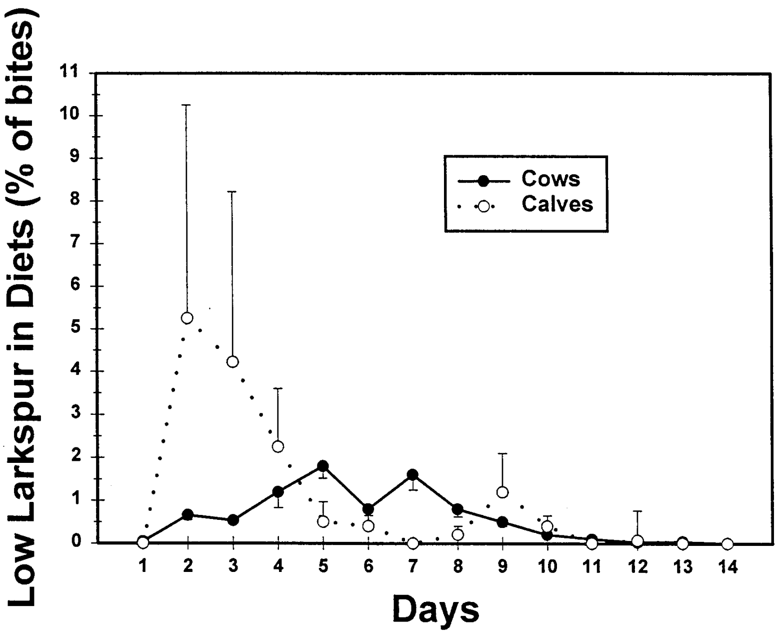

Fig. 1. Consumption of low larkspur (% of bites ± SE) by cows and nursing calves during an early summer (30 May to 12 June) grazing trial near Price, Ut., 1996.

Discussion

Our visual observations during the 1996 trial suggested that cows did not prefer or avoid low larkspur, but rather consumed larkspur in relation to availability in the pasture. Consumption decreased to nearly zero as larkspur density declined from grazing, suggesting that cattle were not actively searching for low larkspur plants.

Calves grazed much more sporadically than cows in 1996, but during the initial days of the study the naive calves appeared to prefer low larkspur. Nonetheless, calves generally ate little low larkspur after day 4 for reasons that are not clear. It is possible that calves ingested sufficient low larkspur early in the study to induce mild intoxication, forming a temporary aversion to larkspur (Pfister et al. 1997a); however, we saw no clinical signs of poisoning in grazing calves. Alternatively, calves may have also been responding to decreasing low larkspur density and/or growth of other forage plants. Calves ate no larkspur during the 1997 summer trial, probably because they were younger by 6 weeks and appeared to graze much less than did the calves used in 1996.

Larkspur density during the 1997 density trial influenced consumption by cattle on only 2 of 21 days. Because the density trial began when low larkspur was vegetative or in the early flower stage, and other forages were still initiating growth, the experimental pastures were purposely made sizable so that selection was not impeded. In general, low larkspur consumption was low during the trial, and larkspur density was not an important factor on most days. Nonetheless, on days when cattle did eat significant amounts of low larkspur, most of that consumption occurred in the high density rather than low density pastures. This suggests that density may be important during those times when low larkspur is palatable and eaten in relatively large amounts by grazing cattle. It is not clear what other environmental or forage factors were positively or negatively influencing cattle consumption of low larkspur during the density trial.

The grazing pressure trial suggested that amount of available forage and the relative amount of low larkspur are major factors influencing consumption of low larkspur by cattle. These results must be interpreted cautiously, however, because of the short duration of the trial. Concentrating cattle in the smaller pasture immediately increased the amount of low larkspur eaten, as cows that had previously taken few bites of larkspur began to consume larkspur in greater amounts. It is possible that social facilitation was also a factor in increased consumption; consumption increased within a few hours after the trial began for some cows that previously had eaten little larkspur. Consumption of low larkspur reached a peak on day 4 when other forage was declining in abundance, and then low larkspur consumption decreased as the amount of low larkspur in the pasture also declined.

Low larkspurs matured rapidly during both summers, and generally developed from the early flower stage (flowers visible but not open) to the late flower/pod

Table 3. Standing crop (kg/ha ± SE) during low larkspur grazing trials during summer, 1996 and 1997 in central Utah.

Forage Class	Sample Period	
Trial 1, 1996	Begin[1]	End[1]
	- - - - - - - - - - - -(kg/ha)- - - - - - - - - - - -	
Grass	70 ± 10	111 ± 13
Forbs	246 ± 37	110 ± 15
Larkspur	30 ± 4	3 ± 2
Trial 2, 1997	Begin: High Pasture[2]	Begin: Moderate Pasture[2]
Grass	197 ± 16	172 ± 18
Forbs	34 ± 8	35 ± 9
Larkspur	67 ± 12	18 ± 6
Trial 3, 1997	Begin[3]	End[3]
Grass	198 ± 29	76 ± 7
Forbs	48 ± 18	8 ± 5
Larkspur	38 ± 12	6 ± 2

[1]Trial 1 began on 30 May, 1996 and ended on 12 June, 1996
[2]Trial 2 began on 11 June, 1997 with standing crop averaged over 2 replicate pastures for both the High Density and Moderate Density treatments; no end clip was done as forage was abundant on all pastures.
[3]Trial 3 began on 1 July, 1997 and ended on 7 July, 1997; the pasture included portions of both high and moderate density pastures used during Trial 2.

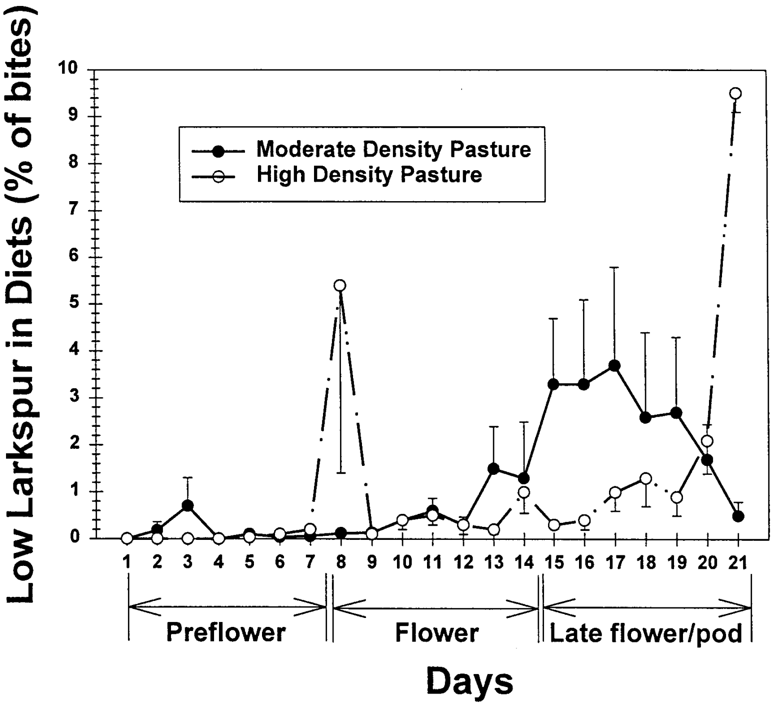

Fig. 2. Consumption of low larkspur (% of bites ± SE) by cows grazing in pastures containing either moderate or high densities of low larkspur during summer (11 to 30 June) near Price, Ut., 1997. Dominate low larkspur phenology is indicated below the x-axis.

stage (mix of mature flowers and immature pods on each stem) within 14 to 21 days. Inouye et al. (1991) reported that there was an 18 day interval between first and last flowering in *D. nelsonii* growing at 2,900 m elevation in Colorado. Majak (1993) found that methyllycaconitine concentration declined substantially as low larkspur matured from the vegetative to reproductive stages of growth, but was relatively stable thereafter. Further, Majak et al. (1987) reported that nudicauline was a relatively minor alkaloid in low larkspur with a concentration < 0.5 mg/g, although roots and seed pods were substantially higher in nudicauline compared to leaves and stems (Majak and Engelsjord 1988). In our studies, the toxic alkaloid concentration of low larkspurs was relatively low but stable in maturing plants; even dry, shattered low larkspur plants retained over 1 mg/g of methyllycaconitine in addition to low concentrations of nudicauline. This relative stability contrasts with tall larkspur alkaloid concentrations which usually decrease greatly with maturity (Pfister et al. 1994, Ralphs et al. 1997).

When ingested by cattle, each low larkspur plant formed a single bite, regardless of plant height. Low larkspur plants taller than 15 to 20 cm were simply folded into the cow's mouth, and both short and tall plants were usually broken off near ground level whatever the height or stage of growth. These observations contrast with those of Majak and Engelsjord (1988), who suggested that cattle ate only the upper portion of the low larkspur plants.

Cattle typically show clinical signs (i.e., tremors and periodic collapse) when given a methyllycaconitine + 14-deacetylnudicauline dose from tall larkspur (*D. barbeyi*) of about 20 mg/kg b.w. Nudicauline has not been found in tall larkspur, and is about twice as toxic per unit of weight compared to methyllycaconitine or 14-deacetylnudicauline (Manners et al. 1995). Assuming an average dry weight per plant of 0.5 g, and also assuming a methyllycaconitine + 14-deacetylnudicauline concentration of 1.5 mg/g, plus a nudicauline concentration of 1 mg/g (dry wgt), low larkspur plants would contain a toxic alkaloid concentration equivalent to 3.5 mg/g plant dry weight [methyllycaconitine + 14-deacetylnudicauline + (nudicauline x 2)]. Thus, a 450 kg cow may show clinical signs after eating 2.5 kg (dry weight) of low larkspur. Cattle would need to eat about 20% of their daily diet as low larkspur to become intoxicated, given a dry matter intake of 13 kg/day.

Viewed in a different way, cattle in our grazing studies on mountain ranges often have a biting rate of 50 bites/min or 24,000 total bites during active, daylight grazing hours. A cow in this scenario would have to eat about 5,000 bites of low larkspur in a single day to

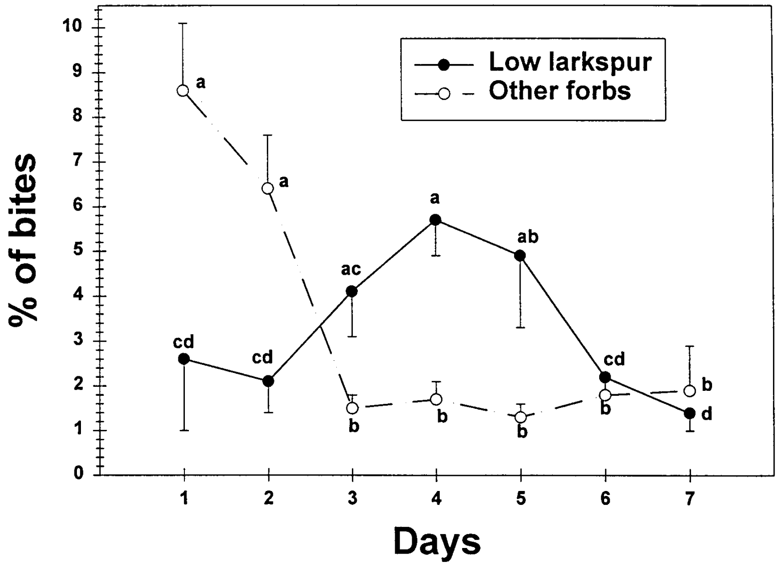

Fig. 3. Consumption of low larkspur (% of bites ± SE) by cows grazing in a single pasture during a grazing pressure trial to deplete available forage during summer (1 to 7 July), near Price, Ut., 1997. Different superscript letters within each plant category indicate significant differences between days (P<0.05).

be poisoned. We estimate that the greatest number of total larkspur bites by any individual cow that we observed in 1997 was about 3,000 bites (≈1.5 kg) in a single day. We did not observe any indications of clinical toxicity in cows in our grazing studies, and our bite counts showed that their diets did not approach a toxic dose.

Our results suggest that cattle eat only small amounts of low larkspur before flowering, as we have noted with tall larkspurs (Pfister et al. 1997b), and that cattle may eat little low larkspur if sufficient other forage is available. Further, we suggest that losses may be reduced by ensuring that grazing pressure and/or stock density are low. Additional research will be necessary to confirm these findings. Because low larkspurs are short-lived plants (4 to 6 weeks), for many livestock producers the management scheme of choice may be to simply wait until low larkspurs are very mature, and other forage is abundant, before placing cattle in heavily infested pastures. On moderate- to high-elevation (> 2,500 m) ranges, onset of flowering in low larkspurs may coincide with the growth of adequate amounts of other forage to support moderate stocking rates. More information on factors influencing cattle to eat low larkspurs is clearly needed, and research will continue on such aspects as the relationship between consumption, larkspur and forage phenology, particularly early in the season, and forage availability.

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