UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 947
Contribution from the Bureau of Animal Industry
JOHN R. MOHLER, Chief

Washington, D. C. PROFESSIONAL PAPER. October 11, 1921

WESTERN SNEEZEWEED (HELENIUM HOOPESII) AS A POISONOUS PLANT

By

C. DWIGHT MARSH, Physiologist in Charge of Investigations of Stock Poisoning by Plants; A. B. CLAWSON, Physiologist; JAMES F. COUCH, Pharmacological Chemist, and HADLEIGH MARSH, Veterinary Inspector, Bureau of Animal Industry

CONTENTS

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INTRODUCTION.

HISTORICAL SUMMARY.

In 1903, V. K. Chesnut, who was at that time in charge of poisonous-plant investigations in the Department of Agriculture, while visiting Sevier County, Utah, was told that a disease of sheep was prevalent in that part of the State. The disease was characterized by vomiting and wasting away, the sheep dying after a time varying from a week or two to a month. Nothing further was heard of this disease by the department until January, 1914, when the senior author, who was making an address to the stockmen of Salina, Utah, was told that the sheep on the summer ranges in the Wasatch Mountains suffered from a disease commonly known as "spewing sickness." The symptoms, as described, seemed to correspond fairly well with those caused by *Zygadenus* (death camas), and the men were told that this plant was the probable cause. A picture of the plant was shown, and some of them recognized it as growing on the ranges where the trouble occurred.

A botanical examination of the ranges in question was made by W. W. Eggleston in the following summer, and two visits were made by Dr. Hadleigh Marsh to see the sick animals. On the first visit, from July 25 to August 7, 1914, a number of spewing cases were seen and some autopsies made. The "sneezeweed," *Helenium hoopesii*, was seen where some of the sheep were grazing, and one of the herders expressed his belief that this plant was the cause of the trouble. It was found, however, that quite generally *Zygadenus* grew near where cases of poisoning occurred, and it was concluded that this plant was the probable cause of the trouble, although it was noted that the cases were not typical of *Zygadenus* poisoning, and that *Zygadenus* was not found in some of the localities. It was also found that many cases occurred in September, which was rather late for *Zygadenus*. The second visit was made by Dr. Hadleigh Marsh, from September 12 to 21. This was just after the sheep had left the summer range. The localities where sheep had been reported poisoned were examined carefully. Dried leaves and seed of *Zygadenus* were found in many places. It was thought that the *Zygadenus* was abundant enough to account for some of the losses, but not for all. The fact, too, that most of the herders believed in the sneezeweed as the poisonous agent was not to be ignored, and it was felt that definite experimental work should be undertaken which would verify or eliminate the sneezeweed theory.

This experimental work was commenced when the Salina Experiment Station was established on the Fishlake National Forest in 1915, and has been continued for five years. The installation of a station on a range where the spewing sickness was common, with the opportunity of observing the field cases, together with feeding experiments with the fresh plant, soon established proof that the spewing sickness was not caused by *Zygadenus*, but was the result of eating sneezeweed (*Helenium hoopesii*). A preliminary publication, Circular A-9, United States Department of Agriculture, was issued concerning this work in 1916. The effects of the plant were of such a character, however, as to make the detailed experimental work very slow and tedious, and in the course of the work many perplexing questions arose, so that it was only after several seasons' work that it was possible to make a fairly complete report on the subject.

The following references to the poisonous properties of *Helenium hoopesii* have been found in the literature:

Pammel (1910, p. 140) says that it is "said to be poisonous to sheep."

In 1911, page 781, he says:

> It is said to be poisonous like other species of the genus. Sheep carefully avoid it, feeding on the grass and other herbaceous plants, leaving the plant standing.

Barnes (1913) states that "sneezeweed (*Helenium autumnale, Helenium montanum*)" grows all over the West and is poisonous to sheep. He also says that water from tanks in the sneezeweed region may poison sheep and has poisoned men. With very little doubt the sneezeweed he speaks about is *Helenium hoopesii.*

Glover and Robbins (1915, pp. 66–67) give a brief description of "*Dugaldia hoopesii*" and state that "in the mountainous districts of Colorado bitter milk and meat are not uncommon, and it can no doubt be safely attributed in many instances to the eating of this plant. Severe poisoning may result from eating large quantities of the plant."

Hall and Yates (1915, p. 246) include *Helenium hoopesii* in a list of plants "either definitely known to be poisonous to stock or are under suspicion, but which seldom, if ever, cause serious trouble in California."

Pammel (1917, p. 462) says:

> The Rocky Mountain *D. hoopesii* is a much larger plant than the eastern species. This is very common in Utah and western Colorado. I saw a great deal of this in the Uintah Mountains. Sheep were abundant on the range where I noted this plant. I found that, though sheep will eat all kinds of herbage, they carefully avoid this species. I feel sure that when forage is scarce they sometimes eat this weed and may sometimes die. The summer I was on this range hundreds of sheep died from various causes, some, perhaps, from this sneezeweed.

Marsh (1918, pp. 19 and 20) makes a summarized statement in regard to the plant.

Beath (1919, p. 45) says:

> Recently western sneezeweed is reported to have occasioned losses among sheep in certain States, especially Utah. The poison is slow in action and said to be cumulative. Its specific nature has not as yet been announced.

DESCRIPTION OF THE PLANT.[1]

Helenium (*Dugaldia*) *hoopesii* (fig. 1) belongs to the composite family and is a strong perennial, growing to a height of 1 to 3 feet with one or several stems. It often develops a large crown and spreads vegetatively by this crown. (Fig. 3.)

The plant, when young, is often hairy or woolly, particularly the stems, but later becomes glabrous. The stem is leafy; the thick

[1] The description of the plant was prepared by W. W. Eggleston, Bureau of Plant Industry, U. S. Department of Agriculture.

entire leaves of a deep green color are dotted, have several parallel veins, are oblong, lanceolate, sessile, or in the root-leaves spatulate with a long tapering base. There may be one or several flower heads. The heads are 2 to 3 inches broad, with oblong-lanceolate scales. The ray flowers are of an orange color, numerous and fertile, about an

FIG. 1.—*Helenium hoopesii.* Mature plant in blossom.

inch long; the disk flowers are brownish orange. The seeds are numerous and hairy.

The plant occurs at elevations from 5,200 feet to 12,500 feet, but its usual limits are from 7,000 feet to 10,500. It is found in the yellow-pine belt, grows abundantly in the aspen and spruce belts, and somestimes reaches the Arctic alpine zone. Its best habitat is on sunny slopes of the aspen-spruce belt in moist well-drained soil. It thrives in the higher mountain parks of Colorado and Utah and in the upper Kern River watershed in the southern Sierra Nevadas of California. *Helenium hoopesii* is also found in the Wind River and Teton Mountains, Wyo.; the Caribou Mountains, Idaho; in the Stein Mountains, Oreg.; the Ruby Mountains, Nev.; and in the Warner Mountains, Calif. In the Sierra Nevadas it has been found north from the Kern River to Clarks Fork, north of Sonora pass on both sides of the range, and also in Washoe County, Nev. In the higher mountains of Arizona and New Mexico it is well distributed. In the Black Mountains and the Mogollon Mountains of New Mexico it is abundant along the streams in the higher mountain canyons. In the Sacramento Mountains, N. Mex., it occurs in the bottoms of many of the

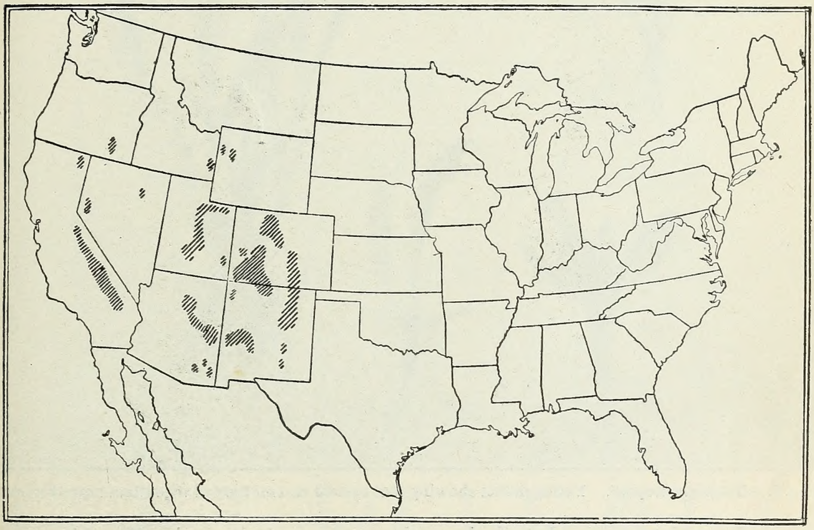

FIG. 2.—Distribution of *Helenium hoopesii* in the United States.

higher canyons that are destitute of streams. The White and the Mogollon Mountains of New Mexico and the San Francisco Peaks of Arizona have high mountain parks similar to those of the Rocky Mountains of Colorado and the Wasatch, and in these parks sneezeweed is abundant.

In the Wasatch Mountains the blossoming period is from the middle of June to the middle or last of August. In many overgrazed areas it has become the predominant plant. Figure 4 shows how thickly it grows in some localities.

From the color of the flowers it is sometimes called "yellowweed," and some stockmen called it "sunflower," but in Utah it is most commonly known as "sneezeweed." The Navajos have a name meaning owl's claws. Figure 2 shows the distribution of the plant in the United States.

EXPERIMENTAL WORK.

The feeding experiments were carried on at the Salina Experiment Station, in Utah, and were continued through the summer months from 1915 to 1919.

Facilities for chemical work were provided at the Salina station so that such work as was dependent on field conditions was conducted

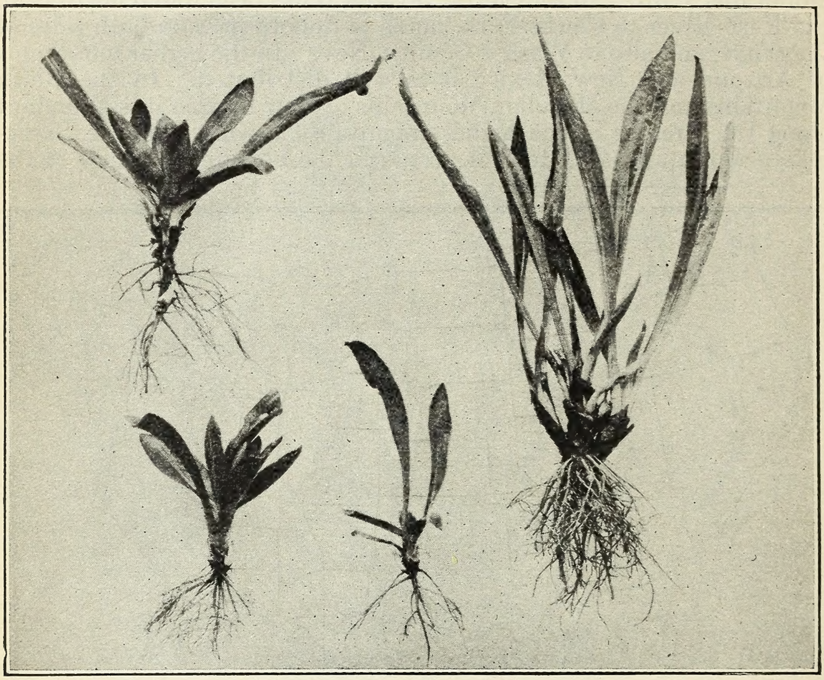

FIG. 3.—*Helenium hoopesii.* Young plants showing root system and method of vegetative reproduction.

there, but the more detailed work was carried on in Washington, where laboratory facilities were more complete.

The plants used were all collected in the immediate neighborhood of the Salina Experiment Station, in the Fishlake National Forest in Utah. The weights of the plants are all given in the equivalent of the green plant.

The following table gives a summarized statement of the work with sheep and cattle and will give an idea of the extent of the experimental work on which this paper is based.

TABLE 1.—*Summary of 5-year feeding experiments with sneezeweed (Helenium hoopesii) at Salina Experiment Station, Utah, 1915 to 1919.*

Animal.		Date of feeding.	Method of feeding.	Part of plant used.	Quantity of plant fed.			Length of feeding period.	Severity of sickness.	Remedy.
Designation.	Weight during experiment.				Total weight.	Per hundredweight of animal.	Daily average per hundredweight of animal.			
	Pounds.	1915.			*Pounds.*	*Pounds.*	*Pounds.*	*Days.*		
Sheep 316	68.5 to 77.5	June 23 to 26	Fed in hay	Leaves, stems, and young flowers.	1.5	2.19	2.19	1	Not sick	None.
Sheep 319	77 to 60.5	June 25 to July 15	Fed	do	63.5	82.468	3.927	21	Died	Do.
Sheep 328	87 to 65	July 3 to 22	Fed. Flowers often left uneaten.	Leaves, stems, and flowers.	65	74.713	3.932	19	Sick	Do.
Sheep 329	87 to 76.5	July 7 to 23	Fed	do	29.25	32.865	1.933	17	Not sick	
Sheep 338	79	July 15	2 forced feedings	Flowers	2.204	2.790	2.790	1	Died	Do.
Sheep 325	94.5 to 89.5	July 15 to 18	Fed	Leaves	3	3.175	.794	4	Not sick	
Sheep 335	86	July 17 and 18	1 forced feeding	Flowers	.859	.999	.499	2	Died from choking	
Sheep 343	86 to 75.25	July 17 to 22	Fed	do	7	8.140	1.357	6	Not sick	
Sheep 346	96.5 to 71	July 18 to Sept. 14	do	Leaves, stems, and flowers.	77.5	80.311	1.361	59	Sick	Do.
Sheep 348	83.5	July 19 to 29	11 forced feedings (1 per day).	Flowers	9.191	11.007	1.001	11	Died	Do.
Sheep 344	101.25 to 93.75	July 20 to 22	Fed	Leaves, stems, and flowers.	2.5	2.469	.823	3	Not sick	
Sheep 355	85.5	July 23 to 25	4 forced feedings	Radical leaves	3.421	4.001	1.334	3	Died	Do.
Sheep 357	125.5 to 101.5	July 24 to Aug. 1	Fed	Flowers	20	15.936	1.77	9	Not sick	
Sheep 341	118.5 to 104.5	July 24 to Aug. 7	do	Radical leaves	25.5	21.519	1.434	15	do	
Sheep 333	107.5 to 81	July 29 to Aug. 21	do	Leaves, stems, and flowers.	30.5	26.372	1.182	24	Weakness	Do.
Sheep 358	94	Aug. 2 to 4	5 forced feedings	Radical leaves	3.891	4.139	1.380	3	Sick	Do.
Sheep 354	95.5	Aug. 2 to 6	10 forced feedings	Flowers	7.892	8.264	1.653	5	do	Oil.
Sheep 320	93 to 88	Aug. 7	2 forced feedings	Radical leaves	2.595	2.790	2.790	1	Not sick	
Sheep 339	105.5 to 81	Aug. 8 to 27	Fed	do	28.5	27.014	1.351	20	Weakness and trembling.	None.
Sheep 314	95	Aug. 9	2 forced feedings	do	3.141	3.306	3.306	1	Died	
Sheep 326	97 to 80	Aug. 18 to Sept. 14	Fed	Leaves, stems, and flowers.	42	43.299	1.546	28	Not sick	
Sheep 330	102.5 to 88	Aug. 23 to 31	do	Radical leaves	8	7.805	.967	9	do	
Sheep 323	138 to 112.5	Aug. 23 to Sept. 19	do	do	47	34.058	1.261	27	Symptoms	Do.
Sheep 315	92 to 83	Aug. 24	2 forced feedings	do	2.434	2.646	2.646	1	Sick	Do.
Sheep 318	101 to 89	Aug. 27	do	do	2.672	2.646	2.646	1	Not sick	
Sheep 332	82.5	Aug. 31	do	do	2.051	2.486	2.486	1	Sick	Do.
Sheep 331	86.5	Sept. 1	1 forced feeding	Stem leaves	2.288	2.645	2.645	1	Died	Do.
Sheep 340	84 to 72.5	Sept. 3	3 forced feedings	do	2.222	2.645	2.645	1	Sick	Do.

TABLE 1.—*Summary of 5-year feeding experiments with sneezeweed (Helenium hoopesii) at Salina Experiment Station, Utah, 1915 to 1919*—Contd.

Animal.		Date of feeding.	Method of feeding.	Part of plant used.	Quantity of plant fed.			Length of feeding period.	Severity of sickness.	Remedy.
Designation.	Weight during experiment.				Total weight.	Per hundredweight of animal.	Daily average per hundredweight of animal.			
	Pounds.	1915.			*Pounds.*	*Pounds.*	*Pounds.*	*Days.*		
Sheep 341	121.5 to 118	Sept. 3 to 25	Fed in bran	Ripe fruits	8.629	7.102	0.309	23	Not sick	
Sheep 343	96.5 to 85.5	Sept. 6	2 forced feedings	Flowers	2.340	2.425	2.425	1	Symptoms	None.
Sheep 347	92.5 to 80.5	Sept. 7	do	Stem leaves	2.549	2.756	2.756	1	Not sick	
Sheep 328	93 to 89	Sept. 8	1 forced feeding	Leaves, stems, and flowers.	1.018	1.095	1.095	1	do	Do.
Sheep 352	107 to 90	Sept. 8 to 12	Fed	Radical leaves	2.75	2.570	.514	5	do	
Sheep 345	94.5 to 83.5	Sept. 10	3 forced feedings	Leaves, stems, and fruit.	2.500	2.646	2.646	1	Possible symptoms	Do.
Sheep 353	73 to 63	Sept. 10	1 forced feeding	Radical leaves	.805	1.103	1.103	1	Not sick	
Sheep 327	80	Sept. 11 to 17	12 forced feedings	do	6.349	7.936	1.134	7	Sick, died from choking.	Do.
Sheep 357	130 to 107	Sept. 13 to 25	Fed	do	19.75	15.192	1.169	13	Not sick	
Sheep 333	102 to 102	Sept. 15	3 forced feedings	Leaves, stems, and fruits.	2.623	2.572	2.572	1	Sick	Do.
Sheep 360	49.5 to 42	Sept. 17 to 25	Fed	Radical leaves	4.5	9.091	1.010	9	Not sick	
Sheep 366	93.5 to 88.5	Sept. 18	1 forced feeding	do	2.061	2.204	2.204	1	Sick	Do.
Sheep 380	60	May 30 to July 21	Fed in alfalfa hay	do	68.292	113.82	2.107	54	Died	Do.
Sheep 384	73 to 53.5	May 30 to July 23	do	do	87.834	120.319	2.149	56	Very sick	Alfalfa and service-berry leaves.
		1916.								
Sheep 394	70.5	June 3 to 23	do	do	35	49.645	2.364	21	Died	None.
Sheep 377	81.5 to 57.5	June 3 to 28	do	do	51	62.577	2.407	26	Very sick	Epsom salt, strychnin, oak leaves, and alfalfa.
Sheep 386	78.5	June 18 to Aug. 8	do	Stems, stem leaves, and flowers.	60.575	77.166	1.484	52	do	Alfalfa and bran.
Sheep 389	71 to 63	June 20 to July 22	do	Radical leaves	55.875	78.697	2.385	33	do	Alfalfa and service-berry leaves.
Sheep 378	71.5 to 65.5	June 29 to Aug. 13	do	Flower heads	64.095	89.643	1.949	46	Sick	Alfalfa and pasture.
Sheep 373	99 to 85	July 5 to Aug. 22	do	do	71.334	72.055	1.471	49	Very sick	Epsom salt and pasture.
Sheep 385	93.5 to 76	July 22 to Aug. 26	do	Stems, stem leaves, and flowers.	45.844	49.074	1.363	36	do	Epsom salt, strychnin, and pasture.
Sheep 333	102.5 to 92	July 22 to Aug. 22	do	Radical leaves	52.751	51.464	1.715	30	do	Epsom salt and pasture.
Sheep 339	120 to 111	July 24 to Aug. 25	do	do	77.833	64.861	1.965	33	do	Epsom salt, strychnin and pasture.
Sheep 357	130 to 121.5	Aug. 5 to Sept. 1	do	do	65.285	50.219	1.794	28	do	Pasture.
Sheep 401	117.5 to 113.5	Aug. 9 to Sept. 7	do	do	60.113	51.160	1.705	30	Sick	Linseed oil, glycerin, and pasture.

Sheep 393	93.5 to 83	Aug. 11	2 forced feedings	do	2.346	2.509	2.509	1	Very sick	None.
Sheep 403	111.5 to 110	Aug. 26 to Sept. 2	Fed in alfalfa hay	do	2.355	2.112	.264	8	Not sick	
Sheep 392	121.5 to 104	Sept. 6 to 23	Dried and fed in alfalfa hay.	do	44	36.214	2.012	18	Very sick	Raw linseed oil.
Sheep 395	114 to 105.5	do	do	do	32.752	28.730	1.596	18	Probable symptoms	Pasture.
Sheep 374	115 to 105.25	Sept. 8 to 23	do	do	54.832	47.680	2.980	16	Very sick	Linseed oil and glycerin.
Sheep 375	113 to 105	do	do	do	32.168	28.467	1.779	16	Sick	Linseed oil, glycerin, and pasture.
Sheep 377	79 to 76.25	Sept. 10 to 13	Fed in alfalfa hay	do	4.583	5.801	1.450	4	Not sick	
Sheep 376	101.5 to 99.5	Sept. 21	Dried and given in 2 forced feedings.	do	3.527	3.475	3.475	1	Slight depression	None.
		1917.								
Sheep 411	65.5 to 57	June 8 to 23	Fed in alfalfa hay	Radical leaves	33.5	51.145	3.196	16	Very sick	Paraffin oil.
Sheep 412	55 to 44	June 8 to July 6	do	do	35.25	64.091	2.210	29	do	Paraffin oil and strychnin, Fowler's solution.
Sheep 423	88.5 to 77.5	June 8 to July 13	do	do	47	53.107	1.475	36	do	Linseed oil and glycerin.
Sheep 414	89.5 to 85.25	June 11 to 23	do	do	[1] 2	[1] 2.236	[1] .172	13	Not sick	
Sheep 418	77 to 75	June 8 to July 5	do	do	47.75	62.013	2.215	28	Very sick	Epsom salt.
Sheep 424	98.5	June 20	1 forced feeding	do	[1] 1.81	[1] 2.306	[1] 2.306	1	do	None.
Sheep 430	67.5 to 59.5	June 20 to July 6	Fed in alfalfa hay	Stems and stem leaves.	[1] 47	[1] 69.630	[1] 4.096	17	Very sick	Epsom salt and strychnin.
Sheep 415	67 to 63.5	June 22	1 forced feeding	do	1.541	2.3	2.3	1	Died	None.
Sheep 413	58.75	June 24	do	do	[1] 1.400	[1] 2.383	[1] 2.383	1	do	Paraffin oil.
Sheep 432	70.25 to 62.5	June 25	do	do	[1] 1.757	[1] 2.501	[1] 2.501	1	Sick	None.
Sheep 428	76.5 to 70.5	June 26	do	Radical leaves	[1] 1.757	[1] 2.999	[1] 2.299	1	Symptoms	None.
Sheep 425	83.5 to 81.5	July 6 to 22	Fed in alfalfa hay	do	10	11.975	.704	17	Not sick	
Sheep 416	106 to 87.5	July 6 to Aug. 8	do	do	69.5	69.566	1.928	34	Very sick	Sodium cacodylate.
Sheep 409	72.5 to 58	July 7	1 forced feeding	do	[1] 1.668	[1] 2.301	[1] 2.301	1	Diarrhea	None.
Sheep 419	99.5	July 8 to Aug. 8	Fed in alfalfa hay	do	59.75	60.050	1.877	32	Died	Do.
Sheep 420	137 to 114	July 8 to Aug. 9	do	do	58.542	42.731	1.295	33	Sick	Sodium cacodylate.
Sheep 433	88.25 to 84.5	July 11 to 15	do	Flowers	[1] 2.75	3.116	.623	5	Not sick	
Sheep 454	101 to 92.5	July 18 to 22	do	do	1.75	1.733	.346	5	do	
Sheep 410	71.5 to 62.5	July 19	1 forced feeding	do	[1] 1.641	12.294	2.294	1	Symptoms	None.
Sheep 448	108.25 to 86	July 27 to Sept. 16	Fed in alfalfa hay	Radical leaves	99.75	92.148	1.772	52	Symptoms, weakness	Do.
Sheep 446	122.5 to 104.75	July 30 to Sept. 4	do	Flowers	103	84.082	2.272	37	Very sick	Sodium cacodylate.
Sheep 437	136 to 113	Aug. 21 to Sept. 8	do	Radical leaves	55.25	38.419	2.022	19	do	Do.
Sheep 421	126.5	Aug. 27 to Sept. 18	do	do	60.625	47.925	2.083	23	do	Epsom salt and strychnin.
Sheep 439	99.5 to 86.75	Sept. 5 to 8	3 forced feedings	do	[1] 11.25	[1] 11.305	.565 / [1] 2.826	4	Sick	None.
Sheep 422	115.5	Sept. 10 to 14	5 forced feedings	do	12.448	[1] 10.776	[1] 2.156	5	Symptoms, died from choking.	Do.
Sheep 444	105.25 to 95	Sept. 13	1 forced feeding	do	2.333	2.217	2.217	1	Symptoms	Do.
Sheep 420	126 to 114	Sept. 22 to 25	5 forced feedings	do	8	6.350	.587	4	Nauseated	Do.

[1] Dry plant fed; estimated as green.

TABLE 1a.—*Summary of feeding experiments with sneezeweed (Helenium hoopesii) at Salina Experiment Station, Utah, 1918 and 1919.*

Animal.		Date of feeding.	Method of feeding.	Part of plant used.	Quantity of plant fed.			Days fed.	Severity of sickness.	Remedy.
Designation.	Weight during experiment.				Total weight.	Per hundredweight of animal.	Daily average per hundredweight of animal.			
	Pounds.	1918.			*Pounds.*	*Pounds.*	*Pounds.*			
Sheep 486	98 to 82	June 13 to July 5	Fed in alfalfa hay.	Radical leaves	52	53.061	2.307	23	Sick	Tannic-acid drench.
Sheep 490	81 to 64.5	do	do	do	57	70.370	3.060	23	do	Tannic acid in salt.
Sheep 506	126 to 99.5	June 13 to July 15	do	do	99.75	79.167	2.399	33	do	Tannic-acid drench.
Sheep 467	108 to 94	June 13 to July 22	do	do	58	53.704	1.343	40	Not sick	
Sheep 481	80 to 87	June 17 to July 4	do	do	45	56.250	3.125	18	Sick	Oak leaves.
Sheep 492	113 o 103	June 17 to July 7	do	do	41	36.283	1.728	21	Not sick	Do.
Sheep 468	82 to 79	July 13	Force fed	do	1.75	2.134	2.134	1	do	
Sheep 479	93 o 83.5	July 17	do	do	2.3	2.473	2.473	1	Not sick (depressed)	
Sheep 461	80 to 75.5	July 22	do	do	2.268	2.835	2.835	1	Symptoms	None.
Sheep 471	127 to 112.5	Aug 9 to 29	Fed in alfalfa hay.	do	[1] 56	[1] 44.094	[1] 2.1	21	do	Do.
Sheep 472	104.5 to 88.5	Aug. 9 to 30	do	do	[1] 36	[1] 34.45	[1] 1.566	22	Sick	Do.
Sheep 505	95.5	Aug. 17	Force fed	do	2.375	2.484	2.484	1	Died	Do.
Sheep 469	104 to 77.5	Aug. 26 to Sept. 19.	Fed in alfalfa hay.	do	51.5	49.519	1.981	25	Sick	Do.
		1919.								
Cattle 824	366 to 324	June 2 to Aug. 3	do	Leaves, stems, buds, and flowers.	373	101.91	1.62	63	do	Do.
Cattle 827	447 to 324	Aug. 5 to Sept. 12	do	Leaves and stems.	216	48.32	1.24	39	do	Do.

[1] Dry plant fed; estimated as green.

FEEDING EXPERIMENTS WITH SHEEP.

In the experimental feeding two distinct plans were followed—corral feeding and forced feeding.

Corral feeding.—In the early experience in corral feeding the animals were given nothing but sneezeweed, which was supplied in as large a quantity as they would eat. Inasmuch as some of these feedings were continued for a considerable period, in some cases three weeks or more, the question naturally arose whether insufficient nutrition did not play a large part in the production of symptoms. This was later definitely proved to be not the case. It was found, moreover, that the animals could be induced to eat only a limited quantity of the plant, and that this quantity was fully as great when hay was supplied with it. Some of the animals were fed as long as they would eat the plant without regard to whether it produced death, while in other cases the feeding was continued only to the time when definite symptoms appeared.

Forced feeding.—In the forced feedings the balling gun was used and the material, ground up, was administered as rapidly as possible. As the animals did not, in all cases, take the material readily, it was sometimes necessary to repeat the feeding in order to give a toxic dose. As shown by the table, also, the forced feedings were sometimes extended over a number of days to determine the effect of definite repeated feedings given in this manner.

Typical Case of Sheep 413.

Sheep 413 may be taken as a type of the effect of a single forced feeding of *H. hoopesii*. This animal was a wether, weighing at the time of the experiment 54½ pounds. The temperature shortly before the experiment was 104.7° F., its pulse 114, and its respiration 60. The high pulse and respiration are accounted for because this animal had not been handled before and was somewhat excitable. On June 24, 1917, between 10.45 and 11.08 a. m., it was given, by the balling gun, 2.383 pounds of *H. hoopesii* leaves and stems. This material had been finely ground. At 2.05 p. m. the temperature was 103.8, the pulse 140, the respiration 60. June 25, 8 a. m., the temperature was 102.5, pulse 144, the respiration 36. At this time the animal appeared dejected and the femoral pulse could not be detected. At 2.30 p. m. the animal was very sick; the heart was beating irregularly and no femoral pulse could be felt. At 3 p. m. the pulse was not only rapid, being 156, but was irregular. At 4 p. m. the respirations became irregular. The animal showed no inclination to move about. This condition continued during the evening, the pulse rate remaining very high. On June 26, 6.25 a. m., the animal was extremely weak, while the rapid, irregular pulse and the irregularities of the respiration continued. At 10.55 a. m. the animal appeared to be somewhat bloated, and breathing was noted as very irregular and noisy. The respiration was in groups of two or three, followed by holding of the breath after inspiration. These conditions continued unchanged during the day, the animal growing worse. On the morning of June 27 it was found dead.

In regard to the symptoms, it should be noted that the temperature continued during the sickness practically unchanged, the extremes being 100.6° to 105.3°. The high temperature, however, was noted only once and in repeated observations the temperature was only between 102° and 103.6°. The respiration varied somewhat more widely, running from 36 to 150. There was, however, no continued period of rapid respirations. The animal apparently had naturally a somewhat rapid pulse, as, on the day before the experiment, it was found to be 114. During the whole period of the illness, however, it ran high, going up as high as 156 and not falling below 121.

In the autopsy petechiæ were found on the surface of the heart and the trachea was somewhat congested, as were the lungs. In the alimentary canal the mucous membrane of the first, second, and fourth stomachs was congested. Congestion also was found in the duodenum, jejunum, and ileum, but not in the rectum.

There was a small mass of coagulated serum in the rumino-reticular groove and in the anterior groove of the rumen. It was noted that the blood vessels beneath the skin were somewhat congested.

Typical Case of Sheep 421.

This sheep can be taken as typical of those cases of prolonged feeding in which the principal symptom produced by the *H. hoopesii* was weakness, and in which vomiting was not exhibited. The sheep was a ram received at the station June 6, 1917, and at that time weighed 95 pounds. On August 6 and 7 an attempt was made to have the animal eat *Zygadenus elegans*. This feeding did not produce any effect. On August 27 a beginning was made of feeding *H. hoopesii*. At this time the sheep weighed 126.5 pounds. The general plan of feeding was to give the animal all the *H. hoopesii* it would eat, and with it was mixed more or less alfalfa hay to induce the animal to eat more readily. In preparing the material for feeding, ordinarily there was used from 3 to 5 times as much *H. hoopesii* as hay. In some instances, however, more hay was mixed with the uneaten *H. hoopesii*. Between August 27 and September 18 the animal ate 47.925 pounds of *H. hoopesii* per hundredweight of animal. The total days of feeding were 23, but symptoms appeared in 19 days after an average daily ration of 2.83 pounds of the plant.

The sheep ate quite readily and appeared to be in good condition until September 6, when it did not seem quite right. Distinct symp-

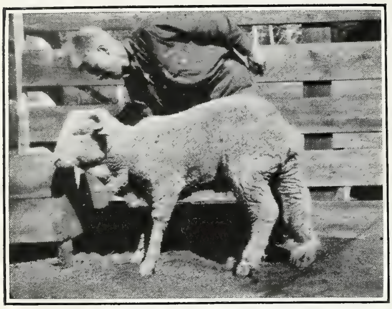

FIG. 1.—SHEEP 421, AT 10.44 A. M., SEPTEMBER 18, 1917.

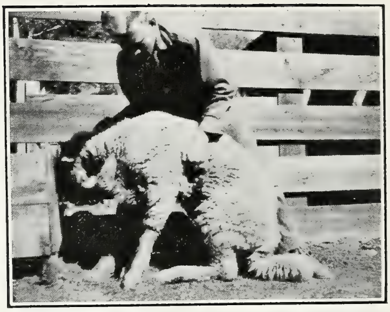

FIG. 2.—SHEEP 421, AT 10.45 A. M. SEPTEMBER 19, 1917.

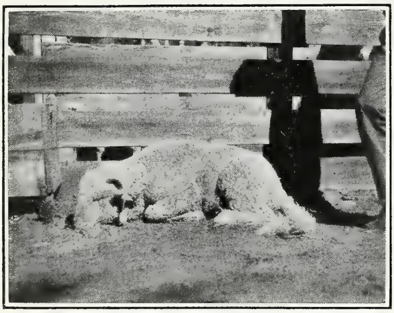

FIG. 3.—SHEEP 421, AT 10.46 A. M., SEPTEMBER 19, 1917.

FIG. 4.—SHEEP 332, IN THE ACT OF VOMITING.

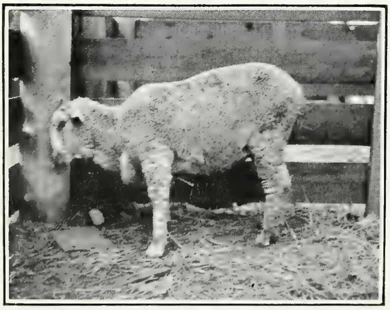

FIG. 5.—SHEEP 314, IN ATTITUDE SHOWING WEAKNESS.

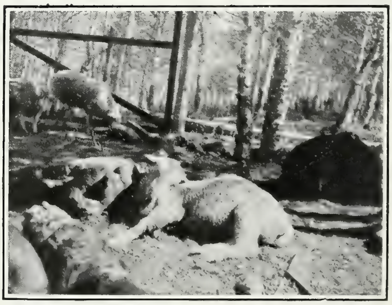

FIG. 6.—SHEEP 314, JUST BEFORE DEATH.

toms, however, did not appear until September 15. At that time it was still eating freely of the plant, but was gradually getting weaker, would lie down much of the time, and, when walking, dragged its hind legs. On the next day (September 16) the animal was not only lying down much of the time, but, when attempting to walk, acted as though the hind legs were stiff. On September 18 the weakness had so much increased that when standing it trembled and found great difficulty in keeping its feet. Plate I, figure 1, shows the animal at 10.44 a. m. On the afternoon of September 18 it was lying down with head stretched out, and when put on its feet was unable to stand more than a minute or two at a time. On September 19 the pulse was weak and the animal was down and did not attempt to rise. On the morning of this day it was given 3 ounces of Epsom salt and a subcutaneous injection of one-tenth of a grain of strychnin. The pulse was noted as irregular and the respirations rapid. The pictures, Plate I, figures 2 and 3, were taken at 10.45 a. m. and 10.46 a. m., and show very clearly the extreme weakness of the animal at this time. On September 20 it was given 1 ounce of Epsom salt and a subcutaneous injection of one-tenth of a grain of strychnin. The sheep was so weak that it was unable to raise the hinder part of the body from the ground. On this day the animal was regurgitating; some green mucus ran from its mouth and nostrils, but it did not vomit. On September 21 it appeared somewhat better, perhaps as the result of the action of the Epsom salt, and on this day it was given two doses of one-tenth of a grain of strychnin. The sheep was given alfalfa hay and bran and this feeding of hay was continued on the succeeding days. On September 24 the animal received 2 ounces of Epsom salt, and on September 25 appeared very much stronger. From this time there was a continual gain in the sheep's condition, and on September 28 it was turned out into the pasture. On September 30, the last day of observation, the animal weighed 103 pounds. It was evident, however, that recovery at this time was only partial, for the animal's general condition was rather bad.

Typical Case of Sheep 380.

Sheep 380 may be taken as a type of those animals subjected to prolonged feeding which, in addition to weakness, showed a pronounced tendency to vomit. The animal, a ewe weighing 60 pounds, was brought to the station May 28, 1916. The feeding was commenced on May 30 and was continued until July 21, 53 days. During that time the animal ate 113.82 pounds of *H. hoopesii*. Symptoms of poisoning, however, appeared in 25 days from the commencement of the feeding, at which time the animal had eaten 64.583 pounds.

The plan of feeding, as with Sheep 421, was to have the animal eat as much of the *H. hoopesii* as it would take. The plant was cut up and mixed with a certain amount of alfalfa hay, as the animal would not eat it without hay. The quantity of hay mixed with the *H. hoopesii* varied, being sometimes as much as one-half of the quantity of the poisonous plant. This feeding was continued from May 30, and the animal appeared in good condition with no evident symptoms of poisoning until June 23. On June 18 it was turned into the

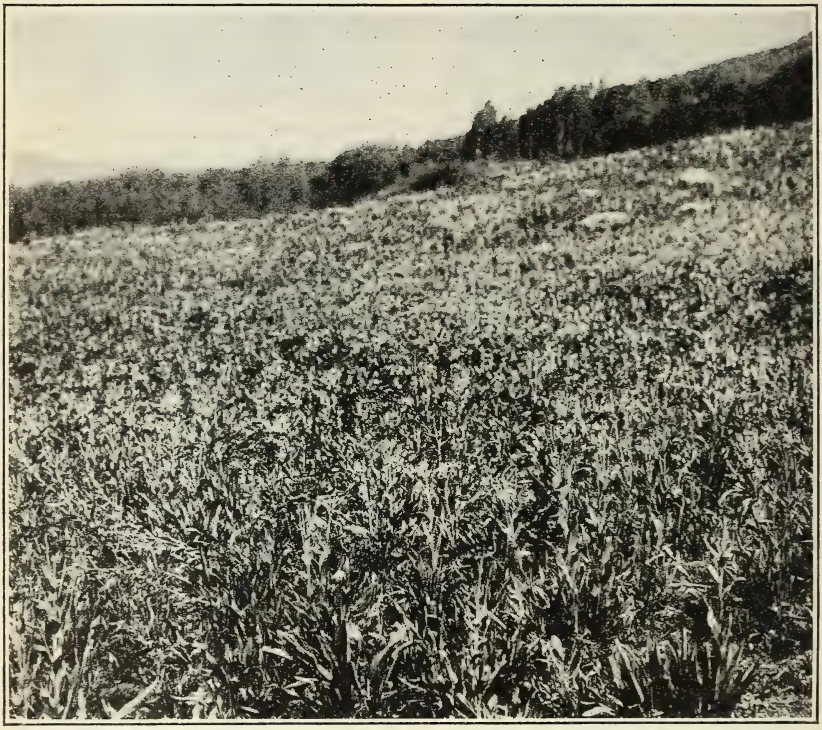

FIG. 4.—An overgrazed range on which *Helenium hoopesii* has taken almost complete possession.

pasture with the other animals, but during the rest of the time it was confined to the corrals.

On June 23 it was noticed that while lying down the sheep regurgitated, and there was some belching of stomach gas. On June 24 some green material was noticed about the mouth, and on June 25 it was found that she had vomited. On June 27 the animal had become quite weak and was not inclined to stand. At this time she evidently, to some extent, had lost her appetite for any kind of food. The feeding, however, was continued. On June 29 the pulse was noted as somewhat irregular and the animal was lying down most of the time, although still strong enough to stand. From this time on there were, every day, evidences of vomiting, and at times there was marked regurgitation and belching of gas and rumbling of the intestines. On July 1 it was noted that both pulse and respiration were very irregular. These symptoms continued with little change until July 7. On this day, in addition to vomiting, the animal was troubled with coughing; doubtless the coughing was caused by the irritation produced by some of the stomach contents getting into the larynx. There was no marked change after this except that the symptoms became gradually more marked. The irregularity and weakness of the pulse were more apparent and vomiting was more frequent, while the appetite gradually grew less, the animal not even caring to eat hay. On the morning of July 23 the sheep was found dead, having died some time during the night.

As there might be a question whether lack of sufficient food might not be the cause of sickness and death in cases like this, it should be stated that it was clearly proved by checking up in other cases that the weakness was not due to lack of food, but was distinctly due to the poisonous effects of the plant. In the autopsy which followed the death of the animal the only abnormal feature noted was some congestion in the fourth stomach, duodenum, jejunum, ileum, cecum, and rectum.

FEEDING EXPERIMENTS WITH CATTLE.

On the Utah ranges where the spewing sickness affects sheep there are no accounts of the poisoning of cattle by *H. hoopesii.* In following the cattle upon the range where it has been so closely grazed that very little remains except *H. hoopesii,* no evidence has been obtained of cattle grazing upon this plant. Certain reports, however, from Colorado ranges have led to the belief in the possibility of cattle being poisoned by *H. hoopesii.* Accordingly it seemed important to prove conclusively whether the plant would or would not affect cattle. Two head of cattle were treated in 1919 and both became sick as a result of the feeding, with typical symptoms resembling those produced in sheep. The following experiment with Cattle 827 may be considered as typical of the possible effect of the plant.

Case of Cattle 827.

Cattle 827 was a yearling steer received at the station on June 1, 1919, weighing at that time 340 pounds. From June 6 to 8, and on July 28, an attempt was made to have it eat aconite. The aconite produced no effect, although the animal as shown by the curve, figure 5, lost weight while in the corrals. Except for this experiment with aconite, the animal remained in the pasture until the experimental feeding of *H. hoopesii* was commenced, on August 5. The steer had prospered up to this time and weighed on August 4, 447 pounds. The feeding continued from August 5 until September 12. The stems and leaves of the *H. hoopesii* used were ground up and mixed with chopped hay in order to induce the animal to eat. Generally speaking, about 10 pounds of the plant were prepared and mixed with 5 pounds of hay. The plan of the experiment was that the animal should be induced to eat as large a quantity of the *H. hoopesii* as possible. Both this and the other animal very much preferred hay and frequently would pick out the hay, leaving a large portion of the *H. hoopesii.* Under such circumstances more hay was mixed with the *H. hoopesii,* so that a fairly good average daily ration of hay was fed during this period.

Up to September 13 no symptoms were noted other than a certain amount of inactivity in the animal. The curve of weight, figure 5,

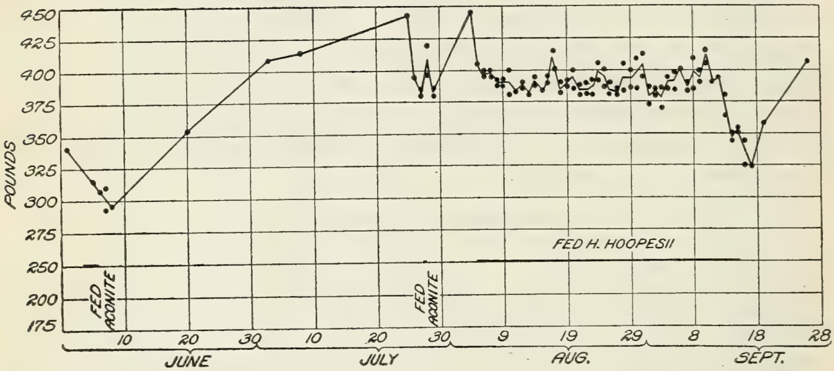

FIG. 5.—Weight curve of Cattle 827, fed aconite June 6 to 8 and July 28, and *Helenium hoopesii* August 5 to September 12, 1919.

shows that during this time the weight of the animal was maintained fairly well. On the morning of September 13 it was noticed that the animal must have been vomiting, as there were several patches of the material in the pen. The steer at this time was frothing at the mouth and regurgitating. A little later in the day he was seen in the act of vomiting. On September 14 the pulse was found to be very weak, so weak in fact that it was very difficult to count. The animal was much depressed and showed marked weakness. He was still vomiting at intervals. Figure 8 shows his attitude at 10.50 in the morning when he was regurgitating and frothing at the mouth and occasionally belching sour-smelling gas from the stomach.

These conditions continued on the succeeding days, the vomiting being more pronounced, the pulse continuing weak, and the general weakness of the animal increasing. No more *H. hoopesii* had been fed after September 12, and comparatively little hay had been eaten. On the afternoon of September 17 the animal was turned into the

FIG. 1.—SHEEP 374, SHOWING DEPRESSION AND WEAKNESS.

FIG. 2.—SHEEP 358, EXHIBITING SALIVATION.

FIG. 3.—SHEEP 361, A RANGE ANIMAL (LARGE SHEEP IN FOREGROUND), IN POSITION OF VOMITING.

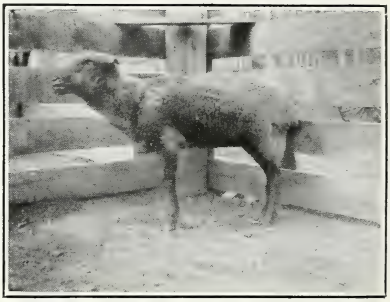

FIG. 4.—SHEEP 420, NAUSEATED.

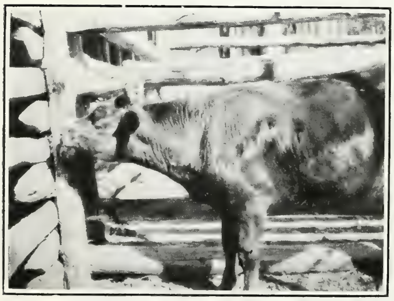

FIG. 5.—CATTLE 827, SHOWING NAUSEA.

FIG. 6.—CATTLE 827 VOMITING.

pasture; an observer followed him and succeeded in getting photographic records of the vomiting, one of which is shown in Plate II, figure 6. He was kept in the pasture the rest of the season until about the first of October. During this time as shown in the curve of weight, figure 5, he gained a little in weight, but was not in good condition. On September 26 he weighed 409 pounds. A report received from the owner of the animal December 17, 1919, indicates that after being taken from the range the animal remained in poor condition, and there is reason to assume that the injury produced by the feeding of *H. hoopesii* was permanent.

CHEMICAL EXAMINATION OF THE PLANT.

No previous analysis of *Helenium hoopesii* has been published. A nearly related plant, *Helenium autumnale*, the sneezeweed of the eastern United States, has been investigated by Koch (1874) and Reeb (1910). The latter isolated the substance of the formula $C_{20}\ H_{25}\ O_5$, which he called "helenic acid." The pharmacology of this was investigated by Lamson (1913), who named it "helenin"—an unfortunate choice, since that name was already established in science and commerce for a mixture of lactones obtained from *Inula helenium.* It was thought probable that the *H. hoopesii* would be found to contain helenic acid or a nearly related substance. A thorough chemical search, however, failed to reveal the presence of helenic acid or of any toxic compound which resembles it in physical and chemical characteristics.

The poisonous properties of *Helenium hoopesii* depend upon the presence of very small quantities of an exceedingly toxic glucosid to which the name "dugaldin" has been given. This occurs most abundantly in the leaves. It is found also in the stems, flowers, and seeds and in minute amounts in the root. Careful investigation of all the other constituents of the plant has shown that they are nontoxic to sheep and guinea pigs.

Dugaldin may best be prepared from the juice of the fresh radical leaves of *H. hoopesii.* The juice is expressed from the shredded leaves, which yield 40 to 60 per cent of brown, very bitter juice, the quantity depending on their age and the climatic conditions. The juice is preserved with 0.5 per cent of chloroform, allowed to stand 12 hours to settle, and filtered. The filtrate is then treated with animal charcoal which is kept suspended in the liquid by frequent stirring or shaking. After 4 to 7 days, the glucosid and coloring matters will have been adsorbed by the charcoal. The mixture is now filtered, when the filtrate appears colorless and slightly sweet instead of bitter and is nontoxic even in large doses. The animal charcoal which remains on the filter paper is washed with water, dried at ordinary temperature, and extracted with warm alcohol, which dissolves the dugaldin with a little coloring matter and sugar. The alcoholic solution is evaporated to dryness at a low temperature; the residue is treated with absolute alcohol, and the solution is filtered off. This is boiled with a little fresh animal charcoal, filtered, cooled, and a large volume of ether is added, when the glucosid precipitates out in white flocks. The yield is less than 0.01 per cent of the green leaves taken.

As thus prepared dugaldin is a white, amorphous substance soluble in alcohol; less soluble in water, chloroform, acetone, and pyridine; sparingly soluble in acetic ether; insoluble in ether, benzene, and petroleum ether. It is soluble in aqueous solutions of the alkalies and forms a slightly soluble compound with lead. Its barium salt is insoluble in alcohol. The glucosid is readily decomposed; when treated with acids or on heating with water it hydrolyzes, yielding a sugar which reduces Fehling's solution in the cold, and a brown resin which is still being studied. Attempts to crystallize the glucosid in quantity have not been successful.

Reactions of the glucosid.—Ferric chlorid gives no coloration. Tannic acid precipitates the glucosid from its solutions. Bromin water precipitates an addition compound which is soluble with decomposition in hot water. On acetylation the glucosid is decomposed. Acid solutions of the glucosid form a cloud with Mayer's solution. Uranyl acetate produces a transient precipitate insoluble in alkalies and soluble in hydrochloric acid. Potassium permanganate is immediately reduced. Cold chromic-acid mixture gives no change, but on heating, the mixture is completely reduced, forming a green solution. A mixture of hot nitric and sulphuric acids nitrates the glucosid, forming a yellow solution. On dilution with water a yellow nitro derivative is precipitated which is soluble in alkalies.

CHEMICAL EXPERIMENTS.

The material used for the chemical examinations was collected at the experiment station, Salina, Utah. When green material was used, it was collected and ground through a meat chopper immediately before being used. The dry material used was air-dried under cover until the weight was nearly constant. It was then preserved in cloth bags.

1. *Moisture, ash, extract.*—Air-dried samples of radical leaves in No. 60 powder were used for the following determinations:

	Per cent.
Moisture	9.70
Ash	16.86

Ten grams were extracted with various solvents in succession:

	Grams.	Per cent.
Petroleum ether extracted	0. 5065	5. 06
Ether extracted	0. 4800	4. 80
Chloroform extracted	0. 1611	1. 61
Alcohol extracted	1. 5834	15. 83
Total		27. 30

The ash contained a large proportion of calcium carbonate. The petroleum-ether fraction contained a phytosterol. The ether extract contained fats and a trace of tannin; the chloroform extract consisted of resins, tannin, and dugaldin; the alcohol extract contained resin, sugar, dugaldin, tannin, and coloring matter.

2. *Juice.*—Total solids, 9.80 grams per 100 ml.; specific gravity, 1.042 to 1.052 at 25°; tannin precipitates, 0.335 to 0.364 per cent.

3. *Alkaloids.*—The various samples of juice and of aqueous and alcoholic extracts of the plant, after acidification, yield precipitates with Mayer's solution. They were, therefore, investigated for the presence of an alkaloid, but no substance of this class could be isolated from any part of the plant.

4. *Hydrocyanic acid.*—Samples of green and of air-dried leaves were tested for cyanides as a routine procedure without yielding any evidence of their presence.

5. *Toxic saponins.*—Extractions of green and of air-dried leaves were made to isolate toxic saponins and several other extractions, as well as the juice from the leaves, were tested for saponins without revealing their presence. Extracts of the plant strike a green color with aqueous ferric chlorid, but this is due to the presence of a tannin which is precipitated by gelatin solution.

6. *Volatile toxins.*—Eight hundred and fifty grams of air-dried *H. hoopesii* radical leaves were placed in a still and 3 gallons of water added. The mixture was heated to boiling. The distillate had the characteristic odor of *H. hoopesii*, due to the presence of a minute quantity of essential oil. It reduced potassium permanganate; gave no color with ferric chlorid; and was neutral in reaction. The total volume of the distillate was 6 liters. This was fed to Sheep 429, in divided doses, without producing any effect.

7. *Search for helenic acid.*—(*a.*) A chloroform extract from 1 kilogram of dried radical leaves was freed from chloroform. Following Reeb's procedure, the extract was heated with successive portions of water on the steam bath and filtered. After cooling, the aqueous solution was greenish-yellow in color and had a very small amount of oily matter floating on the surface. It was evaporated to convenient bulk and extracted with several portions of chloroform. The chloroform dissolved out 4 grams of green solid, which was not bitter and was nontoxic.

(*b*.) Two hundred twenty-five grams of dried blossoms and seeds of *Helenium hoopesii* were ground to No. 20 powder and were extracted with chloroform in a Soxhlet. The chloroform was distilled off on a steam bath. The residue weighed 28.95 grams (12.86 per cent) and was brownish, fatty, and fluid. It was heated on a steam bath with successive portions of water for several hours and filtered. The filtrate was bitter; it was evaporated to dryness on the steam bath. The residue was a yellowish resin. This was extracted with benzene. The white insoluble residue was very bitter and contained dugaldin. The benzene soluble matter was not bitter and was nontoxic.

(*c*.) A second extraction with chloroform of 400 grams of dried blossoms and seeds yielded 12.62 per cent extract, in which no helenic acid could be found.

A tabular statement of pharmacological experiments will be found in Table 2 on page 23.

8. *Water-soluble constituents.*—Fifteen kilograms of air-dried basal leaves ground to about a No. 12 powder were extracted with water by percolation. This did not remove all the bitterness from the leaves. The percolate was brown and bitter. It was concentrated to a small volume. During this process a light-brown precipitate appeared, which consisted of albuminoids and calcium salts. This was collected, washed, and tested for toxicity to sheep. Sheep 409 received daily doses of 5 grams of this precipitate from September 4 to September 16, inclusive, receiving two doses on September 10, 11, 12, and 16—a total of 80 grams—without effect. Fifty grams were fed to Sheep 425 on September 10 without producing any effect. The concentrated aqueous solution was divided into two portions. One portion was boiled over a free flame for several hours, when a further quantity of the brown, nontoxic precipitate separated and the solution lost its bitterness, due to hydrolysis of the glucosid. During a period of four days Sheep 450 received 2,400 mils of this orally in five doses, but beyond some abdominal disturbance showed no effect. The other portion of the concentrated percolate was treated with lead acetate, and the precipitate was filtered off; the filtrate was neutralized with ammonia and precipitated with basic lead acetate. This precipitate was filtered off, and the lead removed from the filtrate with hydrogen sulphid. The lead-acetate precipitate was washed, suspended in water, and decomposed with hydrogen sulphid. The solution was bitter and contained part of the glucosid. It was very toxic. The basic lead-acetate precipitate, freed from lead with hydrogen sulphid in the same way, was not bitter, contained no glucosid, and was nontoxic. The filtrate from the lead precipitations was bitter, contained a portion of the glucosid, and was very toxic.

The marc from this extraction still contained some of the glucosid. It was dried and tested for toxicity. Small amounts fed to sheep caused nausea. Sheep 445 was force-fed small amounts of this marc moistened with water 3 times a day for 12 days, receiving in all 30 doses of marc. The animal developed the characteristic spewing and died on the twelfth day.

9. *Nauseant substances.*—(*a*) In order to investigate the question of whether the glucosid or the water-insoluble constituents of the plant are responsible for the spewing cases, 1,500 grams of the marc from number 8 was taken. This had been extracted with water to which it yielded part of its dugaldin, but still contained resins, fats, etc. It was thoroughly extracted with alcohol, which removed all the bitterness. The marc from this alcohol extraction was carefully dried and force-fed in quantity to a sheep without producing any effect. The alcohol was distilled off the extract which was green, fatty, and bitterless, the glucosid having been decomposed by the heat to which it had been subjected during the distillation. The alcohol extract was treated with chloroform, when about 75 per cent of it dissolved. The residue was fed to Sheep 447 and produced no effect. The chloroform was removed from the soluble portion and this residue was fed to Sheep 456 without effect.

(*b*) Two and one-half kilograms of the marc from number 8 was boiled two hours with 9 liters of (1 per cent) sodium-hydroxid solution and the liquid portion was pressed out. The insoluble matter was again boiled two hours with 9 liters of water, which was pressed out. Both of these liquids gelated on cooling. The residue was boiled a third time for two hours with 9 liters of water and pressed out. The mixed colates were heated to boiling and acidified with hydrochloric acid, when a curdy, green precipitate in quantity fell. This was washed thoroughly and tested for toxicity. Sheep 428 received one-fourth of it orally and showed no effect.

(*c*) The marc was extracted with dilute hydrochloric acid, which dissolved a small quantity of inorganic matter. It was then washed, dried, and tested on sheep, when it was found nontoxic.

10. *Alcohol-soluble constituents.*—Fifty-six and one-half pounds of fresh radical leaves were shredded in a meat chopper and immediately put into two 5-gallon cans, which were then filled up with strong alcohol and sealed. After two months the cans were opened. The material was packed in percolators and exhausted with alcohol. The marc from this extraction was carefully dried and tested for toxicity. A large part of it was fed to Sheep 541 for an extended period without producing any abnormal conditions.

From the alcohol extract the glucosid was isolated, but owing to much decomposition only a small amount was obtained.

11. *Experiments with the juice.*—(*a*) The juice is very toxic and small amounts of it fed daily for an extended period produce spewing cases. It was shown that all of the dugaldin might be precipitated from the juice, leaving a liquid which is not acutely toxic. Sheep 460 received on separate days three doses of 650 mils each of juice which had been precipitated with tannic acid and filtered. This produced no effect. Inasmuch as 250 mils of the untreated juice were sufficient to kill in a short time, it is evident that the tannin had removed the toxin.

(*b*) It was desired to see whether juice precipitated with tannic acid would cause the spewing cases. Accordingly three sheep, Nos. 463, 473, and 501, were given from June 25 to August 23, inclusive, daily doses of juice from 2 pounds of fresh leaves from which the dugaldin had been removed by precipitation with tannic acid. As a precaution against tannic-acid poisoning, the precipitant was added only in slight excess to the juice and, after filtering off the precipitated glucosidal tannate, the excess of tannic acid was removed by neutralizing the solution with ammonia when the tannic acid precipitated as a calcium compound. At the end of the experiment each sheep had received the detoxicated juice from 118 pounds of fresh *H. hoopesii* radical leaves. None developed spewing symptoms and all survived.

(*c*) Part of the tannic compound of the glucosid produced in these experiments was dried and fed to Sheep 482 in 2-gram doses daily (1½ pounds green leaves) for 31 days and in 4-gram doses for 25 days without producing any definite effect.

(*d*) A quantity of moist glucosidal tannate from 49.5 pounds of radical leaves was warmed with water and magnesium oxid in an attempt to decompose the compound and liberate the dugaldin. This mixture was fed in divided doses to Sheep 503 twice daily for 24 days. The animal did not become seriously sick, but the urea excretion was markedly diminished, which indicated that the glucosid was being partly absorbed. It was later found impossible to regenerate the glucosid quantitatively from its tannic acid compound, and it is believed that in these cases the larger part of it was excreted without having ever been absorbed from the alimentary tract.

(*e*) A quantity of the juice was treated with animal charcoal and after seven days had lost its bitterness and color; 500 mils of this juice (about 2 lethal doses of untreated juice) were drenched into Sheep 539 without producing any effect.

12. *Toxicity experiments with dugaldin.*—A number of animals were given doses of a solution of dugaldin in order to test the toxicity of that glucosid. The details of some representative cases are published in Table 2.

TABLE 2.—*Results of toxicity tests with dugaldin.*

Animal.	Weight.	Date.	Dose.		Material.	Effect.	Termination.	Autopsy.
			Quantity.	How given.				
	Grams.	1919.	*Ml.*					
Guinea pig 17.	500	Mar. 26	4	Orally......	Solution of dugaldin.	Sick.....	Died......	Characteristic.
Guinea pig 18.	355	...do	2	.....do......	.....do..........	...do.....	...do.......	Do.
Guinea pig 19.	400	...do	.5	Subcutaneously.	.....do..........	...do.....	Killed.....	Do.
Guinea pig 20.	425	...do. ...	.5	.....do......	.....do..........	...do.....	Recovered	
Guinea pig 20.	....	Mar. 27	1	.....do......	.....do..........	...do.....	...do.......	
Guinea pig 20.	....	Mar. 28	.5	.....do......	.....do..........	...do.....	...do.......	
Guinea pig 20.	....	Mar. 29	.5	.....do......	.....do..........	...do.....	...do.......	
Guinea pig 20.	....	Mar. 30	.5	.....do......	.....do..........	...do.....	...do.......	
Guinea pig 21.	380	Mar. 27	1	Orally......	.....do..........	...do.....	...do.......	
Guinea pig 22.	365	...do	1	Subcutaneously.	.....do..........	...do.....	...do.......	
Guinea pig 23.	250	Mar. 28	4	Orally......	Solution precipitated by tannic acid.	...do.....	...do.......	
Guinea pig 24.	240	Apr. 9	2	Rectally...	.....do..........	...do.....	Killed.....	Do.
Rabbit 21....	1,800	Mar. 27	1.5	Intravenously.	.....do..........	...do.....	...do.......	Do.

CHEMICAL SUMMARY.

1. The poisonous principle of *Helenium hoopesii* is an easily decomposed glucosid to which the name "dugaldin" has been given. It is a bitter, white, amorphous solid; soluble in alcohol; less soluble in water and chloroform; insoluble in ether, benzene, and petroleum ether.

2. Dugaldin is most poisonous when administered orally, but is also toxic when given intravenously, subcutaneously, or rectally.

3. Dugaldin may be precipitated from its solutions by tannic acid, with which it forms a sparingly soluble compound of low toxicity.

4. Helenic acid, the active principle of *Helenium autumnale,* does not occur in *H. hoopesii,* nor do alkaloids, toxic saponins, or hydrocyanic acid.

URINE EXAMINATION.

In order to determine what effect is produced in the urine following the ingestion of *H. hoopesii,* a number of 24-hour samples of urine from several sheep were examined chemically and microscopically. It was found that the total volume of the urine was diminished, in some cases enormously so. The urea excretion was also markedly diminished, while the content of ammonium compounds was much increased. Sugar was not found, but albumin frequently appeared, especially after prolonged feeding. When the feeding of *H. hoopesii* was discontinued the volume and urea content of the urine increased, while the ammonia quickly fell to normal. These results indicate a functional disturbance of the liver, since it is in this organ that the conversion of ammonium compounds to urea is largely effected. The presence of albumin in the urine further indicates an alteration of the kidney.

Sheep 469 was fed small amounts of fresh *H. hoopesii* daily, and frequent examinations of the urine voided were made, as shown in Table 3.

TABLE 3.—*Examination of urine of Sheep 469.*

Date.	Condition of animal.	Volume.	Specific gravity.	Reaction.	Albumin.	Bile pigment.	Urea.	Biliary acids.
1919.		*Mils.*					*Grams.*	
Aug. 24	Normal	1,704	1.019	Alkaline	0	+	48.78	0
Sept. 7	Fed *Helenium hoopesii.*	905	1.027	do	Trace.	0	31.76	0
Sept. 13	do	610	1.031	do	do	+	21.11	0
Sept. 19	do	254	1.043	do	do	+	5.19	
Sept. 23	Spewing	780	1.024	Acid	0	+	4.45	0
Sept. 26		750	1.015	Alkaline	+	+	22.28	

The volume of urine voided rapidly diminished, as did the quantity of urea, but not proportionately. The amount of ammonical nitrogen could not be quantitatively determined in the field, but rough tests showed beyond question that the proportion of this was greatly increased. On September 19 the animal began to spew, when it was taken off the *H. hoopesii* ration and fed hay. The volume of urine voided immediately rose, the quantity of urea increased more slowly, and the proportion of ammonical nitrogen slowly dropped to normal.

Sheep 503 was investigated at the same time. This animal was fed a mixture of tannic-acid compound of dugaldin and magnesia. The result was an ultimate reduction in the amount of urine voided, a quick drop in urea, and an increase in ammonical nitrogen. The results of the examination are given in Table 4:

TABLE 4.—*Examination of urine of Sheep 503.*

Date.	Condition of animal.	Volume.	Specific gravity.	Reaction.	Albumin.	Bile pigment.	Urea.	Biliary acids.
1919.		*Mils.*					*Grams.*	
Sept. 6	Normal	1,525	1.018	Alkaline	0	0	32.88	0
Sept. 14	Dugaldin tannate.	2,145	1.014	do	Trace.	+	20.98	0
Oct. 1	do	230	1.052	do	0	++	8.68	0

DISCUSSION AND GENERAL CONCLUSIONS.

SYMPTOMS.

There is a definite line of symptoms in *H. hoopesii* poisoning, but they differ in detail according to the severity of the illness, and there is a fairly clear distinction between the symptoms in acute cases and those from prolonged feeding. In general the symptoms resemble those of other kinds of plant poisons, but are not so violent as in some and are not accompanied by convulsions.

Depression.—The first symptom noted in the corral cases is depression. In very mild cases this may be the only symptom noted, and probably in most range cases is overlooked. This is shown in the attitude of Sheep 314. (Pl. I, fig. 5.)

Pulse.—In most cases the pulse is weak, irregular, and somewhat rapid. Of these characteristics the irregularity is most noticeable, and in mild cases this and depression may be the only symptoms noted. Of course in range cases this is never recognized.

Weakness.—Accompanying the depression and weak and irregular pulse is a general weakness, which is more pronounced in the prolonged cases. This is shown in Sheep 374 (Pl. II, fig. 1) and still more clearly in Sheep 421 (Pl. I, figs. 1, 2, 3, 4, 5, and 6). In some of the acute cases this weakness does not appear at all.

Restlessness.—Both in the early and later stages of the sickness, the animals generally exhibit marked restlessness. If they are strong enough to stand on their feet they will remain standing but a short time, when they will lie down and then very soon get up again and move about in an uneasy way.

Stiffness.—During the sickness a peculiar stiffness in gait frequently is noticed. This accompanies the weakness, though it is not a result simply of weakness, and may be considered somewhat characteristic of the intermediate stages.

Temperature.—There are no marked changes in the temperature, and it remains practically normal during the period of illness.

Respiration.—The respiration is quickened when the animal attempts to get up on its feet, and is also more rapid during the acute stages of the sickness. There are no peculiarities of respiration which can be considered as characteristic of *H. hoopesii* poisoning.

Salivation.—Salivation occurred in many of the force-fed animals and in some of those poisoned by prolonged feeding. In some cases the salivation resulted in profuse frothing at the mouth. Doubtless this was due in some measure to mechanical irritation caused by the method of forced feeding, but this was not the complete explanation; salivation may be considered as a common symptom in the forced-feeding cases and as a symptom which occasionally occurs in chronic cases. Sheep 358 (Pl. II, fig. 2) is a good example of a salivated animal.

Nausea.—Nausea was exhibited in many of the animals; it did not however, always result in vomiting. In some of the acute cases vomiting did not take place, although it did in some of those in which repeated forced feeding were made. Generally speaking, in the prolonged cases vomiting, or "spewing," as it is called by the sheepmen, is the most prominent symptom of *H. hoopesii* poisoning. In range animals it is practically the only symptom which is noticed by the herders. It is not unusual, when a flock of sheep has been feeding upon a *H. hoopesii* area, to see large numbers of them throwing up their heads and vomiting. The large sheep in the foreground of figure 3, Plate II, shows the typical attitude of one of these animals in a flock feeding upon the range, and figure 4 of Plate I shows the attitude assumed by a corral force-fed animal in the act of vomiting. Sheep 420, which became ill from prolonged feeding, is shown in Plate II, figure 4, in an attitude produced by nausea. The pictures of Cattle 827 (Pl. II, figs. 5 and 6) show nausea and vomiting.

This tendency to vomit may continue for a prolonged period after the feeding upon *H. hoopesii* has been stopped. The experiences with the animals in 1917 may be quoted as giving a definite idea of the frequency of this symptom. Out of 12 prolonged feedings and 2 repeated forced-feeding cases in this year vomiting occurred in 8 feedings and in 1 of the repeated forced-feeding cases. Of the 8 acute cases in this year only 1 showed a tendency toward vomiting.

Coughing.—Many of the poisoned sheep were noticed to be frequently coughing. This was particularly noticeable in the animals poisoned upon the range. It is probably due to mechanical irritation caused by material from the stomach getting into the larynx.

Bloating.—Bloat occurred in some of the experimental animals in both acute and chronic cases, and when it occurred was sometimes accompanied with the belching of gas from the stomach. Bloating can not be considered as a usual symptom of the experimental animals. In range cases, however, most of the spewing cases apparently are bloated.

Trembling.—Trembling was noticed in a number of the cases, but can hardly be considered a characteristic symptom, as it probably results simply from the general weakness of the animal.

Diarrhea.—In some of the animals diarrhea followed the severe stages of the sickness and was noticeable before complete recovery took place. It was not, however, a usual symptom, and neither it nor constipation can be considered as characteristic of *H. hoopesii* poisoning.

Most Prominent Symptoms.

The especially prominent symptoms, then, of *H. hoopesii* poisoning are general depression, weak and irregular pulse, weakness, and nausea, followed by more or less chronic vomiting. Vomiting is not a characteristic of the acute cases and does not always appear in the chronic cases. Apparently the chronic cases of sheep can be divided into two types—one characterized by extreme weakness with rapid and irregular pulse, and the other with the added symptom of vomiting.

Death comes on quietly and is not accompanied by convulsions. Plate I, figure 6, shows Sheep 314 in the last stages.

AUTOPSY FINDINGS.

In 1915 there were 6 autopsies on sheep, 7 in 1916, 7 in 1917, and 1 in 1918. In the results of these autopsies no uniform picture was presented which could be considered as characteristic of *H. hoopesii* poisoning. In some there were congested lungs and kidneys, but this condition was by no means found even in the majority of cases. Generally speaking there was, however, distinct congestion of parts of the alimentary canal. In nearly all cases there was congestion of the duodenum and ileum, and in most of them congestion of the walls of the stomachs. In some cases this congestion was found in the cecum and even in the rectum, but this was not ordinarily the case. It can hardly be said that the autopsies gave any diagnostic characteristics of *H. hoopesii* poisoning.

In 4 of the 5 acute cases on which autopsies were held a considerable mass of serous coagulum was found on or near the rumino-reticular groove. This, doubtless, was caused by the marked effect of the *H. hoopesii* poison upon the circulatory system, as explained in the discussion of the pathology which follows.

MICROSCOPIC PATHOLOGY OF H. HOOPESII POISONING.

The pathological changes occurring in the tissues of sheep poisoned with *Helenium hoopesii*, or its extracts, vary with the type of the case and the method of administering the material.

Liver.—In all types of cases the liver is affected, the hepatic cells varying in condition. In acute cases the liver cords may appear compressed from edema, and the hepatic cells themselves often contain large, irregular-shaped, open spaces. In other cases the hepatic cells are swollen so as to obscure the capillaries. In the chronic type, mild cloudy swelling or fatty degenerative changes may occur. In one case interstitial hepatitis, and in another a well-marked small-cell infiltration occurred. Bile ducts are very frequently catarrhal or sometimes badly broken down.

The quantity of blood varies between wide limits, a few cases being severely congested, while in others very little blood is present.

In all cases the blood stream in the liver is affected, this being seen best in the central lobular and sublobular veins. In many such veins, besides normal erythrocytes, there are leached or degenerate erythrocytes, granular material, areas of numerous leucocytes, and sometimes fibrous material. Hepatic cells sometimes are floating in the blood stream. These bodies may or may not be attached to the wall of the vein. While some of them may be formed about the time of death when the blood flow becomes very sluggish, their structure would indicate that they are thrombi.

The thrombi and the edematous, or swollen, liver cells occasion some resistance to the blood flow, and sometimes cause the mesenteric veins, the spleen, and the pancreas to be more or less congested.

Lungs.—There is no more uniformity of condition found in the lungs than in the liver. As a rule the acute cases have congested lungs, the capillaries in some being greatly distended, and there is much blood in the arteries. In some cases the pronounced capillary congestion has led to a transudation of serum, and some diapedesis of erythrocytes. Generally, too, there is a marked catarrhal condition of the bronchi, which may contain desquamated epithelial cells and red blood corpuscles. Alveoli in places contain coagulated serum.

The blood contained in and sometimes filling the arteries is similar in condition to that seen in the veins of the liver, except that normal leucocytes are rarely seen.

The lungs of the three chronic cases examined were found to be diseased. In the sections of the lung of Sheep 319 there were necrotic areas. The alveoli surrounding such areas contain numerous leucocytes and some exfoliated epithelial cells. Some small blood vessels were engorged. In the lung of Sheep 348 there were areas of serous transudation, which, with the thickened alveolar walls and marked invasion of leucocytes, obliterated many alveoli. This condition probably results from spewed material being drawn down the trachea and accounts for the cough so common in old "spewers."

Sheep 437, an old spewer killed later with *Asclepias galioides*, had lung adhesions and necrotic areas. In sections of the least diseased parts of the lung there was an excess of connective tissue.

Kidneys.—The kidneys are equally variable in their pathological condition. In none of the cases examined was there severe congestion. In all those studied there was an edematous condition of the capsule of Bowman, the edema separating the folds of the glomeruli and leaving a large clear area between the glomeruli and the capsule wall. This is sometimes accompanied with a small quantity of stainable material resembling degenerated cytoplasm. In most of the cases examined the cells of some portions of the convoluted tubules had undergone degenerative changes. Some are swollen, while others are beginning to disintegrate the granular material lying in the lumina.

Alimentary tract.—The most pronounced change occurred in the alimentary tract of the acute cases, the exact portion varying with the method of administering the material. In four sheep—Nos. 338, 314, 331, and 413—which died from single forced feedings, the most severe changes were in the rumen and reticulum near the opening of the esophagus. In one sheep which was drenched with an extract the severe changes occurred in the walls of the abomasum, colon, and rectum, with less severe changes in the small intestine.

The changes found in the rumen and reticulum walls are of the same character, consisting of a very pronounced serous infiltration and an invasion of great numbers of leucocytes. The serum which has become coagulated is in all tissues, pushing the tissue elements apart and greatly thickening the walls. It is a portion of this serous transudate which was found in the serous coat in the neighborhood of the rumino-reticular groove. In these cases, with one exception, erythrocytes are not abundant, though vessels just beneath the mucosa are distended.

The leucocytes are very abundant in the submucosa in places and are grouped, resembling lymph nodules. These areas may extend up through the muscular layers and into the serosa. The cells of these areas differ from those of lymph nodules. They are apparently more or less degenerated, but on the whole more resemble polymorphonuclear leucocytes than the cells of the lymph nodules. The abomasum wall is edematous, and in areas in the mucosa is sometimes hemorrhagic.

Sheep 451, which was given an extract of *Helenium hoopesii* in a drench, differed from the foregoing in that the point of irritation was mainly in the abomasum, colon, and rectum. The walls of these portions of the alimentary tract were highly congested, the congestion being accompanied by edema and hemorrhage. This condition was most pronounced in the mucosa in which layer degenerative changes had occurred. The abomasum wall was most thickened and the serum was more coagulated there than elsewhere. The condition differed from that found in the first and second stomachs of the force-fed cases in that there was not so marked an invasion with leucocytes; more blood was present, and the serum was less coagulated. In this case the duodenum and jejunum were quite edematous but not severely congested. No sections of the ileum were made, though the autopsy report shows it to have been inflamed in portions.

This inflammation of portions of the alimentary tract does not occur in chronic cases. There may be mild congestion and some edema present in the abomasum and ileum, but this is not severe. In many places in the digestive tract the erythrocytes of the venous blood take the eosin stain much less strongly than those in the neighboring arteries. This, taken with the finding of degenerated erythrocytes in the veins of the liver, indicates a certain amount of direct action of the toxin on the red blood corpuscles. That this is not severe in chronic cases has been shown by hemoglobin tests on sick as compared with normal sheep.

Tissues from a number of guinea pigs killed or made sick on extracts of *Helenium hoopesii* were studied and agreed fully with the findings on sheep tissues.

Dugaldin, then, appears to be highly irritant and to be absorbed in any portion of the alimentary tract of the ruminant. It is probable, however, that to be absorbed in the rumen or reticulum it must be in sufficient concentration to damage the epithelium.

TOXIC DOSE FOR SHEEP.

In determining the toxic dose a distinction should be made between poisoning by a single administration of the plant and the toxic result of prolonged feeding. It was found that no animal would eat enough in a single day to produce symptoms, but by the use of the balling gun it could be compelled to swallow enough to produce intoxication or death. Moreover, the whole aerial part of the plant including stems, leaves, and flowers was used with some animals while in other cases use was made of stem leaves, radical leaves, flowers or stems, leaves, and fruit.

Toxic dose of whole plant, including leaves, stems, and flowers when fed.—Eight sheep were used in the feeding of the whole plant in 1915 and two in 1916. Table 5 shows the result:

TABLE 5.—*Summary of feedings of leaves, stems, and flowers.*

Animal.	Total fed per hundredweight of animal.	Total days fed.	Average daily feed per hundredweight of animal.	Days before sick.	Quantity per hundredweight of animal to produce sickness.	Daily average to produce sickness.	Result.
1915.	*Pounds.*	*Days.*	*Pound.*	*Days.*	*Pounds.*	*Pounds.*	
Sheep 316	2.19	1	2.19				Not sick.
Sheep 319	82.468	21	3.9	21	75.3	3.1	Died.
Sheep 326	43.299	28	1.546				Not sick.
Sheep 328	74.713	19	3.932	19	74.713	3.9	Sick.
Sheep 329	32.865	17	1.933				Not sick.
Sheep 333	28.372	24	2.182	24	28.372	1.182	Weak.
Sheep 344	2.469	3	.835				Not sick.
Sheep 346	80.311	59	1.361	23	35.7	1.5	Symptoms.
1916.							
Sheep 386	77.166	52	1.434	20	37.579	1.879	Very sick.
Sheep 385	49.074	36	1.363	23	34.626	1.505	Do.
Average				21.6	47.715	2.17	

In all the cases of 1915 except sheep 316 the animals were given only the *H. hoopesii*. In the cases of 1916, hay was fed with the plant.

Averaging these cases, a daily feeding of 2.17 pounds continued 21.6 days produced sickness or death. The limits of the daily dosage, however, were rather wide, varying from 1.18 pounds in Sheep 333 to 3.9 pounds in Sheep 328. There was nothing in the conditions of the experiments to explain this wide divergence.

TOXIC DOSE FOR CATTLE.

Cattle 824 was made sick in 21 days, receiving in that time 52.6 pounds while Cattle 827 was made sick in 39 days, receiving in that time 48.32 pounds. The two cases average in 30 days of feeding with a daily dosage of 1.68 pounds per hundredweight of animal. This, it will be seen, does not differ materially from the average obtained for sheep, so that the inference is a reasonable one that *H. hoopesii* is about equally poisonous to sheep and cattle.

ACUTE CASES.

Table 6 gives a summary of the animals to which the green plant was given by forced feeding in one day in order to produce acute cases.

TABLE 6.—*Summary of forced feedings of green leaves in one day which produced intoxication.*

Animal.	Number of feedings.	Quantity fed per hundred-weight of animal.	Time from end of feeding to symptoms.	Result.
1915.		*Pounds.*	*Hours.*	
Sheep 315	2	2.646	6¼	Sick.
Sheep 332	2	2.846	[1]	Do.
Sheep 340	3	2.645	2	Do.
1916.				
Sheep 393	2	2.509	3¼	Do.
1917.				
Sheep 424	1	2.306	8½	Very sick.
Sheep 432	1	2.501	5½	Sick.
Sheep 428	1	2.299	24	Symptoms.
Sheep 444	1	2.217	6½	Do.
1918.				
Sheep 461	1	2.835	31½	Sick.
Average		2.494		

[1] Immediate effect.

The average dosage in the table above was 2.494 pounds, with a minimum limit of 2.217 pounds and a maximum of 2.846 pounds. In general it may be stated that 2.5 pounds of green leaves fed in one day may produce intoxication. It should be noticed, however, that none of these feedings resulted in death. Reference to Table 1 will show that—

Sheep 320 received 2.79 pounds without effect.
Sheep 318 received 2.646 pounds without effect.
Sheep 347 received 2.756 pounds without effect.
Sheep 479 received 2.473 pounds without effect.

It is recognized that there is some difficulty in noting slight symptoms and that some of these animals may have been affected by the plant, although no positive symptoms appeared. It is fair, however, to draw the inference that while 2.5 pounds may be considered as the toxic dose of the green plant in acute cases, it does not follow that all animals receiving this quantity in a single day will be poisoned.

Comparing these results with those in Table 8, showing the effect of feeding green leaves in the corrals, it is interesting to note that the average quantity, about 2.5 pounds, necessary to produce acute cases, is only slightly greater than the average quantity, fed in the corrals for three weeks, which produced chronic cases—namely, 2.2 pounds. While as large a quantity as 3.143 pounds has been fed daily for 22 days before producing intoxication, it is evident that when the feeding is not made in a single dose, but is continuous and spread over a considerable period of time, much of the toxic principle must be eliminated.

Continued Forced Feeding.

In some animals the forced feeding of green leaves was continued in smaller doses for several days. The following table shows those in which positive results were obtained:

Table 7.—*Forced feedings of green leaves, in two or more days, which produced intoxication.*

Animal.	Days fed.	Number of feedings.	Quantity fed per hundredweight of animal.		
			Total.	Daily average.	Result.
1915.	*Days.*		*Pounds.*	*Pounds.*	
Sheep 355	3	4	4.001	1.33	Died.
Sheep 358	3	5	4.139	1.379	Sick.
Sheep 327	7	12	7.936	1.134	Do.
Average	4⅓		5.359	1.281	

According to Table 7, an average daily feeding of 1.281 pounds continued for 4⅓ days produced sickness or death, or, in round numbers, 1¼ pounds given daily for 4 or 5 days produced intoxication. As compared with voluntary feeding upon leaves (p. 33) these force-fed animals were poisoned on a smaller dosage and in less time.

TOXICITY OF LEAVES OF PLANT.

It is to be presumed that sheep on the range, when eating *H. hoopesii* feed mainly on the leaves. It is of special interest, therefore, to know the dosage of leaves that will produce sickness or death. A large number of feeding experiments were carried on, and Table 8 summarizes the results of corral feeding of green leaves.

TABLE 8.—*Summary of corral feeding of green leaves.*

Animal.	Days fed.	Quantity fed per hundredweight of animal.		Days before sick.	Quantity fed per hundredweight of animal to produce sickness.		Result.
		Total.	Daily average.		Total.	Daily average.	
1915.	*Days.*	*Pounds.*	*Pounds.*	*Days.*	*Pounds.*	*Pounds.*	
Sheep 323	27	34.058	1.261				Symptoms.
Sheep 325	4	3.175	.794				Not sick.
Sheep 330	9	7.805	.967				Do.
Sheep 339	20	27.014	1.351				Symptoms.
Sheep 341	15	21.519	1.434				Not sick.
Sheep 352	5	2.57	.514				Do.
Sheep 357	13	15.192	1.169				Do.
Sheep 360	9	9.091	1.01				Do.
1916.							
Sheep 380	54	113.82	2.1	25	64.583	2.583	Died.
Sheep 384	56	120.3	2.149	29	73.544	2.536	Very sick.
Sheep 394	21	49.65	2.364	15	37.589	2.506	Died.
Sheep 377	26	62.577	2.4	16	40.491	2.53	Very sick.
Sheep 389	33	78.697	2.385	17	43.662	2.568	Do.
Sheep 333	30	51.464	1.715	24	43.008	1.792	Do.
Sheep 339	33	64.861	1.965	18	45.625	2.535	Do.
Sheep 357	28	50.219	1.794	25	43.296	1.732	Sick.
Sheep 401	30	51.16	1.705	26	47.969	1.845	Very sick.
Sheep 326	30	37.427	1.248				Not sick.
Sheep 403	8	2.112	.264				Do.
1917.							
Sheep 411	16	51.145	3.196	12	36.641	3.053	Very sick.
Sheep 412	29	64.091	2.210	18	36.818	2.045	Do.
Sheep 423	36	53.107	1.475	33	47.469	1.438	Do.
Sheep 418	28	62.013	2.215	26	55.844	2.148	Do.
Sheep 416	34	65.566	1.928	19	38.433	2.023	Do.
Sheep 419	32	60.050	1.877	20	28.894	1.445	Died.
Sheep 420	33	42.731	1.295	18	27.099	1.505	Sick.
Sheep 448	52	92.148	1.772	47	69.977	1.489	Symptoms.
Sheep 437	19	38.419	2.022	13	25.368	1.951	Very sick.
Sheep 421	23	47.925	2.083	19	43.281	2.278	Do.
1918.							
Sheep 486	23	53.061	2.307	16	44.898	2.806	Sick.
Sheep 490	23	70.370	3.060	22	69.136	3.143	Do.
Sheep 506	33	79.167	2.399	26	56.150	2.16	Do.
Sheep 467	40	53.704	1.343				Not sick.
Sheep 481	18	56.250	3.125	18	56.250	3.125	Sick.
Sheep 492	21	36.283	1.728				Not sick.
Sheep 469	25	49.519	1.981	16	36.058	2.254	Sick.
Average	26	49.395	1.795	21.58	46.340	2.228	

It is seen from the averages of this table that a sheep will be poisoned by eating 2.228 pounds daily for 21.58 days, getting in this time a total of 46.34 pounds. These figures must not be construed, however, as giving very exact limits, for the time necessary to produce intoxication varies from 12 to 47 days, and the daily dosage from 1.438 to 3.143 pounds. Moreover, there is no clear relation between the quantity fed and the time necessary to produce results. In some cases it was necessary to continue the smaller dosage a longer time, as in Sheep 448 and Sheep 423; but Sheep 420 had nearly the smallest daily feeding and became sick in 18 days. Neither in the three cases which ended fatally is it clear that it was because of greater feedings or longer period of experimentation.

TOXICITY OF FLOWERS.

Table 9 gives the results obtained when flowers of *H. hoopesii* were fed in the corrals:

TABLE 9.—*Summary of corral feeding of flowers.*

Animal.	Days fed.	Quantity fed per hundredweight of animal.		Days before sick.	Quantity fed per hundredweight of animal to produce sickness.		Result.
		Total.	Daily average.		Total.	Daily average.	
1915	*Days.*	*Pounds.*	*Pounds.*	*Days.*	*Pounds.*	*Pounds.*	
Sheep 343	6	8.14	1.36				Not sick.
Sheep 357	9	15.936	1.77				Do.
1916							
Sheep 378	46	89.643	1.949	34	66.768	1.964	Sick.
Sheep 373	49	72.055	1.471	19	30.303	1.595	Very sick.
1917							
Sheep 446	37	84.082	2.272	22	47.755	2.171	Do.
Average				25	48.275	1.943	

These results show that the toxicity of the flowers is practically the same as that of the leaves.

TOXICITY OF STEM LEAVES.

The summaries of forced feeding of green leaves, in Tables 6 and 7, were of experiments in which radical leaves were used. For the purpose of comparison, forced feedings of stem leaves were made in 3 cases, as shown in Table 10.

TABLE 10.—*Summary of forced feedings of stem leaves.*

Animal.	Days fed.	Number of feedings.	Quantity fed per hundredweight of animal.		Result.
			Total.	Daily average.	
1915	*Days.*		*Pounds.*	*Pounds.*	
Sheep 331	1	1	2.645	2.645	Died.
Sheep 340	1	3	2.645	2.645	Sick.
Sheep 347	1	2	2.756	2.756	Not sick.

With these animals the feeding was given in one day. Comparing the results with Table 6, in which are summarized the feedings of radical leaves in one day, it is evident that the dosage is practically the same, not far from 2.5 pounds, with a considerable margin of possible variation.

COMPARATIVE TOXICITY OF DIFFERENT PARTS OF THE PLANT.

Summarizing the averages of the feedings of different parts of the plant we get the following:

Whole plant produced sickness when 2.17 pounds was fed daily for 21.6 days.
Leaves produced sickness when 2.228 pounds was fed daily for 21.58 days.
Flowers produced sickness when 1.943 pounds was fed daily for 25.1 days.

The difference in the toxicity of the different parts of the plant therefore is negligible; also the comparison just mentioned shows that there is practically no difference between the radical leaves and stem leaves.

EFFECT OF DRYING ON TOXICITY OF LEAVES.

A few feedings were made to determine whether drying of the leaves caused any loss of toxicity. Table 11 shows the results.

TABLE 11.—*Summary of forced feeding of dry leaves.*

Animal.	Days fed.	Number of feedings.	Quantity fed per hundredweight of animal (estimated as green plant).		Result.
			Total.	Daily average.	
1916	*Days.*		*Pounds.*	*Pounds.*	
Sheep 376	1	2	3.475	3.475	Symptoms.
1917					
Sheep 409	1	1	2.301	2.301	Do.
Sheep 439	4	3	11.305	2.826	Sick.
Sheep 422	5	5	10.776	2.155	Symptoms.

Averaging the two cases fed in one day, the toxic dose of dry leaves in terms of green plant is 2.888 pounds. Averaging the two cases given prolonged feeding, 2.49 pounds daily for 4½ days produced sickness.

As it is shown in Table 6 that the toxic dose of green leaves given in one day is 2.494 pounds, and in Table 8 that 1.281 pounds of green plant given for 4⅓ days produce sickness, it appears that the dry plant given by forced feedings is not so toxic as the green plant.

The prolonged feedings of the dry plant, however, gave somewhat different results. The cases are listed in Table 12:

TABLE 12.—*Summary of prolonged feedings of dry leaves.*

Animal.	Days before sick.	Quantity per hundredweight of animal to produce sickness.		Result.
		Total.	Daily average.	
1916	*Days.*	*Pounds.*	*Pounds.*	
Sheep 392	15	34.011	2.267	Very sick.
Sheep 395	18	21.712	1.206	Symptoms.
Sheep 374	14	43.043	3.074	Very sick.
Sheep 375	15	28.467	1.898	Sick.
1918				
Sheep 471	21	44.094	2.1	Symptoms.
Sheep 472	16	34.45	2.15	Sick.
Average	16.5	34.296	2.116	

The results show that an average daily feeding of dry leaves of 2.116 pounds continued for 16.5 days produces sickness. On page 33 it is shown that an average daily feeding of 2.228 pounds of green leaves produces sickness if continued for 21.58 days. Judging by these figures alone it would appear that the dry plant is more toxic than the green. After making allowances for the small number of cases and the necessary inaccuracies of the detail of the experiment, it seems probable that there is no material difference in toxicity between the green and dried plant. It should be noted in this connection, however, that the dry plant used in the experiments had been collected and dried under cover and that this conclusion might not apply to the plant dried standing on the range.

SEASONAL VARIATION IN TOXICITY OF THE PLANT.

For practical purposes it is desirable to know whether the plant is especially toxic at any particular season. Part of the experiments of 1917 and 1918 can readily be divided into two groups, one occurring in June and early July, and the other in late July, August, and September.

In June, 1917, Sheep 424, 415, 413, 432, and 428 were given single forced feedings with an average dose of 2.358 pounds, three being made sick and two dying. Sheep 444, on September 13, showed symptoms from a forced feeding of 2.217 pounds. The difference between the two groups evidently is very slight.

The sheep receiving prolonged feedings of leaves in 1917 can be divided into three chronological groups, as shown in Table 13.

TABLE 13.—*Seasonal variation in toxicity of plant.*

Animal.	Date of feeding.	Days to produce sickness.	Quantity per hundredweight of animal to produce sickness.		Result.
			Total.	Daily average.	
	1917.	*Days.*	*Pounds.*	*Pounds.*	
Group 1:					
Sheep 411	June 8 to 23	12	36.641	3.053	Very sick.
412	June 8 to July 6	18	36.818	2.045	Do.
423	June 8 to July 13	33	47.469	1.438	Do.
418	June 3 to July 5	26	55.844	2.148	Do.
Average		22.25	44.190	2.171	
Group 2:					
Sheep 416	July 6 to Aug. 8	19	38.443	2.023	Do.
419	July 8 to Aug. 8	20	28.894	1.445	Died.
420	July 8 to Aug. 9	18	27.099	1.505	Sick.
Average		19	31.479	1.657	
Group 3:					
Sheep 448	July 27 to Sept. 16	47	69.997	1.489	Symptoms.
437	Aug. 21 to Sept. 8	13	25.368	1.951	Very sick.
421	Aug. 27 to Sept. 18	19	43.281	2.278	Do.
Average		26	46.209	1.902	

If Table 13 is taken at its face value, we must consider the plant as most toxic in midsummer and more toxic in September than in June.

It may be seen from Table 1 that in 1918 four sheep were poisoned by feeding in June and July, while only one sheep, No. 469, was poisoned by feeding late in the season; this from August 26 to September 19 received 36.058 pounds—an average daily feeding during 25 days of 1.442 pounds. In these cases, again, the dosage of the latter part of the season was rather smaller than it was earlier.

While the numbers of cases in different parts of the year are too small to permit of reliable averages, it seems that there is an apparent tendency to slightly greater toxicity in the latter part of the season. This probably is explained by the greater quantity of water contained by the plant early in the season. In general, it may be stated that there is no marked seasonal variation in toxicity.

PERMANENT EFFECT PRODUCED BY THE POISON.

It was noticed in the corral cases that the effect of *H. hoopesii* poison was continued for a prolonged period, and that complete recovery, if it occurred at all, was slow in appearing. People who handle sheep in the *H. hoopesii* region have a theory that a spewing sheep never completely recovers. It is stated that if a band of sheep is brought from the outside to a *H. hoopesii* range, there are comparatively few cases the first year, more the second, and still more the third. This is explained by supposing that the effects of *H. hoopesii* feeding continue over from year to year. In connection with the experiments at the Salina station, some sheep were kept for two or more years and notes made in regard to the outcome of cases that were poisoned and apparently recovered. The results appear to show quite conclusively that the effect of *H. hoopesii* poison may be permanent; that sheep once affected by this plant are likely to succumb more quickly to a succeeding feeding, and, even if they apparently recover, are likely to prove worthless.

HELENIUM HOOPESII A CUMULATIVE POISON.

As previously shown, if about 2 pounds of *H. hoopesii* leaves are fed daily for about 20 days, sickness is produced, although a considerably smaller amount may have a toxic effect. For instance, in 1918 Sheep 469 was made sick on a daily feeding of 1.6 pounds, while on the other hand 1.5 pounds was fed daily for more than 20 days without producing any effect. If less, however, than 1.5 pounds a day is fed, positive symptoms do not develop. For example, Sheep 467 ate on the average of 1.3 pounds a day for 40 days without showing any distinctive symptoms. It will be remembered also that a single day's forced feeding of 2.494 pounds produced toxic symptoms.

It seems clear that if the daily feeding is less than 1.5 pounds, the toxic substance is eliminated to such an extent that no injurious effect follows. If, however, the daily ration is between this limit and a toxic dose of one day's feeding, the effect of the plant accumulates. It should be added that there is every reason to think, as stated elsewhere, that the poisonous principle of *H. hoopesii* produces a permanent effect upon the animal, and, when it is stated that the poisonous substance is eliminated, it is by no means certain that some effect has not been produced. This has a distinct bearing on range poisoning, for it is probable that sheep that feed freely upon the range show the effect of eating *H. hoopesii* only after many days or perhaps weeks of feeding.

REMEDIES.

Three classes of remedies were tried:

1. On the assumption that increase of the processes of elimination would be of assistance in reducing the effects of the *Helenium hoopesii* poisoning, a number of substances were used, including Epsom salt and Epsom salt combined with strychnin, linseed oil, and linseed oil combined with glycerin, linseed oil combined with turpentine and strychnin, sodium cacodylate, paraffin oil, and paraffin oil combined with strychnin. Most of the animals treated with these agents showed improvement. It was not clear, however, that the improvement was due to the remedy.

2. It having been found by chemical examination that the toxic agent of *H. hoopesii* is a glucosid, and that this is precipitated from the plant juice by tannic acid, tannic acid was used experimentally as a preventive of poisoning. Two sheep (Nos. 486 and 506) were fed upon the plant and received daily a drench of tannic acid. No. 486 was fed upon the radical leaves from June 13 to July 5. From June 18 to July 10 it received twice daily a drench containing one-half gram of tannic acid. On June 28, or the sixteenth day of feeding, the sheep started spewing. During the remainder of the experiment the sheep continued to spew and showed other symptoms of *H. hoopesii* poisoning. This sheep was poisoned in 16 days on 44.9 pounds, or an average of 2.8 pounds per day. Sheep 506 was fed upon radical leaves from June 13 to July 15. Until June 20 it ate very little of the plant, but at that time began to eat more freely. From June 18 to July 15 she was drenched twice daily with 1 gram of tannic acid in solution. The animal showed positive symptoms of poisoning in 26 days after eating 56 pounds, or a daily average of 2.16 pounds. Feeding was continued for 7 days following the symptoms, and the tannic-acid treatment for a considerable time longer. In these two cases the tannic acid appeared to have no beneficial effect.

Two sheep (Nos. 490 and 467) were fed on this plant and during the feeding a mixture of tannic acid and salt was kept in the pen. Sheep 490 showed symptoms in 22 days after eating 69 pounds of the plant. Sheep 467 after 40 days feeding with a daily average quantity of 1.34 pounds showed no symptoms. This animal, however, did not eat the plant freely and did not get enough during the period of feeding to produce toxic symptoms. Neither of the sheep ate very much of the tannic acid and salt mixture. In the case of these sheep, as of the other two, there was no evidence of any beneficial effect from the tannic acid.

3. Because of the general practice on the Fishlake National Forest of moving spewing sheep to a lower level, where they could graze on browse, and as the browse consisted largely of oak and service berry, it was thought worth while to try out the effect of feeding these plants to animals that were receiving *H. hoopesii* leaves. This was tried with several animals, but with no resulting benefit. From these experiments it seems probable that the benefits which the sheepmen say follow the removal of the animals to browse result not from the effect of the browse but from the removal of the animals from the sneezeweed and the consequent change of forage.

The general result of these experiments on remedies was discouraging, and it can only be said that at the present time no effective remedies are known which can be used for *H. hoopesii* poisoning.

TREATMENT OF PLANT ON THE RANGE.

Possibility of Exterminating Helenium hoopesii.

The question has been asked, Is it not possible by digging to rid the range of *H. hoopesii?* In order to determine this somewhat exactly, an area where the plant was fairly thick was measured off and two men were set to work—one with a hoe and the other with a spade—to dig up the plant. The plant was not simply cut off, but was dug up and the roots exposed to the sun. On the basis of the work done by these two men it would require 81 hours and 20 minutes to clear an acre. This at the present price of labor on the range would cost at least $30 an acre. This cost evidently is prohibitive.

The area was cleared on September 8, 1918, and was kept under observation during the season of 1919. When examined on September 19, 1918, it was found that the plants had been almost entirely killed. A few small plants had been overlooked and a considerable number of very small plants were found which probably started after the area was dug over.

The plot was examined again August 4, 1919, when it was found that the few plants which were growing were for the most part from seedlings. On the whole area of 4 square rods, 14 flower stalks were counted. Very little grass had come in, and the area, which was on a slight incline, had been somewhat washed by the rains.

On July 27, 1920, seventy-two flowering stems of *H. hoopesii* were counted, and besides there was a considerable number of small plants from which no flowering stems had grown. Nineteen bunches of *Symphoricarpos* had come in, and there were a few grass plants and dandelions, with considerable chickweed. On August 18 the *H. hoopesii* plants were cut out with a hoe, the work requiring 16 hours and 40 minutes per acre. A sharp hoe was used, so that many of the plants were cut out rather than pulled out, the cutting being done 2 or 3 inches below the surface of the ground. When the ground was examined again September 11, 1920, it was found that a few more seedlings had started, and that there was a fairly vigorous growth from the cut plants. In these cut plants the growth was generally from buds which had started near the cut surface, but in some of them adventitious buds were found upon the larger roots well below the surface. Apparently buds may appear from almost any part of the root which remains in the ground.

Time at the rate of 30 hours per acre was spent in going over the patch again with a hoe, especial pains being taken to remove the plants so that the roots should be exposed upon the surface. Of course, many of the smaller roots were torn off and left in the ground.

The patch will be kept under observation for a longer time, but it is evident that the destruction of the plant on the range by digging is not likely to be a success. The plant grows so thickly that in order to clear a given area it is necessary to dig up almost the whole surface, so that if a range were to be cleared it would be necessary not only to dig up the plant but to reseed the area, as after the digging it would be left almost devoid of vegetation. The great expense of this work would make this method of clearing the range a practical impossibility.

Effect of Cutting Off with a Scythe.

In order to determine what effect would be produced by repeated cutting down of the aerial parts of the plant an area was staked off July 25, 1918, and a similar area by its side as a control. On this date the plants were cut with a scythe from the experimental area.

An examination of the area, September 9, 1918, showed the plants apparently in a more thrifty condition than those on the control patch. More new leaves had been put forth on the cut plants than upon those that had not been injured. Cutting off the tops appeared to have a stimulating effect upon the plants. This is perhaps what should have been expected, for, as stated above, adventitious buds readily start not only from the crown but also from the roots, and these buds doubtless grow more numerously because of the cutting off of the top.

The scythe cutting was repeated in the summers of 1919 and 1920, with no change in results.

It seems clear that scythe cutting has no deleterious effect on the growth of the plant.

Effect Produced on the Plant by Restriction of Grazing.

Inasmuch as it is recognized that the present abundance of *H. hoopesii* on some ranges is correlated with the overgrazed condition, it is desirable to determine what effect would be produced by removing grazing animals for a period. The *H. hoopesii* is not particularly palatable to any grazing animals. Cattle very rarely eat it even when the range is reduced to an almost pure stand of this plant. The sheep eat it only after most of the desirable forage has been removed. Under such circumstances the *H. hoopesii*, which is a rank-growing plant, takes almost complete possession of the range. If the grazing animals were removed and the range allowed to reseed itself, it might be possible that by the growth of grasses and weeds the *H. hoopesii* would be gradually diminished in abundance. In order to test this possibility, a locality was selected on an evidently overgrazed range where the *H. hoopesii* was very abundant, and about one-fourth of an acre was fenced off, the plan being to keep it under observation for a term of years. This area was on a very heavily grazed cattle range on which little remained except the *H. hoopesii*, and that was very abundant.

The land was fenced off on September 16 and 17, 1915, and on September 24 half of the plot was sowed to grass seed. Timothy was seeded on a part of this and orchard grass on the rest. The grass seed was scattered broadcast and was not raked in.

The area was visited on June 23, 1916. It was found that the fence had been broken down during the winter and the ground more or less trampled. There was no evidence that any of the grass seed which had been sowed had germinated; in fact there was more grass on the part of the plot which had not been sown than on the remainder. The general appearance of the tract was very much better than that of the ground outside of the fence. Evidently considerable grass had grown in the inclosure.

On August 12, 1916, it was noted that an abundance of wild grasses was coming in so that the *H. hoopesii* at this time was more or less obscured. Outside the area very little grass was seen.

September 6, 1917, practically two years after the plot was fenced off, another examination was made. To superficial observation the *H. hoopesii* seemed nearly as abundant within the inclosure as outside, but there was a good growth of wheat grass with a good deal of yarrow and many dandelions. Actual count of the number of *H. hoopesii* plants on measured typical areas inside and outside showed that the outside range had about one-third more *H. hoopesii* plants than the area inside. This would indicate that at this time there was an actual reduction in the abundance of the *H. hoopesii.*

July 25, 1918, the patch was visited and it was found that sheep had broken in on the upper part of the inclosure and had grazed it considerably, eating especially the dandelions. The *H. hoopesii* of this season was very abundant and thrifty from the fact that the season was wet and favored the growth of the plant. It was very evident, however, that the *H. hoopesii* was much more abundant outside the inclosure than within. The area had been somewhat washed by the rains and the grass was not so abundant as would have been expected.

September 9, 1918, a careful examination of the patch was made. By counting the plants on measured typical areas, it appeared that the *H. hoopesii* was nearly twice as abundant outside the inclosure as it was inside. The exact proportion was five to three. Inasmuch as the area outside had been badly trampled and many plants destroyed, it is probable that the difference between the two areas was really greater than that established by the count, for all the plants on a given area of the inclosure would be recognized, while many of those on the outside would have been destroyed by grazing animals. The difference in vegetation between the areas within and without the fence was very marked, and stockmen who had been observing the experiment considered it very good evidence of the beneficial effect produced upon the range by giving it an opportunity to recover.

July 29, 1919, an examination showed that the *H. hoopesii* was still abundant, but, as in the preceding year, was in much smaller numbers than outside.

August 5, 1919, a detailed examination was made. The *H. hoopesii* was matured and on account of the dry season was very nearly in the same condition that it was in September of the preceding year. Cattle had broken into the inclosure and had grazed upon the grass, apparently having, to a large extent, eaten the seed stems of the grasses. The grass was not quite so thick as early in the season, but this appearance may have been due, in part at least, to the accidental grazing. Again a count was made of the relative number of the *H. hoopesii* plants inside and outside of the inclosure, and it was found that the average was in the ratio of 11$\frac{4}{5}$ to 19.

During the summer of 1920 there was an abundance of rain in the mountains, with a consequent vigorous growth of all forms of vegetation. When the patch was examined August 23 it was well covered, the wheat grass which grew all over it being especially marked. There was a considerable quantity of *Gymnolomia multiflora,* which being in blossom at the time, gave the patch a general yellow color when seen from a distance. The other plants present were dandelions, yarrow, a few plants of *Agastache* and a bunch of *Rudbeckia occidentalis*. The wheat grass stood between 2 and 3 feet high.

Actual count of *H. hoopesii* plants on measured areas, as in preceding years, showed an average of 14 plants inside to 22 outside.

In summing up the results of these experiments to date, the following statements may be made:

1. The sowing of grass seed was a failure, for all the grasses which came in were from reseeding of the natural grasses of the range.

2. The relative number of *H. hoopesii* plants on a given area had been reduced about one-half as the result of the prevention of grazing.

3. The *H. hoopesii* still remained in considerable abundance and was growing with vigor, and it is by no means clear that this method would accomplish anything more than a reduction of the *H. hoopesii* plants with an opportunity for the growth of grasses and other palatable forage.

4. While, without doubt, the prevention of grazing will do much toward the restoration of the range, in localities where *H. hoopesii* has taken possession, it will take a long time for it to be overcome by other plants. It is a very thrifty plant, propagating both by seeds and vegetatively; so far as known, it has no insect enemies and is likely to hold its own in competition with others. The probabilities of real restoration of the range, in any brief period, are not good. While the resting will benefit a range, it probably would take many years to make anything like a complete restoration.

This experiment will be continued for a further period of years in order to determine as nearly as may be what length of time may be necessary to restore the range to a reasonably good condition.

Prevention of Losses.

The ways by which losses of livestock by poisonous plants may be prevented were discussed in Farmers' Bulletin 720, and, in recapitulating the facts about *H. hoopesii* it may be well to follow, in general, the classification of that bulletin.

Medicinal remedies.—As stated in Bulletin 720, medicinal remedies in most cases of plant poisoning are of minor importance. It has been shown in the case of *H. hoopesii* that the effects of the plant are of such a character that little or no help can be expected from remedies.

Eradication.—This is discussed in detail on pages 39–43, where it is shown that eradication is practically impossible.

Use of range when plants are least poisonous.—Some plants are especially dangerous at certain seasons; *H. hoopesii* is dangerous during the whole season, so that nothing can be gained by confining the grazing to a part of the season.

Allotment of range to animals not affected by H. hoopesii.—It has been shown that cattle are seldom affected by *H. hoopesii* and horses rarely if ever. A partial solution of the difficulty may be made in some cases by allotting sneezeweed ranges to horses or cattle rather than to sheep.

Management of range to secure abundance of forage.—*H. hoopesii* is not eaten because of its attractiveness to grazing animals, but is taken after the supply of other forage plants has been exhausted. On ranges where *H. hoopesii* is abundant, but accompanied by a sufficient supply of other plants, sneezeweed poisoning seldom or never occurs. It is on overgrazed ranges, when little is left but *H. hoopesii*, that the sheep are injured. Such ranges, because of the thriftiness of the plant, grow rapidly worse. It is obvious that an attempt should be made by proper management to restore the range. Theoretically this can be done by so restricting grazing as to permit an abundant growth of desirable range plants and natural reseeding. Unfortunately, as shown on pages 41–43, this is a long and somewhat discouraging process. Yet it seems clear that it is the only way by which the ranges can be made safe. Experience has shown that little can be expected from artificial reseeding. The practical question of so reducing allotments as to permit a range to become restored and remain in good condition is a difficult one to handle, but it does not appear that there is any other way of handling the problem successfully. This means that it is desirable that a range should never be stocked to its full capacity, but that a generous margin of safety should be left. It is appreciated that an ideal management of the range might work hardship on existing permittees, and that the handling of the problem demands not only trained ability and experience to recognize the needs of a particular range, but a high order of tact to bring about desirable changes.

PRACTICAL SUGGESTIONS FOR STOCKMEN ON THE RANGE.

From the standpoint of the owner handling sheep on *H. hoopesii* ranges the question of greatest importance is what practical methods he may use to eliminate or reduce his losses. His interest is in the deductions which may be made from the results of an investigation. It must be recognized that there are some things that man can not change, and that a thorough investigation of a subject may sometimes simply show that under a given set of conditions nothing can be done in the way of relief. It is a decided advantage, however, in such cases to know positively the facts and the conditions controlling the poisoning, so that one can combat the trouble intelligently and not waste his energies in attempting to do impossible things.

By management of the flocks so as to avoid poisoning while on the range very much may be accomplished. Herders should be taught to recognize the plant and to avoid any extended grazing upon it. It must be remembered that *H. hoopesii* does not ordinarily produce acute cases, but is a cumulative poison with permanent effects. If the herder waits until his flock begins to show symptoms of sickness before removing them from grazing on the plant, he has waited too long. His flock is more or less permanently injured, and recovery after removal to another range will be only partial. It is essential that he should anticipate the trouble. It is not true, of course, that sheep can not be grazed at all where *H. hoopesii* is present, but if the range is so overgrazed that other forage is scarce and the *H. hoopesii* is abundant, the sheep will eat this plant. When the herder perceives that this condition exists, the animals should be moved *before cases of sickness occur*. It is recognized that on some ranges change of location may be difficult, but whether difficult or not it must be done if the flocks are to be preserved from loss. The continued grazing of flocks on *H. hoopesii* is a dangerous custom, and may reasonably be expected to have disastrous results. It should be remembered, too, that these results do not consist simply in immediate losses, but that such flocks are permanently injured and weakened, and lessened in value for succeeding years.

Especial care should be used in trailing sheep from one range to another. Where definite trails are laid out and many sheep pass over them, overgrazing results, and *H. hoopesii* may be practically the only remaining plant. Such trails should be avoided whenever possible, and when they must be used, care should be taken that the animals are well fed before entering them. If they pass through them when hungry, they naturally eat what they can get, and hungry animals on a trail eat with especial eagerness.

SUMMARY.

1. The western sneezeweed, *Helenium* (*Dugaldia*) *hoopesii*, has become very abundant on some of the more elevated and overgrazed stock ranges of the West, especially in Utah.

2. The plant has been proved to be the cause of the disease of sheep known as the "spewing sickness" and has also been shown to be poisonous to cattle.

3. The symptoms produced by the plant, the pathology, and the toxic dosage have been worked out in detail, and it has been shown that a permanent, injurious effect may be produced upon the animals eating any considerable quantity of it.

4. The study of the habits of the plant and experimental work on methods of control have shown that little can be accomplished by attempts at extermination, and that restoration of the range by growth of other plants is an exceedingly slow process.

5. The poisonous principle of *Helenium hoopesii* is an easily decomposed glucosid to which the name "*dugaldin*" has been given. This is a white, amorphous solid, soluble in alcohol, less soluble in water and chloroform. With tannic acid it forms a sparingly soluble compound which is only slightly poisonous.

6. There has been found no medicinal remedy which can be used effectively in treating poisoned animals.

7. From the practical standpoint of the man handling livestock on a sneezeweed range, it is important that the herders should know the plant and appreciate the serious results from grazing upon it. Then it may be possible by proper handling of herds to prevent most of the losses.

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