INCREASING GERMINATION IN SOME IMPORTANT

ARIZONA FORAGE SPECIES

by

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INTRODUCTION

The emphasis given to range reseeding and other soil conservation practices during recent years has brought several species of native and introduced grass into commercial prominence. Germination of many of these species is normally low. Any method of increasing this germination would enhance their use in reseeding. In order to find a possible method for increasing germination of grass seed and also to obtain information on the best season for planting, research was conducted on the germination requirements of the following six forage species:

Common Name	Scientific Name
Bush Muhly	Muhlenbergia Porteri Scribn.
Lehmann Lovegrass	Eragrostis Lehmanniana Nees.
Rothrock Grama	Bouteloua Rothrockii Vasey
Sand Dropseed	Sporobolus cryptandrus (Torr.) A. Gray
Sideoats Grama	Bouteloua curtipendula (Michx.) Torr.
Turkestan Bluestem	Andropogon ischaemum L.

These grasses were chosen because they are representative of the native vegetation or show possibilities of being adapted for reseeding in Arizona.

An adequate study of the germination requirements of these species would require several years' experience with many seed samples tested under a wide variety of conditions. The results presented are based upon a single sample of seed and are therefore not to be considered as conclusive. However, they do indicate considerable variation in the germination requirements of the different species.

REVIEW OF THE LITERATURE

Factors influencing seed germination have been of interest to many workers.

Crocker (5)[1] lists the causes of dormancy as follows: (a) seed coats impermeable to water; (b) seed coats mechanically resistant to expansion of the embryo; (c) seed coats impermeable to oxygen; (d) rudimentary embryo; and (e) a state of dormancy in the embryo itself.

Atwood (1) found that germination of <u>Avena fatua</u> was delayed by a restriction in the oxygen supply. The seed coat was probably an obstruction to oxygen entry.

Evenari (6) has shown that the presence of germination-inhibiting substances in plants is a wide-spread phenomenon. They occur in all parts of plants - in fruit pulp, fruit coats, endosperm, seed coats, embryo, leaves, bulbs and roots.

During the past score of years many investigators have studied methods of treating hard seeds to expedite germination. According to Whitcomb (19) these treatments may be grouped under three general heads: (a) scratching or

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1. Figures in parentheses refer to literature cited.

breaking the seed coat; (b) rendering the seed coat permeable with chemicals; and (c) rendering it permeable by the application of varying degrees of heat.

Germination of Johnson grass can be hastened and germination capacity increased by removal of the restraining hard seed coat. Harrington (8) treated Johnson grass with concentrated sulphuric acid for two or three minutes followed by successive washings with distilled water and sodium bicarbonate. By this method he obtained practically complete germination in a few days. Opening the seed covering with a needle over the entire length of the embryo had the same effect as sulphuric acid treatment (7).

According to Bryan (4) a ten minute, concentrated sulphuric acid treatment greatly hastened and improved germination of Bermuda grass seed. Huntamer (11) found that chemical scarification of Oryzopsis hymenoides with concentrated sulphuric acid greatly increased germination of that species.

Various devices have been invented to scratch or break seed coats. Literature concerning these devices is reviewed by Whitcomb (19), who also summarized the literature dealing with sulphuric acid scarification and rupture of seed coats by freezing and thawing. He stated that sulphuric acid was the only solvent which is efficient in rendering hard seeds permeable.

The seed coat of some Sporobolus species is impermeable to water and hence delays germination. Jackson (12) found that mechanically scarifying the seed coat hastened germination.

Under natural conditions dormancy in seeds has often been broken by freezing and thawing. Brusse (3) found that impermeable seed coats of sweet clover and alfalfa seeds could be made permeable by exposure to very low temperatures under artificial conditions.

Barton's (2) method of continuous cold storage for hastening after-ripening of pine seeds is now of considerable commercial importance. Germination of short-leaf, slash, and loblolly pines was improved by chilling at 5° C. for one month in moistened peat. Germination of long-leaf pine was best when seeds had been chilled at 0° C. for one or two months.

McIlvain (14) found that treatment of six forage grasses in the Hordeae tribe with varying concentrations of 2,4-D (2,4-Dichlorophenoxyacetic acid) gave no significant increases in percentage of germination. He also noted that higher concentrations greatly retarded germination.

Hseuh and Lou (10) soaked seeds of barley and rice for 24 hours in concentrations of 2,4-D ranging from 35 p.p.m. to 1000 p.p.m. They reported a slight increase in the rate and percentage of germination in both rice and barley at the lowest concentrations. The highest concentration prevented the germination of barley but only slightly retarded that of rice. They concluded that 2,4-D at low concentrations promoted germination, but that higher concentrations inhibited aerobic respiration and checked germination.

Toole (16) used a 0.2 per cent solution of potassium nitrate to determine the effect of nitrate on Panicum obtusum. The treatment resulted in an increase in the percentage of germination.

MATERIAL AND METHODS

The seed used in these studies was furnished through the courtesy of the Soil Conservation Service Nursery at Tucson, Arizona. "Seed" as used in this paper refers to the caryopsis. Only seed that was entirely free from the lemma and palea was used.

Seed used in the tests was placed in soil-filled petri dishes. The soil was a Tumacacori coarse sandy loam that originally supported good stands of perennial grasses. One hundred seeds were used for each test. Germination counts were made at 5 and 14 days. Seeds were considered to be germinated when the coleoptiles had emerged sufficiently to indicate normal development.

No attempt was made to evaluate light as a factor. All seed, however, was exposed to light in the glass-topped germinator.

The effects on germination of potassium nitrate, potassium phosphate, 2,4-D, sulphuric acid, and prechilling at constant and alternating temperatures were tested. Distilled water was used to determine the normal germination of each seed sample at each temperature. Thermostatically controlled alternating temperatures were used to simulate day and night temperature fluctuations.

Tests were conducted at constant temperatures of 40°, 60°, 70°, 80°, 90°, and 100° F. and at temperatures that alternated between 35° and 45°, 40° and 60°, and 70° and 100° F.

For the nitrate and phosphate tests the seeds were germinated in soil saturated with 0.2 percent solutions of potassium nitrate or potassium phosphate.

Treatment with 2,4-D consisted of placing the seeds in beakers containing concentrations of .01, 0.1, 1.0, 10, and 100 p.p.m. (acid equivalent) of the sodium salt, and allowing them to remain for 30 minutes. The seeds were then washed with running water and dried on filter paper prior to being germinated at the various temperatures.

In the sulphuric-acid treatment dry, intact seeds were placed in beakers of 80 percent sulphuric acid and allowed to remain for 15, 30, and 60 minutes. The acid was then drained and the seeds immersed in running water until litmus indicated a neutral condition.

For the prechilled treatment the seeds were placed on moistened filter paper in petri dishes and subjected to a temperature of 35° F. for 15 and 30 days. At the end of each of these periods the seeds were tested for germination at various constant and alternating temperatures.

EXPERIMENTAL RESULTS

BUSH MUHLY

Temperature

Highest germination of bush muhly was obtained at constant temperatures of 90° and 100° F.[1] (fig. 1). Germination decreased as temperatures were lowered below 90°. There was no germination at a constant temperature of 40°, or at alternating temperatures of 35° and 45°, and 40° and 60°. Germination at a constant temperature of 40° or at alternating temperatures of 35° and 45°, and 40° and 60° was rare. Throughout the text these temperatures are mentioned only if germination occurred.

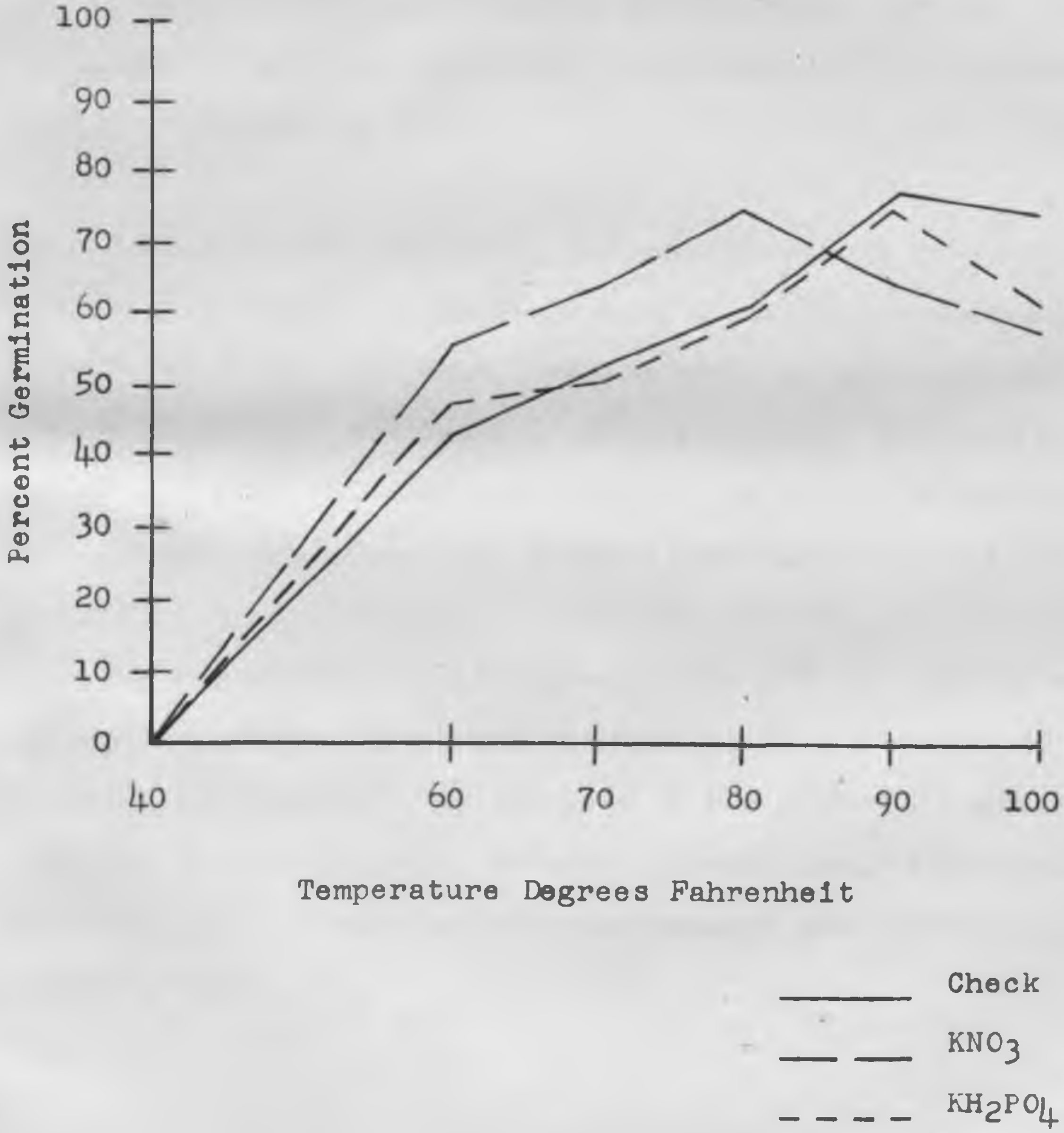
Sixty-one percent of bush muhly seed germinated at temperatures alternating between 70° and 100°. This species germinated more slowly at these alternating temperatures than any of the other species tested.

Potassium Nitrate

Potassium nitrate was beneficial only at temperatures of 80° or less (fig. 1). It was detrimental to germination at higher temperatures that were more favorable for untreated

1. All temperatures recorded in degrees Fahrenheit.

Fig. 1-Effect of potassium nitrate and potassium phosphate at different temperatures on germination of bush muhly.



seed, causing decreases in germination of 13 and 16 percent at constant temperatures of 90° and 100°.

Potassium Phosphate

Potassium phosphate caused an increase in germination only at a constant temperature of 60° (fig. 1). An inhibiting effect occurred at all other temperatures, varying from a minimum of zero as temperatures approached 40° to a maximum of 12 percent at 100°.

2,4-D

Treatment with extremely low concentrations of 2,4-D showed an increase in germination at a constant temperature of 60° (table 1). At higher temperatures no appreciable increase occurred. Detrimental effects occurred with 1.0 p.p.m. at 90° and with all concentrations of .01 p.p.m. or more at 80°. Higher concentrations reduced germination at all temperatures.

One-hundredth and 0.1 p.p.m. at the 70° and 100° alternating temperature increased germination from a normal of 61 percent to 67 percent, an increase of six percent. Concentrations above 0.1 p.p.m. retarded germination. A germination low of 13 percent at this temperature was attained with 100 p.p.m.

Table 1.-Effect of 2,4-D on germination of bush muhly.

Temperature	2,4-D concentration (p.p.m.)					
	0.00	0.01	0.1	1.0	10.0	100.0
Degrees F.	Percent germination					
60	43	59	60	48	29	8
70	53	52	54	41	20	18
80	61	59	60	48	29	8
90	77	79	77	75	29	
100	74	74	74	76	30	

Sulphuric Acid

Sulphuric-acid treatment was of some benefit at those temperatures at which germination was normally lowest (table 2). There appeared to be a greater beneficial effect at 60° than at any of the higher temperatures. At all temperatures the greater the length of treatment the greater the increase in germination.

Table 2.-Effect of sulphuric-acid scarification on germination of bush muhly.

Temperature	Length of H_2SO_4 treatment (minutes)			
	None	15	30	60
Degrees F.	Percent germination			
60	43	55	61	62
70	53	52	56	58
80	61		60	64
90	77		78	80
100	74		76	78

Prechilling

Prechilling produced a harmful effect on bush muhly, reducing germination from 16 to 22 percent at 90° (table 3). The inhibitory effect was directly proportional to length of the chilling period.

Table 3.-Effect of prechilling on germination of bush muhly.

Temperature	Length of prechilling treatment (days)		
	None	15	30
Degrees F.	Percent germination		
80	61		49
90	77	61	55
100	74	50	41

LEHMANN LOVEGRASS

Temperature

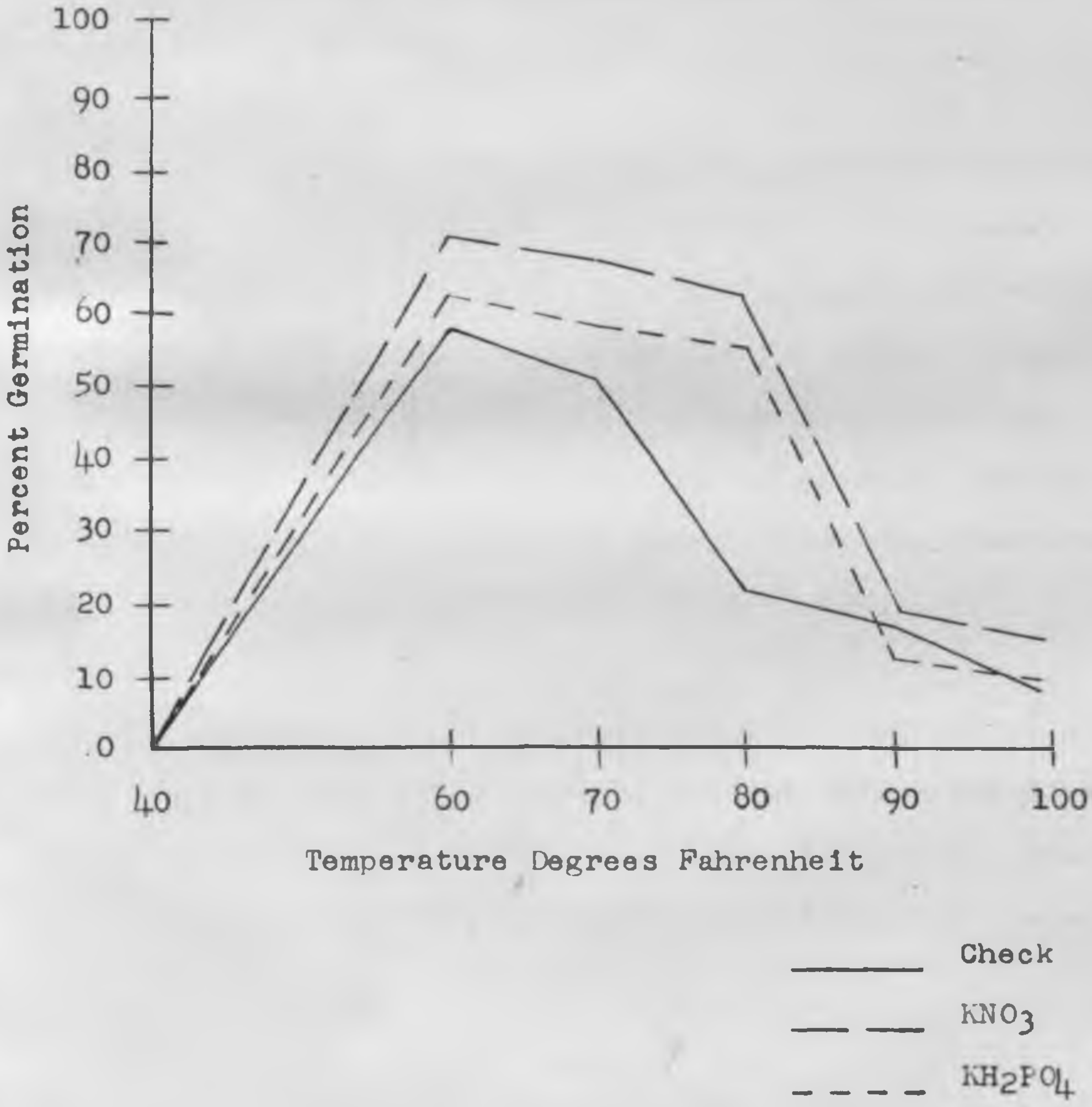
A maximum germination of 58 percent occurred at 60° (fig. 2). From this point germination progressively decreased as temperatures increased, reaching a minimum of eight percent at 100°.

Alternating temperatures of 70° and 100° gave 42 percent germination. This was 16 percent lower than germination at the optimum constant temperature. Only eight percent of the seed germinated at temperatures alternating between 40° and 60°.

Potassium Nitrate

Lehmann lovegrass treated with a 0.2 percent solution of potassium nitrate showed a germination rate of 71 percent at 60° (fig. 2). This was 13 percent higher than germination

Fig. 2-Effect of potassium nitrate and potassium phosphate at different temperatures on germination of Lehmann lovegrass.



of untreated seed. At 70° the difference was even greater, with an increase of 17 percent. Whereas germination of untreated seed decreased 36 percent from 60° to 80°, potassium-nitrate treated seed decreased only eight percent. Possibly more important, the treated seed showed 63 percent germination at 80° which was five percent higher than untreated seed at its 60° maximum.

Potassium Phosphate

Lehmann lovegrass seed treated with potassium phosphate germinated 63 percent at 60°, an increase of five percent over untreated seed (fig. 2). Germination of untreated seed decreased 36 percent as the temperature was raised from 60° to 80°, while germination of treated seed decreased only seven percent. Therefore, germination of treated seed was 34 percent higher than untreated seed. Potassium-phosphate treatment slightly retarded germination at 90°.

2,4-D

2,4-D appeared to be toxic to Lehmann lovegrass at all concentrations (table 4). This inhibitory effect was five percent or less with concentrations below 1.0 p.p.m. Inhibition was extreme with concentrations of 10 and 100 p.p.m.

Table 4.-Effect of 2,4-D on germination of Lehmann lovegrass.

Temperature	2,4-D concentration (p.p.m.)					
	0.00	0.01	0.1	1.0	10.0	100.0
Degrees F.	Percent germination					
60	58	57	57	56	34	10
70	56	55	51	54	29	10
80	22	21	21	17	13	0
90	17	16	14	14	9	
100	8	8	6	4	0	

Sulphuric Acid

Lehmann lovegrass seed treated with sulphuric acid showed a lower rate of germination in all cases than untreated seed (table 5). A definite correlation was noted between germination rate and the length of time the seed was treated. The greater the time of treatment the lower the germination. No germination was obtained at the higher temperatures (90° and 100°). However, this effect may not be due entirely to the acid treatment, as even untreated seed germinated relatively poorly at these temperatures.

Table 5.-Effect of sulphuric-acid scarification on germination of Lehmann lovegrass.

Temperature	Length of H_2SO_4 treatment (minutes)			
	None	15	30	60
Degrees F.	Percent germination			
60	58	41	33	26
70	56	54	51	37
80	22		19	17
90	17		0	0
100	8		0	0

Prechilling

Prechilling of Lehmann lovegrass resulted in satisfactory germination only at 90° (table 6). Germination of untreated seed was low (17 percent) and only slightly lower after chilling (15 percent when chilled for 15 days and 12 percent when chilled for 30 days).

Table 6.-Effect of prechilling on germination of Lehmann lovegrass.

Temperature	Length of prechilling treatment (days)		
	None	15	30
Degrees F.	Percent germination		
80	22		23
90	17	15	12
100	8	6	8

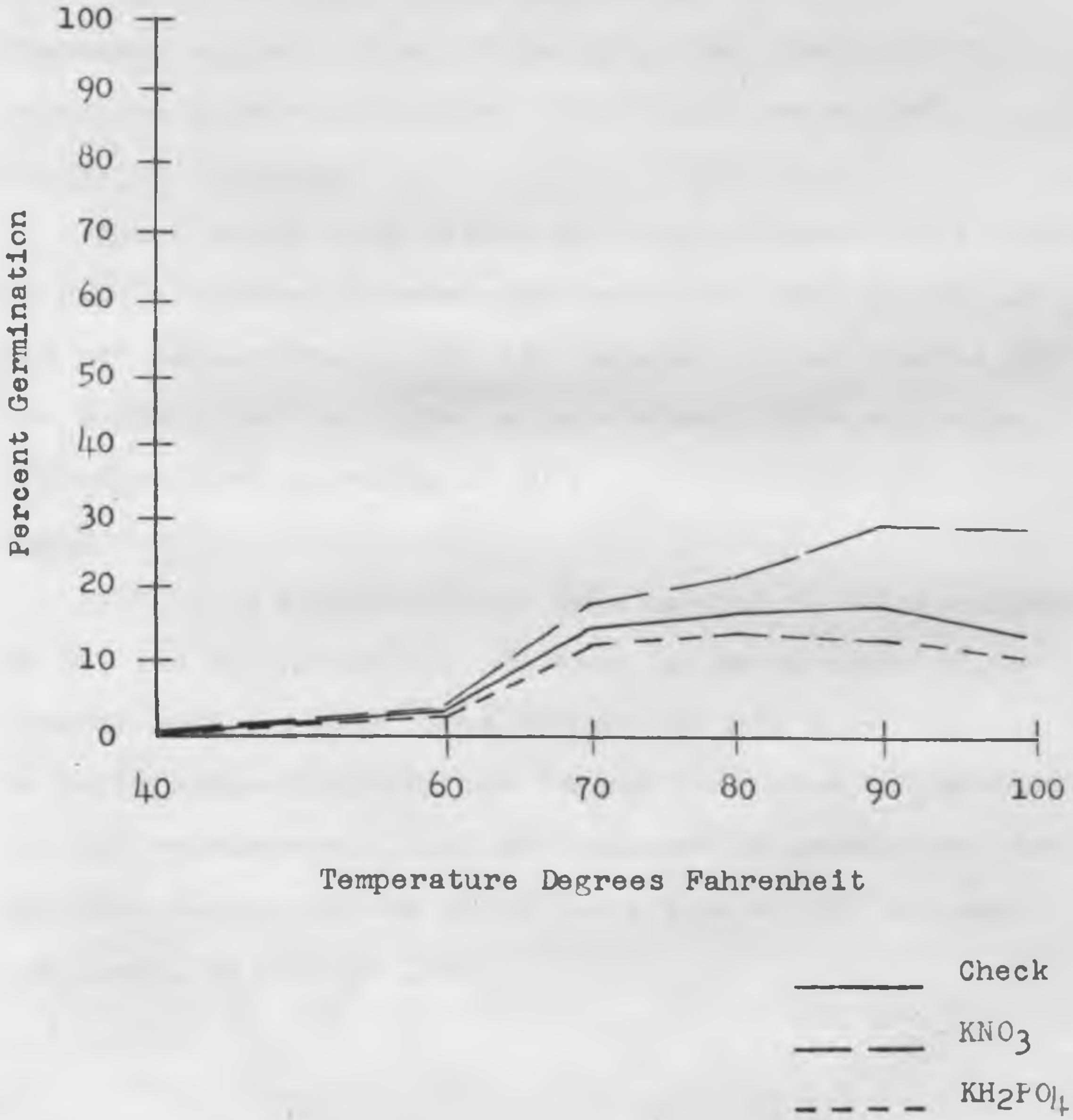
ROTHROCK GRAMA

Temperature

Rothrock grama had a low germination rate at all temperatures (fig. 3). No seed germinated at 40° and only three percent at 60°. At 70° there was a definite increase up to 15 percent. A further slight increase occurred at 80° and the maximum of 18 percent was reached at 90°.

Sixteen percent germination at alternating temperatures of 70° and 100° was only two percent lower than the 18 percent obtained at the optimum constant temperature.

Fig. 3-Effect of potassium nitrate and potassium phosphate at different temperatures on germination of Rothrock grama.



Potassium Nitrate

Potassium nitrate had no measurable effect at temperatures of 40° and 60° (fig. 3). It did, however appear to increase germination at all higher temperatures until a constant maximum was reached at 90° and 100°. It is of interest to note that while germination of untreated seed decreased slightly from 90° to 100°, seed treated with potassium nitrate maintained its 90° maximum at 100°.

Potassium Phosphate

There was no appreciable difference between seed treated with potassium phosphate and untreated seed at the 40° and 60° temperatures (fig. 3). Germination of treated seed was below normal at higher temperatures. This retarding effect reached a maximum at 90°.

2,4-D

All 2,4-D concentrations were harmful to Rothrock grama at 60° and 90° (table 7). However, as germination of untreated seed was only three percent at 60°, 2,4-D may not be fully responsible for the further reduction in germination at that temperature. A slight increase in germination occurred with concentrations below 1.0 p.p.m. at 70° and with .01 p.p.m. at 80° and 100°.

Table 7.-Effect of 2,4-D on germination of Rothrock grama.

Temperature	2,4-D concentration (p.p.m.)					
	0.00	0.01	0.1	1.0	10.0	100.0
Degrees F.	Percent germination					
60	3	2	0	0	0	0
70	15	16	16	15	6	0
80	17	19	16	13	10	0
90	18	13	11	15	4	
100	14	17	13	13	3	

Sulphuric Acid

Sulphuric-acid treatment increased germination of Rothrock grama. The effect was more noticeable at 60° than at higher temperatures (table 8). At all temperatures there was a positive correlation between length of treatment and percent of germination.

Table 8.-Effect of sulphuric-acid scarification on germination of Rothrock grama.

Temperature	Length of H_2SO_4 treatment (minutes)			
	None	15	30	60
Degrees F.	Percent germination			
60	3	13	17	22
70	15	17	19	27
80	17		18	24
90	18		21	29
100	14		18	23

Prechilling

Germination of Rothrock grama seed prechilled at 35° was significantly less than germination of untreated seed (table 9). This retarding effect was increased as the chilling period was lengthened.

Germination of seed prechilled for 30 days was only two percent at alternating temperatures of 70° and 100°, or 14 percent lower than the normal 16 percent germination.

Table 9.-Effect of prechilling on germination of Rothrock grama.

Temperature	Length of prechilling treatment (days)		
	None	15	30
Degrees F.	Percent germination		
80	17		7
90	18	7	3
100	14	5	4

SAND DROPSEED

Temperature

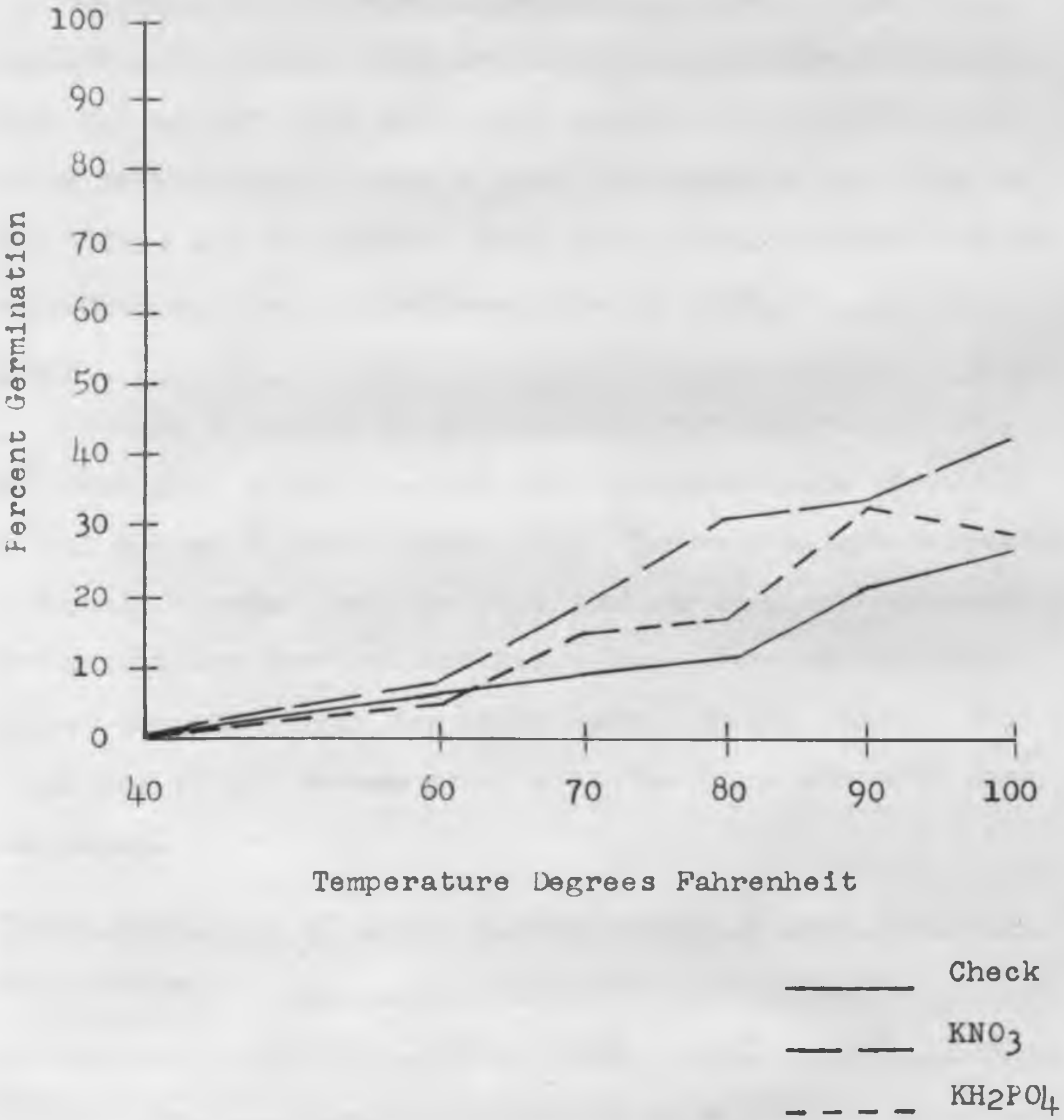
There was a constant positive correlation between increase in rate of germination and increase in temperature (fig. 4). Germination increased from 0 to 27 percent as temperatures were raised from 40° to 100°.

Germination at alternating temperatures was very low. The only germination that was attained occurred at alternating temperatures of 70° and 100°. The 13 percent germination attained at these temperatures was 14 percent lower than the maximum obtained at a constant temperature of 100°.

Potassium Nitrate

Potassium nitrate had no particular effect at the 40° and 60° temperatures, but it increased germination at all

Fig. 4-Effect of potassium nitrate and potassium phosphate at different temperatures on germination of sand-drop seed.



higher temperatures (fig. 4). Maximum germination of 42 percent occurred at 100°, an increase of 15 percent over untreated seed. An average increase of more than 12 percent occurred at all temperatures above 70°.

Potassium Phosphate

Germination of potassium-phosphate treated seed was significantly higher than untreated seed at temperatures from 70° to 90° (fig. 4). At a temperature of 100°, phosphate treated seed showed a lower germination rate than at 90°. This was in contrast with the nitrate treatment which continued to show an increase, even at 100°.

2,4-D

Slight increases in germination were secured at 70°, 80°, and 100° after treating with concentrations of 2,4-D of 0.1 p.p.m. or less (table 10). The very slight increases attained, however, and the fact that no increase occurred at 90° make these data of doubtful value. Germination with higher concentrations was below normal in all cases. This retarding effect became greater as the 2,4-D was more concentrated.

Table 10.-Effect of 2,4-D on germination of sand dropseed.

Temperature	2,4-D concentration (p.p.m.)					
	0.00	0.01	0.1	1.0	10.0	100.0
Degrees F.	Percent germination					
60	6	5	6	3	1	0
70	9	11	10	11	3	0
80	16	18	18	11	2	0
90	22	21	23	20	11	
100	27	29	29	14	8	

Sulphuric Acid

Treatment with sulphuric acid increased germination at all temperatures (table 11). There was a positive correlation between length of treatment and rate of germination.

Table 11.-Effect of sulphuric-acid scarification on germination of sand dropseed.

Temperature	Length of H_2SO_4 treatment (minutes)			
	None	15	30	60
Degrees F.	Percent germination			
60	6	8	9	14
70	9	33	39	47
80	16		32	41
90	22		53	62
100	27		36	48

Prechilling

Prechilling of sand dropseed appears to increase germination (table 12). Germination at 90° was increased from 22 to 28 percent by prechilling for 15 days. Prechilling for 30 days increased germination from 27 to 39 percent at 100°. At this temperature there was no difference in germination rate between seed prechilled for 15 days and the check.

Table 12.-Effect of prechilling on germination of sand dropseed.

Temperature	Length of prechilling treatment (days)		
	None	15	30
Degrees F.	Percent germination		
80	16		25
90	22	28	36
100	27	27	39

SIDEOATS GRAMA

Temperature

Highest germination of sideoats grama was obtained at a constant temperature of 80° (fig. 5). It is interesting to note that germination at 70° was six percent lower than germination at 60°.

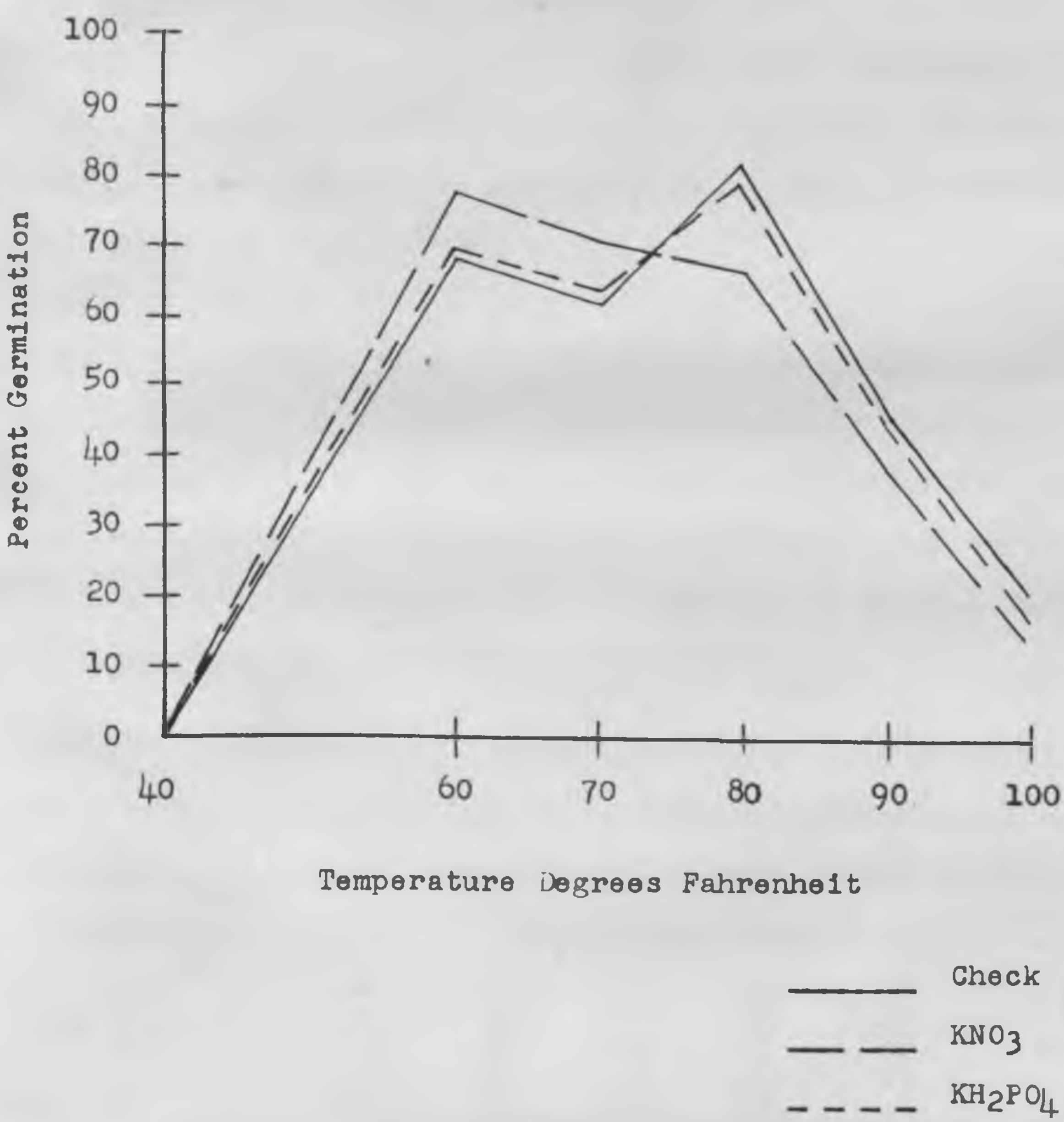
The results of this study indicate that high temperatures are detrimental to germination of sideoats grama. This is shown by comparing the 80° and 100° temperature tests. Germination at 80° was 60 percent higher than at 100°. Toole (17) observed somewhat similar results with the same species, finding maximum germination at temperatures of 75° and 85°. Jackson (12), on the other hand, obtained a high germination at 120°.

Germination of sideoats grama was low at all alternating temperatures. A maximum of 12 percent was reached at temperatures that alternated between 40° and 60°. This was in marked contrast with the maximum of 78 percent under a constant temperature of 60°.

Potassium Nitrate

There was no appreciable difference in germination rate between seed treated with potassium nitrate and untreated seed at a constant temperature of 40° (fig. 5). The nitrate treatment appeared to stimulate germination at 60° and 70°. Highest germination was obtained at 60° with 78 percent of

Fig. 5—Effect of potassium nitrate and potassium phosphate at different temperatures on germination of sideoats grama.



the seed germinating, an increase of ten percent over the check. Potassium nitrate lessened germination at temperatures of 80° and above.

Potassium Phosphate

Seed treated with potassium phosphate germinated at a rate only slightly higher than untreated seed at temperatures of 60° and 70° (fig. 5). An equally slight detrimental effect was noted at temperatures higher than 70°. However these difference from the check appear too small to ascribe any effect to the treatment.

2,4-D

At constant temperatures of 60° and 70° germination was six to eight percent higher with concentrations of .01 and 0.1 p.p.m. of 2,4-D than with untreated seed (table 13). At higher temperatures germination of seed treated with these concentrations was essentially the same as the check. Higher concentrations all retarded germination.

Table 13.-Effect of 2,4-D on germination of sideoats grama.

Temperature	2,4-D concentration (p.p.m.)					
	0.00	0.01	0.1	1.0	10.0	100.0
Degrees F.	Percent germination					
60	68	76	76	61	13	9
70	62	68	69	50	17	7
80	81	80	80	78	41	12
90	47	47	49	31	19	
100	21	22	21	17	0	

Sulphuric Acid

Sideoats grama seed treated with sulphuric acid had a consistently lower germination rate than untreated seed (table 14). The effect was more noticeable at 80° than at other temperatures. A definite negative correlation was observed in all cases between germination and length of treatment.

Table 14.-Effect of sulphuric-acid scarification on germination of sideoats grama.

Temperature	Length of H_2SO_4 treatment (minutes)			
	None	15	30	60
Degrees F.	Percent germination			
60	68	30	27	21
70	62	28	26	21
80	81		25	23
90	47		40	34
100	21		16	11

Prechilling

Prechilled sideoats grama seed had a higher germination rate at 90° and 100° than untreated seed (table 15). The increase in germination was directly proportional to length of the chilling period. As germination of untreated seed decreased at temperatures above 80°, it might be concluded that prechilling sideoats grama seed partially overcomes the inhibiting effect of high temperatures.

Table 15.-Effect of prechilling on germination of sideoats grama.

Temperature	Length of prechilling treatment (days)		
	None	15	30
Degrees F.	Percent germination		
80	81		80
90	47	59	76
100	21	36	48

TURKESTAN BLUESTEM

Temperature

Germination of Turkestan bluestem decreased with an increase in temperature (fig. 6). Maximum germination at constant temperatures was obtained at 70°, minimum at 100°. The 70° and 100° alternating temperature range gave three percent lower germination than the optimum constant temperature.

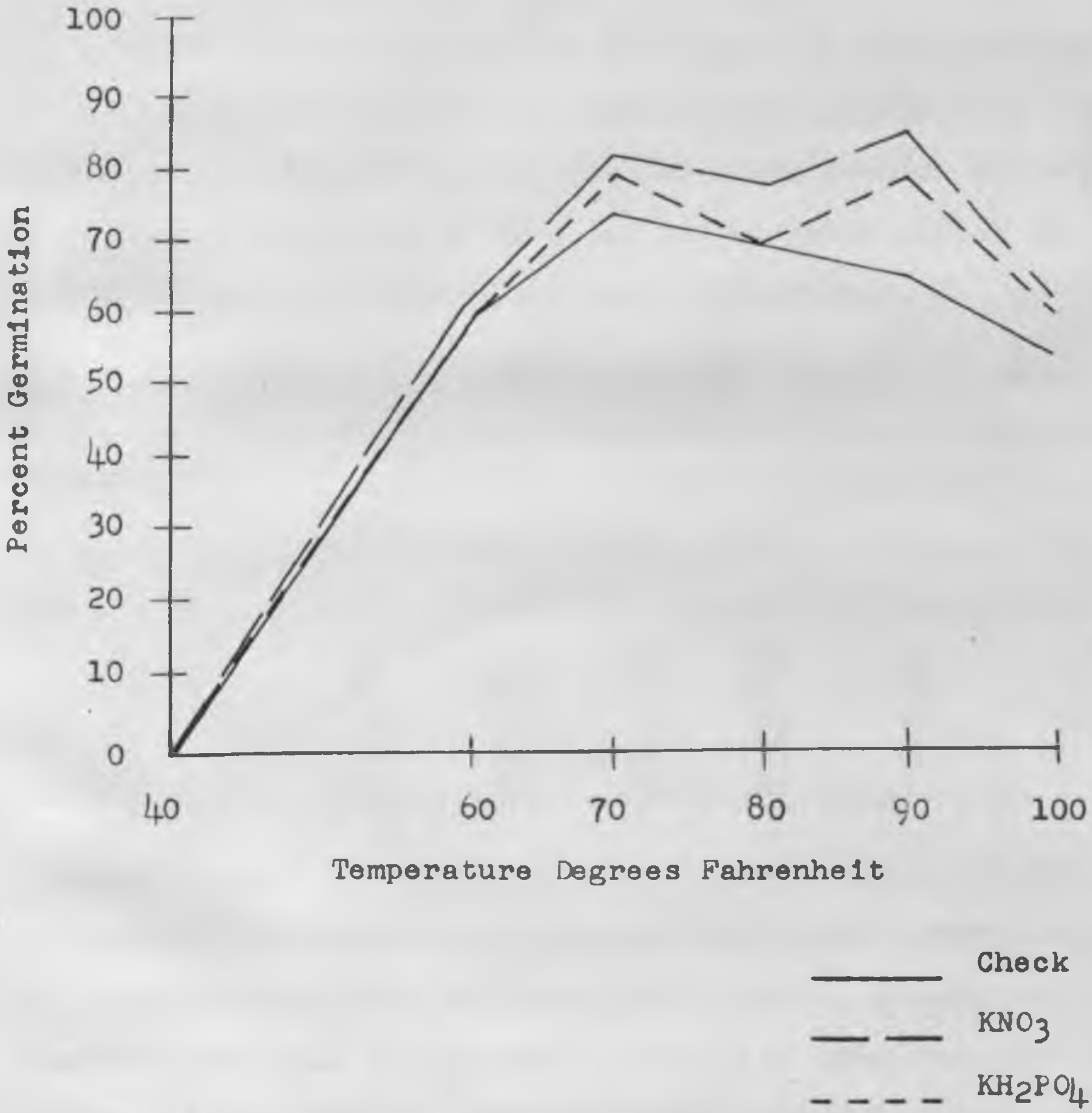
Potassium Nitrate

Maximum germination with potassium-nitrate treatment was obtained at 90°. Eighty-five percent of the seed germinated, an increase of 19 percent over the check at the same temperature (fig. 6). Germination of untreated seed, on the other hand, reached a maximum at 70° and decreased at higher temperatures. Germination of both treated and untreated seed decreased between 90° and 100°.

Potassium Phosphate

Turkestan bluestem treated with a 0.2 percent solution

Fig. 6-Effect of potassium nitrate and potassium phosphate at different temperatures on germination of Turkestan bluestem.



of potassium phosphate had an appreciably higher germination rate than untreated seed at 70°, 90°, and 100° (fig. 6). The rate at 80° was identical with that of the check. Germination at 90° reached a maximum of 79 percent as compared with 66 percent for the check.

2,4-D

Turkestan bluestem treated with 2,4-D at concentrations of 0.1 p.p.m. or less had a slightly higher germination rate at almost all temperatures (table 16). Germination decreased at concentrations greater than 0.1 p.p.m. This effect increased as the solution became more concentrated.

Table 16.-Effect of 2,4-D on germination of Turkestan bluestem.

Temperature	2,4-D concentration (p.p.m.)					
	0.00	0.01	0.1	1.0	10.0	100.0
Degrees F.	Percent germination					
60	58	58	59	49	42	18
70	71	72	72	64	56	15
80	70	69	71	69	51	17
90	66	68	69	65	22	
100	54	53	55	24	14	

Sulphuric Acid

Slight increases in germination were noted after chemical scarification with sulphuric acid, but in no case was the increase more than ten percent (table 17). Seed immersed in the acid for 60 minutes usually showed slightly higher germination than those treated for shorter periods. The only exception to this occurred at 70° where germination decreased slightly as time of treatment increased. These changes were so slight, however, that their significance is doubtful.

Table 17.-Effect of sulphuric-acid scarification on germination of Turkestan bluestem.

Temperature	Length of H_2SO_4 treatment (minutes)			
	None	15	30	60
Degrees F.	Percent germination			
60	58	56	56	61
70	71	76	75	74
80	70		67	72
90	66		70	73
100	54		58	64

Prechilling

At a constant temperature of 100°, 73 percent of prechilled seed germinated as compared with 54 percent of untreated seed (table 18). At other temperatures prechilled seed had a lower germination rate than unchilled seed. The longer the chilling period the lower the germination.

Table 18.-Effect of prechilling on germination of Turkestan bluestem.

Temperature	Length of prechilling treatment (days)		
	None	15	30
Degrees F.	Percent germination		
80	70		67
90	66	64	62
100	54	73	71

DISCUSSION

Lehmann lovegrass, sideoats grama, and Turkestan bluestem all showed a decrease in germination with an increase in temperature. Optimum temperatures for germination were in the 60° to 80° range. These species would probably germinate best when seeded during the fall, winter or spring. This observation should not be considered a recommendation against seeding these species during the summer months, as other factors may be of more importance in seedling establishment than temperature.

Rothrock grama, bush muhly and sand dropseed germinated best in the 90° to 100° range. This seems to indicate that these species are summer germinators.

Germination at alternating temperatures was noticeably lower than at constant temperatures. The specific reason for this reduction is unknown. It seems likely that a fairly narrow range of temperatures is essential to optimum germination of these grasses, and that inhibition came from undue fluctuation beyond this range.

Normal germination of Lehmann lovegrass decreased rapidly at temperatures above 70°. Both nitrate and phosphate treatments enabled Lehmann lovegrass to germinate at essentially the maximum for untreated seed at a temperature increase of 10° above that at which maximum germination of untreated seed was reached. This should be of special interest to reseeding technicians in the Southwest, where high temperatures usually prevail at the time of optimum moisture for seed germination.

Treatment with 2,4-D did not significantly increase the rate of germination of any species. Not only was there a lack of any beneficial stimulation, but concentrations of 10 and 100 p.p.m. had a retarding effect upon germination of every species. This and other experiments (10, 14) indicate that 2,4-D may have some slight stimulating effect if used in extremely low concentrations, but that larger concentrations are definitely harmful to germination of most grasses.

Resistance of the seed coat to moisture penetration offers a problem in germination of sand dropseed (12). This was substantiated in the present study by the marked increase in germination from sulphuric-acid treated caryopses of that species.

Sand dropseed and sideoats grama were the only two species that gave a higher rate of germination after being prechilled. Normal germination of sideoats grama at 80° was almost four times that at 100°. Prechilling gave no increase at 80°, but it more than doubled germination at 100°. From this it would seem that prechilling compensated for the higher, less favorable temperature.

Prechilling sand dropseed for 15 days had no effect on germination at 100°. Prechilling for 30 days increased germination 12 percent. It might be concluded, therefore, that the prechilling period should be lengthened as germination temperatures are raised.

SUMMARY

1. The effects of potassium nitrate, potassium phosphate, 2,4-D, sulphuric acid, and prechilling on germination of six range grasses were tested at various constant and alternating temperatures.
2. With untreated seed highest germination was obtained at temperatures of 90° for bush muhly; 60° for Lehmann lovegrass; 90° for Rothrock grama; 100° for sand dropseed; 80° for sideoats grama; and 70° for Turkestan bluestem.
3. Germination of Turkestan bluestem, Rothrock grama, Lehmann lovegrass, and sand dropseed was higher after treatment with potassium nitrate. Potassium nitrate was detrimental to germination of bush muhly and sideoats grama at higher temperatures.
4. Response of Lehmann lovegrass, sand dropseed, sideoats grama, and Turkestan bluestem to potassium-phosphate treatment was similar to potassium-nitrate treatment, but the response was not as great. Germination of phosphate treated bush muhly and Rothrock grama was lower than untreated seed at temperatures above 60°.
5. Germination of seed treated with weak concentrations of 2,4-D was essentially the same as that of untreated seed.

Concentrations of 10 and 100 p.p.m. were highly detrimental to germination of every species.

6. Sulphuric-acid scarification greatly increased germination of sand dropseed. Germination of Rothrock grama, Turkestan bluestem, and bush muhly was slightly higher following sulphuric-acid treatment for 60 minutes. Germination of Lehmann lovegrass and sideoats grama was considerably lower following acid treatment for even a short period.
7. Prechilling increased germination of sand dropseed and sideoats grama.

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