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Contribution from the Bureau of Plant Industry, Wm. A. Taylor, Chief,
and the Bureau of Animal Industry, A. D. Melvin, Chief

Washington, D. C. PROFESSIONAL PAPER May 13, 1915

ZYGADENUS, OR DEATH CAMAS

By

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and HADLEIGH MARSH, Veterinary Inspector

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ZYGADENUS, OR DEATH CAMAS.

By C. Dwight Marsh and A. B. Clawson, *Physiologists, Drug-Plant and Poisonous-Plant Investigations*, and Hadleigh Marsh, *Veterinary Inspector, Bureau of Animal Industry.*

INTRODUCTION.

HISTORICAL SUMMARY AND REVIEW OF LITERATURE.

Chesnut and Wilcox (1901, p. 52)[1] say that "the earlier explorers of the Western, and especially of the Northwestern, United States frequently mention the poisonous character of the bulbs of one or the other of the various species of Zygadenus and refer to them as poison camas or poison sego in order to distinguish them from bulbs of two other groups of plants, Quamasia and Calochortus, which were commonly known as camas and wild sego and were much used for food, both by the Indians and by travelers. Accounts of the poisoning of stock from eating the roots and leaves of various species have but recently been sent to this Department."

This statement, perhaps, covers the knowledge of the subject up to that date, although the writers have failed to find much in the way of definite statement among the earlier writers that can be referred to this plant.

In Wyeth's journal of his second expedition to Oregon (Wyeth, 1899) occurs this statement:

> 16th. Made down the Sandy S. W. by W. 15 miles then 4 S. E. by E. and camped on this stream so far the grass is miserable and the horses are starving and also at last night's camp they eat something that has made many of them sick the same thing happened two year since on the next creek west.

This happened on June 16, 1834, somewhere between Big Sandy Creek and Leckie, in Fremont County, Wyo. The present knowledge of the botany of that region makes it almost certain that the poisonous plant in that place at the time of year mentioned must

[1] For the complete titles of works cited, see the list of literature on pages 45 and 46.

Note.—This paper is intended to supply general information on the relation of Zygadenus to the losses of live stock on the western stock ranges; it is suitable for distribution throughout the western third of the United States.

have been Zygadenus. This is the earliest reference to probable poisoning by Zygadenus which has been found by the writers.

Asa Gray (1848) says of *Amianthium nuttallii*, now known as *Zygadenus nuttallii*, "Crescent cum *Kamassa* esculenta, quo bulbi nocentes viatoribus saepe confusi sunt."

Hooker (1838) says of *Leimanthium nutallii*, which is the same as the species mentioned by Gray, " 'Poison or Death Camass' of the Chenooks, from the violent effects of the roots, which create vomiting."

Watson (1880) speaks of *Zygadenus venenosus* as poisonous and known to the Indians as "Death-Camass," and says, on page 184, that the bulb of *Z. paniculatus* is also poisonous.

Apparently the Lloyds (1887) were the first to state definitely the symptoms produced by the plant in human beings.

Irish (1889) fed "cammers" to steers without effect.

Hillman (1893) published a newspaper bulletin calling attention to the poisonous character of Zygadenus, and in 1897 he published another newspaper bulletin on the same subject. Also, in another publication (1897*b*, p. 115), he states that a horse is reported to have been made sick by the seeds of *Zygadenus paniculatus* in hay.

Coville (1897) says that *Zygadenus venenosus* causes extreme vomiting and that it is sometimes used by medicine men of the Klamath Indians, mixed with the dried roots of *Iris missouriensis* and a little tobacco, to give a person a severe nausea, in order to secure a heavy fee for making him well again.

Chesnut (1902, p. 321–322) tells of the knowledge of this plant by the Indians of Mendocino County, Cal., and their use of it for medicinal purposes.

Hunt published an abstract in 1902 announcing the discovery of the alkaloid.

In a copy of McCarthy (1903), apparently annotated by the author, the statement is made that *Zygadenus glaberrimus* and *Z. leimanthoides* are poisonous.

Nelson (1906) demonstrated by feeding experiments the poisonous effect of Zygadenus upon sheep.

REVIEW OF PHARMACOLOGICAL WORK.[1]

The bulbs of *Zygadenus paniculatus* were found by Collier (1882) to give several alkaloidal reactions, but the first attempts to isolate and determine the chemical and toxic properties of the poison of Zygadenus seem to be those of Reid Hunt,[2] special expert of the Bureau of Plant Industry in 1901, who worked with the leaves and flowering tops of *Z. venenosus*. Hunt prepared an alcoholic extract

[1] The review of pharmacological work was prepared by Dr. Reid Hunt, of the Harvard Medical School.

[2] Hunt's results were submitted in a report to the Department in 1901 and also reported at a meeting of the American Physiological Society. (Hunt, 1902.)

and removed various oily and resinous substances by precipitation with water and extraction with petroleum ether. These resinous bodies were not toxic. Vejux-Tyrode (1904) later obtained similar resinous bodies to which he ascribed a high degree of toxicity, but Heyl and Hepner (1913) could not confirm this.

Hunt purified the extract further, and then, by extraction with chloroform, obtained an amorphous substance alkaline to litmus and giving the usual alkaloidal reactions. It was very slightly soluble in water, but readily soluble in dilute acids. When treated with concentrated sulphuric acid this substance dissolved with the formation of an orange-yellow solution; the color soon became a blood orange, and finally a bright cherry red. This play of colors corresponds almost exactly to that caused by cevadin and to that recently described by Heyl, Hepner, and Loy (1913) for zygadenin, an alkaloid obtained by them from *Zygadenus intermedius*. Hunt found, as did Heyl, Hepner, and Loy later, that the alkaloid was not readily extracted with ether. When the alkaloid or mixture of alkaloids was further purified, dissolved in alcohol, and the alcohol allowed to evaporate, a clear, glassy residue with a few cubes or prisms was obtained. This began to darken at 185° C. At 197° C. part of it melted to form a red solution, but all of it did not melt until a temperature of 220° C. was reached. It is quite probable that this mixture consisted in part of the alkaloid since isolated by Heyl, Hepner, and Loy and named by them zygadenin. Zygadenin crystallizes from alcohol in "orthorhombic blocks" and melts to a red oil at 200° to 201° C. Hunt pointed out a number of resemblances and also certain differences between the reactions of the alkaloids obtained from Zygadenus and those given by cevadin and other veratrin alkaloids and concluded that both chemically and pharmacologically the two series were closely related.

Torald Sollman, in a report submitted to the Department of Agriculture in 1903, stated that he could find no poisonous principle in Zygadenus other than the alkaloid or mixture of alkaloids found by Hunt.

These results were confirmed by Slade (1905) and by Heyl, Hepner, and Loy. The latter authors carried the work to the point of isolating in pure form an alkaloid which they named zygadenin, although the question whether this may not be identical with some one of the veratrin alkaloids is, perhaps, still open. It may also be doubted whether zygadenin is the most important toxic agent in Zygadenus, for these authors quote Mitchell as reporting that "it (zygadenin) kills guinea pigs slowly and only in comparatively large doses." Hunt found 4 milligrams per kilo of his alkaloidal preparation to be fatal to rabbits in an hour or two. Sollman found about the same amount of cevadin to be fatal.

Hunt found, as did Heyl and Raiford (1911), that the leaves and flowering tops contain more of the alkaloid than the bulbs. By performing an extensive series of experiments on animals with the Zygadenus alkaloids, he found that their action was in all essential particulars the same as that of veratrin. They were very irritating to the mucous membranes, as was the powdered plant itself; they produced an intense burning sensation and a very acrid, bitter taste in the mouth; when applied to the skin in alcoholic or chloroform solution, they caused a burning, painful sensation, but the spot later became anæsthetized; they had the typical veratrin effect upon the muscles and, as kymograph experiments showed, affected the respiration, blood pressure, and heart in the same way as does veratrin. It was also shown that the death of animals poisoned with Zygadenus was hastened by attempts to arouse them. This was attributed to the rapid failure of the respiration, circulation, and the muscular system. It was concluded that under laboratory conditions (and probably under field conditions) an essential part of the treatment should consist in allowing the animals to rest.

Hunt also isolated the alkaloids from the urine of animals poisoned with Zygadenus. He found that they were excreted with the urine quite rapidly and demonstrated that under laboratory conditions it was often possible to save the life of poisoned animals (rabbits, sheep, etc.) by the administration of diuretic drugs (caffein, theobromin, sodiosalicylate). Atropin and strychnin seemed to hasten death.

Sollman, after satisfying himself that the toxic action of Zygadenus is identical with that of veratrin, made a study of poisoning by the latter. He found that a single dose often caused prolonged sickness and that small, repeated doses caused no tolerance, but increased the susceptibility, and suggested demulcents, such as linseed decoction, to counteract the corrosive action on the alimentary tract.

It is evident from these chemical and pharmacological studies that the poisonous properties of Zygadenus are essentially those of veratrin, the indications for treatment being the same in the two cases.

DESCRIPTION OF ZYGADENUS.

The genus name Zygadenus is used in this paper as defined in Robinson and Fernald's revision of Gray's Manual and in Coulter and Nelson's New Manual of Botany of the Central Rocky Mountains. It includes the three genera, Zygadenus, Anticlea, and Toxicoscordion, of Britton and Brown's Illustrated Flora. The plants are erect, perennial, glabrous herbs, growing from a rootstock, or, as in the case of all the western species, from a tunicated bulb, with a leafy stem. The leaves are grasslike, long, narrow, and keeled. The flowers are greenish yellow or white, borne in a terminal raceme or panicle. This raceme varies in the different species from an almost solid head, as seen in Plate I, to a very loose, elongated panicle, there being a considerable range of variation in the inflorescence within the limits of the same species. The perianth is spreading, withering-persistent, the sepals bearing one or two glands near the base. The stamens are free or attached to the bases of the segments. The capsule is three lobed and dehiscent to the base in maturity.

The species of Zygadenus are spring and summer plants. On May 8, 1913, in the neighborhood of the Greycliff station, Mont., *Z. venenosus* was about 4 inches high, the largest plants not exceeding 6 inches, and the flower scape was not visible. On May 11 the plants were in bud, and they blossomed through the month of June. Seeds were formed the last of June and early in July, and after the middle of August the plants had largely disappeared.

Zygadenus elegans was in full blossom near Red Lodge, Mont., on July 20, at an altitude of approximately 6,000 feet. In 1910 *Zygadenus coloradensis* was in blossom in Colorado at about the same time (July 20) at an altitude of about 10,000 feet.

In Montana, *Zygadenus venenosus* grows typically at lower levels than *Z. elegans*. As stated by Chesnut, its favorite habitat is in the shallow ravines occurring on hillsides. It does not grow abundantly on dry hillsides nor in wet ravines, but it is very commonly found in the shallow depressions on the north slopes of bench lands. *Z. elegans* grows at higher levels (Rydberg gives as its limits 6,500 to 12,500 feet) and in locations where more water is available than is necessary for *Z. venenosus*. While it grows readily on hillsides, it reaches its best development in size in distinctly wet places, sometimes immediately in contact with rivulets.

In California and Oregon, *Zygadenus venenosus* grows in the meadows, while *Z. paniculatus* grows upon the hillsides. *Z. venenosus* is more common on north slopes and *Z. paniculatus* on south slopes.

The species of Zygadenus may grow as more or less scattered individuals, but sometimes they are massed together in large areas, including, perhaps, several acres, in which, at the time of flowering, they seem to be the principal vegetation and give a characteristic greenish yellow color to the landscape.

The species of Zygadenus are distributed very widely in the United States and are found as far north as Alaska. They occur most abundantly from the Rocky Mountains west to the Pacific, and their importance as stock-poisoning plants is confined almost entirely to this part of the United States. Plate I shows the general appearance of *Zygadenus venenosus*. This is an Oregon plant and shows the flowers as they appear at the beginning of blossoming. Later, the raceme is more extended, as shown in Plate II, which is reproduced from a photograph of a Montana plant. Plate III shows the plant after the seed is formed.

COMMON NAMES OF ZYGADENUS.

The species of Zygadenus are known under a large number of popular names. The most common perhaps is death camas. In the Northwest perhaps lobelia is the name used even more generally than death camas. Other names are soap plant, alkali grass, water lily, squirrel food, wild onion, poison sego, poison sego lily, mystery grass, and hog's-potato. *Z. glaberrimus* is said to be called cow-grass.

POISONOUS SPECIES OF ZYGADENUS.

The following species of Zygadenus are said to be poisonous: *Z. elegans, Z. falcatus, Z. fremontii, Z. glaberrimus, Z. intermedius, Z. mexicanus, Z. nuttallii, Z. paniculatus, Z. venenosus.*

This list is given in accordance with the statements of various authors, and no attempt has been made to revise it from the standpoint of the systematic botanist. Apparently all species of this genus may be presumed to be poisonous. Even *Zygadenus coloradensis*, which has been shown not to be injurious to stock in Colorado, has the same poisonous principle as the other species, but in smaller quantity.

LOSSES OF LIVE STOCK BY ZYGADENUS.

As already stated, there is reason to think that deaths of cattle and horses from Zygadenus poisoning are not numerous. With sheep, however, the losses are very heavy, but it is impossible to make even an approximate estimate of these losses. It is probable that they are much greater than is generally supposed, for in the sheep-grazing regions many, perhaps most, of the herders do not know the plant and consequently do not recognize it as the cause of illness and death in the bands under their charge. The lupines, without any doubt, have been blamed for many of the cases of poisoning by Zygadenus.

Chesnut and Wilcox (1901, p. 53) state that 636 sheep died from Zygadenus poisoning in Montana in 1900 and that 3,030 were poisoned. In one locality in Wyoming 500 sheep died out of a total of 1,700 poisoned, and in one county it was said that 20,000 died in 1909. The writers of this paper investigated a case in Montana in which 500 sheep died within a few hours, the probable cause being Zygadenus.

There is no doubt that this plant is one of the sources of heaviest loss to sheep owners, especially in Wyoming and Montana. There is good reason, too, for thinking that many of the losses in Oregon, Utah, and California which have been ascribed to other plants were really caused by Zygadenus.

ZYGADENUS VENENOSUS FROM KLAMATH AGENCY, OREG.

ZYGADENUS VENENOSUS FROM MONTANA, IN BLOOM.

ZYGADENUS VENENOSUS FROM MONTANA, IN FRUIT.

FIG. 1.—SHEEP NO. 160, SHOWING SALIVATION AND POSITION INDICATING NAUSEA.

FIG. 2.—SHEEP NO. 192, SHOWING SALIVATION AND ATTITUDE INDICATING NAUSEA AND GENERAL DISCOMFORT.

ANIMALS POISONED BY ZYGADENUS.

Swine are said to eat Zygadenus bulbs with no bad results (Parsons, 1904, p. 8).

Cattle are susceptible to the poison and there are reports of resulting deaths. So far as has been learned, however, deaths of cattle from this cause are not common, and it is not especially to be feared by the cattlemen.

Many cases of horses poisoned by this plant are reported. The animals are made very sick, but apparently most of them recover. Mr. Uttermohl, of Bigtimber, Mont., who has had considerable experience with Zygadenus, is of the opinion that some of those that recover are permanently injured.

Sheep are the animals most frequently poisoned. This is probably due in part to a greater susceptibility to the toxic principle of Zygadenus, but very probably it is to a considerable extent due to the way in which sheep are managed upon the range. While grazing, they are frequently herded rather compactly, so that they eat the forage closely, and when passing over a Zygadenus area many of them may eat a large quantity of this plant.

The cases of human poisoning are mostly of children, who find the bulbs attractive and sometimes collect them instead of the edible camas, species of Calochortus and Camassia. Most of these cases recover, but there have been a number of fatalities.

SYMPTOMS PRODUCED BY ZYGADENUS POISONING.

With the exception of the work of Chesnut and Wilcox, nothing has been published in regard to the symptoms exhibited by grazing animals. These authors (1901, p. 61) state that the principal symptoms of poisoning in sheep are salivation, nausea, uneasiness, staggering, muscular incoordination, paralysis, and convulsions. The animals sometimes lie many hours before death. The writers mentioned state also that cattle and horses have spasms.

Several investigators have mentioned some of the symptoms in man. Heller (1909, p. 52) gives the symptoms (quoting from Dr. Lee, of Carson) as "nausea, headache, followed by more or less stupor." He states that the heart's action was lessened in frequency, while the strength of the pulse remained normal. The respirations were almost normal. In another case vomiting was followed by the loss of all power of feeling.

Heyl and Raiford (1911, p. 64) and Hunt (manuscript) speak of the irritating character of the dust when the dry plant is being ground, which leads to sneezing on the part of those doing the work.

The Lloyds (1887) give as symptoms in man "extreme thirst, constant vomiting, dilation of the pupil, coma, and inflammation of the stomach." They also say that one case had very violent convulsions.

Chesnut (1902, p. 321) says that the symptoms in poisoned Indians are "burning and smarting in the mouth and esophagus, dumbness, nausea, profuse vomiting, foaming at the mouth, dizziness, and mania."

Mitchell and Smith (1911) experimented with the extract on guinea pigs, both by subcutaneous injection and by feeding per os, and found salivation, vomiting, excitement, paralysis (first of the hind legs), rapid respiration becoming slow and labored, heightened reflexes, spasms, heartbeat slowed, and death, under fatal dosage, in 20 to 30 minutes. When injected into dogs under anæsthesia, the general effect was to reduce the rate of heartbeat and respiration and to produce marked intestinal peristalsis. The heart stopped before the cessation of respiration.

Hunt, Vejux-Tyrode, and Mitchell and Smith experimented on frogs, producing paralysis, which showed itself in an inability to draw up the legs readily after extension. Hunt considers that it produces an effect directly on the muscles as well as on the central nervous system.

Chesnut and Wilcox (1901) and Hunt (manuscript) experimented with rabbits, Hunt stating that the rabbits exhibited salivation, nausea, muscle changes, heightened reflexes, and convulsions.

Summarizing the published statements in regard to the symptoms of Zygadenus poisoning, it may be said that the most evident symptoms in the higher animals are salivation, nausea, more or less complete paralysis, reduced rate of heartbeat and respiration, and convulsions. The results on frogs are not so marked, as would be expected from the less complicated nervous system, and the principal thing noticed apparently is paralysis.

GENERAL STATEMENT OF EXPERIMENTAL WORK.

Experimental work upon Zygadenus has been carried on for five seasons, in 1909 and 1910 at Mount Carbon, Colo., and in 1912, 1913, and 1914 at Greycliff, Mont. Table I gives a summary of these experiments. In 1909 six head of cattle were fed experimentally on *Zygadenus coloradensis* (Table I, section A). In 1910 a steer and four sheep were fed (Table I, sections B and E). In 1912 there were 18 cases of experimental feeding of *Zygadenus venenosus* to sheep (Table I, section F). In 1913 *Zygadenus venenosus* from the neighborhood of the station was fed to 61 sheep. In this section of the table are also given the results of one experiment in feeding *Zygadenus venenosus* from the Stanislaus National Forest, Cal., to a sheep. In 1913 *Zygadenus elegans*, collected near Red Lodge, Mont., was fed to 6 sheep (Table I, section H). In 1914 there were 110 cases of feeding of *Zygadenus venenosus* to sheep (Table I, section I) and five experiments of feeding to sheep *Zygadenus elegans* from the

Fishlake National Forest, Utah (Table I, section J). There were also two experimental feedings of *Zygadenus paniculatus* from Ephraim, Utah (Table I, section K). Three head of cattle in 1913 were fed upon *Zygadenus venenosus* (Table I, section C), and a horse was fed twice upon *Zygadenus venenosus* and once upon *Zygadenus elegans* (Table I, section D).

So far as possible, the feeding experiments were carried on under natural conditions. To this end the animals were, ordinarily, deprived of food for about 24 hours, and then the plant to be tested was offered to them. If they did not eat readily, they were tempted by mixing the plant, sometimes ground up, with hay or grain. As it was difficult to get any large number of cases by feeding, on account of the dislike of the animals to the plant, resort was had to drenching and forced feeding. In the drenching experiments, the plant was ground and suspended in sufficient water to make the administration possible, the drenching being done in most cases with the animal upon its haunches. Forced feeding was conducted in some cases by placing the plant by hand, a little at a time, in the animal's mouth. In the majority of experiments in forced feeding, however, a veterinarian's ordinary balling gun was used, and the ground material was fed as fast as the animal would swallow it.

The terms under "Severity of illness" are used in the following way:

"Not sick" includes cases in which no symptons appeared.

"Symptoms" includes cases in which there was slight salivation for a few minutes, some regurgitation, some licking of the lips, indicating nausea, or indications of uneasiness.

"Slightly sick" includes those in which salivation was continued for an hour or more, with considerable regurgitation. Depression, slightly labored respiration, and temperature reduction may occur.

"Sick" includes cases exhibiting vomiting, weakness, and sometimes hypersensitiveness and trembling.

"Very sick" cases were characterized by prostration, extreme respiratory difficulty, and subnormal temperature.

TABLE I.—*Summary of feeding experiments with Zygadenus in 1909 and 1910 at Mount Carbon, Colo., and in 1912, 1913, and 1914 at Greycliff, Mont.*

[Animals designated by an asterisk (*) preceding the serial number were given dry material; but the weight is stated in the form of an equivalent amount of green plant, the loss in drying having been determined by a number of experiments.]

Animal.		Weight of plant used.	Date of experiment.	Part of plant used (fed unless otherwise stated).	Severity of illness.	Remedy.	Result.	Pounds used per stated weight of animal.	Location from which plant used was obtained.
Designation.	Weight.								
A.—Cattle given Z. coloradensis:	*Pounds.*	*Pounds.*	1909.					*Per 1,000 pounds.*	
No. 112	610	5.07	July 14 to 16	Leaves and buds	Not sick	None		8.31	
No. 117	620	1.87	July 15	Bulbs (in chop)	do	do		3	
No. 97	500	6.58	July 17 to 19	Leaves and buds	do	do		13.16	
No. 113	750	5.94	July 19 and 20	Bulbs (in chop)	do	do		7.92	
No. 115	610	12.22	July 20	Leaves, stems, and flowers.	do	do		20	
No. 107	420	7.62	Aug. 1 and 2	Leaves, stems, flowers, and bulbs.	do	do		18.14	
B.—Steer given Z. coloradensis:			1910.						
No. 119	300	97.5	Aug. 8 to 13	Leaves, stems, fruit, and bulbs.	do	do		325	North of camp.
C.—Cattle given Z. venenosus:			1913.						
No. 655	±500	2	June 6 and 7	Leaves	do	do		4	Station.
No. 660	±500	29	June 12 to 17	Leaves, stems, and flowers.	Symptoms	do	Recovery	58	Do.
No. 659	±500	55.5	June 21 to 27	do	Symptoms after eating 46½ pounds.	do	do	111	Do.
D.—Horse:			1913.						
No. 125	±700	8.5	June 15 to 18	Leaves of Z. venenosus.	Not sick	do		12.1	Do.
		9	July 9 to 12	Leaves, stems, and flowers of Z. venenosus.	do	do		12.9	Do.
		10.5	July 24 to 29	Leaves, stems, flowers, some fruit, and bulbs of Z. elegans.	do	do		15	Beartooth National Forest.
E.—Sheep given Z. coloradensis:			1910.					*Per 100 pounds.*	
No. 112	100	16	July 15 to 19	Leaves, stems, flowers, and bulbs.	do	do		16.7	North of camp.
No. 112	100	82	July 24 to Aug. 5	Leaves, stems, flowers, and fruit.	do	do		82	Do.
No. 111	72	45.5	Aug. 15 to 24	Leaves, stems, and fruit.	do	do		63	Do.
No. 118	97	39.5	Aug. 25 to 31	do	Symptoms	do	Recovery	40.7	Do.

F.—Sheep given Z. venenosus:			1912.						
No. 167	68	.771	June 25 to 27	Leaves, stems, and flowers (drench).	Not sick	do		1.134	George Hughes's.
No. 163	65 to 57½	5.5	June 26 to July 4	Leaves, stems, flowers, and fruit.	do	do		8.461	Do.
No. 175	77 to 71	14.5	June 26 to July 7	Leaves, stems, flowers, and fruit; partly dry.	do	do		18.831	Do.
No. 181	53 to 45	5.5	do	Leaves, stems, flowers, and fruit.	do	do		10.377	Do.
No. 176	75	1.322	July 6	Leaves, stems, and fruit (drench).	Sick	do	Recovery	1.762	Do.
No. 159	73	1.565	July 7	do	Slightly sick after taking 0.79 pound; very sick.	do	do	2.144	Do.
No. 172	77		do	Water control (drench)	Not sick	do			
No. 168	67½	1.102	July 10	Leaves, stems, and fruit (drench).	Slightly sick after taking 0.33 pound; very sick.	Potassium permanganate; whisky.	Recovery	1.632	Do.
No. 162	102½ to 84½	1.212	July 11	do	Slightly sick after taking 0.771 pound; very sick.	Caffein sodiobenzoate.	do	1.182	Do.
No. 161	77½	.661	July 13	Seed heads (drench)	Sick after taking 0.33 pound; death.	do	Death	.853	Do.
No. 171	83 to 75½	.771	do	Leaves and stems (drench).	Symptoms after taking 0.33 pound, slightly sick.	None	Recovery	.929	Do.
No. 174	55	.308	July 14	Seed heads (drench)	Death	Ammonia; caffein sodiobenzoate; tannic acid.	Death	.560	Do.
No. 172	78	.110	July 17	do	Symptoms	None	Recovery	.141	Do.
No. 177	51½	.121	July 18	do	Sick	do	do	.235	Do.
No. 160	92	.275	July 19	do	Death	Potassium permanganate; caffein sodiobenzoate; whisky; digitalis.	Death	.299	Do.
No. 176	75	.198	July 20	do	Sick	None	Recovery	.264	Do.
No. 181	50	.132	July 23	do	Sick from Zygadenus; killed in drenching with potassium permanganate.	Caffein sodiobenzoate; potassium permanganate.	Death	.264	Do.
No. 175	83	.143	July 24	do	Symptoms	None	Recovery	.172	Do.

TABLE I.—*Summary of feeding experiments with Zygadenus in 1909 and 1910 at Mount Carbon, Colo., and in 1912, 1913, and 1914 at Greycliff, Mont.*—Continued.

Animal. Designation.	Animal. Weight.	Weight of plant used.	Date of experiment.	Part of plant used (fed unless otherwise stated).	Severity of illness.	Remedy.	Result.	Pounds used per stated weight of animal.	Location from which plant used was obtained.
G.—Sheep given Z. venenosus:	*Pounds.*	*Pounds.*	1913.					*Per 100 pounds.*	
No. 196	$65\frac{1}{2}$ to 64	1.378	May 11 and 12	Leaves	Sick	None	Recovery	2.104	George Hughes's. Station.
No. 191	64	.631	May 11 to 13	do	Not sick	do		.986	
No. 197	66	.397	May 12 and 13	do	do	do		.601	Do.
No. 193	74	.441	May 13	Bulbs (drench)	Sick	do	Recovery	.595	Do.
No. 187	59 to 61	.441	May 14	Leaves (drench)	Very sick	Strychnin	do	.747	Do.
No. 195	72	.441	do	Bulbs (drench)	Slightly sick	None	do	.612	Do.
No. 186	64 to 64	.331	May 15	do	do	do	do	.517	Do.
No. 198	64 to $61\frac{1}{2}$	1.219	May 15 and 16	Leaves	Sick	do	do	1.905	Do.
No. 188	74 to 71	.661	May 16	do	do	do	do	.893	Do.
No. 189	65	.485	May 17	Leaves (drench)	Death	Strychnin; gin.	Death	.746	Do.
No. 190	71 to $62\frac{3}{4}$	.220	May 17 to 20	Leaves	Not sick	None		.310	Do.
No. 192	$59\frac{1}{2}$ to $53\frac{3}{4}$	2.094	May 18 to 20	Bulbs (in alfalfa)	do	do		3.519	Do.
No. 184	64 to $58\frac{3}{4}$	.375	May 19	Leaves (drench)	Sick	do	Recovery	.586	Do.
No. 191	64 to $58\frac{1}{4}$	.375	do	do	do	Potassium permanganate.	do	.586	Do.
No. 205	$48\frac{1}{2}$ to $46\frac{3}{4}$	.276	May 22	do	do	Diuretin; caffein citrate.	do	.569	Do.
No. 204	71 to $63\frac{1}{2}$	.441	May 22 to 24	Leaves (in alfalfa)	Not sick	None		.621	Do.
No. 200	$77\frac{1}{4}$ to $72\frac{1}{2}$	.452	May 23	Leaves (drench)	Very sick	Diuretin; caffein citrate.	Recovery	.585	Do.
No. 206	$69\frac{1}{2}$ to $67\frac{1}{2}$	.386	May 24	Leaves, stems, and buds (drench).	do	None	do	.555	Do.
No. 203	97 to $91\frac{1}{2}$	.551	do	Leaves (drench)	Sick	Diuretin; caffein citrate.	do	.568	Do.
No. 197	$68\frac{1}{2}$	.392	May 26	do	Death	Diuretin; caffein citrate; gin; ammonia.	Death	.572	Do.
No. 198	$70\frac{1}{2}$	.403	do	do	Sick	None	Recovery	.571	Do.
No. 186	71	.992	May 26 to 31	Leaves	Death	Eserin; strychnin; morphin.	Death, due to morphin.(?)	1.397	Do.
No. 188	$78\frac{3}{4}$	.430	May 27	Leaves (drench)	do	Apomorphin; eserin; strychnin.	Death	.546	Do.
No. 191	$57\frac{1}{2}$ to 53	.883	May 28 to 31	Leaves	Very sick	None	Recovery	1.536	Do.
No. 190	71 to $67\frac{1}{2}$	.276	May 29	Leaves, stems, buds, and flowers (drench).	Sick	Eserin; strychnin.	do	.389	Do.
No. 192	62	.238	May 30	Leaves (drench)	Death	Gin	Death	.384	Do.

No. 195	83½	.322	....do	....do	Sick	Eserin; strychnin.	Recovery	.385	Do.
No. 196	65 to 58¼	.220	June 3 to 5	Leaves	Not sick	None		.338	Do.
No. 198	63¼	1.146	June 3 to 7	Leaves, stems, and flowers.	Symptoms	....do	Recovery	1.812	Do.
No. 206	69¼ to 69¼	.298	June 4	Leaves, stems, and flowers (drench).	Not sick	Tannic acid [1]		.430	Do.
No. 200	76	.293	June 5	....do	....do	None		.386	Do.
No. 201	79 to 73¼	.304	....do	....do	....do	Tannic acid [1]		.385	Do.
No. 199	50½ to 52	.220	June 5 to 7	Leaves, stems, and flowers.	....do	None.		.435	Do.
No. 210	80¼ to 77¼	.399	June 6	Leaves, stems, and flowers (drench).	Slightly sick	Tannic acid [1]	Recovery	.496	Do.
No. 209	79¼ to 75¼	.392	....do	....do	Sick	None	...do	.495	Do.
No. 212	93¾ to 90	.516	June 7	....do		Tannic acid [1]		.550	Do.
No. 213	91¾	.505	....do	....do	Death	None	Death	.550	Do.
No. 208	89½ to 78	3.307	June 7 to 10	Leaves, stems, and flowers.	Sick	Tannic acid [1]	Recovery	3.695	Do.
No. 207	67¾ to 59¾	.220	June 7 to 11	....do	Not sick	None		.325	Do.
No. 211	84½ to 71	1.455	June 9 and 10	....do	Sick	....do	Recovery	1.728	Do.
No. 214	64 to 57	1.146	June 10 and 11	....do	....do	Tannic acid;[1] Epsom salts.	...do	1.789	Do.
No. 216	85¾ to 77	1.834	June 13 to 19	Leaves (in bran)	Symptoms	None	...do	2.139	Avery, Cal.
No. 193	71 to 66	3.274	June 15 to 17	Leaves, stems, and flowers.	Sick	Tannic acid;[1] Epsom salts; diuretin.	...do	4.606	Station.
No. 202	72½ to 65	1.213	June 15 to 18	....do	Not sick	None		1.672	Do.
No. 215	78 to 63	1.102	June 19 to 29	....do	....do	....do		1.413	Do.
No. 200	75	.474	June 20 to 22	....do	....do	....do		.633	Do.
No. 201	73 to 69	5.247	June 22 to 28	Leaves, stems, flowers, and young fruit (in bran).	Symptoms	....do	Recovery	7.188	Do.
No. 210	83 to 67	4.894	June 23 to 30	Leaves, stems, and flowers (in bran).	Not sick	....do		5.896	Do.
No. 209	81½ to 67	2.282	June 26 to 30	....do	....do	....do		2.800	Do.
No. 196	78 to 62½	3.086	June 27 to 30	Leaves, stems, and fruit (in bran).	....do	....do		3.956	Do.
No. 190	73 to 63½	1.731	July 4 to 7	Young seed heads (in bran).	....do	....do		2.371	Do.
No. 216	89 to 76½	1.896	July 6 to 8	Leaves, stems, and flowers (dry).	Sick	Diuretin	Recovery	2.896	Do.
No. 195	84 to 70	.452	July 6 to 11	....do	Not sick	None		.538	Do.
No. 203	110 to 98½	3.472	July 6 to 12	Seed heads with a few leaves and flowers (dry).	Sick	Tannic acid;[1] diuretin.	Recovery	3.155	Do.
No. 193	73½ to 66	4.112	July 16 to 19	Seed heads in bran (dry).	....do	None	...do	5.597	Do.
No. 199	59½	.055	Aug. 13	Seed (in bran)	....do	....do	...do	.092	Do.
No. 196	73 to 70	.110	Aug. 13 and 14	....do	Symptoms	....do	...do	.151	Do.
No. 218	60	.066	Aug. 14	....do	Not sick	....do		.110	Do.
No. 185	64 to 58	.154	Aug. 15 and 16	....do	Symptoms after eating 45 grams.	....do	Recovery	.241	Do.

[1] Drench.

TABLE I.—*Summary of feeding experiments with Zygadenus in 1909 and 1910 at Mount Carbon, Colo., and in 1912, 1913, and 1914 at Greycliff, Mont.*—Continued.

Animal.		Weight of plant used.	Date of experiment.	Part of plant used (fed unless otherwise stated).	Severity of illness.	Remedy.	Result.	Pounds used per stated weight of animal.	Location from which plant used was obtained.
Designation.	Weight.								
G.—Sheep given Z. venenosus—Con.	*Pounds.*	*Pounds.*	1913.					*Per 100 pounds.*	
No. 212	98 to 89	0.441	Aug. 16 and 17	Seed (in bran)	Not sick	None		0.450	Station.
No. 215	74 to 64	.095	Aug. 17	do	do	do		.128	Do.
No. 207	77 to 70½	.311	Aug. 19 and 20	do	do	do		.404	Do.
H.—Sheep given Z. elegans:									
No. 214	61 to 55	.441	July 25 and 26	Leaves, stems, flowers, and some bulbs.	do	do		.723	Beartooth National Forest.
No. 198	64	4.045	July 25 to 31	Leaves, stems, flowers, fruit, and some bulbs.	do	do		.632	Do.
No. 201	69 to 59	3.858	do	Leaves, stems, flowers, some fruit, and bulbs.	do	do		5.591	Do.
No. 199	60 to 54	.264	July 28	Leaves, stems, flowers, and some fruit (drench).	Symptoms	do	Recovery	.440	Do.
No. 217	58 to 55	.412	July 29	do	Not sick	do		.710	Do.
No. 185	61 to 56	.403	Aug. 1	do	Slightly sick	Tannic acid [1]	Recovery	.660	Do.
I.—Sheep given Z. venenosus:			1914.						
No. 278	79½ to 69½	0.254	May 27 to 29	Leaves, stems, flowers, and buds (with grass).	Not sick	None		.319	Greycliff
No. 269	96 to 88½	.287	May 27 to 30	do	do	do		.299	Do.
No. 276	85½	.551	May 28	Leaves, stems, flowers, and buds (forced feeding).	Death	Tannic acid; [1] eserin; pilocarpin; whisky; gin (enema).	Death	.644	Do.
No. 237	83½	(2)	May 28 to 30	Leaves, stems, flowers, and buds.	Not sick	None			
No. 255	89 to 85	1.543	do	Leaves, stems, flowers, and buds (with grass).	do	do		1.734	Do.
No. 234	89 to 85	.441	May 29	Leaves, stems, flowers, and buds (forced feeding).	Slightly sick	do		.495	Do.
No. 282	85 to 80	.421	do	do	do	Tannic acid [1]	Recovery	.495	Do.
No. 232	93 to 86	.483	June 1	Leaves and some young buds (forced feeding).	Not sick	None		.519	Station.

No. 248	94 to 85½	.441	....do	Leaves and some young buds (with grass).	....do	....do		.469	Do.
No. 267	106 to 98	.529	....do	Leaves and some young buds (forced feeding).	Symptoms	....do	Recovery	.499	Do.
No. 239	84½ to 78½	.465	June 2	....do	....do	....do		.550	Do.
No. 256	83 to 78	.457	....do	....do	Not sick (?)	....do	Recovery	.551	Do.
No. 243	80½ to 76	1.323	June 2 and 3	Leaves, some young buds, and a few flowers (with grass).	Not sick	....do		1.643	Do.
No. 229	104 to 100½	.539	June 3	Leaves, stems, flowers, and buds (forced feeding).	Sick	Tannic acid [1]	Recovery	.518	Do.
No. 235	101½ to 89½	.526	....do	....do	....do	None	...do	.518	Do.
No. 245	100 to 97½	.529	June 4	....do	Slightly sick	Tannic acid [1]	...do	.529	Do.
No. 257	95 to 87¾	.503	....do	....do	Sick	None	...do	.529	Do.
No. 231	107 to 101	1.323	June 4 and 5	Leaves, stems, flowers, and buds (with grass).	Not sick	....do		1.236	Do.
No. 265	90 to 84	.476	June 5	Leaves, stems, flowers, and buds (forced feeding).	....do	....do		.529	Do.
No. 249	89 to 81	.471	June 6	....do	....do	....do		.529	Do.
No. 266	90½ to 81½	.479	....do	....do	....do	....do		.529	Do.
No. 264	107	.666	June 8	....do	Sick	Raw oil and charcoal.	Recovery	.622	Do.
No. 268	110 to 102⅜	.649	....do	....do	....do	None	...do	.590	Do.
No. 246	98 to 93	1.874	June 9	Leaves, stems, flowers, and buds (with grass).	Very sick	Tannic acid (in capsules).	...do	1.912	Do.
No. 247	105 to 109	.441	....do	....do	Not sick	None		.420	Do.
No. 255	91 to 84	.602	June 15	Leaves (forced feeding).	....do	....do		.661	Do.
No. 269	92½ to 87	.612	....do	....do	Slightly sick	Tannic acid (in capsule).	Recovery	.662	Do.
No. 282	85 to 79	.562	June 16	....do	....do	....do	...do	.661	Do.
No. 283	75 to 71	.269	....do	Stems, flowers, and young fruit (forced feeding).	Not sick	None		.359	Do.
No. 237	83 to 79	.628	June 17	Leaves, stems, flowers, and young fruit (forced feeding).	Symptoms	....do	Recovery	.757	Do.
No. 238	83 to 74	.639	....do	....do	Not sick	....do		.770	Do.
No. 235	103 to 95½	.851	June 18	....do	Symptoms	....do	Recovery	.826	Do.
No. 245	102 to 95	.843	....do	....do	....do	....do	...do	.826	Do.
No. 239	79½ to 75	.789	June 19	....do	Slightly sick	Tannic acid (in capsule).	...do	.992	Do.
No. 256	79 to 75	.784	....do	....do	Not sick	None	...do	.992	Do.
No. 231	109½ to 99½	.882	June 20	Leaves, stems, and flowers (with grass).	....do	....do		.805	Cabin Corral.

[1] Drench.

[2] Very few grams.

TABLE I.—*Summary of feeding experiments with Zygadenus in 1909 and 1910 at Mount Carbon, Colo., and in 1912, 1913, and 1914 at Greycliff, Mont.*—Continued.

Animal.		Weight of plant used.	Date of experiment.	Part of plant used (fed unless otherwise stated).	Severity of illness.	Remedy.	Result.	Pounds used per stated weight of animal.	Location from which plant used was obtained.
Designation.	Weight.								
I.—Sheep given Z. venenosus—Con.	*Pounds.*	*Pounds.*	1914.					*Per 100 pounds.*	
No. 234	86 to 81	1.043	June 20	Leaves, stems, and flowers (forced feeding).	Slightly sick	Tannic acid (in capsule).	Recovery	1.213	Cabin Corral.
No. 249	84½ to 79	.838	do	do	Sick	do	do	.992	Do.
No. 265	85 to 78	.843	do	do	Slightly sick	None	do	.992	Do.
No. 266	92 to 88½	1.093	do	do	Symptoms	do	do	1.188	Do.
No. 251	90½ to 86½	1.300	June 22	Leaves, stems, flowers, and buds (forced feeding).	do	do		1.436	Do.
No. 263	95	1.362	do	do	Not sick	do	Recovery	1.434	Do.
No. 232	78 to 70½	1.455	June 23	do	Sick	Tannic acid (in capsule).	do	1.865	Do.
No. 253	75½ to 70½	1.413	do	do	do	None	do	1.871	Do.
No. 229	112½ to 98½	2.231	June 24	do	Slightly sick	Tannic acid (in capsule).	do	1.983	Do.
No. 264	102½	2.033	do	Leaves, stems, flowers, and buds (in 7 forced feedings).	Not sick	None		1.983	Do.
No. 268	111 to 101½	2.202	do	Leaves, stems, flowers, and buds (forced feeding).	Sick	do	Recovery	1.984	Do.
No. 240	103½ to 98½	2.282	June 25	Leaves, stems, and flowers (forced feeding).	Slightly sick	Tannic acid (in capsule).	do	2.205	Do.
No. 250	103½ to 99½	1.142	do	Leaves, stems, and flowers (drench).	Sick	None		1.103	Do.
No. 280	99 to 94½	2.183	do	Leaves, stems, and flowers (forced feeding).	Slightly sick	do	Recovery	2.205	Do.
No. 262	80 to 78	2.205	June 26	do	do	do	do	2.756	Do.
No. 278	82 to 81	2.260	do	do	do	Tannic acid (in capsule).	do	2.756	Do.
No. 247	112½ to 100	2.425	June 27	do	Not sick	None		2.156	Do.
No. 255	96½ to 95½	1.064	do	Leaves, stems, and flowers (drench).	do	do		1.103	Do.
No. 277	99	.655	do	do	do	do		.662	Do.

No. 243	85½	.377	June 29	Seed heads, nearly developed (forced feeding).	do	do		.441	Station.
No. 281	77 to 64	.679	do	do	Slightly sick	do	Recovery	.881	Do.
No. 255	95½ to 90½	1.053	June 30	do	do	do	do	1.103	Do.
No. 257	95	1.047	do	do	Sick	Tannic acid (in capsule).	Killed by choking on capsule.	1.102	Do.
No. 237	89 to 83½	1.177	July 1	do	do	do	Recovery	1.322	Do.
No. 238	88 to 82½	1.164	do	do	do	None	do	1.323	Do.
No. 281	71 to 68½	1.024	July 2	Seed heads, some fully developed and others half developed (forced feeding).	Not sick	Tannic acid (in capsule).		1.442	Cabin Corral.
No. 283	82½ to 76½	1.182	do	do	Slightly sick	None	Recovery	1.432	Do.
No. 259	115½ to 98½	3.968	July 2 and 3	Leaves, stems, flowers, and young fruit.	Not sick	do		3.435	Do.
No. 235	102½ to 101	1.582	July 3	Seed heads, very young (forced feeding).	Symptoms	do	Recovery	1.543	Station.
No. 267	105½ to 98½	1.628	do	Seed heads, half developed (forced feeding).	do	Tannic acid (in capsule).	do	1.543	Cabin Corral.
No. 282	93	1.640	July 5	do	Very sick	Tannic acid (in capsule); whisky.	do	1.763	Do.
No. 256	85½ to 80	1.508	do	do	Sick	None	do	1.764	Do.
No. 239	83½	.828	July 7	Seed heads, fully developed (forced feeding).	Death	Tannic acid (in capsule); oil and turpentine.	Death	.992	George Hughes's.
No. 245	105½ to 100½	1.047	do	do	Sick	Tannic acid (in capsule).	Recovery	.994	Do.
No. 269	101 to 95	1.002	do	do	do	None	do	.992	Do.
No. 231	112 to 111½	1.111	July 8	do	do	Tannic acid;[1] caffein sodiobenzoate.	do	.992	Do.
No. 233	130½ to 126½	1.295	do	do	do	None	do	.992	Do.
*No. 249	87	.862	July 9	do	Death	do	Death	.991	Do.
*No. 251	86 to 79	.853	do	do	Sick	Tannic acid (put into rumen).	Recovery	.992	Do.
No. 246	98½ to 92	.326	July 10	Seed heads, fully developed (drench).	Symptoms	None		.331	Do.
*No. 266	94	1.554	do	Seed heads, fully developed, mixed with potassium permanganate (drench).	do	Potassium permanganate.	Recovery	1.653	Do.

[1] Drench.

TABLE I.—*Summary of feeding experiments with Zygadenus in 1909 and 1910 at Mount Carbon, Colo., and in 1912, 1913, and 1914 at Greycliff, Mont.*—Continued.

Animal.		Weight of plant used.	Date of experiment.	Part of plant used (fed unless otherwise stated).	Severity of illness.	Remedy.	Result.	Pounds used per stated weight of animal.	Location from which plant used was obtained.
Designation.	Weight.								
I.—Sheep given Z. venenosus—Con.	*Pounds.*	*Pounds.*	1914.					*Per 100 pounds.*	
No. 234	79 to 74	0.348	July 11	Seed heads, fully developed (drench).	Sick	None	Recovery	0.441	George Hughes's.
No. 253	77 to 76	.340	do	Seed heads, fully developed, mixed with potassium permanganate (drench).	Not sick	Potassium permanganate.		.441	Do.
*No. 252	89 to 85	.392	July 13	Seed heads, fully developed (forced feeding).	Slightly sick	Potassium permanganate (put into rumen).	Recovery	.440	Do.
*No. 264	105 to 98	.463	do	do	Symptoms	None	do	.440	Do.
No. 254	90 to 88	.683	July 14	do	Slightly sick	Tannic acid [1]	do	.759	Do.
No. 268	102 to 96	.899	do	do	Sick	Potassium permanganate.	do	.881	Do.
No. 262	84	.741	July 15	do	Death	Caffein	Death	.882	Do.
No. 283	81½ to 70	.719	do	do	Sick	Potassium permanganate.		.882	Do.
No. 290	83½ to 85	.736	do	do	Very sick	Charcoal; atropin.	Recovery	.881	Do.
No. 259	120 to 108	.888	July 22	Seed heads, ripening (forced feeding).	do	Charcoal	do	.740	Do.
*No. 247	113 to 100	.838	July 23	do	do	Atropin	do	.741	Do.
*No. 263	91 to 88½	.802	Aug. 7	Seed heads, fully developed (forced feeding).	Slightly sick	Tannic acid (repeated doses).	do	.881	Do.
*No. 269	92 to 80½	.811	Aug. 10	do	Very sick	None	do	.882	Do.
*No. 231	92	.612	Aug. 11	do	Not sick	do		.665	Do.
*No. 259	106½ to 101	.939	Aug. 13	do	Very sick	Sodium bicarbonate (repeated doses).	Recovery	.882	Do.
No. 267	100½ to 91	.886	Aug. 14	do	Sick	Tannic acid (repeated doses).	do	.882	Do.
*No 294	65½ to 60½	.578	Aug. 15	do	Very sick	None	do	.882	Do.

*No. 296	72½ to 72½	.639	do	do	Sick	Tannic acid (repeated doses).	do	.881	Do.
*No. 265	89 to 84½	.981	Aug. 17	do	do	do	do	1.102	Do.
*No. 291	86 to 77½	.758	do	do	Very sick	Magnesium sulphate; tannic acid (repeated doses); atropin.	do	.881	Do.
*No. 293	68 to 61	.600	Aug. 21	do	Sick	Sodium bicarbonate (repeated doses).	do	.882	Do.
*No. 292	87 to 77½	.959	Aug. 22	do	Very sick	do	do	1.102	Do.
*No. 246	102½	1.506	Aug. 24	do	do	do	do	1.469	Do.
*No. 247	111 to 106½	.368	Aug. 25	Seed heads, fully developed (in bran).	Not sick	None		.331	Do.
*No. 264	95	1.047	do	Seed heads, fully developed (forced feeding).	Death	Sodium bicarbonate (repeated doses).	Death	1.102	Do.
*No. 240	80½ to 81	.705	Aug. 26	do	Sick	do	Recovery	.876	Do.
*No. 277	84 to 68	.772	do	do	Very sick	do	do	.919	Do.
*No. 299	77 to 68	.416	Sept. 8	Seed pods, with seed removed (forced feeding).	do	Bled	do	.540	Do.
No. 235	79	.087	Sept. 11	Seed (forced feeding)	Slightly sick	None	do	.110	Do.
No 251	66	.145	do	do	Death	do		.219	Do.
No. 245	75½	.149	Sept. 12	do	Very sick	Bled	Recovery	.197	Do.
No. 297	76½	.152	do	do	Death	do	Death	.199	Do.
No. 266	69½	.153	Sept. 13	do	do	do	do	.220	Do.
J.—Sheep given Z. elegans:									
No. 233	111	.244	Aug. 8	Leaves, stem, flowers, and pods (forced feeding).	Not sick	None		.219	Fishlake National Forest, Utah.
No. 246	97	.434	do	do	do	do		.447	Do.
No. 281	64 to 60	.846	Aug. 9	do	Not sick (?)	do		1.322	Do.
No. 292	82 to 78	.723	do	do	do	do		.882	Do.
No. 232	75 to 71½	1.267	Aug. 11	Leaves, stems, flowers, and some young pods (forced feeding).	Not sick	do		1.689	Do.
K.—Sheep given Z. paniculatus:									
No. 278	80½	.444	June 10	Leaves, stems, and fruit (forced feeding).	Slightly sick	do	Recovery	.551	Ephraim, Utah.
No. 281	72	.317	do	do	Symptoms	do	do	.440	Do.

[1] Drench.

Following are the details of three cases which may be considered typical:

Sheep No. 193.—This animal (Table I, section G) was a 2-year-old ewe, lent for experimental purposes by Mr. Ole Birkeland. She was received at the station on May 9, 1913. An attempt was made on May 12 to feed to her the bulbs of *Zygadenus venenosus* ground and mixed with bran. As she would not eat this, a trial was made on May 13 of feeding her with Zygadenus tops, but these also she refused to eat; so at 1.40 p. m. of the same day she was drenched with 200 grams of *Z. venenosus* bulbs ground fine and suspended in water. At 2.35 p. m. she was frothing at the mouth and vomiting, with violent contractions of the diaphragm and abdominal muscles. She was lying down, but was able to stand. At 3.50 p. m. she was still frothing at the mouth, but was fairly strong. At 5.30 p. m. her temperature was 101° F. She was fairly strong, but acted as though in much discomfort. On May 14, at 7 a. m. she appeared entirely normal, and at 8.30 she was turned out to pasture.

On June 14, 1913, she was kept in for feeding, and at 8.15 a. m. she was fed 100 grams of fresh tops of *Zygadenus venenosus*, which were collected on June 12. At this time the plant was in flower. At 4.40 p. m. she was fed 200 grams of the plant, and at 7.40 p. m. 135 grams.

On June 16, at 7.10 a. m., she was fed 200 grams; at 6.40 p. m., 200 grams; and at 7.15 p. m., 250 grams. All the Zygadenus fed on June 16 had been collected on the preceding day.

On June 17, at 6.45 a. m., all the Zygadenus given on the preceding day had been eaten. The animal appeared bright, but showed sensitiveness to sudden noises and there was some trembling of the surface muscles. At 7 a. m. she was run around the corral. It was found that she moved in a stiff-legged manner and was somewhat weak. The stiffness was most noticeable in the hind legs. She was licking her lips and rubbing her nose against the fence and moving her head about in a jerky way. At 8.45 a. m. the symptoms were about the same as at 7. a. m. At this time she was fed 200 grams of Zygadenus. At 11.30 a. m. and 1.50 p. m. she was fed 100 grams of Zygadenus. At 3 p. m. her temperature was 103.8° F. She was more nervous than in the morning and her movements were somewhat more stiff. The jerking movements were more pronounced and continuous. All the Zygadenus which had been previously given had been eaten. At 8 p. m. the symptoms as noted at 3 o'clock still continued She was fed a little alfalfa.

On June 18, at 6.45 a. m., the sheep was trembling almost constantly, with frequent spasmodic movements. Her legs were stiff as she walked about, and there was some lack of control. She was dejected and dull and without appetite. At 9 a. m. she was given 5 grams of tannic acid. At 9.40 she was given 4 ounces of Epsom salts in solution. At 10.30 a. m. she was put in a metabolism cage, in order to collect the excretions. At 2 p. m. she seemed to be decidedly better, and continued in about the same condition throughout the afternoon.

On June 19, at 6.30 a. m., the animal trembled, but showed no other symptoms. She had not urinated since being placed in the metabolism cage at 10.30 a. m. on the preceding day. At 8 a. m. she was taken out of the cage and fed some alfalfa. The general appearance of the animal was better than on the preceding day, but she was still unsteady in her gait and exhibited trembling of the surface muscles. At 1 p. m. she defecated as the result of the dose of magnesium sulphate given on the preceding day, and this defecation continued in a mild diarrhea. At 3 p. m. she urinated for the first time after being placed in the metabolism cage. At this time her respiration was 148, and she seemed in general to be worse. At 8 p. m. she was given 1 gram of diuretin in solution, and returned to the metabolism cage. During the afternoon the animal seemed to be gradually getting worse. When standing, her hind legs were drawn forward under her. The muscles of the legs were twitching almost continuously, and it was with difficulty that she could get up and down.

On June 20, at 6.30 a. m., there were about 1½ pints of urine which had accumulated through the night. This was preserved in alcohol, and a chemical examination showed that it contained the alkaloids of Zygadenus. The diarrhea still continued. The general condition of the animal was nearly the same as the preceding night, except that she appeared a little stronger. She was taken out of the cage and fed alfalfa. At 2 p. m. she was somewhat better than in the morning and had an appetite, although she still preferred to lie down. At this time she was given 1 gram of diuretin in solution. At 7.50 p. m. she was much better, standing in a more normal manner and with no noticeable trembling. On June 22 she was turned out, apparently all right.

On July 15, 1913, the sheep was again kept in for feeding, and on July 16, at 10.30 a. m., she was given 200 grams of the mature heads of *Zygadenus venenosus*, consisting of pods and seeds, ground and mixed in bran.

On July 17, at 9.25 a. m., she was fed 270 grams prepared as the day before, and at 1.25 p. m. she was fed 180 grams. At 7.45 p. m. she was fed 210 grams. At the time of the last feeding she showed the effects of the poisoning. She did not move with the usual freedom, and there was some twitching of the surface muscles of the body.

On July 18, at 9.50 a. m., she was fed 235 grams. At 6.30 p. m. she was fed 220 grams. During the day there was little change in the condition of the animal.

On July 19, at 7 a. m., the symptoms were much more pronounced than the preceding night. There was stiffness of movement of the legs, licking of the lips, and slight trembling. This stiffness and accompanying clumsiness were more pronounced in the hind legs. At 9 a. m. she was fed 255 grams and at 3 p. m. 195 grams. At this time the animal was considerably weaker than in the morning.

On July 20, at 8.45 a. m., all the Zygadenus given on the preceding day had been eaten, and the general condition of the animal was about the same as on the preceding night. She moved with some difficulty and with marked stiffness of the legs. There was trembling of the surface muscles accompanied by some shaking of the head and licking of the lips. She was unusually sensitive to noise, as she was easily startled, and at such times there were sudden contractions of the body muscles. She had much difficulty in raising her feet sufficiently to get over elevations of 3 or 4 inches.

On July 21, at 3 p. m., the animal had improved in its general condition, although the symptoms were still well marked. These did not differ from those seen earlier in the sickness, but were less pronounced.

On July 22, at 7 a. m., the animal moved about fairly well, but there was some trembling of the surface muscles, especially in the shoulders. She improved during the day and at 7 p. m. seemed to be quite normal. On July 23, at 7.55 a. m., she was turned out to pasture, appearing strong and active and showing no symptoms except some slight trembling when handled.

Sheep No. 160.—This animal (Table I, section F) was a ewe lent by Mr. Ole Birkeland on June 20, 1912. On July 19, 1912, she was taken in for feeding with *Zygadenus venenosus*. At 11.05 a. m. her respiration was 28, pulse 26, and temperature 105° F. At 11.25 a. m. she was drenched with 125 grams of the seed heads of *Zygadenus venenosus* suspended in water. These seed heads included the pods and seeds. At 11.35 a. m. there was a little frothing at the mouth. At 11.40 a. m. her respiration was very rapid and irregular. It would run as high as 200 per minute for perhaps 50 respirations, then stop, only to be resumed at the same rapid rate. At this time the animal had vomited. At 12.55 her pulse was 95 and very variable; her temperature was 104° F. At 1 p. m. her respiration was 200 or more and the heart action regular and strong. She was then given a solution of potassium permanganate. At 1.17 p. m. she was getting weaker on her legs. She would start to lie down and nearly fall, but would get on her feet after a minute or two and then lie down again. Her respiration was about 180 per minute. At 1.30 p. m. her respiration was still rapid, the mucous membranes of the mouth somewhat cyanotic, and the ears drooped. At 1.47 p. m. she was given subcutaneously 8 grams of caffein. At 1.49 p. m. she threw her head up and held her breath for about a quarter of a minute. She repeated this action several times. At 2.03 p. m., her temperature was 100° F. The animal seemed somewhat stronger. Her respiration was still variable, running as high as 180 per minute. Her pulse was about 80. She was still frothing at the mouth and appeared to be in pain. At 2.20 p. m. she had a hard time to breathe. She shook her head, staggered about, and lay down. Her respiration was slow and labored. At 2.22 p. m. her respiration was getting more rapid. At 2.23 p. m. the animal seemed to be in great pain; her breathing nearly stopped for a minute, but started again in a panting manner. Her respiration continued irregular, first fast and then slow and labored. At 3 p. m. her temperature was 100.2° F. and her respiration 84, but not as labored as at 2.03 p. m. She was still frothing at the mouth. Her pulse was 96 and strong. At 3.30 p. m. her respiration was 160. She fell upon her knees, struggled to get on her feet again, but finally lay down. At 4.15 p. m. she was groaning more or less and staggered as she attempted to walk. Her respiration was 90. At 4.30 p. m. she was lying down and her respiration was very nearly normal. Her temperature was 99.1° F. At 5 p. m. she was down again and in pain, groaning continuously, her respiration slower than for some time previous, the rate being about 60 per minute. At 5.04 p. m. the animal was lying sprawled out upon her belly. Her respiration was 168. At 5.38 p. m. she appeared very stupid, almost as if sleepy. She was given subcutaneously 6 grains of caffein sodiobenzoate. At 5.45 p. m. her temperature was 99.4° F., her respiration 120 and very variable, and her pulse 96. At 7.10 p. m. her temperature was 99.7° F. Her respiration was slow and variable. After expiration there would be a pause followed by two short and shallow inspirations close together. These would be followed by a long inspiration, then a full expiration accompanied by a groan. This was repeated over and over again, the whole cycle taking about 20 seconds. The animal on the whole seemed to be brighter than at 6 p. m.

At 8 p. m. the animal was given 5 grains of caffein sodiobenzoate. Her temperature was 100.8° F., respiration 10, and pulse 120. At 10 p. m. her temperature was 100.2° F., pulse 120, and respiration 4. The inspiration was deep and the expiration was accompanied by a groan. At 10.55 p. m. her temperature was 100° F. At 11.15 p. m. her respiration was 18 and pulse 108. Her general condition was unchanged.

On July 20, at 7 a. m., the animal's pulse was 100, temperature 100.8° F., and respiration 11. She was then lying with her head bent under her body and would probably have died in that position had she not been relieved. She seemed at this time unconscious. At 8.45 a. m. her temperature was 100.6° F, pulse 84, and respiration 12. At 10 a. m. her respiration was 10, and her pulse 84. The animal was in a comatose condition. At 10.50 a. m. her respiration seemed to be getting more shallow. At 11.15 a. m. she seemed somewhat brighter than earlier in the day. At 12 m. her temperature was 102.6° F., respiration 12, and pulse 108. During the afternoon she had been lying in practically the same position, with her head slightly raised, resting upon a support. She was too weak to move herself at all. At 3 p. m. her respiration was 12. At 3.30 she was given subcutaneously 10 c. c. of whisky. At 4.20 p. m. her temperature was 102.8° F., respiration 36, and pulse 116. At 8.05 p. m. she was given subcutaneously 5 c. c. of whisky. At 9.30 p. m. her temperature was 104.6° F., respiration 18, and pulse 120.

On July 21, at 5.45 a. m., she was found in practically the same condition as the preceding night. At 6.45 a. m. her temperature was 104° F., respiration 24, and pulse 148, and weak. At 9.50 a. m. she was given subcutaneously 5 drops of fluid extract of digitalis in 8 c. c. of whisky. At 10.15 a. m. her pulse was somewhat stronger than before the digitalis was given. At 11 a. m. her pulse was 102, temperature 104.6° F., and respiration 48. At 11.15 a. m. her respiration was fairly deep, but was somewhat spasmodic. Her pulse was weak. At 11.45 a. m. her respiration was 68. At 9.30 p. m. her temperature was 105.3° F., respiration 24, and pulse 120, but weak. The animal was given subcutaneously 3 drops of fluid extract of digitalis in 6 c. c. of whisky. During the day there had been very little change in her condition. She lay in a coma, from which she did not rouse herself except occasionally to shake the flies from her ears. Her position had been changed from time to time by the attendants. She was found dead on the morning of July 22.

At the autopsy the venous blood vessels were found congested and the lungs were congested, as were the liver and kidneys. There was considerable inflammation of the walls of the fourth stomach and of the whole length of the intestines. Sections of the kidney showed that the capillaries were much congested, and there was some degeneration of the tubule walls. Sections of the liver showed acute congestion, and the same condition was noticed in the sections of the lung.

Sheep No. 197.—This animal (Table I, section G) was a ewe 2 years old, lent by Mr. Ole Birkeland on May 9, 1913. An unsuccessful attempt was made to feed *Zygadenus venenosus* tops to her on May 12.

On May 26, at 11.25 a. m., she was drenched with 178 grams of *Zygadenus venenosus* tops suspended in water. These plants were collected on May 23. At 11.40 a. m. she was frothing at the mouth. At 11.45 a. m. she was given a drench of 1 gram of diuretin and 0.455 gram of caffein citrate. At 11.50 a. m. she was vomiting, and when observed at 12 m. the vomiting was continuing. At 12.05 p. m. her respiration was getting irregular and deeper. At 12.30 p. m. her respiration was extremely fast and she was panting. At this time she was violently nauseated and threw herself down two or three times and then jerked about in a spasmodic manner. At 12.40 p. m., being extremely nauseated she was trying to vomit, throwing herself down, and the spasmodic movements were followed by quick, panting respiration. At 12.45 p. m. her respiration was about 200. She showed weakness in her legs. At 1.15 p. m. she repeated the spasmodic movements which had been noticed at 12.30 and 12.40 p. m., evidently struggling to get breath. She threw her head from side to side and ran the length of the corral, throwing herself upon the ground and rising again as though having a fit. The mucous membranes of the mouth were cyanotic. These movements were repeated a little later. At 1.30 p. m. she was given a dose of 5 c. c. of gin. Another struggle for breath followed, and it was noted after this struggle that her heart action was very rapid and strong. The beat was audible to the observers. Five c. c. more of gin were given subcutaneously. At 1.36 p. m. she was lying upon her side. Her respiration was 160. At 1.40 p. m. she had another struggle for breath, throwing herself about violently, even throwing herself over upon her back. These struggles were repeated at 1.49 and at 1.53 p. m. The mucous membrane of the mouth at both times was very markedly cyanotic. At 1.55 p. m. she was given 5 c. c. of gin. At this time she was still strong enough to get on her feet. She was urinating freely. At 1.59 p. m. she passed through another spasmodic attempt to breathe. At 2.02 p. m. her pulse was about 200. At 2.06 p. m. there was a spasmodic struggle for breath. At 2.10 p. m. the animal was breathing with very great difficulty. Ammonia was used to stimulate her respiration. Her pulse was 130. At 2.45 p. m. she had great difficulty in respiration, but at this time it was not accompanied by a spasmodic struggle. At 3.06 p. m. she had another spasmodic struggle, and ammonia was used as a stimulant. At 3.30 p. m. her respiration some of the time was very rapid, becoming as high as 200 per minute. Then it slowed down and became labored. On the whole the animal at this time seemed somewhat better. At 3.39 p. m. she made a struggle to get upon her feet but was unable to do so. Her respiration at this time was variable and very labored, the breathing being followed by quick, panting efforts. At 4.10 p. m. her respiration nearly stopped. She was stimulated with ammonia. At 4.15 p. m. ammonia was again used. At 4.45 p. m. her respiration was 132. At

5.19 p. m. the animal was upon her side. Her respiration was labored, but seemed somewhat stronger. Her condition remained very nearly the same until 6 p. m. At 6.30 p. m. she was found dead.

The autopsy showed that the lungs were slightly congested; the inner walls of the ileum were congested and the venous blood vessels, generally speaking, were full. It was evident that death had occurred from respiratory paralysis.

The detailed report of the examination of the internal organs by Dr. Mohler, of the Bureau of Animal Industry, is as follows:

Kidney (cortex and medulla).—Many of the intertubular capillaries in the labyrinth of the cortex and some Malpighian bodies show a marked distention, but not sufficiently pronounced to be called congestion. There is also a general distention of many of the convoluted tubules and the interstices between the capsule of Bowman and glomeruli with a serous, œdematous exudate. This latter has distended the tubules and compressed the renal epithelial cells, many of which, having become atrophic from pressure, disintegrated and desquamated into the lumen of the tube. While these changes are quite marked in the convoluted tubules, the œdema, desquamation, and degeneration are absent in the straight portions of the uriniferous tubules of the medulla. The distention of the capillaries, however, is present even in the medulla. No interstitial alterations are present.

Lung.—The characteristic lesion is the intense congestion of the entire organ, the presence of small lobular areas of consolidation, and occasional minute œdematous areas. The larger pulmonary and bronchial vessels are all overdistended, but the interfundibular capillaries show not only overdistention but also diapedesis and outwandering of the leucocytes. No such capillary hemorrhages or poollike accumulations of the blood can be seen in this lung as were previously observed in lung 716. The bronchial tubes and the smaller bronchi are unaltered. There is no peribronchitis present, although the bronchial blood vessels have all participated in the distention of the other vessels of the lung.

Kidney.—No acute inflammatory changes present. Evidences of a slight subacute catarrhal nephritis accompanied by mild degenerative changes in the renal cells in the cortical portion of the kidney. No interstitial changes present.

Liver.—Moderate amount of physiological fatty infiltration and a slight congestion of the intralobular capillaries between the liver cords, but no diapedesis of red blood cells or outwandering of leucocytes. The hepatic cells proper show a slight amount of cloudy swelling in isolated lobules. No interstitial changes present.

Ileum.—Shows a slight increase in the adenoid tissue in the mucosa and slight fullness of the blood vessels in the submucosa. There is, however, no congestion, desquamation, or degeneration present.

SYMPTOMS IN SHEEP OBSERVED AT THE GREYCLIFF STATION.

The very large number of cases of illness and death observed at the Greycliff station furnished an opportunity for a fairly complete picture of the symptoms produced by Zygadenus poisoning. The symptoms were noted in detail, and the description that follows is drawn from a summarized statement formulated from these notes.

SALIVATION.

Generally salivation, or frothing at the mouth, was the first noticeable symptom and continued through the acute period of the illness. It was not invariably present; sometimes it did not appear, especially in the fed cases. It was seen in nearly all the drenched cases, and was rarely absent when the attack was acute. The salivation was in many cases accompanied by grinding of the teeth. Plate IV, figure 1, of sheep No. 160, and Plate IV, figure 2, of sheep No. 192, illustrate this stage of the illness.

NAUSEA.

Nausea was very pronounced in nearly all cases, and frequently resulted in violent vomiting, this vomiting, like the salivation, being largely confined to the acute stage of the illness.

PULSE.

Routine observations upon the pulse were made in a large number of cases. The rate of the pulse is, of course, very variable under normal conditions. When taken before the experimental feeding it varied from 52 to 144, although in most cases it was between 60 and 100. Generally speaking, when the intoxication was not acute there was very little change from what would be expected in normal variations either in the rate or character of the pulse. In the severer cases, especially in those that ended fatally, the rate was from 125 to 200. While in three cases of sheep not under the influence of a toxic substance the pulse was 144, this condition is unusual; and in a general way it seems to be true that if the rate runs much above 130 a fatal termination of the illness is likely to follow. In the severe cases the pulse was weak and sometimes intermittent.

TEMPERATURE.

Temperature observations were made in detail in a large number of cases. It was considered necessary to get the average of a considerable number, inasmuch as there is in sheep quite a range of variability under normal conditions and also a considerable difference in individuals. The extreme range of temperature was from 97.4° to 105.7° F. From the cases of 1914, 64 records were made. Of these, 8 showed no marked change, 14 exhibited an increase, and 42 a decrease, and the decrease ordinarily was not very great but in some few cases was down to between 97° and 98° F. It is evident that, in general, intoxication by Zygadenus is accompanied by depression of temperature. In some few cases, in which there were no other symptoms of poisoning, a lowering of temperature was noticed; this, however, was not sufficiently general so that it could be considered diagnostic in the absence of other symptoms. Curves are given (figs. 1 and 2) of sheep 282 and 291. These, it should be stated, are not average cases, but they may be considered typical of cases in which the lowering of temperature is more marked.

RESPIRATION.

The rate of respiration had an extremely wide range of variation. Quite uniformly in the acute stages of the poisoning, the rate was very rapid, running in some cases as high as 250 per minute. After this period the rate was very much reduced, falling to normal or below,

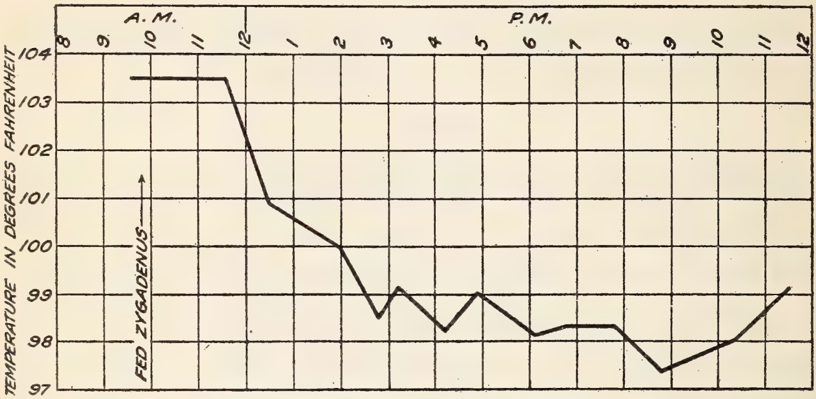

FIG. 1.—Curve of temperature of sheep No. 282.

and the animal sometimes lay for hours breathing most of the time in a slow and labored fashion. This period of comparative quiet might be interrupted, sometimes frequently, by times of rapid breathing, accompanied by panting and followed quickly by a very slow rate. Sometimes, in severe cases, there were times when the animal threw

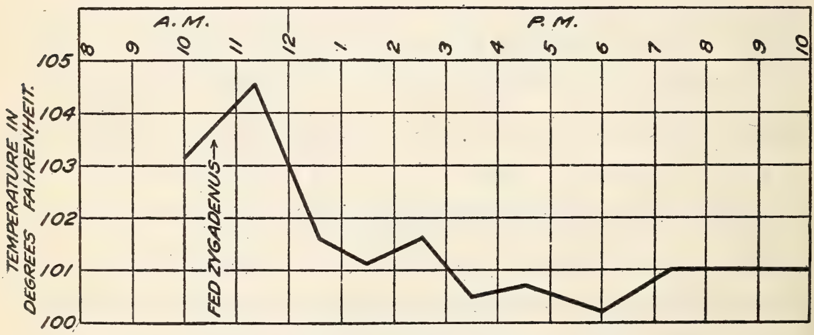

FIG. 2.—Curve of temperature of sheep No. 291.

itself about violently, fighting for oxygen. This condition lasted for perhaps two or three minutes and was succeeded by a period of quiet, which was soon broken by another struggle. During these struggles the mucous membranes of the mouth were frequently cyanotic. The struggles were spasmodic, and when authors state that poisoned animals have spasms or convulsions, it is to be presumed that they refer to this condition. It should be noted, however, that in the cases observed at the Greycliff station there was no indication of any special tonic or clonic contraction of the muscles; the violent movements of the animals were simply those caused by distress from dyspnœa.

Figure 3 gives the curve of respiration for sheep No. 174 and may be considered typical of the average fatal case. The sheep was drenched at 12 o'clock noon and died at 11.15 p.m. The respiratory rate rose to 200 between 2 and 3 o'clock, when the animal had one of the spasmodic struggles for breath. It then fell to 9 and remained low, with comparatively slight variations, until the time of death.

Figure 4 gives the curve of respiration of sheep No. 160, a prolonged case. This animal was drenched with Zygadenus at 11.25 a. m., July 19, and died during the night of July 21. The respiration almost immediately after the dose was given ran up to 200 and during the afternoon varied between 60 and 168. In the evening it fell, and after that time the maximum noticed was 68, but most of the time it was near 20 or 30.

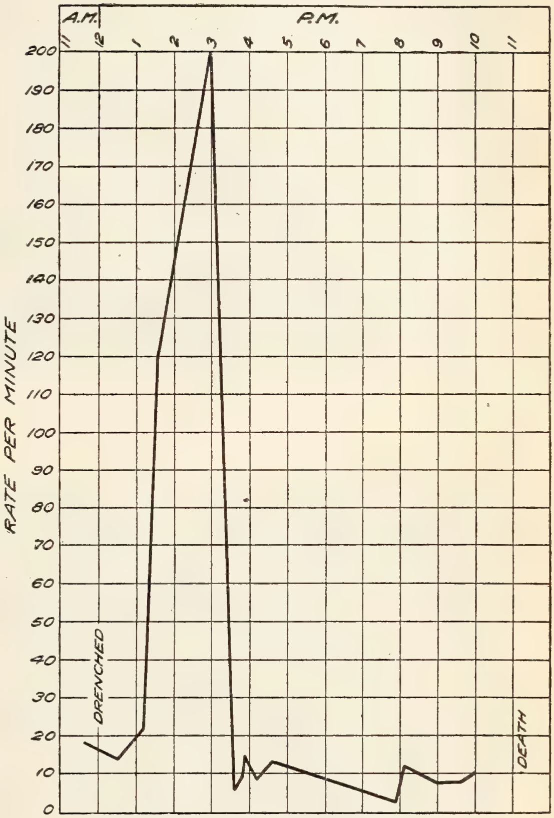

FIG. 3.—Curve of respiration of sheep No. 174.

MUSCULAR WEAKNESS.

In all cases of any severity muscular weakness was noticeable. Early in the illness the animals staggered, and in the more serious cases not only could not rise, but lay flat upon the ground. This weakness was most pronounced in the forelegs. Plate V, figure 1, shows this condition of weakness in the forelegs in sheep No. 162, while Plate V, figure 2, shows the same animal down. Plate VI, figure 1, shows sheep No. 174 when down and very sick. This picture was taken just before a spasmodic struggle for breath.

In many cases in which the animals were strong enough to remain on their feet, the gait was peculiarly stiff legged. Both fore and hind limbs were affected, but the condition was most pronounced in the hind legs. Sometimes the hind legs were moved less readily, approximating, perhaps, the condition noticed by other writers in laboratory experiments. These symptoms were especially noticeable in the cases in which the animals were fed and were not very sick.

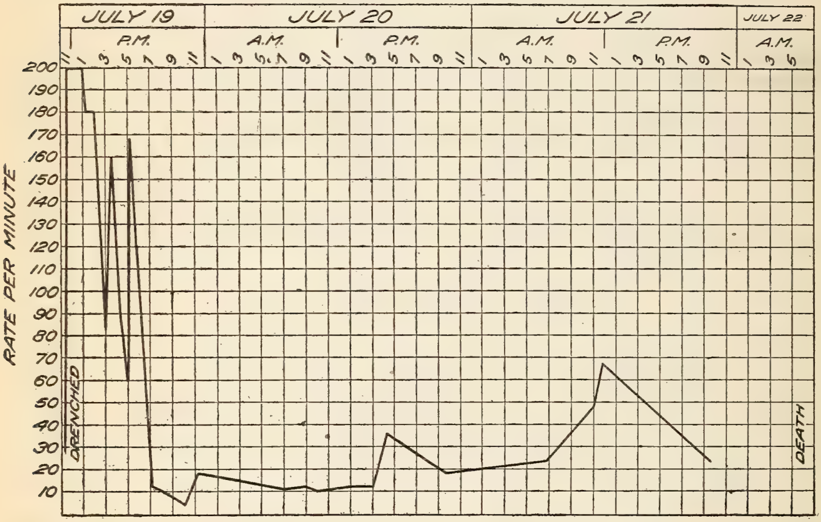

FIG. 4.—Curve of respiration of sheep No. 160.

TREMBLING AND HEIGHTENED REFLEXES.

The fed cases generally exhibited trembling and a sensitiveness to sudden noises or movements. A blow upon the corral fence was followed by a sudden start on the part of the animal, or a light blow upon the animal was followed by a quick reflex movement. This condition was not noticed in the drenched cases and seems to be more characteristic of prolonged illnesses. As stated before, this symptom of heightened reflexes had been noted by both Chesnut and Hunt.

COMA.

While, as already noted under the head of respiration, death resulted from respiratory failure and was frequently preceded by spasmodic attacks of dyspnœa, there were other cases in which the animals lay quietly hour after hour, and sometimes even for days, with labored breathing, in a condition of coma which ended in

FIG. 1.—SHEEP NO. 168 AT 1.30 P. M., SHOWING WEAKNESS IN FORELEGS.

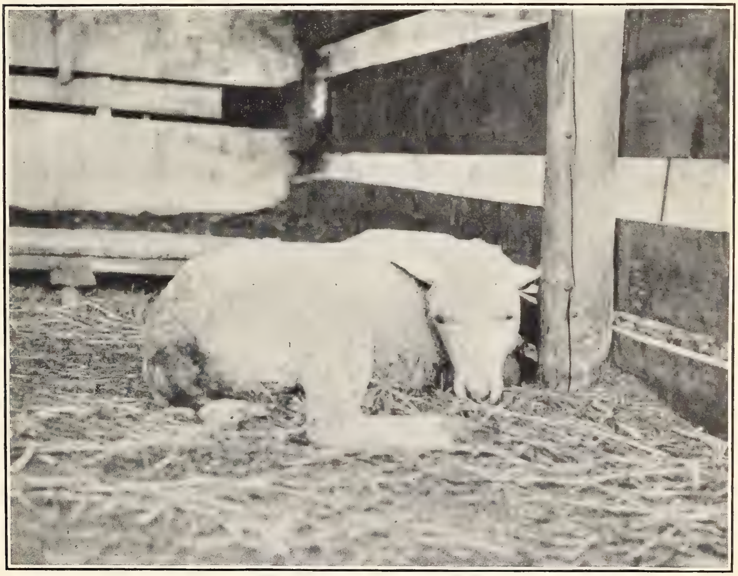

FIG. 2.—SHEEP NO. 168 AT 5.45 P. M., WHEN UNABLE TO RISE.

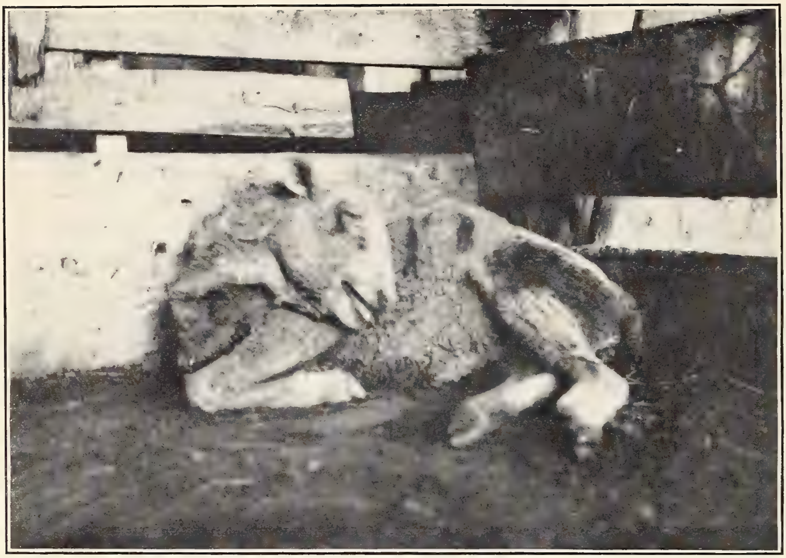

FIG. 1.—SHEEP NO. 174, DOWN AND IN BAD CONDITION. PHOTOGRAPHED JUST BEFORE A SPASMODIC STRUGGLE FOR BREATH.

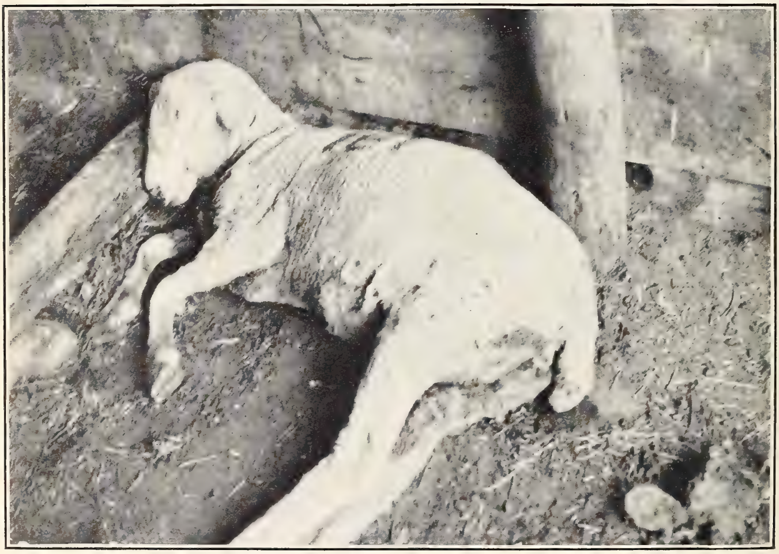

FIG. 2.—SHEEP NO. 161, DOWN ALMOST TWO HOURS AND UNABLE TO RISE.

death without any exhibition of spasms. Plate VI, figure 2, shows sheep No. 161 in this condition of coma. Sheep that are poisoned on the range are more apt to be in this condition of prolonged coma than to show the more violent symptoms of dyspnœa exhibited by animals that are drenched or forcibly fed.

SYMPTOMS IN HORSES AND CATTLE.

No results on horses were reached in the experimental work at Greycliff. From conversations with stockmen who have had experience with horses poisoned by Zygadenus, it appears that, in general, the symptoms resemble those exhibited in sheep.

In the cases of the two head of cattle which showed symptoms, the experiment was carried only to the point of proving the toxic effect of the plant, and no attempt was made to get a complete symptomatic picture. The animals became uneasy, displayed heightened reflexes, and one dragged the hind legs slightly. So far as they went, the symptoms were like those observed in sheep.

AUTOPSIES.

Autopsies were made on four cases in 1912, six in 1913, and seven in 1914. Of the cases in 1913, sheep No. 186, while showing distinct symptoms of Zygadenus poisoning, died as the result of the administration of morphin.

The appearances presented by these animals at the autopsies were quite uniform, though not alike in all details. In six cases there was epicarditis. In nearly all, the inner wall of the ileum was hyperæmic or congested, and in all but one the lungs were congested. The kidneys were congested and more or less degenerated in most cases. Generally the heart was in systole, the contraction being most marked in the left ventricle.

Generally speaking, then, the post-mortem appearances may be stated as including inflammation of the inner wall of the ileum and occasionally of the fourth stomach and large intestines, the heart in systole, congestion of the lungs, and congestion and more or less degeneration of the kidneys. Possibly the condition of epicarditis may be considered typical, although it was not noted in all the cases.

The preserved material from the autopsies was examined by Dr. Mohler, and the following summarized statement of the pathological findings and the inferences to be drawn has been furnished by him:

> The most conspicuous phenomenon shown in all six cases was the high capillary blood pressure, manifested principally in those organs which eliminated the active principle of the ingested substance, that is, kidneys, lungs, and liver, being also shown to a less extent in the intestine.
>
> In the kidney the changes in the capillary varix were fullness to overdistention, which was accompanied by outwandering of leucocytes, diapedesis of the red blood

corpuscles, and all the phenomena of a congestion or an acute or subacute inflammation. Occasional ruptures of the capillary vessels were noted, forming poollike capillary hemorrhages.

The distention of the capillaries in some instances had brought about cloudy swelling, or the early stage of degeneration of the renal epithelium, which in some instances had become desquamated. The supporting or interstitial tissue was not affected.

In the lung the high capillary pressure is even more manifest than in the kidney, owing to the presence of a greater number of capillaries. The variations were from moderate fullness to overdistention, followed by inflammation in the more acute cases, resulting in localized areas of œdema where the serum had oozed out and filled one or more lobules of the lung.

In spite of the fact that the fullness, congestion, and inflammation were more marked in the lung than in the kidneys, the degenerative changes and the desquamation of the pulmonary epithelium were less evident and not as frequent, owing to the greater resistance of the pulmonary cells. While no interstitial changes were present in the kidney, slight interstitial changes in the lungs were present in the peribronchial areas in some of the cases. In others, the interstitial changes were also present in the visceral pleura.

In the liver the vascular changes were either entirely absent or so slight as not to deserve any mention, but the epithelial changes were quite marked, owing to the more delicate composition of the cytoplasm. The absence of vascular changes indicates that the elimination by this organ is but very slight and that the metabolic function is quite able to take care of any of the irritant products that may have reached the liver.

In the intestine the vascular changes are likewise very slight.

TOXIC AND LETHAL DOSE OF ZYGADENUS VENENOSUS FOR SHEEP.

The very large number of feeding experiments with sheep at Greycliff made it possible to determine the toxic and lethal dose with considerable accuracy. Inasmuch as very little has been known in regard to the toxic dose of Zygadenus for sheep, the results of these cases are especially interesting. Table II summarizes the nonfatal cases, showing their number and the quantities of the plant necessary to produce illness.

TABLE II.—*Nonfatal cases of poisoning of sheep by Zygadenus venenosus at Greycliff, Mont., in 1912, 1913, and 1914.*

Feeding experiments.	Number of cases.	Quantity used per 100 pounds of animal.		
		Maximum.	Minimum.	Average.
Season of 1912:		*Pounds.*	*Pounds.*	*Pounds.*
Drenched with leaves, stems, and fruit	2	1.324	0.79	1.057
Drenched with stems and leaves	1			.33
Drenched with stems, fruit, and some leaves	2	.771	.33	.55
Drenched with fruit	5	.264	.141	.228
Season of 1913:				
Fed on leaves	4	2.1	.893	1.607
Drenched with leaves	8	.747	.385	.5746
Drenched with bulbs	3	.612	.517	.5746
Drenched with leaves and buds	1			.555
Drenched with buds and flowers	1			.389
Fed on leaves and flowers	6	4.6	1.728	2.7513
Drenched with leaves and flowers	2	.496	.495	.4955
Fed on leaves, flowers, and fruit	2	7.188	3.155	5.1715
Fed on seed heads	1	5.597		5.597
Fed on seeds	3	.241	.092	.1613

TABLE II.—*Nonfatal cases of poisoning of sheep by Zygadenus venenosus at Greycliff, Mont., in 1912, 1913, and 1914*—Continued.

Feeding experiments.	Number of cases.	Quantity used per 100 pounds of animal.		
		Maximum.	Minimum.	Average.
Season of 1914:		*Pounds.*	*Pounds.*	*Pounds.*
Forced feeding of leaves	2	0.662	0.661	0.6615
Forced feeding of leaves and some young buds	2	.499	.550	.5245
Fed on leaves, some young buds, and a few flowers	1	....	....	1.643
Forced feeding of leaves, stems, flowers, and buds—				
Material collected near the station	8	.622	.495	.5495
Cabin Corral collections	4	1.983	1.436	1.789
Fed on leaves, stems, flowers, and buds	1	....	....	1.912
Forced feeding of leaves, stems, and flowers (Cabin Corral collections)	9	2.756	.992	1.712
Forced feeding of leaves, stems, flowers, and young fruit	4	.992	.757	.851
Forced feeding of very young seed heads	1	....	....	1.543
Forced feeding of seed heads, some fully developed and others half developed	1	....	....	1.432
Forced feeding of half-developed seed heads (Cabin Corral collections)	3	1.754	1.543	1.69
Forced feeding of nearly developed seed heads	6	1.323	.881	1.175
Forced feeding of fully developed seed heads	18	.994	.440	.859
Forced feeding of ripening seed heads	2	.741	.740	.7415
Forced feeding of pods with seeds removed	1	....	....	.540
Forced feeding of seeds	2	.197	.110	.153

Table III summarizes the fatal cases in the three seasons.

TABLE III.—*Fatal cases of poisoning of sheep by Zygadenus venenosus at Greycliff, Mont., 1912, 1913, and 1914.*

Feeding experiments.	Number of cases.	Quantity used per 100 pounds of animal.		
		Maximum.	Minimum.	Average.
Season of 1912:		*Pounds.*	*Pounds.*	*Pounds.*
Drenched with fruit	3	0.853	0.299	0.571
Season of 1913:				
Fed on leaves	1	....	....	1.397
Drenched with leaves	4	.746	.384	.537
Drenched with leaves and flowers	1	....	....	.550
Season of 1914:				
Forced feeding of leaves, stems, and flowers	1	....	....	.544
Forced feeding of fully developed seed heads	2	.991	.882	.936
Forced feeding of seeds	3	.220	.199	.213

As these feedings were carried on during the season as long as the plants could be obtained and as it was practically impossible to have any considerable number of cases at one time, it is evident that the number of cases under any given set of conditions must have been small. As a matter of fact, none of the cases of 1912 were strictly comparable with those of 1913. Consequently, the actual averages of dosage were based on a comparatively small number of cases.

In 1914, there was a much larger number of cases, and some stages of the plant were fed upon which no experiments were made in the preceding years. Even in this year, however, there were only a few cases in which the experiments were under identical conditions.

In the compilation of Tables II and III some of the cases have been excluded. In Table II all cases in which the remedy given was clearly effective were excluded, for some of these received what would have been a lethal dose had it not been for the remedy. In Table III cases were excluded which were known to have received much more than a lethal dose. The uniformity of dosage in 1914 is explained by the fact that the preceding work had shown clearly that the toxic dose was not far from 0.5 pound, and the experiments were made on this basis. It should be noted, too, that most of the work of the summer of 1914 was with reference to the experimental use of remedies, so that the quantity of the plant administered was estimated to be sufficient not simply to produce symptoms, but to make the animal very sick, in order to get a fair test of the remedy. Hence, the average figures for the toxic dose will be rather high.

The "forced feeding" cases of 1914 can be fairly compared with the "drenched" cases of 1912 and 1913, as the difference between the two methods is mainly in the fact that in forced feeding no water is used while in drenching considerable water is necessary as a vehicle for the weed.

The age of the animal played a comparatively small part in these experiments, as all the animals were mature, most of them being 2 years old or older.

It will be noticed that when the plant was given in the form of a drench or by forced feeding, the dosage, as would be expected, was considerably less than when it was given with food. An examination of the complete table of feeding (Table I) shows also very clearly that the size of the dose varied inversely with the time during which the material was eaten. In a large number of cases in which the plant was given with food, the feeding extended over two or more days. In those cases the dosage was considerably greater than when the material was fed in a single day. It may be assumed that if the same quantity of the plant which was received in a drench could have been fed within a short period of time, the effect would have been the same.

The average dose which produced illness when administered in the form of a drench or by forced feeding was practically the same for all parts of the plant except the pods and seed. It appears that the plants are less toxic at the time when the pods are forming, which may be due, in part at least, to the diminished toxicity of the leaves as they dry up. It is not clear, however, from this work, that the leaves lose any appreciable amount of toxicity, and the more probable explanation is that the pods at this time are only slightly toxic. In the single experiment of feeding pods without seeds, the dosage was about like that of other parts of the plants, but it is probable from the detailed history of this experiment that this is not a fair representative of such cases.

The seeds are very much more poisonous than any other part of the plant. Heyl, Loy, Knight, and Prien (1912, p. 17) give the results of determinations of alkaloids in different parts of the plant. Their statement is obscure and contradictory, but apparently they reach the conclusion that the bulbs and leaves contain approximately the same quantity of the alkaloid, the roots much less, and the flowers about twice as much as the bulbs and leaves. This compares very well with the results of the experimental feeding at Greycliff, except that it did not appear that the flowers were more toxic than other parts of the plant.

Table II gives the maximum and minimum dosage, and it will be noticed that there is a considerable range of variation between these two. The individual peculiarities of the animal in cases of poisoning doubtless must be taken into account, and the detailed table of the experiments shows that in some cases a larger quantity of plant than that which this table indicates to be toxic may be administered without effect. In most of the cases, however, where the larger amount was used, the feeding was distributed over a longer time.

In general, the experiments seem to indicate that when any part of the plant except the seed is used the toxic dose varies from 1.6 pounds per hundredweight of animal to 5.6 pounds, this wide range of variation being accounted for by the more or less extended time of feeding. In the drenching and forced-feeding experiments, more uniform results were reached, showing that the toxic dose of all parts of the plant, except the seed, is not far from 0.5 pound per hundredweight of animal.

There is considerable difference in the items of the summarized tables in the exactness of the averages, and some explanation is necessary to indicate their actual value.

In the feeding of leaves in 1914, there were three cases, two becoming sick. The third case received 0.661 pound without symptoms, the same quantity that was received by No. 282, which became sick. It seems probable, then, that the average figure 0.6615 must be pretty close to the toxic limit. In the feeding of "leaves and some young buds" in 1914, while the minimum of sick cases received 0.499 pound, another animal received 0.551 pound without ill effect; it is evident that the toxic limit must be not far from 0.5 pound. In the feeding of eight cases on "leaves, stems, flowers, and buds," with material collected near the station, the toxic limit was practically the same as in the preceding cases. A perusal of Table II shows that during the growth of the seed heads the toxicity was reduced and that the fully developed seed heads were somewhat less toxic than the plant in the earlier stages.

In the two cases of forced feeding of seeds in 1914 the average toxic dose was 0.153 pound; inasmuch as the animal receiving the maximum amount was very sick, the actual toxic limit must be considered to be close to the minimum figure of 0.11 pound. It will be noticed that the cases of feeding of seeds in 1913 had practically the same average dose as the cases of forced feeding in 1914; this is accounted for by the fact that these animals ate the seed in such a short time that the results were similar to those from forced feeding.

It is interesting to note in Table III that the lethal dose is only slightly larger than the toxic dose.

In transferring these results to the probable dosage when sheep are range fed, the feeding habits of the sheep must be taken into consideration. In the corrals the sheep do not, as a rule, eat as readily as when on the range. When the sheep in a band are grazing together, both imitation and jealousy affect the quantity of any plant which a sheep eats in a given time; so it is reasonable to suppose that if feed is short and Zygadenus fairly abundant, sheep may eat much more in a short time than they would under corral conditions. Under such circumstances, the dosage might approximate that of the drenching experiments. Therefore, it appears probable that animals feeding on the range might, because of the more rapid eating, be poisoned with much less than when in corrals.

EXPERIMENTS WITH HORSES AND CATTLE.

Three experiments were made of feeding Zygadenus to a horse, as shown in Table I (section D), *Z. venenosus* being used in two tests and *Z. elegans* in one. The smallest quantity fed in these experiments was 12.1 pounds per 1,000 pounds of weight, and the largest was 15 pounds. In each instance the feeding was extended through several days, and the feeding of 15 pounds extended through 6 days. If the quantity necessary to poison a horse should be in the same proportion to its weight as that required to poison a sheep, it would be, according to our dosage, at least between 11 and 12 pounds, and probably much more. It may be presumed, therefore, that in these cases the amount fed was not sufficient to produce toxic effects. There is, however, abundance of evidence that horses are poisoned by Zygadenus, although not ordinarily with fatal results.

Section C of Table I shows the results of feeding *Zygadenus venenosus* to three cattle. Two of these animals, both of which received leaves and flowers, showed symptoms of poisoning, one on 58 pounds per 1,000 pounds of weight and the other on 46.5 pounds per 1,000 pounds of weight. In these cattle, therefore, the average toxic dose was 52.25 pounds, which was fed in an average of 6½ days. This compares fairly well with the results reached with sheep and would indicate that the toxic dose for cattle, computed in terms of the weight of the animal, does not differ materially from the toxic dose for sheep.

COMPARATIVE TOXICITY OF DIFFERENT SPECIES OF ZYGADENUS.

In the course of the experiments, four species of Zygadenus were used, *Z. venenosus, Z. elegans, Z. paniculatus,* and *Z. coloradensis,* by far the greater part of the work being done with *Z. venenosus.* The number of experiments with *Z. elegans* and *Z. paniculatus* was very small, and the material, especially in the case of *Z. paniculatus,* had been shipped a long distance, so that there was some question of the water content of the plant. Apparently, however, *Z. elegans* and *Z. paniculatus* do not differ materially in toxicity from *Z. venenosus. Z. coloradensis,* however, produced no toxic effects whatever with the exception of slight symptoms in one sheep, although the plant was fed in quantities several times as great as the toxic dose of *Z. venenosus.*

It is evident that in the feeding of cattle with *Zygadenus coloradensis* at Mount Carbon in 1909, the results of which are given in Table I, the quantities fed were too small to produce results, even if the plants were as poisonous as *Z. venenosus.* In the experiment of 1910, however, a large quantity was fed, and sufficiently large quantities in single days to produce symptoms of poisoning if the plant were as toxic as *Z. venenosus.*

In this connection it should be added that Dr. C. L. Alsberg made a laboratory examination of the Colorado plants and found in them a very small quantity of alkaloid. It would appear, then, that the form which is identified by some botanists as *Z. coloradensis* contains the same toxic substance as the other form, but that this substance is present in so small a quantity that it is unlikely that it ever produces toxic effects on domestic animals. While it is not in the province of this paper to discuss the systematic relations of plants, it may be suggested that this difference of toxicity between *Z. elegans* and *Z. coloradensis* may indicate a valid specific distinction between these two forms which are so closely related that by some botanists they are considered identical.

DOES TOXICITY VARY WITH LOCALITY?

The collections of *Zygadenus venenosus* with which experiments were made were obtained at the "Station" (by which is understood the region within a radius of 2 miles of the station), at an elevation of about 4,050 feet; at "Greycliff," 2½ to 3 miles distant from the station, at an elevation of about 3,920 feet; and at "Cabin Corral" and "George Hughes's" (locations from 4 to 7 miles from the station), at an elevation of something over 5,000 feet. Material of this species was also used from Avery, Cal., collected at an elevation of 3,500 feet. The material of *Z. elegans* was from two localities, from near Red Lodge, Mont., at an elevation between 5,500 and 6,000 feet, and from the Fishlake National Forest, Utah, at an elevation of something over 9,000 feet. The *Z. paniculatus* material was collected near Ephraim, Utah, at an elevation between 5,500 and 6,000 feet. All the *Z. coloradensis* material was collected within 4 or 5 miles of the Mount Carbon station, at an elevation of something over 10,000 feet.

As has been stated already, the lack of toxic properties in *Zygadenus coloradensis* is assumed to be characteristic of the species. The experiments with *Z. elegans* and *Z. paniculatus* were few in number, and too much importance must not be attached to the results. Apparently, however, not only did they have, practically, the same toxicity as the *Z. venenosus* collected near the station, but there was no evident difference between the *Z. elegans* of Montana and that collected in Utah. The *Z. venenosus,* collected in California gave the same results as that produced by material from the neighborhood of the Greycliff station.

An entirely unexplained variation in toxicity was exhibited by material collected at Cabin Corral, about 5 miles from the station and at a greater elevation of about a thousand feet. When Table II was being compiled, it was noticed that the cases receiving "forced feeding of leaves stems, flowers, and buds" fell into two distinct divisions, one with an average dosage of 0.5495 pound and the other with an average of 1.789 pounds. This difference was so marked that the two sets were separated in the summary. In searching for some possible explanation of this difference, it was found that all the cases with the larger dosage were treated with material collected at Cabin Corral. Note was then made of the other items in this table which were collected in this locality, and a glance at the table will show that in the other cases the Cabin-Corral material showed much less toxicity. It has been entirely impossible to explain this difference. The number of cases would seem to make it certain that this result was not due to an error of experimentation. There are no local conditions to account for it. The George Hughes place, at which collections were made giving the same results as those produced by the station material, is situated at about the same distance from the camp as Cabin Corral, at about the same elevation, and it has the same soil conditions. The question of the correlation of variation in toxicity with changes in altitude was raised, but the experiments do not indicate any such relation. The fact that the Cabin-Corral material was less toxic is nevertheless substantiated, and it would appear that while *Zygadenus venenosus, Z. elegans,* and *Z. paniculatus* have ordinarily the same degree of toxicity wherever grown, there is a possibility of marked variation.

EFFECT OF REPEATED FEEDING IN PRODUCING IMMUNITY OR INCREASED SUSCEPTIBILITY.

During the course of the experimental work at Greycliff a number of sheep were treated with Zygadenus several times during the same season. It was important to decide whether a sheep after having been poisoned once was more or less likely to be affected a second time. A careful analysis of the results showed that no effect either of immunity or of increased susceptibility was produced. The fact that an animal had suffered from poisoning once neither lessened the effect of another dose, nor, on the other hand, was the sheep any more likely to suffer from a second experience.

REMEDIES.

Because of the heavy losses of sheep from Zygadenus poisoning it was deemed important to investigate thoroughly the possibility of finding some remedial measures to reduce the number of deaths. To this end a large number of experiments were made, as can be seen by an examination of the table giving the summarized account of the work.

It has been shown by Hunt that the poisonous principle of Zygadenus is excreted in the urine, and this has been verified by the authors in the cases of some of the sheep used in the Greycliff experiments. Hunt concluded that the logical remedy is some diuretic which will insure excretion rapid enough to prevent serious effects from the poisoning, and his experiments seem to substantiate this position. He also advised the use of permanganate of potash administered per os to destroy the alkaloid in the stomach.

The experimental work on remedies in 1912 was based upon these conclusions of Hunt. Later, a number of remedies were used in the hope that some method might be found sufficiently simple to be used under range conditions. This work was carried on for three summers in order to get the average of a considerable number of cases, and a brief statement of the results of the more important experiments follows.

CAFFEIN AND DIURETIN.

The conclusions reached by Hunt led to a series of experiments with caffein. In 1912, caffein sodiobenzoate was administered to five animals subcutaneously; in two of these cases potassium permanganate was also used, and in one tannic acid. It was evident that by the use of this drug the excretion of urine was increased, but the observers could not see that any marked improvement followed in the condition of the animals. In the summer of 1913, diuretin and caffein citrate were given per os in four cases, of which one died and three recovered. In these cases, as in those of the preceding year, there was no evidence of any good result. All these experiments had been with single doses. In 1914 two animals were treated, one with two doses of 10 grains each of caffein sodiobenzoate administered subcutaneously, and one with three doses of 5 grains each. One of these animals died and one recovered, but in neither case could it be seen that the remedy was advantageous. It seemed to be clear that while caffein might be considered a logical remedy it failed in practical application.

STRYCHNIN.

Although the work of Hunt quite clearly indicated that strychnin was not beneficial, it seemed best to try a few experiments to see whether, by its stimulating effect, it might not aid in relieving the depression of the animals. Six cases were treated by subcutaneous injections. In two of these cases eserin was also used, and in one case gin. There was an apparently beneficial effect in one case, but a study of all fails to show any good results which could be fairly considered as due to strychnin.

ESERIN, EPSOM SALTS, LINSEED OIL.

With the idea that relief might be brought about by an increase in intestinal elimination, eserin was administered subcutaneously, and Epsom salts and linseed oil per os; no reduction of toxic symptoms could be seen.

CHARCOAL.

Dr. Sollman suggested to the writers that charcoal, by adsorption, might be beneficial. Three experiments were made with this, in one case combined with linseed oil. No beneficial results followed.

WHISKY AND DIGITALIS.

In some cases of extreme depression whisky seemed to have an effect in bridging over a period when death might otherwise have followed. The same thing is true of digitalis, which in one or two cases may have saved the life of the patient. Neither drug, however, had any marked effect. It can only be said that if the symptoms of the animal are carefully watched, times will be found when whisky or digitalis may be administered advantageously. Inasmuch as the life of the individual sheep is of small importance, these remedies are of little practical use.

POTASSIUM PERMANGANATE.

Especial interest attaches to the experiments with potassium permanganate, since it is the remedy that has been most commonly recommended for plant poisoning. The dosage advised for a mature sheep has been 5 to 9 grains. This was used at first in the experimental work, and when no beneficial results appeared it was increased to 30 grains, but still with no evidence of a reduction of the toxic effect. In two cases, 15 grains were introduced directly into the rumen with no better results.

Because of this lack of success it was deemed best to try mixing the permanganate with the Zygadenus before administration to see if the alkaloid would be destroyed in vitro. On May 19, 1913, two sheep of equal weight, Nos. 184 and 191, were each drenched with 0.586 pound of *Zygadenus venenosus* in water. In the dose given to No. 191 there were dissolved 7½ grains of potassium permanganate and 7½ grains of aluminum sulphate. Both animals were sick, and there was no recognizable difference in the degree of illness. The experiment tended to show that the administration of the potassium permanganate was without any definite effect upon the toxicity of the plant, but a similar experiment on July 11, 1914, on sheep No. 253 showed quite clearly that the dosage of the former experiment was insufficient. In this case 0.441 pound of seed heads of *Z. venenosus* was mixed in water with 15 grains of potassium permanganate and 15 grains of aluminum sulphate and the mixture allowed to stand for 20 minutes before being administered. The sheep displayed no symptoms of poisoning, although other cases of the same date receiving the same quantity of Zygadenus, with no remedy, showed distinct symptoms. It seemed clear that a sufficient quantity of permanganate will diminish the toxicity of the plant, when mixed with it before administration. When given after symptoms of poisoning are exhibited, however, the remedy is of no value. This, too, has been demonstrated by practical experience upon the range. Potassium permanganate has been used by many sheep owners in Montana, and it is the almost universal testimony that it is worthless.

TANNIC ACID.

Sheep No. 206, on June 4, 1913, was drenched with 0.43 pound of Zygadenus tops, including leaves and flowers. To this drench were added three grams of tannic acid. The animal showed no signs of illness. On May 29 a sheep was made sick on 0.389 pound, and on May 30 one was made sick on 0.385 pound and one died on 0.384 pound. It seems fair to presume, therefore, that the tannic acid had been of benefit to sheep No. 206.

Sheep No. 210, on June 6, 1913, was drenched with 0.496 pound of leaves and flowers of *Zygadenus venenosus* to which 3 grams of tannic acid had been added. On the same date sheep No. 209 received 0.495 pound of the same material, but without the tannic acid. Both animals were sick and recovered, but it was the impression of the observers that sheep No. 210 was not as sick as sheep No. 209.

On June 7, 1913, sheep Nos. 212 and 213 were each drenched with 0.55 pound of leaves and flowers of *Zygadenus venenosus*. In the drench given to No. 212 were included 4 grams of tannic acid. This sheep had no symptoms of illness, while No. 213 died 1 hour and 17 minutes after the administration of the drench. These two sheep were of very nearly equal weight and the dose was the same (0.55 pound) per hundredweight of animal. There was every reason to expect similar results except for the effect of the tannic acid. Difference of individual susceptibility would seem to be eliminated in this instance, in which one animal died and the other showed no symptoms of poisoning.

During the season of 1913, four animals which had been fed on *Zygadenus venenosus* were given doses of tannic acid after toxic symptoms were well developed. All of these animals recovered. These cases, however, were not connected up with control cases, and it is possible that all would have recovered without any remedial aid.

The general result of all the experiments in 1913 with tannic acid indicated that it can be used with beneficial results. The experiments seemed also to indicate very clearly that, in vitro, the tannic acid was much more effective than potassium permaganate as an antidote for the Zygadenus alkaloid.

In 1914, a large number of cases were treated with tannic acid, in order to try it out thoroughly. In most of these experiments one or more control animals were used. Where the tannic acid was administered in a single dose, in 19 cases, there were only two deaths; in most of these cases, however, the Zygadenus was not given in a quantity necessarily fatal.

A study of the cases in which there was a control shows apparently beneficial results in some instances. For example, sheep Nos. 249 and 251 received the same quantity of Zygadenus on July 9; No. 249 died, while No. 251, which received a dose of tannic acid, lived.

Sheep Nos. 229 and 235 were fed the same quantity of Zygadenus on June 3. No. 229 was treated with tannic acid and was not so sick as No. 235. On the other hand, Nos. 239 and 256 were fed on June 16 with the same quantity, and No. 239, which received the tannic acid, had more marked symptoms than No. 256. Sheep Nos. 269, 255, and 282 were fed the same quantity of Zygadenus on June 15 and June 16. Tannic acid was administered to Nos. 269 and 282; both of these animals were sick, while No. 255 exhibited no symptoms. A consideration of all these cases shows that tannic acid in single doses can not be considered an effective remedy, although under favorable conditions some cases may be benefited.

SODIUM BICARBONATE.

It was suggested by Mr. O. F. Black that, inasmuch as alkaloids are, to a large extent, insoluble in an alkaline solution, sodium bicarbonate might serve to prevent the solution and absorption of the poisonous principle of Zygadenus and thus prove valuable as a medicinal remedy. This was used only in repeated doses, and the results will be discussed under the next head.

REPEATED DOSES OF TANNIC ACID AND SODIUM BICARBONATE.

Inasmuch as tannic acid is a recognized remedial agent for poisoning by alkaloids, it seemed strange that so little benefit followed its use. In seeking for an explanation, it occurred to the writers that it might be accounted for by the fact that, because of the character of a ruminant's stomachs, the remedy does not actually come in contact with any considerable quantity of the poisonous substance. The first stomach of a ruminant always contains a large quantity of material. When an animal feeds upon a poisonous plant, the material taken up goes to the first stomach; some of this, after maceration, proceeds to the third and fourth stomachs, while another part goes on only after rumination. If the remedy is given in the form of a drench, it will be distributed in all the stomachs, although ordinarily the larger part of the drench goes directly to the third and fourth stomachs. That part of the drench which goes to the fourth stomach, we can assume, takes effect on the alkaloid which has arrived at that part of the digestive canal. The portion of the drench which stops in the first stomach meets a mass of organic matter, in which it is lost; there is no reason to think that any antidote for an alkaloid will have any selective effect, so as to attack the Zygadenus alkaloid rather than the multitude of other substances in the stomach with which it can unite. The only hope of destroying the alkaloid under such circumstances would be by flooding the first stomach with the antidote, and that is practically impossible. So even when the antidote is introduced by a canula directly into the first stomach, it would be impracticable to use a quantity sufficient to produce any marked effect.

On the other hand, inasmuch as no absorption takes place in the stomachs, if the antidote could meet the poisonous material as it passes through the fourth stomach good results might be expected. On the basis of this conclusion, it seemed best to the writers to try the effect of antidotes repeated at frequent intervals; it was thought that if the antidote could reach the fourth stomach frequently enough to catch the alkaloid as it passed from the first stomach and render it more or less innocuous before passing into the intestine, the remedy might be distinctly beneficial.

Four experiments of this character were conducted with tannic acid, all with controls, which received no remedy but were fed with the same quantity of Zygadenus. The tannic acid was given in doses of 1 and 2 grams, repeated at intervals varying from 10 to 30 minutes, or longer in some cases, at the latter part of the experiment.

The total time of treatment varied from 4 to 7½ hours, and the total quantity of tannic acid given varied from 14 to 16 grams. The doses and intervals were as follows:

Sheep No. 263: 9 doses, 1 gram each, once in 10 minutes; 2 doses, 1 gram each, once in 30 minutes; 1 dose, 1 gram, in 20 minutes; 2 doses, 1 gram each, once in 30 minutes. Total, 14 grams.

Sheep No. 216: 7 doses, 2 grams each, once in 30 minutes. Total, 14 grams.

Sheep No. 267: 5 doses, 1 gram each, once in 10 minutes; 3 doses, 1 gram each, once in 15 minutes; 8 doses, 1 gram each, once in 30 minutes. Total, 16 grams.

Sheep No. 291: 3 doses, 2 grams each, once in 30 minutes; 1 dose, 2 grams, in 60 minutes; 1 dose, 2 grams, in 30 minutes; 2 doses, 2 grams each, once in 60 minutes; 1 dose, 2 grams, in 3 hours. Total, 16 grams.

All these animals recovered and were not as sick as the controls, Nos. 269 and 294. Sheep No. 291 suffered more than the others, but the tannic acid in this case was administered later in the illness, after a course of small doses of Epsom salts had failed to produce any effect. All these animals and the controls were given Zygadenus collected on the same date. The experiments were considered to prove conclusively that repeated doses of tannic acid are beneficial.

A similar set of experiments was conducted with sodium bicarbonate. Seven animals were used, and all, with one exception, were fed Zygadenus material collected on the same date, and in the exceptional case the material was collected only a few days later. Doses of sodium bicarbonate of 2 and 4 grams were given at intervals varying from 15 to 60 minutes. The total time of treatment was from 2½ to 5 hours, and the total amount of sodium carbonate given varied from 20 to 48 grams. The doses and intervals were as follows:

Sheep No. 246: 10 doses, 4 grams each, once in 30 minutes. Total, 40 grams.

Sheep No. 259: 8 doses, 4 grams each, once in 15 minutes; 4 doses, 4 grams each, once in 30 minutes. Total, 48 grams.

Sheep No. 264: 6 doses, 4 grams each, once in 60 minutes. Total, 24 grams.

Sheep No. 292: 10 doses, 4 grams each, once in 30 minutes. Total, 40 grams.

Sheep No. 293: 4 doses, 4 grams each, once in 30 minutes; 2 doses, 2 grams each, once in 30 minutes. Total, 20 grams.

Sheep No. 277: 5 doses, 4 grams each, once in 30 minutes; 2 doses, 2 grams each, once in 30 minutes; 1 dose, 2 grams, after 1¼ hours. Total, 26 grams.

Sheep No. 240: 3 doses, 8 grams each, once in 60 minutes; 2 doses, 4 grams each, once in 60 minutes. Total, 32 grams.

Of these animals all recovered but one, No. 264. This sheep received a total of 24 grams, given at hour intervals. No. 240 also received the remedy at hour intervals and recovered very slowly, being unable to stand on the morning after the poisonous dose had been given. All the other cases, except No. 277, recovered rather quickly. No. 277 was as slow as No. 240, although the doses of sodium bicarbonate were given frequently, and the total amount was greater than that given to No. 264 and to No. 293, which recovered. If we exclude No. 277, it would appear clear that sodium carbonate given in sufficiently frequent doses is distinctly beneficial. The Zygadenus in the case of No. 277 was given in three doses, and it is possible that there was some accumulative effect, which may explain in part the slow recovery.

The general conclusion from the experiments with sodium bicarbonate is that if the remedy is given at frequent intervals it will prove distinctly beneficial. The dose should be 4 grams, and this should be repeated as often as every 30 minutes.

These experiments with repeated doses of tannic acid and sodium bicarbonate were interesting from a theoretical standpoint and indicate a line of treatment which can be used successfully with valuable animals. It is evident, however, that remedies used in this way can not be recommended for the ordinary band of sheep, for the expense of the treatment would be greater than the value of the animals.

No experiments of repeated doses were made with potassium permanganate; but it is probable that it could be used successfully, although the general trend of the experimental work is to indicate that the potassium permanganate is not, as a remedy, so efficient as tannic acid and sodium bicarbonate.

BLEEDING.

It is customary among sheep herders to bleed sheep poisoned by Zygadenus, the favorite place being the angular artery and vein of the eye. Although there seems to be no logical reason for this practice, it seemed wise to try it, and three sheep were treated in this way; two of the three died, and no beneficial result appeared in any of the cases.

METHODS OF PREVENTING LOSSES.

The most obvious thing to do is, of course, to keep the animals from eating the plant. With this end in view, it is important that all herders should be taught to recognize Zygadenus. When the plant is in flower this is not at all difficult, but it has been a matter of surprise to find to what extent, among the herders and sheep owners, the plant is not known, even at this stage. Before flowering, its grasslike leaves are not so easily recognized, but there is no reason why a fairly intelligent man should not be taught to know it even then. If one knows the plant in the preflowering and flowering stages, he will readily recognize it in the later dried-up condition, when, it will be remembered, it is fully as dangerous as earlier in the season.

When the plant is recognized care should be taken that the sheep do not have an opportunity to eat any large quantity of it. If it be necessary to drive the sheep over a patch of Zygadenus, the herder should take the precaution to have the band well fed before making the drive. If hungry sheep come upon a thick growth of Zygadenus, some of them, in their haste to satisfy their hunger, are almost certain to become poisoned, while if already well fed they are likely to choose their food with more care and to eat less of the Zygadenus.

Special care should be used early in the season, not because the plant is more poisonous at that time, but because, on account of the dry condition of other forage, it is more likely to be eaten. Later in the season sheep are less likely to eat a large quantity, because of the greater abundance of other food. As a matter of fact, most of the cases of extensive poisoning have occurred before the flowering of the plant.

If sheep become poisoned, they should be kept as quiet as possible. Any attempt to make them move about is likely to have disastrous results.

So far as remedies are concerned, none has been found so far that gives much promise of being really useful. The experimental work at Greycliff shows that repeated doses of tannic acid or sodium bicarbonate will aid in recovery, but this method of treatment is not practically possible for animals upon the range.

GENERAL SUMMARY.

Zygadenus grows abundantly on many of the stock ranges of the West and is one of the most important sources of loss to sheepmen. Apparently all species of Zygadenus are poisonous. The plants are poisonous through the whole season of their growth, but the tops are somewhat more poisonous at the time of flowering. The toxicity of the bulbs and tops is about the same, while the seeds are much more toxic than other parts of the plant. Cases of poisoning are more likely to occur before the maturity of the plant, because at that time other forage is scanty.

The toxic dose varies according to the conditions of feeding. In drenched animals it may be put at about one-half a pound for an animal weighing a hundred pounds. In fed animals it varied from 1.6 pounds to 5.6 pounds.

The poisonous principle is an alkaloid or alkaloids allied to veratrin and cevadin.

Sheep, cattle, and horses are poisoned by the plant, but the fatalities are almost entirely confined to sheep.

The principal symptoms are salivation, nausea, muscular weakness, coma, and sometimes attacks of dyspnœa.

To prevent losses, it is important to recognize the plant and avoid grazing upon it. If animals become sick they should be kept quiet, and under this treatment many will recover. There is no satisfactory medical remedy.

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