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A Study of the Variability of Distichlis Stricta Selections from Several Geographical Locations in the Western United States

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A STUDY OF THE VARIABILITY OF *DISTICHLIS STRICTA* SELECTIONS FROM SEVERAL GEOGRAPHICAL LOCATIONS IN THE WESTERN UNITED STATES

by

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INTRODUCTION

Distichlis stricta as indicated by the available literature is rather unpalatable, but has the ability to grow vigorously on wet, saline, or alkali soils where more palatable species will not survive. *D. stricta* can be eradicated quickly where drainage and cultivation can be practiced, but there are thousands of acres in the United States, Canada, Mexico, and Argentina where cultivation or drainage are impractical or impossible.

On such problem soils, where the majority of the vegetation consists largely of *D. stricta*, a great deal of benefit would be derived from any improvement in the forage quality of this species.

In such a breeding program it is first necessary to make a careful study of material available and obtain the most desirable strains by selection. This study will be devoted to testing a number of selections to estimate the variability within this species as a preliminary step in attempting to breed a strain of *D. stricta* with better forage quality.

REVIEW OF LITERATURE

Taxonomy of Distichlis stricta

Distichlis spicata, originally named *Uniola spicata* by Linnaeus (Tidestrom 1925), was later divided into 2 species, *D. spicata* (L) Greene and *D. stricta* (Torr.) Rybd.; the seashore saltgrass which is found on both coasts of the United States being known as *D. spicata* and the inland saltgrass as *D. stricta*. Beetle (1943) maintains that the difference between *D. stricta* and *D. spicata* are not sufficiently constant to treat the entities as more than geographic varieties.

Hitchcock (1935) described *D. stricta*, *D. dentata*, *D. texana*, and *D. spicata*. Hitchcock (1950) recognised that *D. dentata* was merely the pistillate plant of *D. stricta* and combined these 2 species as *D. stricta*.

D. stricta and *D. spicata* are much the same in general appearance. Fassett (1925) has separated them by the following characteristics:

D. spicata	*D. stricta*
Compact panicles	More open panicles
10 to 20 spikelets	16 to 24 spikelets
Female spikelets slightly firmer than the staminate	Female spikelets firm and coriaceous, the staminate papery
Spikelets 4 to 9, rarely 12 flowered	Spikelets 6 to 18 flowered
Lemmas 4.5 to 7.8 mm. long (except in a few plants)	Lemmas 3.2 to 5 mm. in length
Grain 2 mm. long, narrowed below the 2 beak-like styles	Grain 2.5 to 5 mm. long, narrowed to an attentuate style which is sometimes split, but hardly into 2 distinct styles
Leaves smooth-edged and blunt or oblique at the tip	Leaves sharp-pointed and serrate at the tip

D. stricta is found in all the states west of the Mississippi except Arkansas and Louisiana. It is found also in Mexico and Western Canada (Hitchcock 1950). D. stricta is possibly native to parts of South America since Beetle (1943), who feels that D. stricta is a subspecies of D. spicata, mentions that several geographical varieties of D. spicata are found in South America.

Throughout much of the area inhabited by D. stricta the climate is conducive to salt accumulations and to periods of drought. To quote from Agriculture Handbook No. 60 (1954), D. stricta is found:

> . . . on salt flats and wet meadows. Occurs on soils of various textures, but it is most commonly found on loamy soils. The moisture-holding capacity is usually high (SP 45 to 90), and the soils are moist or wet throughout much of the year with a high water table. The salt content of the 4-foot profile is usually high (0.8 to 2.0 percent), with the highest content in the first foot. However, good stands may occur on soils containing very small amounts of salt (0.05 percent). Exchangeable sodium may or may not be present. Indications: Usually indicates wet, strongly saline soils with high water tables, but the plant may occur in areas low in salinity. Drainage and leaching are essential. (p. 57)

If this land could be drained and cultivated D. stricta could be eradicated in one season (Jenkins and Jackman 1941).

Hitchcock (1921) commented on the poor quality forage provided by D. spicata in the Salt Lake Valley, but said that it was grazed when better grasses were not available. Vasey (1887) in his study of native grasses found some who considered it of value and others who said it had no value. Vasey (1887) stated that it could not be considered a first class grass, but on the alkali plains of the Rocky Mountains it affords an inferior pasture.

Hitchcock (1914) stated that in regions where it was abundant, saltgrass was utilized for forage, but due to an excess of mineral constituents it is of inferior quality. Jenkins and Jackman (1941)

found that D. stricta was useful since it furnishes pasture where otherwise only worthless annual weeds would grow.

The leaves of D. stricta are rather harsh and coarse, but according to a study conducted at the Wyoming Experiment Station, of which the results were published in 1908, D. stricta has about the same amount of ash as does Dactylis glomerata. The conditions under which the plants were grown is unknown. Table 1 shows the comparisons between D. glomerata, Bromus inermis, and D. stricta as to composition according to studies made by Knight, Hapner, and Nelson (1908).

Table 1. Chemical composition of 3 grasses

	Analysis Green			Analysis Air Dry		
	D. stricta	B. inermis	D. glomerata	D. stricta	B. inermis	D. glomerata
Water	52.75	52.54	61.90	4.70	5.44	5.09
Ash	5.20	2.95	4.07	10.48	5.87	10.14
Ether Extract	.86	1.29	1.32	1.73	2.56	3.28
Crude Fiber	12.99	14.00	10.38	26.21	27.90	25.85
Crude Protein	6.26	4.49	5.37	12.62	8.95	13.38
N-free Extract	21.94	24.73	16.96	44.76	49.28	42.26

Sex in plants

Two viewpoints on sex in plants are discussed by Murray (1940) and by Jensen (1940). Murray (1940) uses the X Y chromosomes to account for male and female plants, while Jensen (1940) opposes the theory that there are sex chromosomes in plants.

The work of Murray (1940) and Warmke and Blakeslee (1939) on the dioecious tetraploids in Acnida and Melandrium may indicate the type of sex determination involved in D. stricta which is also a dioecious tetraploid.

As indicated by Jensen (1940) and Murray (1940) the ratio of males to females in dioecious diploid plants would be 1:1. A 1:1 ratio would also be expected in a dioecious tetraploid if the male were the heterogamic sex with XXXY sex chromosomes and the female with XXXX. This was found to be the case in the studies of Murray (1940) and Warmke and Blakeslee (1939). Sinnott, Dunn, and Dobzhansky (1950) point out that the Y chromosome in Melandrium is active in producing maleness thus doing away with sterile intersexes which might otherwise occur in polyploids. They also state that in the process of evolution those plants which have only recently become bisexual carry much the same gene loci and they differ only in a single or in a few genes that act as sex differentiators. The difference between a male and a female plant, where the X and the Y chromosomes are nearly identical, may be so slight that environmental effects can cause a male plant to produce female flowers and vice versa.

Buchloe dactyloides is also a dioecious polyploid which has normal progeny although about 5.8 percent of the plants studied by Anderson and Aldous (1936) were monoecious. Since D. stricta is a dioecious polyploid, the production of monoecious plants is a possibility.

Germination

A review of available literature fails to disclose any mention of the ability of D. stricta to reproduce by seed. If a plant is to reproduce sexually it must have seeds which will germinate and produce healthy seedlings. In order for a seed to germinate at least 3

external conditions are required. These are water, suitable temperature and oxygen. Light may also be essential or it may influence the germination of seeds of some species (Meyer and Anderson 1952). As indicated by U. S. D. A. Handbook No. 30 (1952) the optimum temperature for grasses is an alternating temperature of 20 - 30° C., being held at 20° C. for 16 hours and at 30° C. for 8 hours.

Seeds may fail to germinate if their seed coats are impermeable to water or oxygen. In some seeds the embryo fails to grow because of the mechanical strength of the seed coat even though it is permeable to water and oxygen. Other reasons for failure of seeds to germinate are: rudimentary or imperfectly developed embryos, physiologically dormant embryos, and the presence of inhibitors in the plant such as the juice in tomatoes (Meyer and Anderson 1952). Failure of seeds to germinate may also be caused by inhibitors in some part of the seed. Such inhibitors may be removed by leaching in water or by removal of the part of the seed containing the inhibitor (Porter 1949). Porter (1949) also reported that tap water sometimes contains chemicals that are injurious to germination. Calcium may make the seed coat impermeable and chlorine may be injurious to the seed.

U. S. D. A. Handbook No. 30 (1952) outlines the procedures to be followed in setting up and evaluating germination trials. In the germination trials conducted in this study the following definition of seed germination was used:

> Germination is defined as the emergence and development from the seed embryo of those essential structures which for the kind of seed in question are indicative of the ability to produce a normal plant under favorable conditions. Germination is expressed as the percentage of the pure seed of the kind under consideration which produces normal seedlings. (p 86)

Cytological study

D. stricta has 2n = 40 chromosomes. This number has been found in root tip counts by Stebbins and Love (1941) and by Brown (1951).

Stebbins and Love (1941) state that D. stricta is evidently a tetraploid with a basic number n = 10, and that the chromosomes in D. stricta are among the smallest found in the Gramineae. According to Myers (1947) species with n = 7 have large chromosomes while species with n = 10 have small chromosomes. The nearest relatives to Distichlis are the genera Uniola and Aeluropus. All 3 of these genera are widely different cytologically from the typical Festuceae, which usually have large chromosomes and a basic number n = 7. Cytologically, Distichlis resembles the Panicoidae and Chloridae, but appears to form a transition along with Uniola and Aeluropus between these 2 tribes and Festuceae (Stebbins and Love 1941).

D. texana which is larger and more robust than D. stricta and which is found in the United States only in Texas, also has 2n = 40 chromosomes (Brown 1951).

It has been found by Stebbins and Love (1941) that of the species which they studied the polyploid species were more tolerant to the adverse conditions of heat and drought than were the diploid species. Sharp (1943) mentions that the drier and hotter regions in California contain a distinctly higher proportion of polyploids, but states that in general there is no correlation between polyploidy and extremity of habitat.

Flovik (1938) in a study of arctic grasses found that most of them were polyploids. A few species were found that had 2n = 112-114 chromosomes. Myers (1947) states that as a general rule polyploid species have a more northern distribution, but mentions several

exceptions. Myers (1947) found in the grasses which he studied that more than two-thirds were polyploids or have one or more polyploid races.

In their studies of California grasses Stebbins and Love (1941) listed D. stricta as a tetraploid and apparently found no reason to believe it to be an aneuploid.

In discussing fertility in polyploids Stebbins (1940) states that:

> If the original plant is a fertile species, the polyploid derivative will be partially sterile, due to the formation of multivalent associations of chromosomes and their occasional irregular segregation. If, on the other hand, the diploid plant is a sterile hybrid, the polyploid produced from it is generally fully fertile. (p 56)

In the same article Stebbins (1940) mentions several exceptions to the above statement.

MATERIALS AND METHODS

Field planting to determine the variability in the growth habit and morphology of Distichlis stricta

D. stricta seed samples were obtained, as shown in table 2, from individuals or experiment stations located in the various areas. Most of the D. stricta seed from areas in Utah was collected by Dr. D. R. McAllister. As far as could be determined all of the seed was collected in the summer or fall of 1954.

Since the flowering of D. stricta was to be studied and because maximum growth of the individual plant during the first season was desirable, the plants were started in the greenhouse in December 1954. A trial germination test was conducted to obtain the approximate percent of germination. D. stricta seeds were placed in petri dishes containing 2 blotters with 8 cc of water and placed in a germinator with an alternating temperature of 20° C. and 30° C. with light. The higher temperature was maintained for 8 hours. One hundred seeds were placed in each petri dish but under these conditions they failed to germinate.

Subsequent examination of the seed indicated that the seed coat was extremely thick. Sandpaper scarification was found to be a satisfactory method for inducing germination.

In an attempt to raise 30 plants of each selection 100 seeds of each type were scarified and germinated under the previously noted conditions. Seeds began germinating on the third day and were transferred to wooden flats in the greenhouse on the fourth day. The soil into which the seedlings were placed received additional phosphorus

Table 2. Sources of *Distichlis stricta* seed

Selection Number	Source of Seed	Date Received
1	Davis, Yolo County, California	20 Oct. 1954
2	Northern Great Plains Field Station, Mandan, Morton County, North Dakota	18 Aug. 1954
3	Salina, Sevier County, Utah	18 Aug. 1954
4	Goshen, Utah County, Utah	18 Aug. 1954
5	St. George, Washington County, Utah	16 Aug. 1954
6	Hyde Park, Cache County, Utah	20 Sept. 1954
7	Delta, Millard County, Utah	18 Aug. 1954
8	Spanish Fork, Utah County, Utah	18 Aug. 1954
9	Wellington, Carbon County, Utah	29 July 1954
10	Centerfield, Sanpete County, Utah	18 Aug. 1954
11	Ogden Bay Bird Refuge, Weber County, Utah	18 Nov. 1954
12	Ogden, Weber County, Utah	18 Nov. 1954
13	Perry, Box Elder County, Utah	8 Aug. 1954
14	Farmington, Davis County, Utah	11 Aug. 1954
15	Kanab, Kane County, Utah	3 Nov. 1954
16	Logan, Cache County, Utah	5 Nov. 1954
17	Brigham City, Box Elder County, Utah	2 Oct. 1954
18	Sparks, Washoe County, Nevada	28 Oct. 1954
19	Hazen, Churchill County, Nevada	3 Nov. 1954
20	Soap Lake, Grant County, Washington	30 Oct. 1954
21	Leonore Lake, Grant County, Washington	30 Oct. 1954
22	Suisun, Soland County, California	19 Oct. 1954
23	Manti, Sanpete County, Utah	15 Oct. 1954
24	Hazen, Churchill County, Nevada	3 Nov. 1954
25	Salt Lake City, Salt Lake County, Utah	11 Nov. 1954
26	Manti, Sanpete County, Utah	15 Oct. 1954

and nitrogen fertiliser. A large percent of these plants died but were replaced with new seedlings. The seed sample of selection 2 was so small that replacement was impossible and consequently this selection died out completely.

Seedling plants grew rapidly until they had produced 3 or 4 leaves and were about 1 inch high. The plants then ceased to grow visibly and remained relatively inactive for 6 to 8 weeks. During this period a number of plants died and were not replaced due to the difference in age which would have resulted. After 6 to 8 weeks of inactivity the plants began to grow vigorously. The first 1 or 2 shoots produced were very long, lax, and geniculate. Shoots which came later were straighter and coarser.

In April 1955 the individual plants were transferred from the flats to 6 inch clay pots. This was done to prevent intermingling of plants due to rapid rhizome growth after the plant became well established. Rhizome growth was noted as the plants were transferred to the clay pots but the variation between plants within a selection prevented the determination of differences between selections. The differences noted within selections were probably due to differences in time of establishment, competition with other plants, and other environmental effects. In selections 10, 14, 15, and 26 very few plants survived, but of those which survived several were large and vigorous. In order that more plants would be available for study in the field these more vigorous plants were divided and transplanted to individual pots. Plants were clipped to a uniform height April 26, 1955.

The D. stricta plants were transplanted May 13 and 14, 1955 on the Evans Farm (U. S. A. C. Experimental Farm) about 4½ miles south of the U. S. A. C. Campus. The weather was cool, cloudy, and a light

rain fell after the transplanting was completed. Under these favorable conditions very few plants died. Plants were spaced 3 feet apart in 3 foot rows.

The first irrigation was on the 20th and 21st of June 1955. Subsequent irrigations were provided as required to promote maximum growth.

Observations on color, height, and the diameter of the D. stricta plants were made on July 5, 1955. The diameter of the plant was determined by taking a measurement of the width of the plant through the center from one side to the other and then measuring again on a line perpendicular to the first line of measurement. The total of the 2 measurements was determined and divided by 2 which gave an approximate measure of the diameter of the plant.

Observations were also made July 18th, August 12th, and October 4th. For these dates measurements were taken of the height, diameter, and the maximum length of rhizome development per plant. The rhizomes were measured from the center of the plant to the last shoot protruding above ground at the extreme end of the rhizome. Measurements were a few inches short since the rhizomes would have grown past the point of the last visible shoot.

Observations on blade width, blade length, stolon production, flower production, number of leaves per culm, angle of blade with culm, blades per culm, and florets per spikelet were made from October 6, to October 9, 1955. Pubescence and size of ligule were also noted but these 2 characteristics were uniform throughout all the strains. The blade length, blade width, and the angle between the upper surface of the blade and the culm were extremely uniform within each selection. Measurement of blade width and blade length were taken from leaves toward the bottom of the culm. The lower 3 or 4 blades were nearly

the same as to the width and length.

Stolon production and flower production were rated by selections with a rating from 1 to 4. Prolific producers of flowers and stolons were given a 4 rating and those producing few or no flowers or stolons were given a 1 rating. Selections intermediate with respect to these characteristics were rated 2 or 3.

Date of flowering of each plant and the sex of those plants which produced flowers were also noted.

Male-female ratio

Since D. stricta is a dioecious plant, one of the objectives of this study was to determine the ratio of male plants to female plants.

In the greenhouse plants were kept separate within each selection as well as between selections. Separation was necessary since rhizomes could have produced new shoots which might have been mistaken for distinct and separate plants. As mentioned previously the plants were taken out of the flats and placed in individual pots before the rhizomes developed sufficiently to produce new shoots.

A total of 471 plants were studied and the sex of each plant was noted as soon as flowers were produced. Four selections could not be considered for determination of the male-female ratio since they were increased by cuttings from vigorous plants within that selection. All cuttings from an individual plant would probably be of the same sex.

Germination

Beginning on September 12, 1955 germination trials were started to determine why the D. stricta seeds failed to germinate without special treatment and also to determine the best method to use to induce better germination.

On September 26, 1955 a germination test was started to determine any differences in the ability of seed from the various selections to germinate. A completely randomized block design was set up with 5 replications. Two germinators were used and since a cooling system was not available at this time the germinators were held at 25° C., the lowest constant temperature which could be maintained. However, 25° C. is considered optimum for some species and seemed to be entirely satisfactory. Due to lack of seed, selections 1, 2, 6, 15, 16, 24, and 25 were not used. All seed was scarified with 2/0-100 speed-set Garnet paper. Common sandpaper wore out too quickly to be of value. The seed was scarified as uniformly as possible, treated with Arasan, and 100 seeds per selection were placed in each petri dish in each replication. Two blotters and 10 cc of distilled water were used in each petri dish.

Cytological study

Spikelets from individual male plants were collected from July 18, 1955 through September 3, 1955. Spikelets were placed in Newcomer's fixative immediately after they were taken from the plant (Newcomer 1953). Small vials were used and each labeled with the plant selection and the number of the plant within that selection row.

Spikelets were collected while very young so as to obtain anthers in which meiosis would be occurring. When available several spikelets were taken from each plant. Seven out of 24 spikelet collections were too mature for study, or male flowers were not produced. The anthers were used in studying the number and meiotic behavior of the chromosomes in each selection. Temporary slides were prepared of the contents of an anther sac, using aceto-carmine. Slides which proved to be exceptionally clear and in the proper stage of meiotic division were made permanent by the alcohol vapor technique.

RESULTS

Variability of *D. stricta* selections

As shown by tables 3, 4, 5, and 6, there were rather large variations among the different selections. Selections 6 and 18 had 2 distinctly different types of plants within the row, otherwise the plants within each selection were uniform in appearance. The width and length of blades were fairly uniform within selections, but the number of leaves per culm, and florets per spikelet varied considerably within and among selections. In all selections the male spikelets had several more florets than did the female spikelets.

All plants were pubescent on the upper surface of the blade near the base and were particularly pubescent on the upper surface at the junction of the blade and sheath. The sheath and lower side of the blade were smooth. Leaves were conspicuously distichous. The ligule was serrated and of nearly equal size in all selections. Rhizomes were large and coarse.

The color of plants varied from a light green to a dark or bluish green. Stolon production varied from none to 5 or 6 stolons which were up to three feet in length (figure 1). The angle which the blade made with the culm was one of the most invariable characteristics within a selection and had a great deal to do with the general appearance of being tall (figure 2) and erect while those with larger angles appeared to be more prostrate and spreading (figure 3).

Plants of *D. stricta* flowered at approximately the same dates (table 4). However, striking differences in flower production occurred, with selections 9, 24, and 25 producing numerous flowers while selection

Table 3. Blade data, color, and stolon production rating of *D. stricta* selections

Selection Number	Blade Width	Blade Length	Angle of Blade with Culm	Color	Rating* for Stolon Production
	Inches	Inches	Degrees		
1	6/32	4.00	29	Dark green	1.5
3	3/32	4.50	39	Blue green	2.5
4	4/32	5.00	42	Blue green	2.0
5	4/32	3.25	38	Light green	3.0
6	5/32	5.75	15	Dark green	1.0
6a	3/32	3.50	38	Blue green	2.0
7	3/32	3.75	35	Blue green	1.0
8	6/32	5.00	24	Dark green	2.0
9	5/32	3.50	35	Blue green	1.0
10	5/32	5.50	9	Dark green	3.5
11	4/32	3.75	34	Blue green	1.0
12	4/32	4.75	37	Dark green	2.0
13	3/32	4.00	43	Blue green	3.0
14	3/32	4.00	35	Green	3.0
15	3/32	4.50	23	Blue green	2.0
16	4/32	4.50	37	Blue green	1.0
17	4/32	4.50	9	Blue green	1.5
18	5/32	4.00	42	Blue green	1.0
18a	3/32	4.00	26	Blue green	2.5
19	4/32	4.50	52	Light green	2.0
20	5/32	6.50	48	Light green	2.0
21	5/32	7.00	52	Light green	2.5
22	5/32	4.00	38	Light green	2.0
23	4/32	4.50	32	Blue green	1.0
24	4/32	6.50	54	Green	2.5
25	4/32	6.00	32	Green	3.0
26	3/32	4.75	26	Blue green	1.5

* A rating of 4 indicates heavy production of stolons, a rating of 1 indicates few or no stolons.

Table 4. Flowering data for D. stricta selections

Selection Number	Number of Plants per Selection	Date of Flowering	Number Flowering	Rating* For Flower Production
1	18	Aug. 14th-Sept. 3rd	2	1
3	24	Aug. 2nd-Aug. 25th	9	1.5
4	28	Aug. 13th-Aug. 25th	21	3
5	29	July 18th-Sept. 3rd	13	1
6	6	August 25th	1	1 and 2**
7	6	August 13th	6	3
8	6	Aug. 14th-Aug. 25th	5	2.5
9	2	August 2nd	2	4
10	5	Aug. 14th-Aug. 25th	4	2.5
11	7	Aug. 2nd-Aug. 25th	6	3
12	1	August 14th	1	3
13	26	Aug. 2nd-Aug. 25th	25	3
14	22	July 18th-Aug. 25th	21	3
15	4	Aug. 14th-Sept. 3rd	2	2
16	4	None	0	1
17	29	Aug. 2nd-Aug. 25th	22	1
18	28	July 18th-Aug. 25th	24	1 and 2**
19	30	July 18th-Aug. 25th	21	1.5
20	30	Aug. 2nd-Aug. 25th	13	1
21	20	July 18th-Aug. 25th	14	2
22	30	Aug. 2nd-Aug. 25th	22	1
23	22	Aug. 14th-Aug. 25th	11	2
24	29	July 18th-Aug. 25th	26	4
25	25	July 18th-Aug. 25th	23	4
26	20	Aug. 2nd-Aug. 25th	11	2

* A rating of 4 indicates heavy production of panicles, a rating of 1 indicates few or no panicles.

** Two distinct types within the selection

Table 5. Averages per selection for diameter, height, and maximum length of rhizomes of D. stricta plants on July 5, and 18, 1955

Selection Number	July 5, 1955		July 18, 1955		
	Diameter	Height	Diameter	Height	Maximum Rhizome Length
	Inches	Inches	Inches	Inches	Inches
1	1.53	3.36	2.30	4.88	2.80
3	2.31	4.42	3.04	5.83	3.48
4	2.85	4.46	4.39	6.38	5.32
5	3.10	4.58	4.13	6.67	5.17
6	2.42	5.00	2.58	6.67	2.75
7	2.58	5.17	4.83	6.58	5.83
8	2.75	4.83	4.67	6.58	6.00
9	3.25	5.50	5.75	6.50	6.75
10	2.50	5.60	2.90	9.10	4.10
11	3.14	4.14	3.07	6.00	3.50
12	4.00	5.00	3.50	5.50	4.50
13	5.21	4.73	9.06	6.19	10.05
14	2.64	5.00	5.16	6.64	5.25
15	1.88	4.50	2.25	5.50	2.50
16	2.38	4.00	3.12	4.50	2.88
17	3.59	5.93	5.98	7.66	7.22
18	4.11	4.32	6.70	5.64	6.93
19	4.72	7.30	11.30	9.37	13.38
20	4.13	6.48	7.68	8.48	10.17
21	2.75	4.60	4.42	6.55	5.15
22	4.88	6.53	8.50	7.50	10.95
23	2.50	4.45	3.16	5.73	3.73
24	4.00	6.24	6.03	9.09	6.81
25	5.34	6.12	9.28	8.42	10.16
26	2.58	4.15	3.58	5.50	3.60

Table 6. Averages per selection for diameter, height, and maximum length of rhizomes of D. stricta plants on August 12, and October 4, 1955

Selection Number	August 12, 1955			October 4, 1955		
	Diameter	Height	Maximum Rhizome Length	Diameter	Height	Maximum Rhizome Length
	Inches	Inches	Inches	Inches	Inches	Inches
1	6.55	6.09	5.77	16.89	7.61	16.61
3	7.00	8.71	7.17	18.00	10.21	16.04
4	11.28	11.23	11.85	27.32	12.41	23.03
5	9.70	9.32	10.74	22.98	9.58	20.20
6	7.50	11.25	7.83	21.83	11.58	18.00
7	11.00	10.92	12.67	27.67	11.92	21.16
8	12.00	11.92	11.33	21.67	12.08	19.50
9	11.00	12.50	13.50	23.00	13.50	27.00
10	8.40	10.05	8.40	16.00	11.20	14.60
11	8.42	10.21	8.28	15.14	10.57	16.57
12	15.00	13.00	23.00	24.00	12.50	21.00
13	21.08	11.19	21.08	40.35	12.29	33.35
14	10.82	11.57	12.91	24.68	11.77	22.36
15	7.75	8.38	4.50	10.50	9.25	10.75
16	6.00	8.38	5.50	9.25	10.62	11.25
17	15.59	12.55	16.51	32.65	14.24	26.21
18	18.36	9.57	17.82	32.25	11.00	26.04
19	25.80	11.82	26.80	44.50	12.78	41.97
20	22.23	11.38	26.73	43.90	11.43	43.33
21	13.00	9.95	13.40	37.75	11.02	33.55
22	19.97	9.58	21.07	38.60	10.95	36.27
23	9.02	9.91	9.04	21.82	11.52	19.36
24	14.90	13.81	14.69	30.34	14.81	25.66
25	21.21	14.56	9.98	37.28	14.46	30.12
26	8.78	9.75	9.98	20.40	12.22	18.52

Figure 1. D. stricta plant with several stolons. Stolons in general were relatively long but produced little vegetation and were not important in the spreading of the plant.

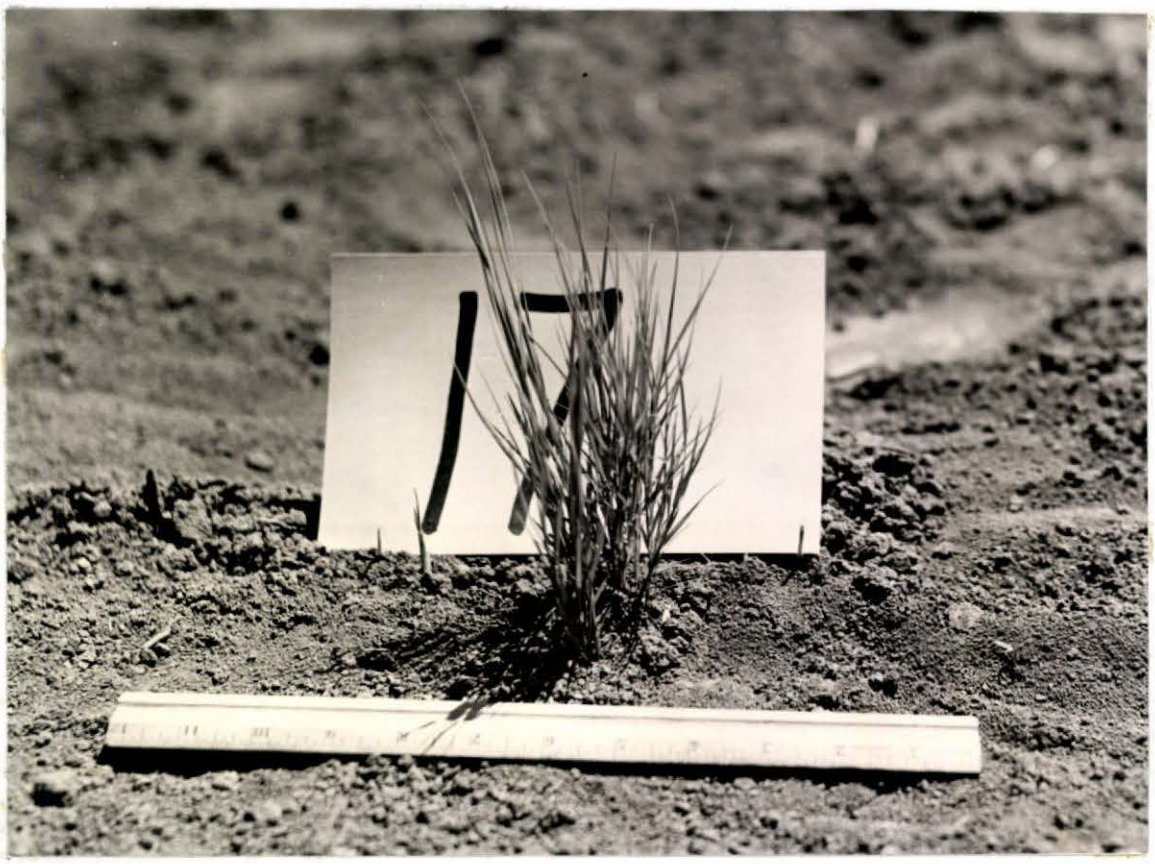

Figure 2. D. stricta plant with an angle of about 9° between upper surface of the blade and the culm. The acute angle of the blade gave this selection the appearance of being tall and erect.

Figure 3. D. stricta plant with an angle of about 52°. The relatively large angle gave this selection the appearance of being short and having a prostrate growth habit.

16 failed to produce flowers.

Selections 1 and 5 were the shortest, being less than 10 inches high. Selections 17, 24, and 25 were the tallest, having an average height greater than 14 inches. All others were intermediate in height.

Selections 1, 3, 10, 11, 15, and 16 had an average diameter of less than 20 inches and showed the least amount of spreading (figure 4). Selections 13, 19, 20, 21, 22, and 25 had the most extensive spread, with diameters greater than 37 inches (figure 5). Figures 6 and 7 show selections 13 and 22 as they appeared early in the growing season. Length of rhizomes as would be expected was closely correlated with the diameter of the plant.

Male-female ratio

Figures in table 7 indicate that for the limited number of plants studied a 1:1 male-female ratio was obtained. Table 7 lists the number of male, female, and monoecious plants. The calculated male to female ratio is 1 to 1 or 132.5 to 132.5 for the 265 plants studied. Actually the male to female count was 137 males to 128 females which gives a X^2 of .306 and a P value of 50-60 percent. This indicates a very close fit and the 1:1 ratio may be assumed correct.

Two and two-tenths percent of the plants examined for the male-female ratio were monecious.

Germination

Preliminary trials were conducted to determine which seed treatments would induce germination. It was found that any method which wore down or broke the seed coat without injuring the embryo induced germination. Treatment with sulfuric acid, freezing and thawing, and sandpaper scarification were all effective in breaking the seed coat. The best germination was obtained following sandpaper scarification.

Figure 4. Spreading of selection 1. This picture taken October 12, 1955 shows the relatively small amount of spreading in selection 1.

Figure 5. Spreading of selection 19. Extensive spreading of selection 19 is shown by a picture taken on October 12, 1955.

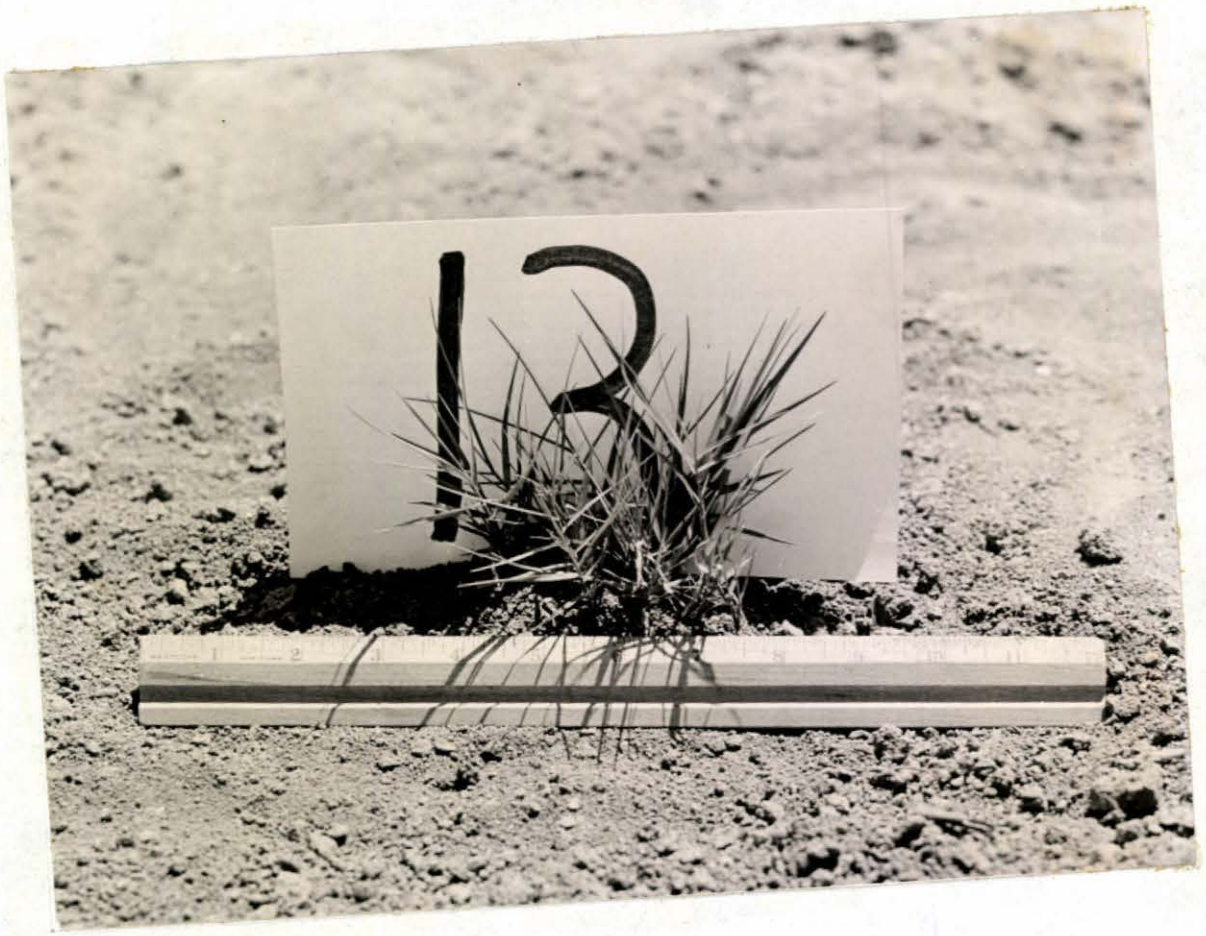

Figure 6. D. stricta plant from selection 13 near the beginning of the growing season

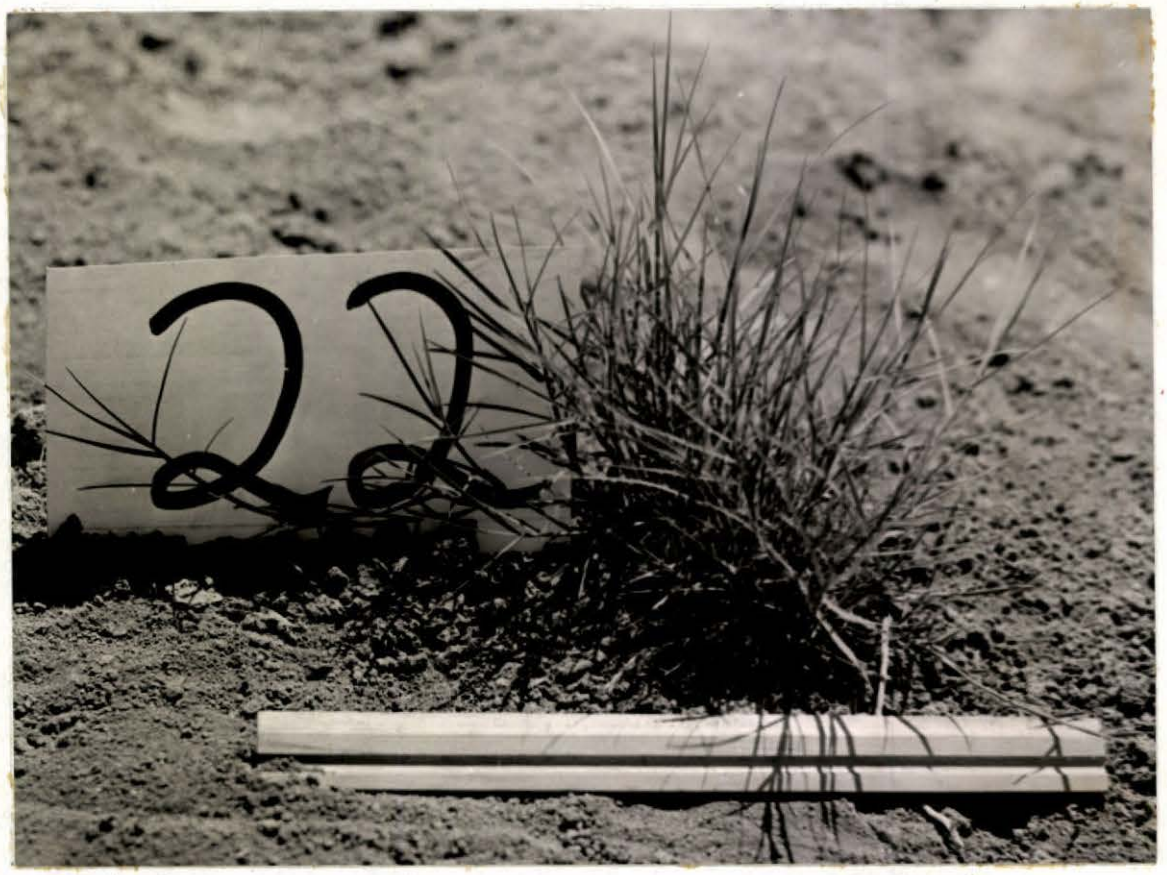

Figure 7. D. stricta plant from selection 22 near the beginning of the growing season

Table 7. Male-female ratio of D. stricta plants

Selection Number	Male Plants	Female Plants	Monoecious Plants
1	1	1	
3	5	4	
4	14	7	
5	6	7	
6	0	1	
7	2	4	
8	1	4	
9	2	0	
11	2	4	
12	1	0	
13	14	11	2
17	11	11	
18	12	12	
19	8	13	
20	7	6	
21	4	10	
22	10	12	
23	8	3	1
24	16	10	2
25	15	8	1
Total	137	128	6

Assuming male-female ratio equal 1:1

$X^2 = .306$
$P = .50 - .60$

Use of KNO_3 along with sandpaper scarification appeared to produce more vigorous plants than did distilled water and sandpaper scarification.

All other treatments, as shown in table 8, failed to improve germination.

Germination tests were conducted to determine whether or not there were differences in the ability of seed from the various selections to germinate. The percent germination for the majority of selections was between 40 and 60 percent. Selection number 12, with an average of 68.6 percent germination, was significantly higher than the average for all the selections, while the germination of selection number 10 was significantly lower (table 9).

Cytological study

Approximately 500 pollen grains for each of 17 selections were examined. Selection 26 having 5.66 percent sterile pollen and selection 23 with .79 percent sterile pollen were the extremes. The average for the selections studied was 2.75 percent sterile pollen (table 10).

In the cytological investigation, several plates from each of the selections were examined. Because of excessive clumping of chromosomes at metaphase and anaphase the best stage of meiosis in which to study the chromosomes was found to be late diakinesis. In the majority of the plates studied 40 chromosomes were observed. However, in many of the plates 40 minus 1 or 2 chromosomes were noted, but the deviation from normal 2n = 40 chromosomes did not appear to be greater than minus 2 chromosomes. The majority of chromosomes were associated as ring bivalents although rod bivalents were also observed.

Table 8. Preliminary germination trials to ascertain type of dormancy of D. *stricta* seeds and method of treatment for improving germination. Petri dishes were used and seeds were treated with Arasan unless otherwise noted.

Treatment	Germination Percent	Seeds Infested with Fungi	Remarks
Sulfuric acid, 5 minutes	14	0	No Arasan
Sulfuric acid, 10 minutes	35	2	No Arasan
Sulfuric acid, 15 minutes	30	2	No Arasan
Sulfuric acid, 20 minutes	13	2	No Arasan
Sandpaper scarification	72	0	
Potassium nitrate, 0.2% sol.	3	0	
Sodium hydroxide, 5 minutes	0	0	
Sodium hydroxide, 10 minutes	0	0	
Hot water, 65° C. 5 minutes	0	0	
Hot water, 65° C. 5 hours	0	0	
Sandpaper scarification	70	5	No Arasan
Held at -5° C. for 1 week	23	0	
Sandpaper scarification and 5/8" soil	58	0	Produced most vigorous plants
Soaked in water 24 hours	3	0	
Held at 0° C. for 24 hours	0	0	
Sandpaper scarification, about 30° C.	45	0	Placed in soil in greenhouse
Sandpaper scarification, covered	36	1	
Sandpaper scarification, 5/8" sand	17	0	
Without hulls	2	0	
With hulls	1	0	
Sandpaper scarification, soaked 24 hours	46	0	
Soaked 24 hours in 35,000 ppm NaCl	0	0	
Sandpaper scarification, with KNO_3 0.2% sol.	63	0	Very vigorous plants
Held at 0° C. for 1 week	14	0	
Blotters moistened with a 10,000 ppm NaCl solution	0	0	No Arasan
Sandpaper scarification, blotters moistened with a 10,000 ppm NaCl solution	21	24	No Arasan
Sandpaper scarification, blotters moistened with a 35,000 ppm NaCl solution	23	0	No Arasan
Control	0	0	

Table 9. Results of germination trials conducted September 29, to November 11, 1955. Seeds scarified with sandpaper. Figures given are in percent.

Selection Number	Replications					Average for Selections
	1	2	3	4	5	
3	61	47	53	58	63	56.4
4	34	39	41	51	46	42.2
5	60	63	38	66	67	58.8
7	26	52	49	37	23	37.4
8	38	46	56	40	42	44.4
9	54	23	57	43	40	43.4
10	34	24	48	33	42	36.2
11	58	55	71	55	52	58.2
12	78	68	65	72	60	68.6
13	54	42	59	63	50	53.6
14	46	47	53	54	38	47.6
17	45	41	43	37	49	43.0
18	58	56	56	51	65	57.2
18	73	42	61	36	35	49.4
20	70	40	47	40	54	50.2
21	43	53	44	41	44	45.0
22	52	63	43	50	41	49.8
23	57	46	49	29	27	41.6
26	47	51	42	32	48	44.0
Means	52	47.3	51.3	46.7	46.6	48.7

F value for selections	344.5*
L. S. D. at .05	11.96
S. E. of Difference	6

Table 10. Percent fertile pollen grains in 17 selections of *D. stricta*

Selection Number	Number Counted	Number of Sterile Pollen	Percent Sterile Pollen	Percent Fertile Pollen
3	508	8	1.57	98.43
4	521	21	4.03	95.97
5	520	20	3.85	96.15
9	511	11	2.15	97.85
12	520	20	3.85	96.15
13	507	7	1.38	98.62
14	507	7	1.38	98.62
17	513	13	2.53	97.47
18	506	6	1.18	98.82
19	507	7	1.38	98.62
20	507	7	1.38	98.62
21	514	14	2.72	97.28
22	522	22	4.21	95.79
23	504	4	.79	99.21
24	518	18	3.47	96.53
25	526	26	4.94	95.06
26	530	30	5.66	94.34
Total	8,741	241	2.75	97.25

DISCUSSION

Variability of selections

The results obtained in the field plantings indicate a substantial amount of variability among selections of D. stricta tested.

The most striking differences were noted in such characteristics as amount of spreading, width of blade, angle of blade, height of plant, stolon production, and flower production. It is not known which characteristics would make D. stricta more palatable, or if there is any difference in palatability among selections. The literature cited on the value of D. stricta is conflicting. This would seem to indicate it has been of value in some areas and that there are selections which have more desirable forage qualities than others. This might indicate only, that in some areas D. stricta is the only forage available and is therefore grazed rather heavily.

The angle of blade would not be expected to make any difference in quality, although it could be used as a marker in distinguishing between selections. The taller growing plants would be desirable since they would probably produce a greater quantity of forage in a solid stand.

The length of rhizomes and the amount of spreading might be very important since seeds must be treated to induce rapid, uniform germination. After the seeds germinate only very weak seedlings are produced which would probably necessitate vegetative propagation. Individual plants studied were started as seedlings in the spring and by the end of the growing season some had attained a diameter of 6 feet. The largest diameter of any individual plant was 82 inches.

The amount of spreading was extremely variable among selections. It will readily be seen that even using vegetative methods of planting that a large area would soon be covered by such rapidly spreading plants. If propagation by vegetative means were used it would become important to use selections which would spread rapidly since there were large differences among selections in this characteristic (figure 8).

Stolon production would not be likely to be important since rhizomes produced much more vegetation than did stolons of equal size. The stolons grew rapidly for a short time, but in most cases roots failed to grow from the stolons and very little vegetation was produced.

Flower production could be of importance if ways were found to obtain stands by planting the seed. Since vegetative propagation seems most feasible, flower production would have little value. Width of blade could be observed in the field, but the desirability of this characteristic is questionable. From observation alone the broad bladed, light green, moderately spreading selections appeared to be most desirable for forage quality.

Results were examined to determine if the better selections were native to this area. It was found that of the 6 selections which were most vigorous, 2 were native to Utah, 2 were from areas in Washington, 1 was from Nevada, and 1 was from California. D. stricta grows under a wide range of environmental conditions and it seems that each selection has the ability to do well in other than its native area.

Sex ratio in D. stricta

Special care was taken to determine differences between male and female plants before flowering. There were no differences found and the sex of plants could not be determined until the panicles were

Figure 8. Variability of spreading among several selections of P. stricta

produced. The male panicles grew above the uppermost leaves (figure 9) while the female panicles were shorter and sometimes nearly hidden by the leaves (figure 10). The female panicles tended to be more compact than the male panicles (figure 11). The majority of plants could easily be separated as to sex by the height of the panicles. When there was any doubt as to the sex of a plant in flower the female could be distinguished by the purple style which protruded noticeably from the florets. In the male the anthers could be seen on the more mature spikelets. As a general rule the male plants within a strain flowered before the females.

Of the 451 plants which were studied in the field plantings only 305 produced flowers. Since male plants could not be distinguished from female plants only those plants which flowered could be included in the study of the ratio of male to female plants. Also because 4 selections were increased by vegetative cuttings they had to be eliminated from the study of the sex ratio. The results obtained from the 265 plants studied indicated that male and female plants would be theoretically produced in equal numbers.

Since D. stricta is a tetraploid and assuming that Murray (1940) was correct in his study of the X Y chromosomes in plants, then the female would have XXXX and the male XXXY. Crossing these 2 genotypes would give, theoretically, equal numbers of both sex. If the male plant were XXYY then the ratio would be expected to be 3 male plants to 1 female plant. If D. stricta is an allotetraploid it might have an X and a Y chromosome from each genome and would be the same as above. However, it is possible that only 1 genome has X and Y chromosomes which would result in the male being XY and the female XX. This would theoretically give only a 1:1 ratio.

Figure 9. Male plant. Male plants had very prominent and rather showy panicles which protruded above the leaves.

Figure 10. Female plant. Female plants had denser more compact panicles which were shorter than the uppermost blades.

Figure 11. Female and male panicles. Female panicles are denser and more compact than the male panicles. Blades grow above the female panicles while the male panicles rise above the leaves.

Selection 14 was increased by vegetative cuttings. Since there were 9 plants added by cuttings from other plants it would be expected that these plants would be of the same sex as those from which the cuttings were made. Twelve or 13 of the plants would be expected to segregate into one-half males and one-half females. Actually all 21 of the plants which flowered were males. This could be simply a coincident, but it is possible that since D. stricta grows primarily vegetatively that parental types of this strain were XXXX and XXYY which, according to Murray (1940), would produce 12 males to 1 female.

Of the plants studied for the sex ratio, 2.26 percent were found to be monoecious (figure 12). According to Sinnott, Dunn, and Dobzhansky (1950) this would be expected in species which have only recently become bisexual. Apparently the X and Y chromosomes in D. stricta are still nearly identical with differences which normally produce a male or a female plant. This condition, however, probably can be altered by the environment to produce a monoecious plant. It is also possible that since sex may be determined by a 1 gene difference that somatic mutations occur which cause a plant to bear both male and female flowers. In the monoecious plants observed in this study the majority of panicles were of one sex, with the other sex being represented by only 1 or 2 panicles.

Germination

In preliminary trials it was found that in order for the seed to germinate rapidly and uniformly it was necessary to scarify it in some manner. Sandpaper scarification was found to be superior to other methods which were tried.

In nature the seeds would probably be capable of germination only after the seed coat had been made permeable by the process of freezing

Figure 12. A monoecious D. stricta plant. A small percentage of the D. stricta plants studied were monoecious. Most of these plants were predominately of one sex. The above plant has only one male panicle.

and thawing, or through decay of the seed coat. The seed of D. stricta would be moved only very short distances by wind, but it could possibly be spread over large areas by animals. With its extremely thick seed coat it could likely pass through the digestive tract of an animal without impairing its germination. Once it is established it appears to spread primarily by rhizomes.

Cytological study

The 2n chromosome number for D. stricta is 40. This figure agrees with studies made by Stebbins and Love (1941) and by Brown (1951) on root tips. In the examination of meiosis in the microsporocytes of D. stricta it was found that by using Newcomers' fixative the chromosomes could be studied only at diakinesis. The chromosomes were badly clumped at metaphase and also at anaphase. During diakinesis the nucleolus was stained very dark and sometimes obscured parts or all of one or more pairs of chromosomes.

Other fixatives should have been used to facilitate spreading at metaphase, but by the time it was discovered that Newcomers' fixative did not prevent clumping all of the material had been collected and fixed.

In most of the plates observed the chromosomes were associated as ring bivalents although rod bivalents were also noted. Ring formations slightly larger than others within the same cell were observed, but the difference in size was probably due to differences in chromosome length. They did not appear to be large enough to be quadrivalents and if they had been so considered the particular plates studied would have had a 2n number of chromosomes greater than 40.

None of the plates which were suitable for study had more than 20 pairs of chromosomes. It appeared, however, that in some of the

plates studied that less than 20 pairs of chromosomes were present. This might indicate that D. stricta has an aneuploid series or it might simply be that other chromosomes were present but were not detected. There were no chromatin bridges or lagging chromosomes noted and the meiotic cycle seemed to be normal.

Since most of the plates observed had 20 bivalent rings and because of the high degree of pollen grain fertility it is believed that D. stricta is an allotetraploid. An autotetraploid would, theoretically, have quadrivalent associations in nearly ever plate, and the percent of sterile pollen would probably be higher than was found in D. stricta.

Further work on D. stricta must be done using other fixatives to gain a clearer picture of chromosome behavior during meiosis.

SUMMARY AND CONCLUSIONS

D. stricta has a wide range of adaptation with a great amount of variability among selections from different areas. With the broad genetic base which this species apparently has it seems that a breeding program to improve its forage quality would be desirable.

It was found that the ratio of male plants to female plants was 1:1, but 2.2 percent of the plants studied were monoecious. Differences between male and female plants were not apparent in the vegetative stage.

The seeds of D. stricta were thick and impermeable. Scarification with sandpaper was superior to other methods of seed treatments tested. Selection 12 was the only selection which had a significantly higher germination than the others.

D. stricta is probably an allotetraploid with a basic chromosome number of n = 10. Meiosis was normal and the percent aborted pollen was only 2.75 percent. Twenty pairs of chromosomes were noted in most of the plates examined, while in several there could have been 1 or 2 chromosomes less. It is possible that D. stricta has an aneuploid series although the size of chromosomes plus the poor quality plates obtained for study made it impossible to be positive that numbers other than 2n = 40 were involved.

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