Selaginella densa Rydb. and its chemical control
by Stephen Francis Wagner

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of
MASTER OF SCIENCE in Agronomy
Montana State University

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ABSTRACT

Selaginella densa plants rarely exceed one inch in height with lateral top growth being less than one-half inch per year. The root system of plants sampled in field infestations was extensive and located near the soil surface. Mega- and microspores, by which sexual reproduction occurs, were observed in distinctly separate zones on the same strobilus.

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INTRODUCTION

Selaginella densa, commonly called little clubmoss is a low, slow growing, sod-forming plant that infests extensive areas of the Northern Great Plains and foothill mountain regions bordering the plains. It is drouth tolerant, being able to survive long periods of extreme dessication. This species, which may occupy as much as 70 percent of the ground surface, is quite useful in reducing soil erosion. However, it has no value in the normal diet of domestic livestock on the range or of the wild game which frequent its habitat. Production of forage on ranges which have large amounts of S. densa is quite low.

Increased yields following mechanical methods of range improvement at the North Montana Branch Experiment Station demonstrated the importance of clubmoss to livestock producers. A grant-in-aid provided by the Bureau of Land Management made the study possible. The investigations were made jointly by the Department of Animal Science and Range Management and the Department of Plant and Soil Science. The former studied mechanical methods of controlling clubmoss while the latter was concerned with chemical methods. Both departments investigated the ecology and various phases of the life cycle of S. densa. This paper reports the first stage of the investigations made by the Department of Plant and Soil Science.

REVIEW OF LITERATURE

Taxonomy

The family Selaginaceae contains but two genera, a fossil genus Selaginellites and the living genus Selaginella, to which all of the present species belong (Smith, 28).

Generally, the Selaginellas are small plants rarely exceeding a few inches in height. They resemble Lycopodium and, because they are as a group smaller in stature, they are commonly referred to as the small or little club mosses or, as in Gray's Manual of Botany (6), the spikemosses.

Eames (5) reports most species to be perennial although a few are annuals. She also says the genus is generally adapted to weak light conditions and grows mostly in the humid tropics although some species do grow in the deserts and cold parts of the world. Uphof (38) found about 6% of the species to be xerophytic.

Tryon (33) reports that various species of Selaginella grow in South America, being absent from the Amazon Basin, Central America and generally from the colder regions. Its distribution is less extensive in the old world; however, some species are found in all countries except the Malaysian-Australian region, in the Pacific Ocean area and in Eurasia.

Considerable variation in growth habit occurs. Some species are erect or even shrubby, others are creeping and scrambling or may even form tufts or mounds (7).

The more than 700 species recognized today (Foster and Gifford, 7) are broken down within the genus by Horner and Arnott (13) as shown below:

Family	Selaginellaceae Beauv.
Genus	*Selaginella*
Subgenus	Heterostachys
	Homostachys
	Stachygynandrum
Series	Decumbentes
	Circinatae
Subgenus	Selaginella
Section	Selaginella
	Tetragonostachys
Series	Eremophilae
	Sartorii
	Arenicolae
	Rupestres
Specie	*densa* Rydb.
variety	*densa*
	scopulorum (Maxon) Tryon
	standleyi (Maxon) Tryon

The plants now known as *Selaginella* were first classified by Linnaeus with *Lycopodium* in his *Species Plantarum*. In all, Linneaus had 24 species of *Lycopodium*. Ten of these, including *L. rupestre*, are now classified in *Selaginella*.

R. Tryon (33) reports that Beauvois segregated the genus *Selaginella* from *Lycopodium* in 1805. At first the differences between the species of *Selaginella* were not very well understood and it was common practice to place everything new under *Selaginella rupestris*.

According to Underwood (36), various workers, doing a more thorough study of the genus, began to identify many new species. Willdenow, in 1810, named 34 species, Spring, in 1848, listed 209 species. In 1887 J. C. Baker raised the number to 335 and Hieronymus brought the number of species to 559 in 1900.

In 1898 Underwood (34) named nine species from the many lumped under S. rupestris. In 1901 Underwood (35) gave United States publication to 10 of the 35 species Hieronymus had separated from the tangle.

Rydberg (26), in 1900, named S. densa from material collected in Montana saying there was scarcely any good technical character by which to separate it from S. rupestris but the striking difference in habitat seemed sufficient. Frye and Jackson (8), not thinking this was criteria enough for specie rank, proposed the name S. rupestris densa in 1913.

Van Eseltine (39) in 1917, separated seven more species from the tangle and redescribed S. rupestris. He also concluded that because of the dissimilarity of the ample herbaria material available there were still more species involved.

In 1920 Maxon (20) described six more species including S. standleyi from Glacier National Park and in 1921 (21) named S. scopulorum, also from Montana.

R. Tryon (33) pointed out that relatively few species possess distinctive traits so they must be distinguished by a combination of characters. In S. densa he reports an interesting but unsatisfactory taxonomic condition. The three variants earlier described as S. densa, S. scopulorum and S. standelyi are quite distinct morphologically and geographically over a large area in the Northern range of the species. In those areas where they are geographically distinct, he says they would rank as subspecies or even as species, but the three variants all grow in the large central portion of the range of the species where such a complete intergradiation of characters is exhibited that only one

highly variable species can be recognized. Therefore, Tryon has classified the three as varieties of S. densa; S. densa var. densa, S. densa var. scopulorum and S. densa var. standleyi. He indicates their geographical distribution extends westward from Manitoba and south to Texas, Arizona and Northern California.

Several workers have attempted to classify the genus on the basis of its sexual reproduction characteristics, which is by spores (31). These spores are contained in sporangia which are borne in axils of sporophylls on a strobilus. The micro (male) and mega (female) sporangia may have several different arrangements on the strobilus.

Mitchell (23) worked with the different sporangial arrangements. She found 4 basic types of arrangement including all micro or all mega sporangiate and mixtures of these two and concluded that the megasporangia usually are found in the basal region of the strobilus. Although she made no attempt to classify the genus on this basis, she did group several species in each of her categories.

More recently, Horner and Arnott (13) examined 30 species in the subgenera Selagenella and Stachygynandrum and found three major patterns and one variation:

I. Basal megasporangia and superior microsporangia.

II. Two vertical rows each of micro and megasporangia.

II'. Variation of II. Two vertical rows of microsporangia and two rows of mixed sporangia.

III. All megasporangiate.

They concluded that usually a single pattern characterized all of the species of each series in the two subgenera studied. S. densa var. densa was studied and pattern I predominated with a rare mega or micro sporangia found in the other zone.

With the exception of S. rupestris, which normally has two megaspores per sporangium (17, 18), the other Selaginella normally have four megaspores per sporangium.

Reproduction by Spores

A. Tryon (32) reports that in S. densa each of the four megaspores in a megasporangium has a hemispherical base, the free surface, and three plane triangular faces, the commissural face. The three plane surfaces are in contact with the tetrad and the hemispherical base is the free outer surface. The commissural face has three prominent commissural ridges which are united at the apex. The surface of the spore may be smooth, granular, rugose, rugose reticulate or tuberculate.

The size of the megaspore may range from 0.15 mm. in S. armata to 0.53 mm. in S. selaginoides.

The microspores of S. armata and S. selaginoides have the same shape and sculpturing as the megaspores but are much smaller in size ranging from 23-64 μ (A. Tryon, 32). The number of microspores per sporangia is several hundred (R. Tryon, 33). In S. kraussiana, Slagg (27) found an average of 600 microspores per sporangia. Robbins et al (25) report that the 250 or so microspore mother cells which do not degenerate may each form a tetrad of four microspores which are shed midway in their

development. The completion of the development of microspores into 128 or 256 biciliated sperm is completed without direct connection with either the plant or the soil.

According to A. Tryon (32), S. densa has pale orange megaspores 0.36 to 0.50 mm. in size and bright orange microspores 34 to 49 μ in diameter.

In 1901 Lyon (16) completed an extensive study of S. apus and S. rupestris. Since mention is made of the two megaspores per sporangium, it is probable the species she studied is the one now known as S. rupestris, a member of the same series as S. densa.

Of S. rupestris, Miss Lyon says the strobili are formed on the new vegetative shoots of the plant in late summer and autumn. Only megaspores develop that season. In the spring, when growth resumes, the first microspores are produced, giving a strobilus with a six month old zone of basal megasporangia and a superior zone of newly produced microsporangia. After this, for as long as the strobilus lives that season, only megasporangia are developed. Their production is halted when embryos are formed in the spores, on the lower-most portion of the strobilus. When these embryos are formed, growth is stopped and a vegetative lateral bud is stimulated to develop horizontal branches and roots. When this new growth becomes independent, the axis bearing the strobilus and the developing embryos decays and the strobilus falls to the soil. The cotyledons and roots of the young sporophyte are then close to the soil and can begin growing.

R. Tryon (33) disagrees with Miss Lyon, saying he has seen nothing to support her report that germination of the megaspore and fertilization of the gametophyte occurs prior to dispersal.

If a strobilus fails to produce an embryo through lack of fertilization or more likely because of unfavorable climatic conditions, the strobilus continues to grow and the sterile spores are shed. In this case, Lyon (16) has observed that the strobili produced fertile spores the next season.

Both Miss Lyon (16) and Miss Mitchell (23) agree that in S. rupestris any spores observed lying on the ground were infertile.

Other workers, including Eames (5), Mitchell (23), R. Tryon (33), Slagg (27) and Foster and Gifford (7) agree that germination of the megaspore probably takes place within the strobilus but fertilization is accomplished only after spores are shed. In fact, Mitchell (23) reports a built-in mechanism for cross fertilization; the megaspores are ejected to a distance of 6-10 cm. while microspores travel only 1-1½ cm. when ejected; microspores germinate sooner than megaspores from the same strobilus and no embryos are obtained when megaspores and microspores of the same strobilus are sown together. Hofmeister (12) also reported that production of spermatozoids from the microspores terminates long before the complete formation of the prothallium in the megaspores. He also found that the prothallium in the megaspores began to form before the sporangia bursts. Further development in the tropical species may occur within a few weeks, while in other species further development may be

preceeded by a dormant period lasting for several months. After formation of the prothallium is completed, the first archegonium, egg bearing organ, develops at the apex and fertilization may now occur.

Two workers besides Lyon (16) have reported seeing young sporophytes. R. Tryon (33) observed sporlings only in S. sibirica of the many species he examined. Webster and Steeves (41) reported finding all stages of young sporlings of S. densa in the field near Saskatoon, Saskatchewan. The smallest of those which they have pictured has a cotyledon and a root which already has two branches and the sporling is less than a centimeter in total length.

Plant Development

Although the Selaginaceae produce a profusion of spores, Lyon (16) doubts that the increase in the number of individual plants in a given locality is due to sexual reproduction. She thinks the prostrate branches root and become separated from the parent plant or, more likely, that bits of old plants which are torn off by the action of wind and rain root and become new plants. R. Tryon (33) disagrees, saying the stems in most species are quite tough and difficult to break and are usually anchored at frequent intervals by rhizophores and roots. It does not seem likely, therefore, that vegetative reproduction would account for the distribution of the species. He also says that since many species occur over large geographic areas, the normal life cycle must be completed although germination and fertilization may occur only at rare intervals

when conditions are particularly favorable. Eames (5) is also of the opinion that vegetative reproduction by fragmentation and by rooting of the frond tips has only occasional occurance.

According to Eames (5), the first root is short-lived and all others arise adventitiously from the underside of stems and from rhizophores. The term rhizophore was originated by Nageli and Leitgeb in 1868 (Uphof, 37) and refers to the prop-like structures which grow downward from the underside of the stems and give rise to roots when they reach the ground. Webster and Steeves (40) in 1963 reported the anatomy of the root of S. densa to be quite similar to that of the stem and that the rhizophore of this plant is a root.

S. densa is included in the 6% of the species Uphof (38) lists as xerophytic. He arranges the xerophytic species into three physiological groups: plants with vertical leaves all of the same size and shape and each leaf apex ending in a long awn containing no chloroplasts; plants having slender wiry trailing stems with the size of the leaves much alike although their shape may vary; plants having a spreading habit in which the stems form a flat dense and close rosette which rolls into a nest-ball during drought. Uphof places S. densa in the first group and further says about the species: "The leaves are folded lengthwise around the stem with the halves being almost at right angles to each other and lying very close to the stem. The structure and position of the leaves minimizes transpiration."

Although the same tissues are present in both hygrophytic and xerophytic species, there are some differences within the tissue (Uphof, 38). The size of xylem tissue ranges from 40-70 μ in hygrophytic species to 8-35 μ in the xerophytics. He reports the size range of the xylem in S. densa to be from 8-30 μ. Cortex cells are small and thick-walled in the xerophytic species. Stomata in the xerophytic species are protected by a thick cuticle. He also found small oil droplets within the cells of xerophytic species; these droplets became larger under drought conditions. He believed these droplets may form aroung the protoplast and protect it during drought.

The characteristic furling of the leaves during drought and unfurling when moisture is present is explained by Uphof (38). The plants have a thick-walled hypodermis and cortex on the lower surface and a thin-walled hypodermis and cortex on the upper surface. During a drought period, the thin-walled surfaces lose more water than the thick-walled ones, causing the plant to curl up. When moisture is present the reverse is true. This is reported by Uphof (38) and R. Tryon (33) to be a mechanical movement which can also be demonstrated on dead plants. Uphof (38) also found that the weight of a dormant plant will increase from 42-54% when moisture is present.

According to Webster and Steeves (41) there is no outward appearance of permanent wilting in the xerophytic Selaginaceae.

R. Tryon (33) reported that a part of a six month old herbarium specimen of S. densa var. densa grew when planted and watered. Webster

and Steeves (41) found that a sod containing a mat of S. densa, which had lain on a shelf two years and nine months without water, grew and produced strobili when watered.

Cytology

Chromosome counts have been reported in several species of Selaginella by Manton (19) and R. Tryon (33). The numbers they have encountered are N = 9 and 2n = 18. Other workers, including Slagg (27) and Graustein (9) report difficulty in obtaining reliable counts for the following reasons: scarcity of cellular divisions, extreme smallness of chromosomes; (1 μ or less), and large amounts of chromatin and granular material in the cells.

Manton (19) reports that because there seems to be a very close cytological similarity between the species in the genus you could expect considerable uniformity throughout the genus.

No reports of chromosome counts of any member of the Rupestres series has been found although Graustein (9) concluded that S. rupestris reveals a "relatively high chromosome number."

Characteristics on the Range

Rydberg (26) reported that S. densa grows on exposed hillsides, among gravel rocks throughout the Rocky Mountain region.

Several workers have reported amounts of S. densa on range lands as percent of ground cover. Clarke et al. (3) report that on the short grass prairie in southern Alberta, Saskatchewan and Manitoba, it is not

uncommon to find 50% of the ground covered by S. densa with the usual range between 10 and 25%. On mixed grass prairie, the amount of S. densa present was not as great and on the sub-montane mixed prairie S. densa was not mentioned as being present. Coupland (4) reported in southern Saskatchewan and eastern Alberta the amount of ground covered by S. densa ranged from 7% in the Stipa - Bouteloua faciation to 30% in the Stipa - Agropyron faciation. Heady (10) reported that 28.7% of the ground on a site at Havre and 0.09% on a site in the Bear Paw Mountains was covered by S. densa. At four other sites, Warren, Deer Lodge, Clyde Park and Red Lodge, also in Montana, he found no S. densa.

In southwestern Saskatchewan, Hubbard (14) found S. densa on all soils except heavy clays. He reported up to 8.7% ground cover on fine sandy loam soils.

Taylor[1/] reports that on the present test site at the North Montana Branch Station, Havre, ground cover is in excess of 85 percent S. densa.

Early workers did not place much importance on the presence of S. densa on the range. Clarke et al. (3) report only that its dense cover is useful in preventing wind and water erosion. Coupland (4) thought the influence of S. densa on the habitat and other vegetation to be small. Clarke stated in 1943 that due to its low stature and slight moisture requirements S. densa is not considered as a dominant of the association despite its great abundance (Coupland, 4).

1/ Taylor, John E. Instructor of Range Science, Montana State University, Bozeman, Montana. Personal Communication. 1965.

Heady (11) in 1952 stated that at Havre S. densa may be an important competitor on the range because "it frequently increases to the extent that it restricts establishment of either native or reseeded grasses." R. Tryon (33) reported that the plant has an extensive network of roots close to the surface and can utilize small amounts of moisture rapidly. This indicates that the associated vegetation may suffer because of the presence of clubmoss.

Control

Several workers have reported change in amounts of S. densa under various treatments. Coupland (4) observed S. densa to have increased under protection from grazing and decrease with trampling from grazing animals. Heady (11) found that where ground was made bare through overgrazing, S. densa frequently increased. Smoliak (29) reports a highly significant increase in amount of S. densa present on sites lightly grazed over those protected for 33 years.

Hubbard and Smoliak (15) used six different methods of spreading runoff water on the range. A syrup pan system, employing a diversion dam and contour furrows, caused a reduction in amount of S. densa. Ryerson et al.[2/] working at Havre have shown a decrease in amount of S. densa after three years of fertilization. In their studies pitting also decreased the amount of S. densa and a combination of the two methods proved to be the most effective.

2/ Ryerson, D. E., Taylor, J. E., and Houlton, H. A. R. Effects of Mechanical Renovation Practices, Fertilization and Seeding on Rangelands of Northern Montana as Measured by Vegetational and Soil Changes. Unpublished annual report. Mont.Agr.Expt. Station. 1962.

Working with the effects of different mulches, Smoliak (30) was able to show highly significant decreases in amounts of S. densa. Thirty tons of barnyard manure per acre, 30 tons of wheat straw per acre or 300 pounds of Nitrogen plus 150 pounds of P_2O_5 or 300 pounds of K_2O all gave highly significant decreases and a fertilizer and straw combination completely eliminated S. densa.

The literature search failed to produce any reference to the control of S. densa with herbicides.

MATERIALS AND METHODS

Growth Characteristics

Pictures showing characteristics of the spores and strobilus of Selaginella densa Rydb[3/]. were taken on an Ultraphot II microscope using a luminar attachment. Two lamps were placed so only reflected light was utilized in the film exposure. Plant material used for the photographs was collected near Norris in a dormant condition and was placed in the greenhouse until green and actively growing. Observations were made within two weeks to minimize the possibility of changes due to environment.

To observe some of the characteristics of the root system of S. densa a sod clump six inches square and five inches deep was taken from the field. Compressed air was used to remove some of the soil from the edge of the profile. The remainder of the soil was removed with running water. When all the soil had been removed all other plant material was separated from the S. densa. This was then separated into underground and above ground portions, dried in a forced air oven at 70°C. for 48 hours and weighed.

Portions of the dried S. densa sample were then submitted to the Chemistry Research Laboratory at Montana State University for analysis. Protein, phosphorus and the ether extractable portion were determined.

3/ This material is believed to be Selaginella densa var. densa. A clump has been sent to Dr. R. M. Tryon at the Gray Herbarium, Cambridge, Massachusetts for positive identification.

To observe the rate of greening of dormant S. densa a sod from the field was positioned under a camera with a close-up attachment. The sod was placed so the same area could be pictured after each timed interval. A series of 12 pictures was taken at intervals from zero to 24 hours after watering. The pictures were then projected and compared for changes.

Chemical Analysis

Four clumps of S. densa from the field were prepared for analysis. Since potassium may be removed by washing with water, one part was separated into S. densa roots and above ground parts without the use of water. To facilitate separation and soil removal, water was used on the other three samples, each of which represented a replication. Previous experience had shown that small soil particles were extremely difficult to remove. In an attempt to overcome this the plant pieces were soaked in a very soapy solution of Dial soap for 24 hours. After repeated washing to remove all of the soap the samples were dried in a circulating air oven for four hours at 120°C.

The dry samples were weighed, placed in a cool oven which was raised to 550°C. and maintained for 18 hours. To insure complete ashing two ml. of 5N nitric acid were added for each gram of original sample. These were evaporated to dryness on a hot plate, placed in a cool ashing oven and brought to 400°C. and maintained for 15 minutes.

Enough concentrated hydrochloric acid was added to cover each of the ashed samples. Each was evaporated to dryness on a hot plate and baked for one hour to dehydrate the silica.

The elements to be analyzed were extracted with 2N nitric acid and washed into a volumetric flask with hot distilled water. The ashing and extraction procedures are as outlined by Greweling[4/].

After proper dilutions were made with 0.2 percent strontium chloride calcium, zinc and iron analyses were completed on an atomic absorption spectrophotometer. Sodium and potassium were determined using a flame spectrophotometer and water dilutions.

Because a high percent of material remained after ashing and extraction, other methods for the removal of organic matter were attempted. One method employed potassium dichromate, concentrated sulfuric acid and titration. With the second method, concentrated sulfuric acid was evaporated from the sample on a hot plate and heated to 900°C. for one hour in an ashing oven.

Determination of silica was as outlined by Piper (24). Because of the high percent silica obtained by this method an additional procedure was employed to confirm it. The residue was dissolved in hydrofluoric acid to which several drops of perchloric acid had been added.

Percent moisture was determined by drying green material from the field in a circulating air oven for four hours at 120°C.

Dessication Experiments

Since S. densa is a xerophytic species and its field behavior is characterized by tight clumping when the soil is dry and very rapid unfolding and greening when moisture is present, several dessication

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4/ Greweling, T. The Chemical Analysis of Plant Material. Agronomy Dept. Cornell University. 1960 (Unpublished).

experiments were conducted in an attempt to get some measure of drought resistance. In the first of these tests, all soil was washed from sod pieces which were uniform in size. They were then permitted to dry in the greenhouse for 0, one, three, six and twelve day periods before replanting in soil. After replanting the soil was kept moist to promote growth. Another experiment involved cutting two-inch squares of S. densa grass sod and allowing some to air dry in the greenhouse and placing others in a forced hot air oven at 70°C. for various periods before replanting.

Chemical Control

In the fall of 1963 four-inch cores of S. densa sod were obtained from Red Bluff Ranch near Norris. The instrument used to cut the cores was a commercially made turf cutter consisting of a four inch tubular bottom connected to a long handle. The cutter was driven into the ground by the use of body weight and a turning motion. After the apparatus and enclosed core was removed from the ground the intact core was pushed from the holder with an attached plunger.

These cores were put in thoroughly cleaned quart oil cans and placed in the greenhouse. When the plants were green and actively growing, herbicides were applied to individual cores using an atomizer with water as a carrier. All treatments were made in duplicate. Periodic checks were made to determine chemical effectiveness. Visual evaluations were recorded on a scale of 0-5 with 0 representing no effect on S. densa and 5 representing complete control.

The chemicals which showed the most promise in the preliminary greenhouse trials were applied to plots in the field at two locations. One plot area is located near Norris on a sandy loam soil where the average annual precipitation is 11.80 inches. The major plant species, in decreasing order or prevalence, are Stipa comata[5/], Carex eleocharis, Bouteloua gracilis, Agropyron smithii, Koeleria cristata, Poa secunda, Phlox hoodii and Chrysothamnus nauseosus. The second area is 300 miles north at the North Montana Branch Experiment Station near Havre. At the experiment station the average annual precipitation is 12.20 inches. The soil on the test site is a Scobey loam and the major plant species are S. comata, B. gracilis, K. cristata, C. eleocharis, P. secunda, A. smithii, Antennaria sp. and P. hoodii.

Applications at Norris were made on two dates, April 20 and June 3, 1964. On the first date, chemicals were applied that are primarily effective through the soil. Chemicals applied on the second date are considered to be most active on foliage. All applications at Havre were made on June 16 and 17, 1964.

The plots at both locations are 16½ feet long by 8¼ feet wide and are arranged in a randomized block design with three replications. Fenuron and ammonium nitrate were applied in a granular form by hand scattering the material evenly over the plot. All other applications were made

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5/ All associated species in this paper are as listed by Booth (1).

with a knapsack sprayer using water as the carrier in a volume equal to 40 gallons per acre. The applications were made with a single 8002 teejet nozzle spraying the entire plot first in one direction, then in the other.

Plots were visually evaluated throughout the growing season for effect on S. densa and associated vegetation. On August 6, 7, and 10, most of the plots at Norris were further evaluated by clipping. All plots except those treated with bromocil at 1 and 2 lbs/A, paraquat at 2 lbs/A and paraquat at 1 lb/A plus X-77 at 1% by volume were clipped. These plots were heavily damaged and yields were considered to be nil.

Clipping evaluation was accomplished by cutting to the ground level all vegetation except S. densa in a ring with a diameter of two feet at two locations on each plot. The vegetation on all plots was divided into five categories - B. gracilis, S. comata, C. eleocharis, miscellaneous grasses and miscellaneous forbs. S. densa at the time was dormant and none was obtained in the clippings. The clippings were then dried in a forced air oven and individually weighed.

In the fall of 1964, additional treatments were made at each of the two previous locations and an additional site was established 6½ miles north and 1½ miles west of Glasgow Air Force Base on a very fine sandy loam soil. Average annual precipitation 12 miles NE of the test site is 12.06 inches. The major plant species present are A. smithii, C. eleocharis, S. comata, K. cristata, B. gracilis, Artemisia cana, and P. hoodi. Plots at Glasgow are 8¼ feet wide by 33 feet long. All applications were made in the manner previously described.

RESULTS AND DISCUSSION

Growth Characteristics

S. densa on the range grows in clumps and where the *S. densa* is not too thick the individual clumps show up readily. In most instances where a heavy *S. densa* cover is present the clumps have grown together forming interlaced areas of live and dead material. When a single clump is located the live material usually forms a ring on the perimeter with the dead material in various stages of decomposition inside this ring. Figure 2 shows a clump of *S. densa* with the ring of live material surrounding that which is decomposing. Also present in the center is one distinct small area of live material (arrow). Whether this is a young plant just beginning expansion or a part of the parent clump which has survived is not known, although the latter is believed to be the case.

The root system of *S. densa* is matted and located near the surface. The roots are fine and could be traced to a depth of only three inches. After the soil was removed from the top two inches of an *S. densa* clump a dense mat of roots remained, almost all of which were *S. densa*. There were only a few roots of other species scattered through this area. Figure 1 shows a typical *S. densa* sod profile with the dense mat of roots near the surface and only an occasional *S. densa* root near the bottom. The thicker roots pictured are not *S. densa*.

Since the species has a shallow root system the total time per year when moisture is available is short, hence the plant is dormant a large part of the time. The lateral top growth of *S. densa* in the field was