SEED GERMINATION IN CERTAIN NEW MEXICO RANGE GRASSES

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY 385

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(WITH FIVE FIGURES)

Introduction

Much work has been carried on in recent years in regard to the viability and germination of seeds of various plants. Seed-testing studies are highly important, because the results obtained influence or affect the work of the farmer, the floriculturist, the amateur gardener, and the rancher or ranger. These people cannot afford to plant seeds, expecting a 95 per cent germination and then perhaps having only a 50 per cent germination, due to poor selection of seed, to its immaturity, or to its adulteration with weed seeds.

Among the plants studied for germination the grasses have a prominent part, and this is especially true of the range grasses of the west. It is necessary for the rancher or ranger to know about what percentage of the seeds of the grasses covering his grazing lands he can expect to germinate, since he can then estimate the amount of grazing his lands will tolerate without becoming depleted. He must know whether his grasses propagate themselves vegetatively or by seed, or by both means.

Various studies have been made with reference to seed germination, and although they have no direct bearing upon the problem which the writer undertook, yet they gave ideas for some tests which were performed after the major problem was completed. The following are short summaries of the work of some of the investigators in the field of seed germination.

In general it is believed that the delay in after-ripening is due to the characters of the embryo and of the seed coat. Miss ECKERSON (6) found that there is a series of metabolic changes going on in the embryo during the period of after-ripening. At first the acidity is increased, and correlated with it is increased activity of catalase and peroxidase. By treating the embryos with dilute acids such as hydrochloric, butyric, and acetic, the after-ripening period can be reduced very much. Those embryos which are treated increase their water-holding power, acidity, and amount of peroxidase more rapidly; and the oxidase appears sooner than in the untreated embryo.

PAMMEL and KING (14) planted mature and immature seeds in the fall and in the spring. In general, stratification in sand and freezing were favorable to germination. *Asclepias syriaca* showed 12 per cent germination, *Ambrosia psilostachya* 18 per cent, *Chenopodium album* 88 per cent, and *Xanthium canadense* 25 per cent.

PACK (13) discovered that the germination of non-after-ripened *Juniperus* seeds under ordinary conditions is very small, amounting to 1 per cent. These seeds are protected by a semi-permeable and thick coat which makes up 75 per cent by weight of the entire seed. Acids enter very slowly, he found, while bases, silver, and mercury salts enter rapidly. PACK thinks that while the coat may act as a protection against fungal attack, and may prevent water-imbibed seeds from expanding and bursting the tissues before after-ripening is accomplished, it takes little or no part in the dormancy of after-ripening of the seed. He was unable to force the germination of non-after-ripened *Juniperus* seeds by high temperature, alternate temperatures, wounding, warm bath, dry air, removal of coats; or by treatment with hydrogen peroxide, mercuric chloride, ether, carbon dioxide, oxygen, light, soil, dilute acids, dilute bases, nitrates, sulphates, or strong acids. Freezing and thawing as such have no forcing action on germination of the *Juniperus* seeds, neither do they hasten after-ripening. They bring about chemical changes in the seed, but these changes are different from those occurring during after-ripening. When seeds are about ready to germinate, PACK found that they are very sensitive and are killed by exposure to 5° C. The *Juniperus* seed has a dormant embryo that must be after-ripened before germination.

Mrs. DAVIS (4) found the sterilization of the naked seeds of *Cornus florida* difficult, due to the fact that the inner testa is very thin or the endosperm rich in food and the seeds are frequently infested with molds. She concludes that the pericarp, the outer testa, and the inner testa take no part in causing the delay; the moisture intake with the pericarp and testas intact is as high as in seeds with these removed. After-ripened seeds break the pericarp readily. Delay is not caused by an immature embryo, as it is well differentiated several weeks prior to shedding. After-ripening of the dormant seed is favored by low temperatures, 0–5° C.

Rubus seeds vary according to species in the time required to weaken the coat with sulphuric acid. After the carbonized coats have been removed from the seeds they must be carefully sterilized, since treated seeds are very susceptible to molds. The delay in *Sphaeralcea remota* is due to the impermeable cuticle forming the outer layer of the seed coat. After this coat has been subjected to a 2–3 hour treatment with sulphuric acid it becomes permeable. Chipping slightly helps, as this method makes it possible for water to enter the seed. Mrs. DAVIS found that untreated seeds failed to swell or germinate, but that may have been due to the fact that the seeds were gathered late in the season. Treated seeds germinated and grew for a time in distilled water, and all seedlings showed remarkable vigor.

CROCKER (3) claims that in *Xanthium canadense* delayed germination is generally due to the seed coat rather than to the embryo. In the upper cockle-bur seed the delay is due to the exclusion of oxygen by the seed coat. No germination appeared in *Iris* seeds because the cap and endosperm stopped the absorption of water before the needed amount was obtained by the embryo. Those seed coats which exclude water are better for causing delay than those which exclude oxygen, because there is less respiration. The length of delay is due in nature to the persistence of the seed coats. In the case of *Xanthium*, the bur helps in causing the upper seed to germinate later. Seed coats reduce the oxygen supply, especially in the upper seed. High temperature brings about the germination of the upper seeds with the coats intact by raising the respiration ratio, which increases the rate of diffusion of oxygen through the seed coat.

DUVEL (5) has discovered that the factors affecting the vitality of the seed are maturity, weather conditions at time of harvesting, methods of harvesting, and curing. Immature seeds sown soon after gathering usually germinate readily, but if they are stored they soon lose their vitality. Seeds which are harvested in damp rainy weather are much weaker in vitality. By special care the life of the seed once injured may be prolonged. Since moisture affects the longevity of seeds, they must be kept in a dry place where the temperature is low. DUVEL found that seeds treated in a sulphuric bath or in a vacuum usually showed delayed germination because the seed coat has hardened. In order to keep the vitality of the seed, it is better to have as little respiration as possible. Respiration brings about a chemical activity in the cells, which causes energy to be transformed, resulting eventually in the death of the seed. Respiration in the light is the same as in the dark if moisture and temperature conditions are the same.

FAWCETT (8) worked with 92 samples of weed seeds, representing 52 species. The seeds were collected in September, October, and November. Fifty seeds of each sample were placed in sand in boxes under the benches in the greenhouse. Every month from November to May this was repeated. Samples were also placed in sacks inside of a wooden box and a thin layer of sand placed around them. The boxes were then sunk in the ground so that just the top was exposed. Comparisons were made with the samples kept indoors. In April both lots were planted outdoors. FAWCETT concludes that weed seeds with thick seed coats require a more or less extended period of rest after maturity. Mustard and pepper grass seeds require little time for rest. Drying out weakens the vitality of nearly all weed seeds, and exposure to the natural periods for best seed germination, fall and spring, increases the power of germination.

HIMMEL (11) also believes that low percentage of germination for honey locust is due to the seed coats, for when the seeds had been treated with concentrated sulphuric acid the germination percentage increased very much. The older the wheat seeds the lower the germination percentage, but *Amaranthus* seeds displayed greater germination in the older seeds. The life of a dandelion seed is less than 8 years, but even the old seeds show good catalase activity. *Typha* seeds germinate better if they are pricked. Only very dilute acids and bases have any forcing effect on *Typha* seeds.

Miss EVANS (7) found that in after-ripened seeds with coats untreated, the restricting effect of the coats showed particularly at low temperatures 8–10° and 11.6° C., and again at high temperatures, 42° for Washington seeds and 46.1° for Indiana seeds. In both cases these effects can be lessened by treating the coats with H_2SO_4, or abrading them with sand.

ATWOOD (1) found that there was less delay in germination in *Avena fatua* after the shell coats had been removed. Restriction of the oxygen supply by the seed coat acts as a limiting factor in germination. These seeds do not seem to be affected by light during germination. ATWOOD concludes that after-ripening occurs with the drying of the seed, but independent of the water content, as air-dried seeds soon after harvest yield lower germinative percentages than seeds of similar moisture content the following spring. Exclusion of water by the true seed coat does not explain after-ripening according to ATWOOD.

Material and methods

The primary purpose of this investigation was to discover the percentage of germination of the 1926 seeds of the following grasses:

1. *Hilaria mutica*
2. *H. mutica*
3. *Muhlenbergia porteri*
4. *Sporobolus airoides*
5. *Aristida purpurea*
6. *Scleropogon brevifolius*
7. *Bouteloua eriopoda*
8. *Muhlenbergia arenicola*
9. *Sporobolus cryptandrus*
10. *Bouteloua gracilis*
11. *Bouteloua eriopoda*
12. *Sporobolus giganteus*
13. *Aristida longiseta*
14. *Sporobolus flexuosus*
15. *Aristida longiseta*
16. *Bouteloua curtipendula*
17. *Sporobolus auriculatus*

Studies of these grasses have been made in previous years at the government laboratories in Washington, D.C., but the 1926 seeds were sent to the Hull Laboratory of the University of Chicago for experimentation by the writer. The seeds were collected by R. S. CAMPBELL on the Jornada Range Reserve Station at Las Cruces, New Mexico, and through him the following seeds from 1925 were obtained:

20. *Sporobolus airoides*
21. *S. auriculatus*
22. *S. cryptandrus*
23. *S. flexuosus*
24. *Epicampes emerslyei*
25. *Muhlenbergia arenicola*
26. *Panicum obtusum*

The seeds were still in the glumes on the spikes, hence it was necessary to separate not only the florets from the spikelets, but also to remove the palea and lemma from the seeds. The seeds for the tests were selected at random, so that the results would be as representative as possible. Since some of the samples contained relatively few seeds, it was found necessary to use smaller amounts of seeds for some tests. In all cases the seeds were soaked for one half-hour in a 0.25 per cent solution of uspulun and then rinsed (washed) in distilled water twice for 15 minute periods. The blotting paper was also treated with the uspulun solution, and the Petri dishes containing cotton and filter paper were sterilized by autoclaving. These precautions were taken to insure the seeds against black mold attack. Only in a few instances were the seeds attacked by molds.

All seeds were tested at 25° C. in the moist chamber germinating oven in blotters and in Petri dishes. Those which did not do so well at 25° were tried at 35° C. Each species was tested for 100 per cent germination. In the preliminary tests, 10 seeds of each species were used. In some instances the lemma and the palea were not removed in the first tests, hence it was not certain that there were seeds present. Afterward it was made a point that all protective bracts be removed from the seeds. Exceptions were made in the case of the *Bouteloua* grasses, in which the writer could find no seeds; hence the entire florets were used in hopes that some might contain seeds.

The *Aristida* seeds were tested for germination in the light, as they were supposed to show better germination results there than in the dark. The *Sporobolus* seeds were treated in several ways. The seed coats of nos. 9, 12, 14 were pricked, and the seeds shaken for 4, 6, and 9 hours in bottles containing coarse white sand, in order to injure the seed coats, thus hastening germination through the more easy entrance of water into the seed. Some of the seeds of nos. 9, 12, 14, which had been shaken for various lengths of time, were planted in sandy loam and kept at room temperature to see whether they would germinate more readily after having their seed coats bruised. Nos. 9, 12, 14, 22, 23 were soaked in distilled water for a period of 4 days and then for one of 9 days. These seeds were then placed in the 5° C. oven for 7 days and 21 days, and then in the 25° C. germinating oven. Nos. 4 and 20 were treated with varying solutions of $CaCO_3$. Ten seeds of all the grasses, excepting the *Bouteloua* species, were planted in sandy loam.

TABLE I A

TABULAR DESCRIPTION OF SEEDS COLLECTED BY R. S. CAMPBELL

Seed no.	Scientific name	Common name	Geographic range	Place of collection	Date of collection (1926)
1........	Hilaria mutica	Tabosa grass	Western Texas to southern Arizona and adjacent Mexico	$1\frac{1}{2}$ m. southwest of Red Lake Well	Sept. 19
2........	Hilaria mutica	Tabosa grass	Western Texas to southern Arizona and adjacent Mexico	1 m. south of Middle Well	Sept. 1
3........	Muhlenbergia porteri	Porter's bush grama	Colorado and western Texas to California and Mexico	2 m. south of Taylor Well	....
4........	Sporobolus airoides	Alkali sacaton	Washington and Nebraska to California and New Mexico	$1\frac{3}{4}$ m. northeast of Hdqrs.	Aug. 31
5........	Aristida purpurea	Purple three-awn	Southwestern U.S. to southern Mexico	$1\frac{3}{4}$ m. northeast of Hdqrs.	Aug. 31
6........	Scleropogon brevifolius	Burro grass	Arizona and western Texas to Mexico and South America	$\frac{3}{4}$ m. northeast of Hdqrs.	Aug. 31
7........	Bouteloua eriopoda	Black grama grass	Arizona and western Texas to Mexico	$1\frac{3}{4}$ m. northeast of Hdqrs.	Aug. 31
8........	Muhlenbergia arenicola	Ring muhlenbergia	Colorado and Kansas to Texas and New Mexico	$1\frac{3}{4}$ m. northeast of Hdqrs.	Aug. 31
9........	Sporobolus cryptandrus	Sand grass	Washington and Maine to Arizona and Texas	$1\frac{3}{4}$ m. northeast of Hdqrs.	Aug. 31
10........	Bouteloua gracilis	Blue grama grass	Manitoba to Mexico, and even to South America	St. Nicholas Canyon enclosure	Sept. 1
11........	Bouteloua eriopoda	Black grama grass	Arizona and western Texas to Mexico	Enclosure no. 10	Nov. 9
12........	Sporobolus giganteus	Gigantic sand grass	Southern New Mexico	$1\frac{3}{4}$ m. northeast of Hdqrs.	Sept. 19
13........	Aristida longiseta	Red three-awn grass	Southwestern U.S. and New Mexico	Aristida enclosure	Sept. 16
14........	Sporobolus flexuosus	Wide-panicled grass	Nevada to Texas and Mexico	$1\frac{3}{4}$ m. northeast of Hdqrs.	Aug. 31
15........	Aristida longiseta	Red three-awn grass	Southwestern U.S. and northern Mexico	$1\frac{3}{4}$ m. northeast of Hdqrs.	Aug. 31
16........	Bouteloua curtipendula	Side oats grama grass	Canada to New Jersey, California, and Mexico	Lion Den Canyon	Sept. 1
17........	Sporobolus auriculatus	Dwarf dropseed	Western Texas to southern New Mexico	$\frac{3}{4}$ m. north of Hdqrs.	Aug. 31

TABLE IB

TABULAR DESCRIPTION OF SEEDS

Seed No.	Scientific name	Altitude of place of collection (feet)	Type of soil	Rainfall				Percentage dissemination	Percentage germination
				Seasonal		Annual			
				Inches	Zone	Inches	Zone		
1	Hilaria mutica	4200	Heavy clay	4.82	1	14.67	1	....	34
2	Hilaria mutica	4200	Low swag heavy clay	7.51	4	18.29	5	....	91
3	Muhlenbergia porteri	4050	Gravelly clay-sand	10.24	6	19.48	5	....	75
4	Sporobolus airoides	4200	Clay loam	9.64	6	17.42	4	....	92
5	Aristida purpurea	4200	Sandy loam	9.64	6	17.42	4	....	60
6	Scleropogon brevifolius	4200	Clay loam	8.53	5	17.42	4	5	46
7	Bouteloua eriopoda	4200	Sandy loam	9.64	6	17.42	4	....	....
8	Muhlenbergia arenicola	4200	Clay loam	9.64	6	17.42	4	....	60
9	Sporobolus cryptandrus	4200	Sandy loam	9.64	6	17.42	4	....	75
10	Bouteloua gracilis	5600	Gravelly loam	11.23	8	21.17	7	5	....
11	Bouteloua eriopoda	4050	Gravelly loam	7.65	4	17.42	4	....	....
12	Sporobolus giganteus	4200	Sandy loam	9.64	6	17.42	4	....	97
13	Aristida longiseta	4300	Very sandy loam	5.73	2	18.53	2	25	17
14	Sporobolus flexuosus	4200	Sandy loam	9.64	6	17.42	4	30	42
15	Aristida longiseta	4200	Sandy loam	9.64	6	17.42	4	....	53
16	Bouteloua curtipendula	4800	Gravelly loam	11.23	7	21.17	6	10	98.6
17	Sporobolus auriculatus	4100	Clay loam	8.53	5	17.42	4	....	100

TABLE II

PRELIMINARY TEST ON BLOTTING PAPER, 25° C.; JANUARY 19–FEBRUARY 18, 1927 (31 DAYS)

No.	Name	No. used	Date of first germination	Final germination percentage
1	Hilaria mutica	10	1/27	10
2	Hilaria mutica	10	1/27	60
3	Muhlenbergia porteri	10	1/27	10
4	Sporobolus airoides	10	1/24	40
5	Aristida purpurea	9	1/24	33.3
6	Scleropogan brevifolius	10	2/3	20
7	Bouteloua eriopoda	10*	....	....
8	Muhlenbergia arenicola	10	2/3	30
9	Sporobolus cryptandrus	10	2/10	30
10	Bouteloua gracilis	10*	....	....
11	Bouteloua eriopoda	10*	....	....
12	Sporobolus giganteus	10	2/10	50
13	Aristida longiseta	10	....	Moldy
14	Sporobolus flexuosus	10	2/15	80
15	Aristida longiseta	10	1/24	50
16	Bouteloua curtipendula	10	....	Moldy
17	Sporobolus auriculatus	10	1/27	20

* Empty lemmas.

TABLE III

PRELIMINARY TESTS ON BLOTTING PAPER, 25° C.; FEBRUARY 4–25, 1927 (22 DAYS)

No.	Name	No. used	Date of first germination	Final germination percentage
1	Hilaria mutica	10	2/7	20
2	Hilaria mutica	10	2/7	100
3	Muhlenbergia porteri	10	2/7	80
4	Sporobolus airoides	10	2/15	20
5	Aristida purpurea	10	2/10	70
6	Scleropogon brevifolius	10	2/25	10 (9 moldy)
7	Bouteloua eriopoda	10*	....	....
8	Muhlenbergia arenicola	10	2/10	30
9	Sporobolus cryptandrus	10	2/15	60
10	Bouteloua gracilis	10*	....	....
11	Bouteloua eriopoda	10*	....	....
12	Sporobolus giganteus	10	2/25	40
13	Aristida longiseta	10	2/7	30
14	Sporobolus flexuosus	10	2/25	30
15	Aristida longiseta	10	2/7	40
16	Bouteloua curtipendula	10	2/7	100
17	Sporobolus auriculatus	10	2/7	20

* Empty lemmas.

TABLE IV

PRELIMINARY TEST IN PETRI DISH, 25° C.; JANUARY 27–FEBRUARY 25 (30 DAYS)

No.	Name	No. used	Date of first germination	Final germination percentage
1	Hilaria mutica	10	2/1	40
2	Hilaria mutica	10	1/29	100
3	Muhlenbergia porteri	10	2/1	60
4	Sporobolus airoides	10	1/29	70
5	Aristida purpurea	10	1/29	80
6	Scleropogon brevifolius	10	....	Moldy
7	Bouteloua eriopoda	10*	....	....
8	Muhlenbergia arenicola	10	2/1	40
9	Sporobolus cryptandrus	10	1/22	40
10	Bouteloua gracilis	10*	....	....
11	Bouteloua eriopoda	10*	....	....
12	Sporobolus giganteus	10	1/22	40
13	Aristida longiseta	10	2/1	10
14	Sporobolus flexuosus	10	2/22	70
15	Aristida longiseta	10	2/1	80
16	Bouteloua curtipendula	10	2/3	100
17	Sporobolus auriculatus	9	2/1	100

* Empty lemmas.

TABLE V

PRELIMINARY TEST IN PETRI DISH, 35° C.; FEBRUARY 2–16 (14 DAYS)

No.	Name	No. used	Date of first germination	Final germination percentage
1	Hilaria mutica	10	2/7	40
2	Hilaria mutica	Not tried	....	....
3	Muhlenbergia porteri	Not tried	....	....
4	Sporobolus airoides	Not tried	....	....
5	Aristida purpurea	Not tried	....	....
6	Scleropogon brevifolius	10	....	0
7	Bouteloua eriopoda	10*	....	0
8	Muhlenbergia arenicola	5	....	0
9	Sporobolus cryptandrus	10	....	0
10	Bouteloua gracilis	10*	....	0
11	Bouteloua eriopoda	10*	....	0
12	Sporobolus giganteus	10	....	0
13	Aristida longiseta	10	2/7	10
14	Sporobolus flexuosus	10	....	0
15	Aristida longiseta	Not tried	....	....
16	Bouteloua curtipendula	10	2/7	100
17	Sporobolus auriculatus	Not tried	....	....

* Empty lemmas.

TABLE VI

PRELIMINARY TEST IN PETRI DISH, 25° C.; FEBRUARY 12–MARCH 15 (32 DAYS)

No.	Name	No. used	Date of first germination	Final germination percentage
1	Hilaria mutica	10	2/15	20
2	Hilaria mutica	10	2/15	80
3	Muhlenbergia porteri	10	2/15	10
4	Sporobolus airoides	10	2/17	90
5	Aristida purpurea	10	2/15	40
6	Scleropogon brevifolius	10	2/15	40
7	Bouteloua eriopoda	10*	....	....
8	Muhlenbergia arenicola	4	2/15	50
9	Sporobolus cryptandrus	10	2/15	100
10	Bouteloua gracilis	10*	....	....
11	Bouteloua eriopoda	10*	....	....
12	Sporobolus giganteus	10	2/15	100
13	Aristida longiseta	10	2/15	10
14	Sporobolus flexuosus	10	2/15	60
15	Aristida longiseta	10	2/15	60
16	Bouteloua curtipendula	10	2/15	100
17	Sporobolus auriculatus	9	2/15	33.3

* Empty lemmas.

TABLE VII

100 PER CENT GERMINATION TEST IN PETRI DISH, 25° C.; FEBRUARY 21–MARCH 16 (24 DAYS)

No.	Name	No. used	Date of first germination	Final germination percentage
1	Hilaria mutica	50	2/28	34
2	Hilaria mutica	100	2/25	91
3	Muhlenbergia porteri	20	2/28	75
4	Sporobolus airoides	100	2/25	92
5	Aristida purpurea	100	2/25	60
6	Scleropogon brevifolius	50	2/28	48
7	Bouteloua eriopoda	100*	....	....
8	Muhlenbergia arenicola	20	2/25	60
9	Sporobolus cryptandrus	100	2/25	75
10	Bouteloua gracilis	100*	....	....
11	Bouteloua eriopoda	100*	....	....
12	Sporobolus giganteus	100	2/25	97
13	Aristida longiseta	100	2/25	17
14	Sporobolus flexuosus	100	2/25	42
15	Aristida longiseta	100	2/25	53
16	Bouteloua curtipendula	75	2/28	98.6
17	Sporobolus auriculatus	25	2/28	100

* Empty lemmas.

TABLE VIII

PRELIMINARY TEST ON BLOTTING PAPER, 25° C.; JANUARY 19–FEBRUARY 18 (31 DAYS)

No.	NAME	NO. USED	DATE OF FIRST GERMINATION	FINAL GERMINATION PERCENTAGE
20	Sporobolus airoides	10	1/29	100
21	Sporobolus auriculatus	10*	....	....
22	Sporobolus cryptandrus	10	2/10	80
23	Sporobolus flexuosus	10	2/10	60
24	Epicampes emersleyi	10*	....	....
25	Muhlenbergia arenicola	10	2/1	30

* Empty lemmas.

TABLE IX

PRELIMINARY TEST IN PETRI DISH, 25° C.; JANUARY 27–FEBRUARY 25 (30 DAYS)

No.	NAME	NO. USED	DATE OF FIRST GERMINATION	FINAL GERMINATION PERCENTAGE
20	Sporobolus airoides	10	2/1	100
21	Sporobolus auriculatus	Empty lemmas	....	....
22	Sporobolus cryptandrus	10	2/22	70
23	Sporobolus flexuosus	10	2/22	80
24	Epicampes emersleyi	Empty lemmas	....	....
25	Muhlenbergia arenicola	10	2/1	40
26	Panicum obtusum	10	2/7	30

TABLE X

PRELIMINARY TEST IN PETRI DISH, 35° C.; FEBRUARY 2–16 (14 DAYS)

No.	NAME	NO. USED	DATE OF FIRST GERMINATION	FINAL GERMINATION PERCENTAGE
20	Sporobolus airoides	Not tried	....	....
21	Sporobolus auriculatus	5	2/10	20
22	Sporobolus cryptandrus	10	....	....
23	Sporobolus flexuosus	10	....	....
24	Epicampes emersleyi	Empty lemmas	....	....
25	Muhlenbergia arenicola	9	2/7	77.8
26	Panicum obtusum	10	....	....

TABLE XI

100 PER CENT GERMINATION TEST IN PETRI DISH, 25° C.; FEBRUARY 21–MARCH 16 (24 DAYS)

No.	Name	No. used	Date of first germination	Final germination percentage
20	Sporobolus airoides	100	2/25	92
21	Sporobolus auriculatus	6	2/25	100
22	Sporobolus cryptandrus	20	2/25	95
23	Sporobolus flexuosus	40	2/25	92.5
24	Epicampes emersleyi	Not tried	....	....
25	Muhlenbergia arenicola	40	2/25	90
26	Panicum obtusum	100	2/28	21

TABLE XII

GERMINATION IN LIGHT IN PETRI DISH, ROOM TEMPERATURE, ROOM LIGHT; MARCH 1–16 (16 DAYS)

No.	Name	No. used	Date of first germination	Final germination percentage
5	Aristida purpurea	10	3/5	40
13	Aristida longiseta	10	3/5	20
15	Aristida longiseta	10	3/5	80

TABLE XIII

SEEDS SOAKED IN DISTILLED H_2O 4 DAYS, THEN IN GERMINATING OVEN AT 25° C. FOR 2 WEEKS

No.	Name	No. used	Germination during soaking	Germination after soaking	Percentage germination
9	Sporobolus cryptandrus	15	0	0	0
12	Sporobolus giganteus	15	0	0	6.6
14	Sporobolus flexuosus	15	0	0	0
20	Sporobolus airoides	40	34	0	85
22	Sporobolus giganteus	15	0	0	0
23	Sporobolus flexuosus	15	0	0	0

TABLE XIV

SEEDS SOAKED IN DISTILLED H_2O 10 DAYS, THEN IN GERMINATING OVEN AT 25° C. FOR 2 WEEKS

No.	Name	No. used	Germination during soaking	Germination after soaking	Percentage germination
9.......	Sporobolus cryptandrus	15	0	2	13.3
12.......	Sporobolus giganteus	15	2	0	13.3
14.......	Sporobolus flexuosus	15	1	0	6.6
20.......	Sporobolus airoides	15	12	0	80
22.......	Sporobolus giganteus	15	0	1	6.6
23.......	Sporobolus flexuosus	15	1	0	6.6

TABLE XV

SEEDS SHAKEN IN COARSE WHITE SAND, THEN IN 25° C. GERMINATING OVEN FOR 2 WEEKS

No.	Name	No. used	No. of hours shaken	No. of days soaked	Percentage germination
9.......	Sporobolus cryptandrus	10	6	5	10
12.......	Sporobolus giganteus	10	6	5	10
14.......	Sporobolus flexuosus	10	6	5	10

TABLE XVI

SEEDS SHAKEN IN COARSE WHITE SAND, THEN PLACED IN SANDY LOAM

No.	Name	No. used	No. of hours shaken	Percentage germination	No. of hours shaken	Percentage germination
9......	Sporobolus cryptandrus	10	6	0	9	0
12......	Sporobolus giganteus	10	6	0	9	0
14......	Sporobolus flexuosus	10	6	0	9	0

TABLE XVII

SEEDS IN GERMINATING OVEN AT 25° C. FOR 21 DAYS

No.	Name (10 seeds of each species used)	Percentage germination
	Without shaking or soaking (control)	
9	Sporobolus cryptandrus	10
12	Sporobolus giganteus	20
14	Sporobolus flexuosus	10
	Shaken four hours	
9	Sporobolus cryptandrus	0
12	Sporobolus giganteus	0
14	Sporobolus flexuosus	0
	Shaken six hours	
9	Sporobolus cryptandrus	10
12	Sporobolus giganteus	10
14	Sporobolus flexuosus	10
	Shaken nine hours	
9	Sporobolus cryptandrus	10
12	Sporobolus giganteus	20
14	Sporobolus flexuosus	10

TABLE XVIII

No.	Name	No. used	Percentage germination	
			5° C. oven 7 days	25° C. oven 21 days
9	Sporobolus cryptandrus	15	0	0
12	Sporobolus giganteus	15	13.3	20
14	Sporobolus flexuosus	15	0	0
22	Sporobolus cryptandrus	15	0	0
23	Sporobolus flexuosus	15	0	0

TABLE XIX

SEEDS TREATED WITH $CaCO_3$ SOLUTIONS INSTEAD OF DISTILLED H_2O

No.	Name	No. used	Percentage germination			
			0.5 per cent $CaCO_3$	1 per cent $CaCO_3$	5 per cent $CaCO_3$	10 per cent $CaCO_3$
4....	Sporobolus airoides (1926)	10	30	70	0	0
20....	Sporobolus airoides (1925)	15	87	80	0	0

TABLE XX

NO SEED SELECTION MADE; GLUMES PLACED IN PETRI DISHES AND THEN IN 25° C. OVEN

No.	Name	Results
7..........	Bouteloua eriopoda	No signs of germination
10..........	Bouteloua gracilis	No signs of germination
11..........	Bouteloua eriopoda	No signs of germination

TABLE XXI

SEEDS PLANTED IN SANDY LOAM AND KEPT AT ROOM TEMPERATURE (70° F.) FEBRUARY 28, 1927

No.	Name	No. used	Date of first plant
1............	Hilaria mutica	10	....
2............	Hilaria mutica	10	3/16
3............	Muhlenbergia porteri	10	....
4............	Sporobolus airoides	10	....
5............	Aristida purpurea	10	....
6............	Scleropogon brevifolius	6	5/4
8............	Muhlenbergia arenicola	10	....
9............	Sporobolus cryptandrus	10	5/5
12............	Sporobolus giganteus	10	4/13
13............	Aristida longiseta	10	....
14............	Sporobolus flexuosus	10	4/14
15............	Aristida longiseta	10	....
16............	Bouteloua curtipendula	10	....
17............	Sporobolus auriculatus	10	....

TABLE XXII

PRECIPITATION JORNADA RANGE RESERVE, 1926

STATION	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	SEASONAL	ANNUAL
Headquarters	0.49	0.05	1.40	0.48	2.43	0.06	4.95	0.38	3.20	2.32	0.04	1.62	8.53	17.42
Midwell	0.56	0.01	2.28	0.59	3.09	0.01	3.21	1.06	3.24	2.23	0.04	1.97	7.51	18.29
Red Lake	0.49	0.01	1.91	0.74	2.97	0.02	1.85	0.42	2.55	1.75	0.02	1.94	4.82	14.67
Road Tank	0.01	0.01	1.82	0.67	1.71	0.00	5.19	0.22	3.91	2.37	0.06	1.78	9.32	18.35
Ropes	0.84	0.12	2.65	0.88	2.71	0.40	2.52	1.09	4.11	2.36	0.00	2.00	7.72	19.68
St. Nicholas	0.90	0.10	2.02	0.53	1.64	0.03	6.07	1.20	3.95	2.67	0.02	2.03	11.23	21.17
South Well	0.53	0.00	1.57	0.91	2.09	T	4.01	0.25	3.48	2.61	0.01	1.84	7.74	17.30
Stuart Well	0.55	0.00	1.97	0.71	1.93	T	4.75	0.25	2.78	2.66	0.04	1.73	7.78	17.37
Ragged Well	0.43	0.00	1.96	1.00	2.21	0.09	6.30	1.16	2.78	2.24	0.00	1.31	10.24	19.48
West Well	0.55	0.00	1.66	0.71	1.98	T	2.48	1.66	4.81	2.53	0.12	2.03	8.95	19.53
Period Study	......	......	1.62	0.51	2.00	0.01	5.42	0.52	3.70	2.52	0.00	1.89	9.64	......
Enclosure no. 1	......	......	1.51	0.68	2.45	0.00	4.00	0.25	3.64	2.35	0.00	2.05	7.89	......
Enclosure no. 10	......	......	1.37	0.88	1.94	0.02	3.81	0.31	3.53	2.34	0.00	2.00	7.65	......
Enclosure no. 2	......	......	......	......	......	......	2.11	0.47	4.16	2.43	0.01	1.78	6.74	......
Aristida	......	......	......	......	......	......	2.77	0.42	2.54	0.89	0.79	2.01	5.73	......
Brown Tank	......	......	......	......	......	......	5.76	0.04	3.21	2.30	0.03	1.36	9.01	......
Sand Hills	......	......	......	......	......	......	5.24	0.39	3.15	2.09	0.00	1.98	8.68	......
New Well	......	......	......	......	......	......	5.76	0.81	3.58	1.84	0.40	1.95	10.15	......
Average	0.59	0.03	1.92	0.72	2.28	0.06	4.23	0.60	3.46	2.25	0.13	1.85	8.29	18.23

TABLE XXIII

COMPARISON OF SEASONAL RAINFALL FOR (A) HILARIA MUTICA NO. 1 AND NO. 2; (B) ARISTIDA LONGISETA NO. 13 AND NO. 15*

PRECIPITATION (INCHES)			
(a) Hilaria mutica, no. 1		Hilaria mutica, no. 2	
July	1.85	July	3.21
August	0.42	August	1.06
September (19 days)	1.61	Total	4.27
Total	3.88		
(b) Aristida longiseta, no. 13		Aristida longiseta, no. 15	
July	2.77	July	5.42
August	0.42	August	0.52
September (16 days)	1.52	Total	5.94
Total	4.71		

* See figs. 1, 2, 3.

TABLE XXIV

SEASONAL PRECIPITATION ON JORNADA RANGE RESERVE JULY, AUGUST, AND SEPTEMBER, 1926

No.	STATION	PRECIPITATION (INCHES)	RANGE (INCHES)
1	Red Lake	4.82	Under 5
2	Aristida Enclosure	5.73	5–6
3	Enclosure no. 2	6.74	6–7
4	Middle Well	7.51	7–8
5	Enclosure no. 10	7.65	7–8
6	Ropes	7.72	7–8
7	South Well	7.74	7–8
8	Stuart Well	7.78	7–8
9	Enclosure no. 1	7.89	7–8
10	Headquarters	8.53	8–9
11	Sand Hills	8.68	8–9
12	West Well	8.95	8–9
13	Brown Tank	9.01	9–10
14	Road Tank	9.32	9–10
15	Period Study	9.64	9–10
16	New Well	10.15	10–11
17	Ragged Tank	10.24	10–11
18	St. Nicholas	11.23	Over 11

The areas allotted to the various stations are based on the records of the individual stations, supplemented by general observation throughout the year. Fig. 4 shows the approximate area covered by the different amounts of rainfall.

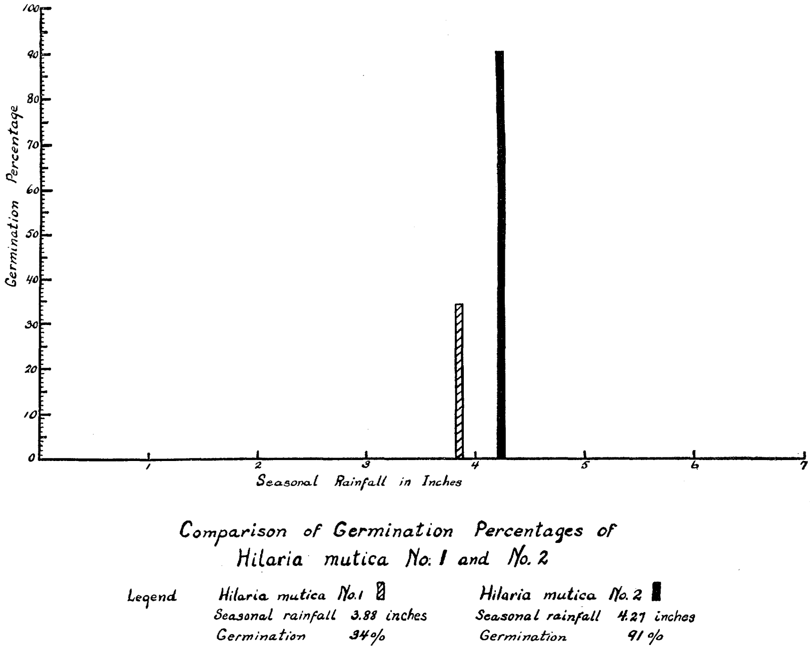
Germination Percentage
100
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
Seasonal Rainfall in Inches
Comparison of Germination Percentages of
Hilaria mutica No. 1 and No. 2
Legend
Hilaria mutica No. 1
Seasonal rainfall 3.88 inches
Germination 34%
Hilaria mutica No. 2
Seasonal rainfall 4.27 inches
Germination 91%

FIG. 1

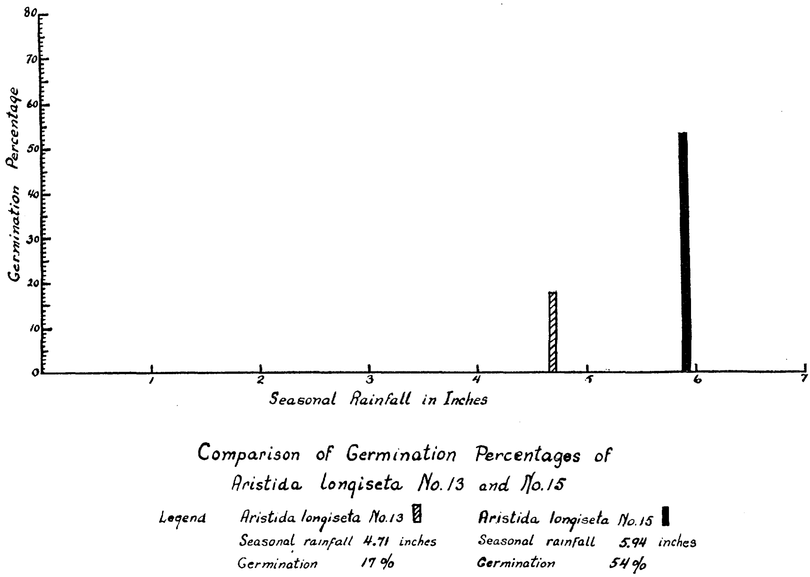
Germination Percentage
80
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
Seasonal Rainfall in Inches
Comparison of Germination Percentages of
Aristida longiseta No. 13 and No. 15
Legend
Aristida longiseta No. 13
Seasonal rainfall 4.71 inches
Germination 17%
Aristida longiseta No. 15
Seasonal rainfall 5.94 inches
Germination 54%

FIG. 2

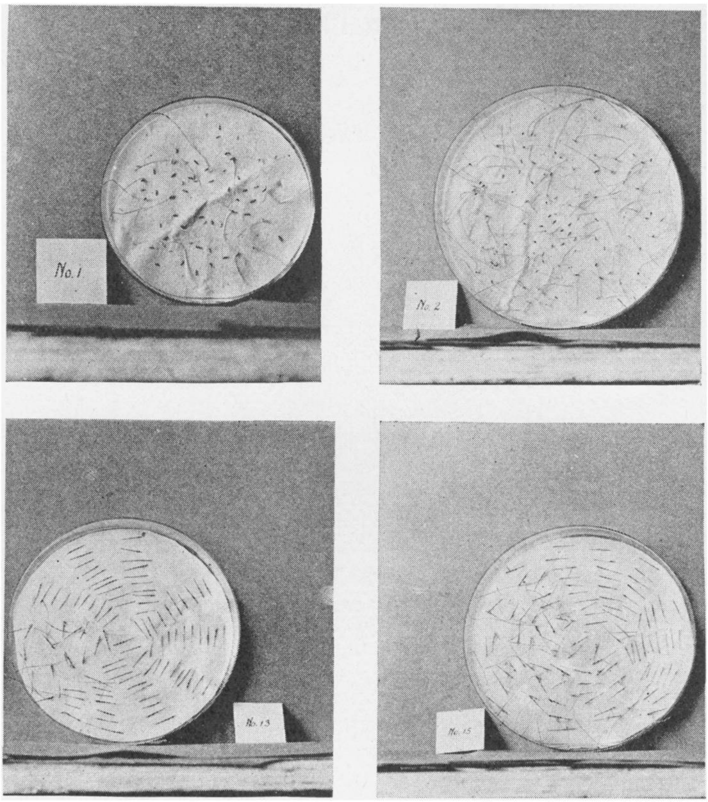

FIG. 3.—Upper row: comparison of germination of *Hilaria mutica* no. 1 (50 seeds, 34 per cent germination) and no. 2 (100 seeds, 91 per cent germination); lower row: comparison of germination of *Aristida longiseta* no. 13 (100 seeds, 17 per cent germination) and no. 15 (100 seeds, 54 per cent germination).

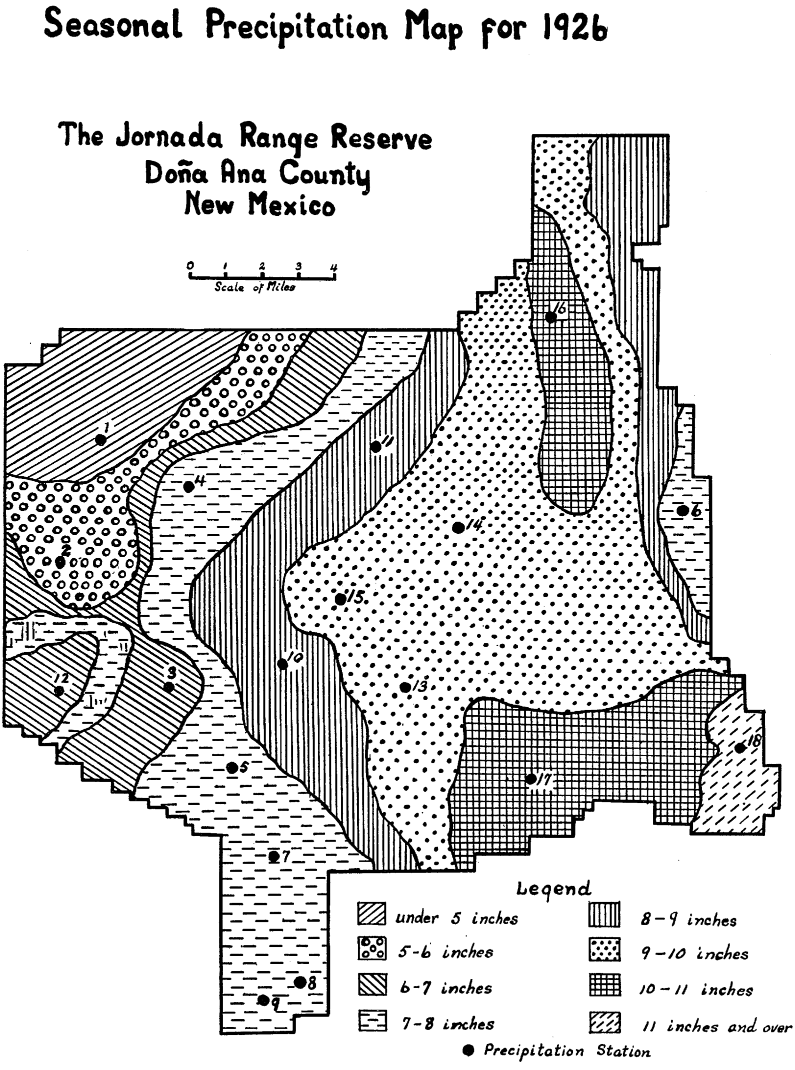
Seasonal Precipitation Map for 1926
The Jornada Range Reserve
Doña Ana County
New Mexico
0 1 2 3 4
Scale of Miles
Legend
under 5 inches
5-6 inches
6-7 inches
7-8 inches
8-9 inches
9-10 inches
10-11 inches
11 inches and over
Precipitation Station

FIG. 4

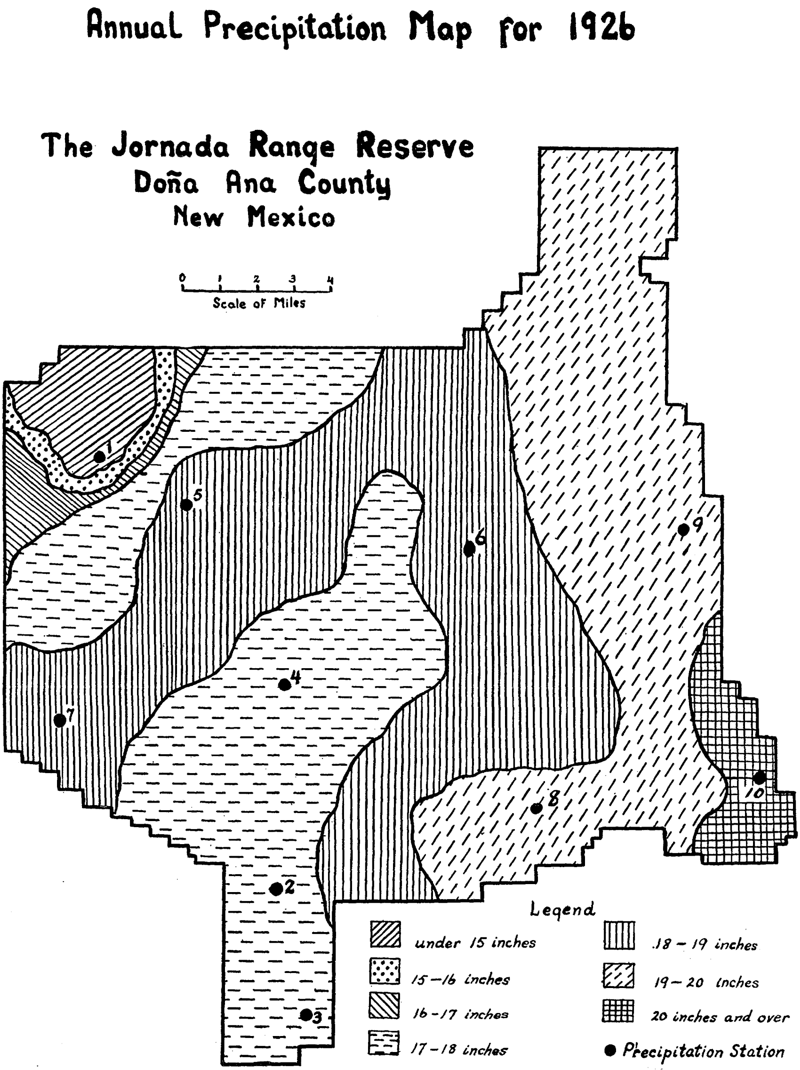
Annual Precipitation Map for 1926
The Jornada Range Reserve
Doña Ana County
New Mexico
0 1 2 3 4
Scale of Miles
1
2
3
4
5
6
7
8
9
10
Legend
under 15 inches
15–16 inches
16–17 inches
17–18 inches
18–19 inches
19–20 inches
20 inches and over
Precipitation Station

FIG. 5

The areas allotted to the various stations are based on the records of the individual stations, supplemented by general observation throughout the year. Fig. 5 shows the approximate areas covered by the different amounts of rainfall.

TABLE XXV

ANNUAL PRECIPITATION ON JORNADA RANGE RESERVE, 1926

No.	Station	Precipitation (inches)	Range (inches)
1	Red Lake	14.67	Under 15
			15–16
			16–17
2	South Well	17.30	17–18
3	Stuart Well	17.39	17–18
4	Headquarters	17.42	17–18
5	Middle Well	18.29	18–19
6	Road Tank	18.33	18–19
7	West Well	18.83	18–19
8	Ragged Tank	19.48	19–20
9	Ropes	19.68	19–20
10	St. Nicholas	21.17	Over 20

Discussion

From the tables of the various tests can be ascertained the germination percentages under different conditions. Table VII gives the final germination percentage for the seeds collected in 1926 and table IX for those gathered in 1925. From all the results it may be seen that the two lots of *Hilaria mutica* (nos. 1, 2) show a decided difference in their germination percentages. In no. 1 the germination percentage is always lower than in no. 2. By referring to the annual and seasonal rainfall figures, especially to the seasonal which includes just the rainfall during July, August, and September, when growth is taking place, one finds that no. 2 was collected in an area which received 2.69 inches more for the whole year than did the area in which no. 1 was growing. This probably accounts for the difference in the germination percentage, even though no. 2 was collected 19 days sooner than no. 1. The same is true of *Aristida longiseta* nos. 13 and 15. No. 15 was collected 16 days sooner than no. 13, but it gives much better germination results. The seeds of no. 15 received 1.23 inches more rainfall during the growing season than did the no. 13 seeds.

The *Bouteloua* (*B. eriopoda* and *B. gracilis*) had no seeds, so there was no germination percentage for either of them. Although tests were made in which the entire spikes were placed in sterilized Petri dishes in the 25° C. oven, no germination results were obtained. It is known that the *Bouteloua* grasses seed rarely, their means of propagation being vegetative rather than sexual.

Tables V and X show that germination is not increased by higher temperatures, as 35° C., nor does the alternation of low and high temperatures, that is from 5 to 25° C., increase germination (table XVIII). The best results are at 25 °C.

In regard to the *Sporobolus* seeds nos. 9, 12, 14, 22, and 23, which have an unusually hard seed coat, it was found necessary to prick them in order to obtain germination results. Shaking the seeds in bottles containing coarse sand helped germination somewhat, but the writer believes that much better results could be obtained if the period of shaking were considerably extended. This method would scratch the coats of the seeds in a way similar to that in nature.

Summary

1. The amount of rainfall during the year, especially during the growing season and at the time of harvesting, affects the vitality of the seed.

2. *Bouteloua eriopoda* and *B. gracilis* do not seed very often. Most of the florets are sterile, and because of their similarity to the fertile florets, are hard to distinguish from them.

3. *Aristida* seeds germinate just as well in the light as they do in the dark.

4. The seed coat is important in *Sporobolus* seeds, as it keeps out water and prevents germination. The seed coat must be punctured by some means before good germination results. Soaking affects the seed coats but little; shaking even for 9 hours in sand has little effect; and scratching or pricking hastens germination greatly.

5. The seeds of *Sporobolus airoides* do not need pricking to produce good germination results. The seed coat is more permeable to water than are the seed coats of the other species.

6. The *Sporobolus* seeds from 1925 retained their vitality very well.

I wish to thank Mr. J. D. SCHOELLER, the Director of the Jornada Range Reserve Station, for supplying the seeds used in this investigation and for the climatic and geographic data of the region. I also wish to express my gratitude to Professor H. C. COWLES for his continued interest and suggestion throughout the work.

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