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Reed Canarygrass Germination at Five Seed Maturity Stages and Sixteen Seed Treatments

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REED CANARYGRASS GERMINATION AT FIVE SEED MATURITY STAGES AND SIXTEEN SEED TREATMENTS

by

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INTRODUCTION

Reed canarygrass (Phalaris arundinacea) has long been recognized as adapted to wetlands and those subject to periodic flooding. In Utah, Wilson (1955) estimates that 40 percent of the valley bottom land is flooded at least part of the year. Much of this land is very dry late in the summer. Forages such as Alsike clover tolerate flooding and some salt but do not perform well under drouth. Work by Bolton (1946) indicated that flooding for 49 days did not cause serious permanent damage to Reed canarygrass. The author has observed Reed canarygrass growing in a shallow reservoir which is flooded 90 days or more. Reed canarygrass is also one of the most drouth tolerant of the cool season grasses when grown on upland soils.

This grass could be used to advantage under such alternating conditions of flood and drouth if it were not difficult to establish under Utah conditions (Van Epps 1955). Spring plantings have usually failed and fall plantings, even though some good stands have been obtained, are not consistent enough to give assurance of adequate stands.

The seed of Reed canarygrass ripen from the top of the panicle downward and shatter soon after ripening. To prevent loss of seed it has been common practice to harvest before all of the seed are ripe. This results in immature seed and green material being threshed with the seed. This condition and the resulting heating in storage may be part of the cause of poor stands. Schoth (1929) states that seed

germinate slowly and may take 30 to 40 days to emerge under field conditions. Because of these and possibly other factors germination varies from 20 to 90 percent.

This thesis reports a series of experiments designed to determine whether or not the germination of Reed canarygrass can be improved or hastened through seed treatment.

REVIEW OF LITERATURE

Personal correspondence with men in areas where Reed canarygrass is grown has shown a number of people who consider the grass easy to establish (Ross 1954, Peterson 1954, Whitt 1954) and a number who consider it difficult to establish (Vary 1950, Harrison 1951, Hawk 1954). Van Epps (1955) reported difficulty in Utah on organic soils, but obtained good results with late fall planting in furrows, whereas spring plantings failed.

There has been little work on the problem of establishment of Reed canarygrass as establishment studies usually cover several crops or groups of crops. There have been a number of germination studies such as those reported by Morris (1938) and Colbry (1953) who studied the germination of untreated Reed canarygrass seed. Morris studied hulless seed over a period of 4 years and concluded that they were of little value for seeding because of low germination (0 to 30 percent) and susceptibility to mold injury during the test period. Colbry studied variations of standard germination testing procedure and found constant temperature and germination in semi-darkness detrimental. Prechilling at 10 degrees centigrade, dry and moist, had no effect on percent germination. Moistening the substrate with a .2 percent KNO_3 solution was beneficial to all ages of seed. Griffith and Harrison (1954) found harvesting of seed in the field should be done when 40 to 50 percent of the seed are brown. Immature seed and green material in combine harvested seed caused heating and subsequent

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damage to germination. They reported that Arasan mixed with freshly harvested seed reduced mold development without reducing germination.

Burton (1939) and Plummer and Frischknecht (1952) reported increased germination of Bahia and Indian Ricegrass respectively by treatment with concentrated sulfuric acid. Plummer and Frischknecht used degree of seed etching rather than a time limit in the acid.

Anderson et al (1953) used alcohol and acetone treatment of okra seed to increase both percent germination and speed of germination.

Barton and Crocker (1929) improved germination of flower seed by storing them at temperatures varying from 33 to 50 degrees Fahrenheit for 4 days to 3 weeks. They found that pretreatment of seed must be adapted to the species of seed involved and even to the lot involved. Presoaking in water at various temperatures was suggested to increase the permeability of seed coats.

PROCEDURE

Collection of seed

During the summer of 1954, 90 to 100 panicles from separate Reed canarygrass plants growing along roadsides and canal banks in North Logan, Cache County, Utah, were staked and labeled as to date and stage of anthesis. These plants were checked daily and notes taken as anthesis progressed from prebloom to fully ripe seed. Length of time from full bloom to the various stages of ripeness of seed was considered the most important in relation to seed maturity and time of harvesting.

As the seed ripened they were collected and dried. Since maturity began at the top of the panicle it was easy to designate a panicle as "green" when only a few florets at the tip of the panicle were turning brown. In like manner panicles were collected which had brown seed one-fourth, one-half, three-fourths, and all the way down the panicle. This provided seed at 5 maturity stages. These seed were dried in paper bags labeled with date collected and maturity stage. After drying they were threshed by hand and cleaned, using a McGill aspirator set at .75 wind, rheostat at 65 volts and feed notch 2. They were then recleaned at settings .8 wind, rheostat at 80 volts and feed notch 2.

All seed from each maturity stage were then placed in a single container, mixed thoroughly, and stored in glass jars with a small amount of paradichlorobenzene chrystals to prevent weevil infestation. Gram weight samples were taken and counted. Also the number of seeds

per panicle was computed at the various maturity stages with the results shown in table 3.

Germination of collected seed

Four replications of 16 seed treatments at 5 maturity stages and 2 germination temperatures were planned. Replications were started on December 24, 1954, January 15, February 6, and March 18, 1955.

Before each replication was started the seed from each maturity stage was divided and subdivided from the whole sample until there were only enough seed for that replication with a margin on the excess side to allow for loss of seed during handling. Just before treatment of the seed was begun these subsamples were again divided into 16 divisions for each maturity and placed in small vials. These vials (80 in all as obtained from 5 maturities times 16 treatments) had been previously supplied with an identifying label which designated the treatment to be received and the maturity stage. (Example: "1-2" on the tag indicated that that particular vial of seed was to receive treatment number 1 and was seed from maturity stage number 2, or one-fourth ripe.) There were approximately 300 seed in each vial.

Seed treatments used were as follows:

Treatment number 1. Check.

Seed were untreated.

Treatment number 2. Alternating - below freezing to room temperature.

The seed were placed in a refrigerated box at -2 degrees centigrade for 16 hours at night and removed to room temperature of 24 degrees centigrade during 8 hours of day. This was repeated daily for 2 weeks.

Treatment number 3. Alternating - -10 degrees centigrade to +10 degrees centigrade.

The seed were placed in a refrigerated box at -10 degrees centigrade for 16 hours at night and placed in a refrigerated box at +10 degrees centigrade for 8 hours during the day. This was repeated daily for 2 weeks prior to the beginning of each replication.

Treatment number 4. Deep freeze.

The seed were placed in a food freezer at -18 degrees centigrade for 2 weeks prior to the beginning of each replication.

Treatment number 5. Preheating dry.

The seed were placed in an oven at 32 degrees centigrade and left in the oven for 3 hours.

Treatment number 6. Preheating dry.

The seed were placed in an oven at 38 degrees centigrade and left for 2 hours.

Treatment number 7. Preheating dry.

The seed were placed in an oven at 43 degrees centigrade for 1 hour.

Treatment number 8. Plus 2 degrees centigrade.

The seed were placed in a refrigerated box at +2 degrees centigrade for 2 weeks.

Treatment number 9. Eight degrees centigrade.

The seed were placed in a refrigerated room at 8 degrees centigrade for 2 weeks.

Treatment number 10. Lemma and palea removed.

The seeds were rubbed between thumb and forefinger until the lemma and palea were removed. Care was excercised to prevent rubbing

of the caryopses. The lemma and palea were blown from the caryopses and the latter returned to the vial.

The remaining vials were treated in like manner.

Treatment number 11. Acid scarification.

The seed from each vial to be treated were placed in a perforated gouch crucible with holes in the bottom small enough to prevent seed from dropping through but large enough to allow quick drainage of liquid. The gouch was then placed in a beaker containing enough concentrated H_2SO_4 at room temperature to cover all seed. The seed were stirred to insure contact with the acid. At the end of 3 mimutes the gouch was removed from the beaker, allowed to drain for a few seconds, and then held under running water for at least 3 minutes to wash off all acid. The seed were then placed on a blotter, allowed to dry, and returned to the original vial.

Treatment number 12. Sandpaper scarification.

The seed to be given this treatment were poured from the vial onto a block of wood which had a sheet of number 6-0 sandpaper on the upper surface. Another block of wood with the same grade of sandpaper on the lower surface was then placed on top of the seed and rubbed back and forth 3 or 4 times. Very little pressure was exerted and an attempt was made to scratch the seed only. The seed were then returned to the vial.

Treatment number 13. Moist treatment at 32 degrees centigrade.

The seed to be treated were poured into a test tube and 5 to 10 cubic centimeters of water at 32 degrees centigrade was added. The 5 test tubes were then placed in a water bath at 32 degrees centigrade. The seed were stirred to be sure that all seed were covered with

water. At the end of 30 minutes the water was drained from the seed and the seed were placed on blotters to dry. After drying, the seed were returned to the original vials.

Treatment number 14. Moist treatment at 38 degrees centigrade.

The seed from the 5 maturity stages were treated the same as treatment number 13 except that the temperature of the water was 38 degrees centigrade and the time of treatment was 20 minutes.

Treatment number 15. Moist treatment at 43 degrees centigrade.

The method of treatment was again the same as treatment number 13, except the temperature of the water was 43 degrees centigrade and the time of treatment was 10 minutes.

Treatment number 16. Arasan.

An amount of Arasan weighing one-half of 1 percent of the weight of seed to be treated was added to each vial and thoroughly mixed with the seed.

Treatments requiring 2 weeks were carried out 2 weeks before germination trials were started, while treatments not requiring 2 weeks were made within the 2 days preceding germination. After treatment the vials of seed were held at room temperature.

Standard germination procedure was used as outlined in Agriculture Handbook 30, (Testing Agricultural and Vegetable Seed, United States Department of Agriculture, 1952). Deviations from the standard procedure were the pretreatments and one-half of each replication which was germinated at alternating temperatures of 15 to 25 degrees centigrade. Light was supplied by a 200 watt bulb suspended 4 feet above the Manglesdorf germinators.

To reduce the incidence of fungus during the germination period of 3 weeks all petri dishes were thoroughly washed and rinsed, then sterilized in an oven at 150 degrees centigrade for 1 hour. The blotters were autoclaved for 20 minutes at 17 pounds pressure. All utensils and forceps were exposed to ultraviolet light for one-half hour.

Two dishes of 100 seeds each were counted from each vial to make 2 sets of 80 petri dishes. Each set was randomized in a separate Manglesdorf germinator, one of which was set for the standard temperature of 20 to 30 degrees centigrade alternation and the other at 15 to 25 degrees centigrade.

Preliminary counts were made on the fifth, seventh, tenth, fourteenth, and eighteenth days with the final count on the twenty-first day. Normal and abnormal seedlings were recorded at each count and removed from the petri dishes. Any unusual conditions were recorded.

This procedure was repeated for all 4 replications.

Comparison of various sources of seed.

Seed from various sources were obtained as shown in table 1 and germinated along with the 5 maturity stages of locally collected seed. Standard germination procedure was used as outlined in the official seed testing rules.

Comparison of Arasan and sulfuric acid treatment on various sources of seed.

Samples of the various sources of seed were treated with Arasan at the rate of .5 percent by weight and similar samples were soaked in concentrated sulfuric acid at room temperature for 3 minutes. Except

Table 1. Sources of seed used

Utah Source No.	Origin	Received from
3	Superior seed from Corvalis, Oregon 1953 seed	J. Ritchie Cowan
4	Aebischer seed from Madison, Wisconsin 1952 seed	D. C. Smith
5	Williams Randolph from Madison, Wisconsin 1951 seed	D. C. Smith
6	Ioreed seed from Ames, Iowa 1953 seed	J. M. Scholl
7	Local seed "green"	Collected by author
8	Local seed one-fourth ripe	Collected by author
9	Local seed one-half ripe	Collected by author
10	Local seed three-fourths ripe	Collected by author
11	Local seed "ripe"	Collected by author
12	Commercial seed Minnesota-Wisconsin	Porter-Walton Seed Co.

for those treatments standard germination procedure was used. Four hundred seeds of each treatment were tested.

Soaking in alcohol and acetone

Separate samples of the three-fourths ripe lot of the locally collected seed were soaked in alcohol for 15 and 30 minutes and in acetone for 15 and 30 minutes. The lemma and palea were removed from a similar sample, and 200 seeds of each treatment were germinated according to the official seed testing rules.

RESULTS

Collection of seed

Florets of the Reed canarygrass plants observed progressed from full bloom to fully ripe seed in 12 days, and from full bloom to one-half ripe in 10 days. The number of days required to progress from full bloom to ripe seed varied from 10 to 14, probably due to differences in soil, moisture, temperature, and other factors. Table 2 gives the number of days from different bloom stages to different seed maturity stages.

Panicles which contained brown seed one-half way down yielded the most seed, followed by three-fourths ripe, one-fourth ripe, fully ripe, and the lowest which was green. Results are given in table 3.

Germination of local seed

Figure 1 shows the general seedling characteristics used to separate abnormal from normal seedlings. Note that normal seedlings have a vigorous appearance, the primary roots are long and fibrous, and the unbroken shoot has emerged from the coleoptile. The point at which the secondary root system develops is prominent.

The abnormal seedlings in figure 1 show a wide variety of differences. The seedling on the extreme left has a very short root and even though the shoot has emerged from the coleoptile it is shriveled. The second seedling from the left has no root at all and the shoot has not emerged from the coleoptile. The third seedling from the left started to grow in a normal manner and then stopped. Seedlings of this type would have an almost transparent coleoptile. The two

Table 2. Days required from stages of anthesis to different stages of seed maturity in Reed canarygrass[1]

Stage of anthesis	Stage of seed maturity		
	1/4 ripe	3/4 ripe	Ripe
Early bloom to	13 days	18 days	19 days
One-half bloom to	9 days	13 days	14 days
Full bloom to	7 days	11 days	12 days

1. The figures given are averages of observations of individual plants. There was a great deal of variation and these figures should be taken as an indication of maturation times and not literally.

Table 3. Yield of Reed canarygrass seed collected in North Logan area (1954)

Maturity stage	Total number of panicles collected	Total grams of seed threshed	Seeds[2] per panicle
Green seed	147	43.7	357
One-fourth ripe	296	97.0	393
One-half ripe	282	96.7	411
Three-fourths ripe	459	155.2	405
Ripe	2,068	645.1	375

2. Based on 1200 seeds per gram after cleaning by aspiration.

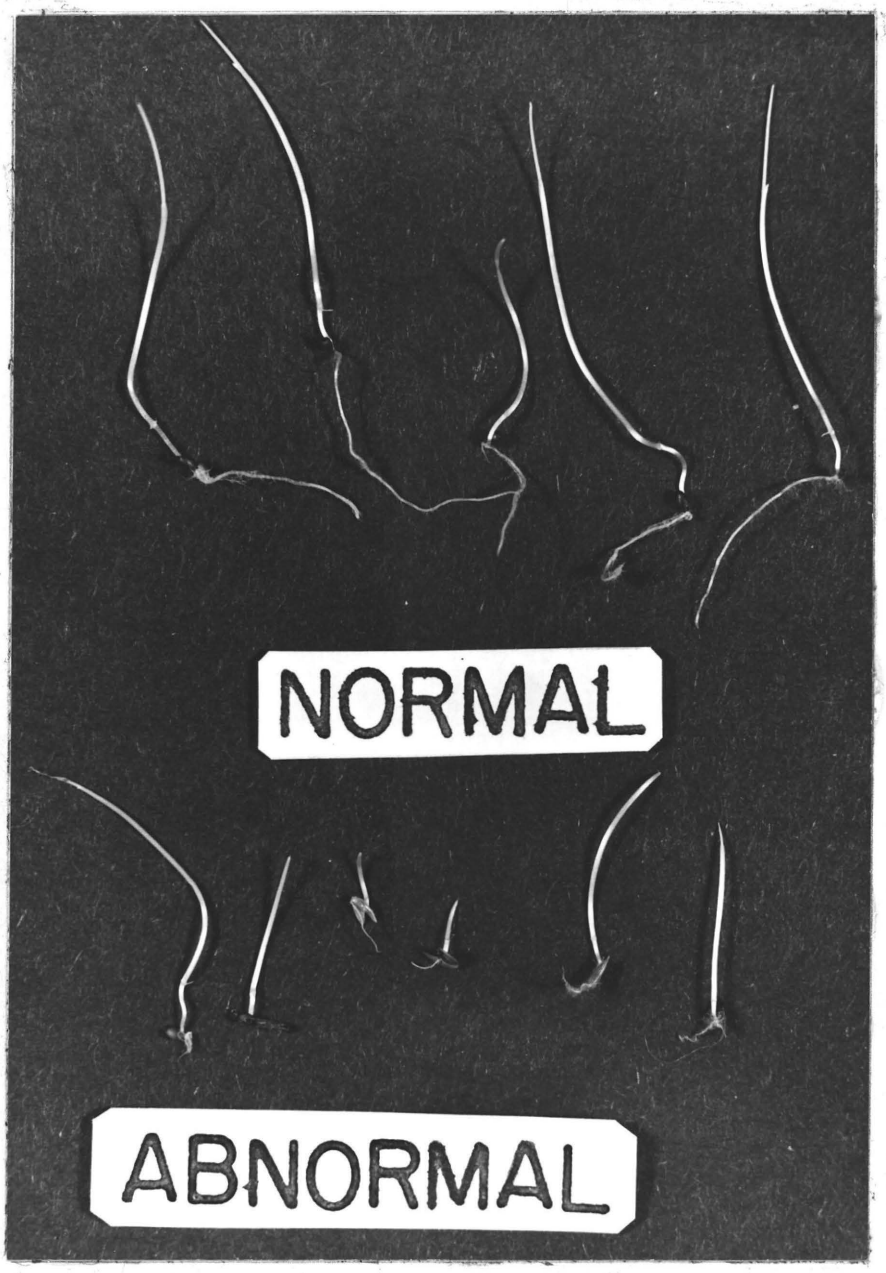

Figure 1. Characteristics of normal and abnormal seedlings of Reed canarygrass

seedlings on the right produced normal appearing shoots but almost no root. Some roots tended to be stubby and lacked root hairs.

Treatment means for the fifth day count of normal seedlings are ranked in table 4. Using Duncan's[3] (1955) Multiple Range for testing significant differences between means we find that treatment number 10 produced significantly higher normal seedlings than any other treatment.

When the lemma and palea were removed from seed (treatment number 10), 71 percent of the local Reed canarygrass seed germinated and produced normal seedlings in 5 days. Treatment with sulfuric acid (treatment number 11) gave an average normal germination of 44.4 percent in 5 days. The untreated check produced only 32.4 percent normal seedlings in 5 days.

Figure 2 shows the appearance of the check (treatment number 1) as compared to removing the lemma and palea (treatment number 10). Note the long, vigorous seedlings in treatment number 10.

Treating with sulfuric acid produced a significantly higher number of normal seedlings than any other treatment except removing the lemma and palea.

In figure 3 we can see the difference between the number of seedlings in the check and in the sulfuric acid treatment (treatment number 11). However, there is not the difference in vigor shown in figure 2.

Treatment with Arasan (treatment number 16) gave the lowest number of normal seedlings on the fifth day count. Figure 4 compares this treatment with the check.

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3. Wherever comparisons of individual treatments, maturities, and seed sources are made in this paper it will be by this method, and will be at the 5 percent level of significance.

Table 4. Treatment means listed according to rank
Fifth day normal seedlings

Treatment No.	Treatment	Fifth day percent normal seedlings
10	Lemma and palea removed	71.4
11	Concentrated sulfuric acid 3 minutes	44.4
5	Preheat dry 32° C. 3 hours	33.8
3	Alternating -10° to +10° C. 2 weeks	32.6
1	Check	32.4
4	Deep freeze -18° C. 2 weeks	29.7
2	Alternating freezing to room temperature 2 weeks	29.3
15	Water bath 43° C. 10 minutes	28.6
8	2° C. 2 weeks	28.4
6	Preheat dry 38° C. 2 hours	27.6
12	Sandpaper scarification	27.4
7	Preheat dry 43° C. 1 hour	27.2
9	8° C. 2 weeks	26.5
14	Water bath 38° C. 20 minutes	25.3
13	Water bath 32° C. 30 minutes	24.8
16	Arasan	20.8
	$\bar{X}$	31.9
	F value for treatment	31.6**
	L.S.D. (.05 level)	5.79
	L.S.D. (.01 level)	7.64
	C.V. percent	42.0

** Significant at 1 percent level

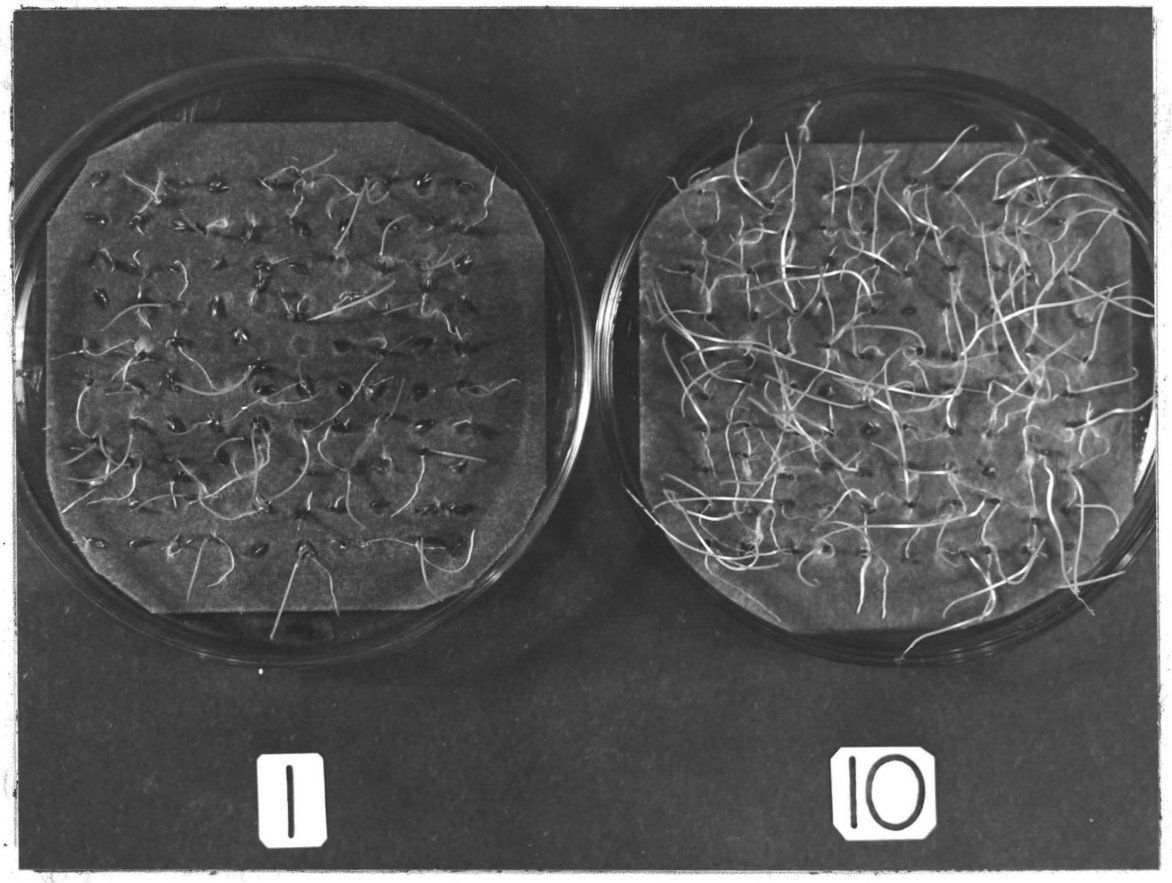

Figure 2. Comparison of check on left with treatment number 10 (lemma and palea removed)
Fifth day

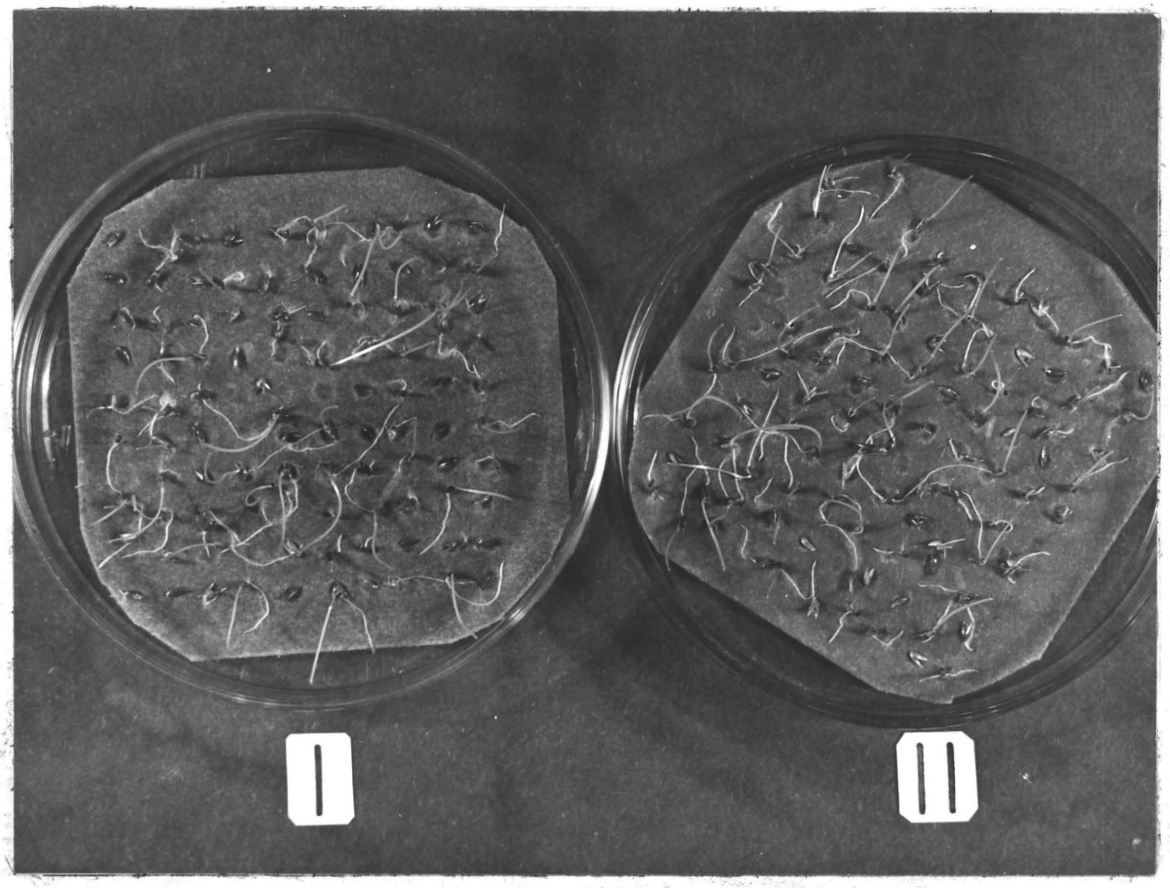

Figure 3. Comparison of check on left with treatment number 11 (concentrated sulfuric acid) Fifth day

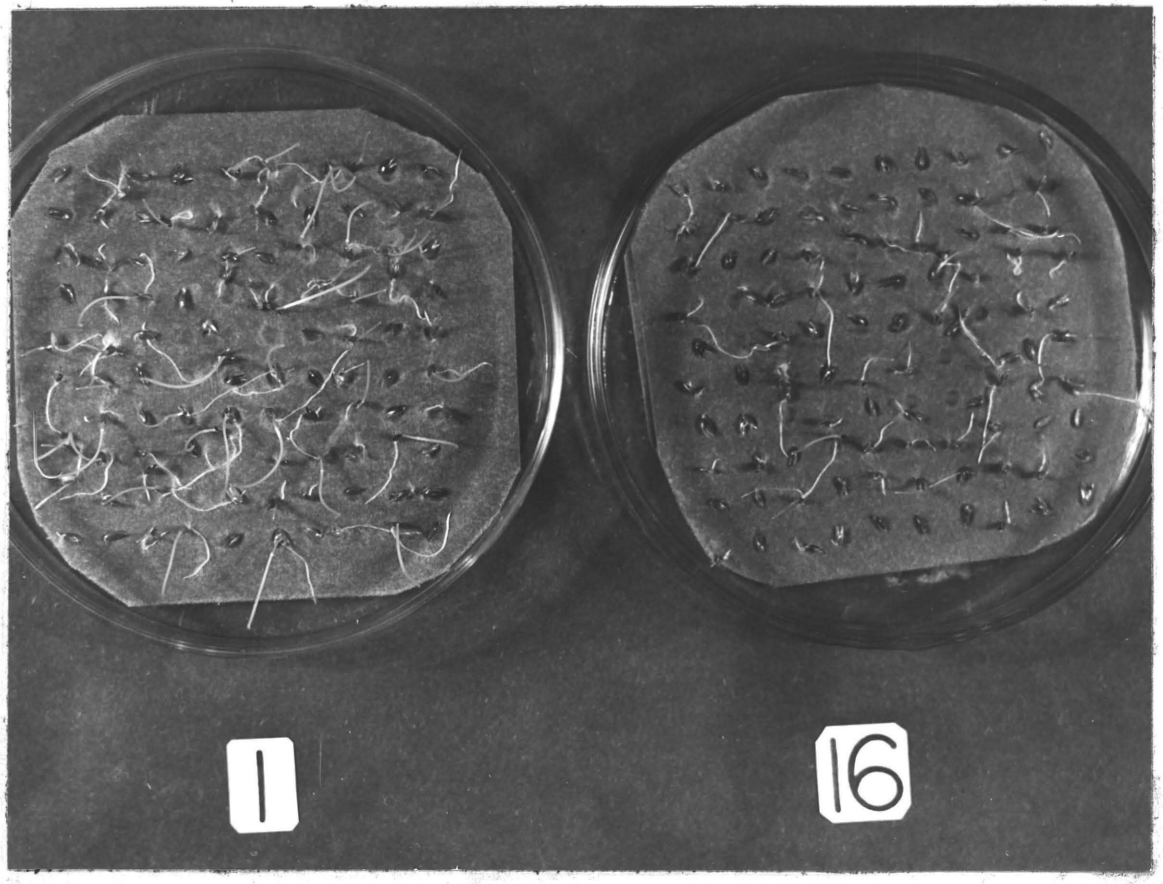

Figure 4. Comparison of check on left with treatment number 16 (Arasan)
Fifth day

Treatment number 12 (sandpaper scarification) was not significantly different from the check, but the difference in germination should be noted. Bacterial and fungal action accounted for most of the lack of germination. Figure 5 shows a comparison of the 2 treatments. The white glossy appearance of the check in this photograph is due to light reflecting from moisture on the blotter.

A majority of the treatments had no effect on the number of normal seedlings produced by the fifth day.

Seeds which were three-fourths ripe produced the highest number of normal seedlings of the maturity stages (average 37.2 percent). Green seed produced 24.5 percent. The one-fourth, one-half, and three-fourths ripe seed were not statistically different, but were significantly higher than the green and fully ripe seed. Average percent normal seedlings for each maturity stage at the fifth day count are shown in table 5.

The analysis of variance for fifth day normal seedlings is shown in table 6. Note that both treatments and maturity produced significantly different results but the interaction did not. Germination temperatures produced significantly different results (5 percent level). The mean of the 15 to 25 degrees centigrade alternation was 41 percent normal seedlings while the standard temperature (20 to 30 degrees centigrade) mean was 22.8 percent on the fifth day.

The fifth day abnormal seedling count (table 7) showed the sandpaper scarification treatment was more detrimental than helpful. Nine and six-tenths percent of the seeds produced abnormal seedlings. The surprising thing is that treatment number 10, which was high in normal seedlings, was second high in abnormal seedlings produced. However,

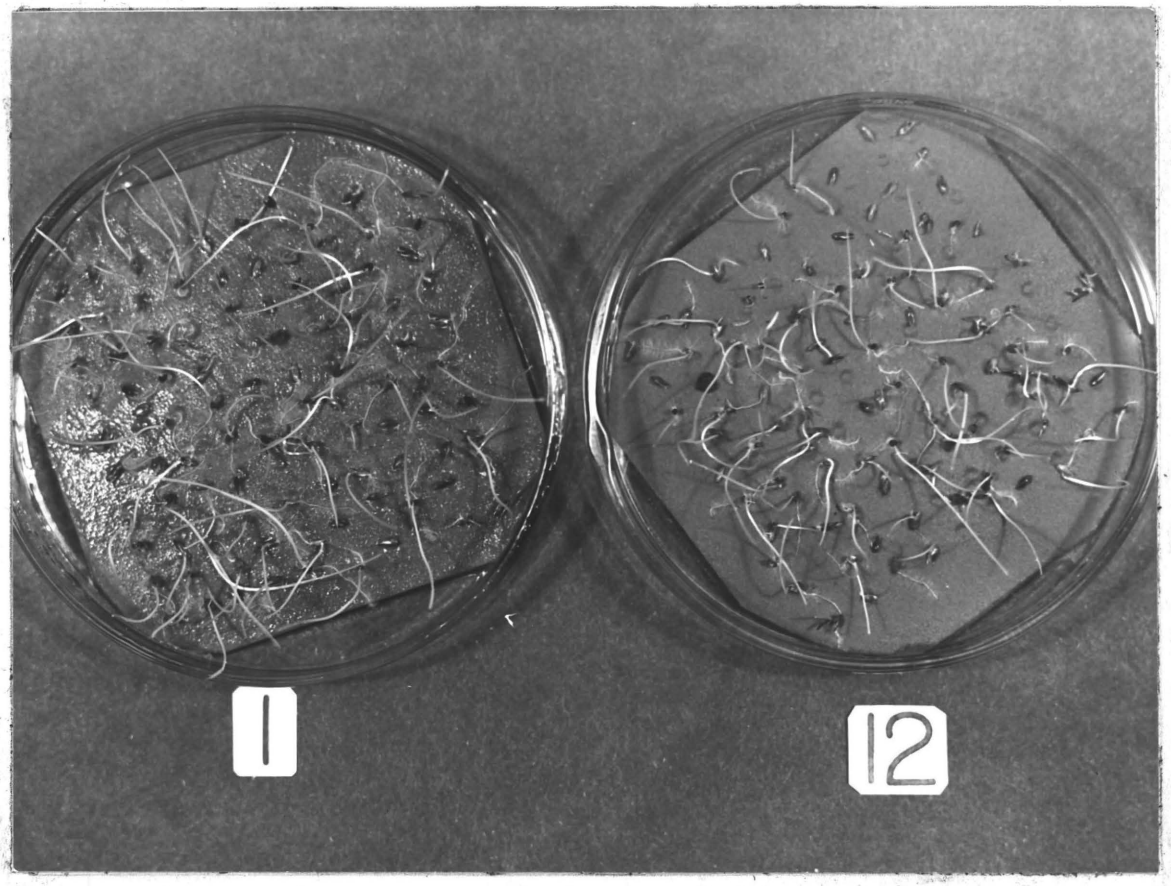

Figure 5. Comparison of check on left with treatment number 12 (sandpaper scarification)
Fifth day

Table 5. Means of maturity stages for germination of local seed

Maturity stage No.	Maturity stage No.	Fifth day			Total			Number of seeds affected by fungus
		percent normal seedlings	percent abnormal seedlings	percent seeds not germinated	percent normal seedlings	percent abnormal seedlings	percent seeds not germinated	
1	Green	24.5	4.6	67.7	67.1	23.4	9.5	79
2	1/4 ripe	35.7	5.4	55.7	73.3	19.8	6.9	83
3	1/2 ripe	35.4	5.5	52.9	74.7	19.4	6.0	51
4	3/4 ripe	37.2	4.1	57.1	78.9	15.0	6.2	76
5	Ripe	26.5	3.8	65.0	74.0	16.8	9.4	62
X		[illegible]	[illegible]	[illegible]	[illegible]	18.9	7.4	
F value for maturity		25.42**	2.24	13.15**	11.31**	9.64**	5.96**	
L.S.D. (.05 level)		3.23	-	4.86	3.51	2.86	1.72	
L.S.D. (.01 level)		4.27	-	6.42	4.64	3.78	2.28	
C.V. percent		42.0	120.0	33.0	19.0	62.0	95.0	

** Significant at 1 percent level

Table 6. Analysis of variance of germination of local seed Fifth day normal seedlings

Source	D.F.	M.S.	F.
Total	639		
Replications	3	4,995.62	2.44
Temperature	1	52,707.60	25.76*
Replications x temperature	3	2,046.36	Error (a)
Treatment	15	5,501.00	31.60**
Maturity	4	4,424.39	25.42**
Treatment x maturity	60	153.66	
Temperature x treatment	15	166.28	
Temperature x maturity	4	340.38	1.96
Temperature x treatment x maturity	60	169.95	
Error (b)	474	174.06	

* Significant at 5 percent level
** Significant at 1 percent level

C.V. = 42 percent

Table 7. Treatment means for germination of local seed

Treatment No.	Treatment	Total percent normal seedlings	Fifth day percent abnormal seedlings	Fifth day percent seeds not germinated	Total percent abnormal seedlings	Total percent seeds not germinated	Number of seeds affected by fungus
1	Check	74.8	4.1	61.1	18.8	6.4	2
2	Alternating freezing to room temperature 2 weeks	69.5	4.4	58.8	21.2	9.3	16
3	Alternating -10 to +10° C. 2 weeks	74.8	4.0	63.4	17.7	7.5	17
4	Deep freeze -18° C. 2 weeks	76.5	3.0	64.9	16.4	7.2	8
5	Preheat dry 32° C. 3 hours	77.9	4.3	59.4	16.3	5.8	11
6	Preheat dry 38° C. 2 hours	77.4	3.4	66.6	15.6	7.1	2
7	Preheat dry 43° C. 1 hour	77.8	3.0	64.8	16.0	6.3	3
8	2° C. 2 weeks	76.7	3.7	65.5	15.7	7.7	18
9	8° C. 2 weeks	76.5	3.7	69.9	17.3	6.3	9
10	Lemma and palea removed	85.8	8.6	20.1	11.8	2.4	12
11	Concentrated sulfuric acid 3 minutes	78.4	6.1	47.0	17.1	4.5	1
12	Sandpaper scarification	57.6	9.6	63.1	25.0	21.4	242
13	Water bath 32° C. 30 minutes	75.4	3.2	62.0	18.9	7.7	4
14	Water bath 38° C. 20 minutes	73.9	2.8	61.9	19.9	6.2	2
15	Water bath 43° C. 10 minutes	77.0	3.7	60.3	17.5	5.5	3
16	Arasan	54.1	7.7	66.5	39.0	7.0	1
	$\bar{X}$	73.7	4.7	59.7	18.9	7.4	
	F value for treatment	13.77**	5.64**	13.94**	10.77**	13.28**	
	L.S.D. (.05 level)	6.29	2.46	8.69	5.13	3.08	
	L.S.D. (.01 level)	8.31	3.25	11.48	6.78	4.07	
	C.V. percent	19.0	120.0	33.0	62.0	95.0	

** Significant at 1 percent level

this is not as important as it may seem. Nearly all abnormal seedlings from this treatment were in the third replication and were abnormal in that the roots were not as long in proportion to the shoots as they are normally. Even so, the seedlings were more vigorous than those of any other treatment. Apparently something on the blotters or some root inhibiting substance was introduced to that treatment and replication alone, although a survey of the process did not reveal how. In the first, second, and fourth replications there were 70 abnormal seedlings which represents 1 3/4 percent of the seeds of treatment number 10. This leaves 6.85 percent for the third replication. Treatment numbers 12 (sandpaper scarification), 10 (lemma and palea removed), and 16 (Arasan) were significantly higher in abnormal seedlings produced than the check. None of the treatments were significantly lower.

In the analysis of variance only the treatments are significantly different as indicated by the F value (5.64**) for treatment.

Seeds treated with Arasan developed short stubby roots but there was no fungal development. Since fungus was not a factor in any treatment except sandpaper scarification, Arasan was not of apparent value. Sandpaper scarification injured the seeds and thus made them easy prey for bacteria and fungi.

The analysis of variance for the fifth day count of seeds not germinated (table 8) follows the pattern of the fifth day normal count. Treatment and maturity are highly significant and temperatures are significantly different at the 5 percent level. Treatment numbers 10 and 11 (lemma and palea removed and concentrated sulfuric acid treatment) were low with means of 20.1 percent and 47 percent respectively. All other treatment means ranged from 58.8 percent to 69.9 percent

Table 8. Analysis of variance of germination of local seed
Fifth day seeds not germinated

Source	D.F.	M.S.	F.
Total	639		
Replications	3	2,166.40	1.46
Temperature	1	32,761.30	22.14*
Replications x temperature	3	1,479.75	Error (a)
Treatment	15	5,472.22	13.94**
Maturity	4	5,164.38	13.15**
Treatment x maturity	60	357.44	
Temperature x treatment	15	266.30	
Temperature x maturity	4	451.04	
Temperature x treatment x maturity	60	374.29	
Error (b)	474	392.65	

* Significant at 5 percent level
** Significant at 1 percent level

C.V. = 33 percent

(table 7). Maturity stages 2, 3, and 4 (one-fourth, one-half, and three-fourths ripe seed) were significantly lower (table 5) than maturity stages 5 and 1 (ripe and green seed).

The differences between treatment means for total normal seedlings narrowed down by the end of the germination period. Only treatment number 10 was significantly higher than the check in total normal seedlings, while Arasan and sandpaper scarification treatment means were significantly lower (table 7) than the check.

In the analysis of variance for total normal seedlings (table 9) temperature was not significantly different as in the fifth day normal seedlings. Treatment and maturity were significant at the 1 percent level. Maturity 4 (three-fourths ripe) produced 78.9 percent normal seedlings (table 5) which was significantly higher than the other 4 stages. Maturities 2, 3, and 5 were grouped together in the center and maturity 1 was significantly lower than all others.

For the total abnormal seedling count there was a reversal of the position of treatment number 10. Instead of being near the highest, it was the lowest at 11.8 percent, while Arasan treated seed produced 39.0 percent abnormal seedlings compared to 18.8 percent for the check (table 7).

In table 5 green seed show the highest percent abnormal seedlings (23.4 percent). The other maturity stages are grouped close together.

By examining the figures for total percent seeds not germinated we get an indication of relative viability or dormancy of seeds (table 7). Treatment number 10 was low with 2.4 percent followed by treatment number 11 with 4.5 percent. The highest percent not

Table 9. Analysis of variance of germination of local seed
Total normal seedlings

Source	D.F.	M.S.	F.
Total	639		
Replications	3	2,592.52	4.03
Temperature	1	2,665.06	4.14
Replications x temperature	3	643.39	Error (a)
Treatments	15	2,833.75	13.77**
Maturity	4	2,328.38	11.31**
Treatment x maturity	60	109.12	
Temperature x treatment	15	74.30	
Temperature x maturity	4	117.05	
Temperature x treatment x maturity	60	139.92	
Error (b)	474	205.82	

** Significant at 1 percent level

C.V. = 19 percent

germinated was from treatment number 12 (21.4 percent), while the untreated check had 6.4 percent not germinated.

For the maturity stages (table 5) the green and ripe seed were high with 9.5 and 8.4 percent seeds not germinated. The one-half ripe seed were low with 6.0 percent.

In all of the separate analyses of variance for the germination of local seed there was no significance due to the first or second order interactions of treatment, maturity, and temperature.

Reference was made earlier to the effect of fungus on germination. Table 7 shows the total number of seeds of each treatment affected by fungus. Of the 4000 seeds in each treatment all treatments except number 12 had less than 20 seeds affected by fungus, which would mean that less than .5 percent of the seeds were attacked by fungus. Treatment number 12 had 242 seeds or 6.0 percent affected by fungal and bacterial action.

Comparison of seed sources

The Aebischer seed from Wisconsin gave the highest percent normal seedlings on the fifth day (table 10), but fell below the percentage of the total normal seedlings of the one-fourth, one-half, three-fourths, and ripe local seed. The Superior seed were low in percent normal seedlings on the fifth day (12.7 percent). The Porter Walton commercial seed produced 18.0 percent normal seedlings by the fifth day and a final total of only 25.2 percent. Labeled germination of the commercial sample was 70 percent.

For the fifth day abnormal seedlings there was a significant difference between replications as well as between sources. The Aebischer seed produced 8.2 percent abnormal seedlings by the fifth

Table 10. Mean germination percentages for comparison of sources

Utah source No.	Source of seed	Fifth day			Total			Percent of seeds affected by fungus
		percent normal seedlings	percent abnormal seedlings	percent seeds not germinated	percent normal seedlings	percent abnormal seedlings	percent seeds not germinated	
3	Superior seed	12.7	5.8	81.5	35.2	17.8	47.0	14.0
4	Aebischer seed	57.8	8.2	34.0	70.2	12.3	17.5	5.2
5	Williams Randolph seed	22.2	2.5	75.2	30.5	7.7	61.8	47.5
6	Ioreed seed	26.5	3.0	70.5	40.0	10.2	49.8	28.5
7	Local seed "green"	17.2	4.8	78.0	63.2	23.3	13.5	0.0
8	Local seed 1/4 ripe	45.5	6.2	48.5	79.2	14.6	6.2	0.0
9	Local seed 1/2 ripe	37.5	4.2	58.2	78.5	10.7	10.8	0.0
10	Local seed 3/4 ripe	40.8	5.8	53.5	77.5	12.8	9.7	0.2
11	Local seed "ripe"	28.5	4.2	67.25	74.2	15.0	10.8	0.7
12	Porter Walton Seed Co. Commercial seed	18.0	2.2	79.8	25.2	5.0	69.8	60.0
	$\bar{X}$	30.68	4.7	64.65	57.38	12.95	29.7	
	F value for source	18.36**	2.5*	18.77**	44.43**	4.25**	58.85**	
	L.S.D. (.05 level)	9.72	3.42	10.48	9.57	7.11	9.28	
	L.S.D. (.01 level)	13.13	-	14.15	12.94	9.61	12.52	
	C.V. percent	21.8	50.0	11.0	12.0	39.0	21.5	

* Significant at 5 percent level
** Significant at 1 percent level

day and the Williams Randolph and Porter Walton seed (2.5 and 2.2 percent respectively) produced the lowest number of abnormal seedlings.

Superior and Porter Walton seed had the highest percent seed not germinated at the fifth day count (81.5 percent and 79.0 percent respectively). The Aebischer seed from Wisconsin were low with 34.0 percent.

The one-fourth, one-half, three-fourths, and ripe local seed and the Aebischer seed were not statistically different but were significantly higher than the Superior, Ioreed, and Porter Walton commercial seed on the total normal seedling count.

Williams Randolph and Porter Walton commercial seed were low in total abnormal seedlings but high in total seeds not germinated and percent seeds affected by fungus. The local green seed was higher in total abnormal seedlings than all other seed sources except Superior. All local seed maturities were lower in total seeds not germinated than all other seed sources except green and Aebischer seed which were not statistically different (table 10).

The F values for source of seed considering fifth day seeds not germinated, total normal seedlings, total abnormal seedlings, and total seeds not germinated show significance at the 1 percent level for source of seed (table 10).

Comparison of Arasan and concentrated sulfuric acid treatments on various sources of seed

The analyses of variance for this experiment show that the seven sources of seed used were significantly different at the 1 percent level both at the fifth day and total seedling counts for normal and abnormal seedlings and seeds not germinated.

The Aebischer seed from Iowa gave the highest percent normal seedlings on both the fifth day and total normal seedling counts (table 11). On the fifth day count it was statistically higher than any other seed source but on the total normal seedling count it was not significantly different from the one-half and three-fourths ripe local Reed canarygrass seed. Seed from the remaining sources used (table 11) were significantly lower than the 3 sources cited above for normal seedlings. It should be noted that the 3 sources which were high in normal seedlings were also high in abnormal seedlings on the fifth day count. The Williams Randolph seed from Iowa were low in percent abnormal seedlings but were high in percent seeds not germinated.

The two treatments, Arasan and concentrated sulfuric acid, were significantly different for the fifth day normal and seeds not germinated counts (1 percent level) and for the total seeds not germinated (5 percent level) (table 12). The average figures for the 2 treatments in table 12 show that the concentrated sulfuric acid treatment gave a higher percent normal seedlings on the fifth day count and a resulting lower seeds not germinated count.

The combination of treatment and source of seed had more effect on germination in this experiment than did treatment or seed source alone (table 13). The Aebischer seed treated with concentrated sulfuric acid gave a higher percent normal seedlings on the fifth day and for the total normal count than was produced by the average effect of the seed source. There was very little increase in normal seedlings after the fifth day count (82.5 percent on the fifth day and 84.8 percent total normal seedlings). The local Reed canarygrass seed

Table 11. Means for sources of seed for germination of various sources of seed treated with concentrated sulfuric acid and Arasan

Utah source No.	Source of seed	Fifth day			Total			Percent of seeds affected by fungus
		percent normal seedlings	percent abnormal seedlings	percent seeds not germinated	percent normal seedlings	percent abnormal seedlings	percent seeds not germinated	
4	Aebischer seed	66.3	7.9	25.8	74.5	10.4	15.1	0.0
9	Local seed 1/2 ripe	45.3	8.4	46.3	73.9	18.2	7.9	0.0
10	Local seed 3/4 ripe	38.5	7.5	54.0	72.1	19.6	8.3	0.2
6	Ioreed seed	28.0	4.1	67.9	43.5	13.0	43.5	12.1
5	Williams Randolph seed	14.6	1.9	83.5	20.6	7.3	72.1	40.4
3	Superior seed	12.5	3.2	84.3	32.2	19.0	48.8	7.8
12	Porter Walton Seed Co. Commercial seed	11.8	3.0	85.2	24.1	12.0	63.9	24.0
	$\bar{X}$	31.0	5.1	63.9	48.7	14.2	37.07	
	F value for source	67.49**	326.21**	68.74**	168.83**	9.99**	170.99**	
	L.S.D. (.05 level)	7.39	0.46	8.15	5.54	4.52	6.07	
	L.S.D. (.01 level)	10.14	0.6	11.17	7.6	6.19	8.32	
	C.V. percent	24.5	8.5	12.2	10.9	30.2	15.5	

** Significant at 1 percent level

Table 12. Means for the treatments used in the experiment involving the treatment of various sources of Reed canarygrass seed with concentrated sulfuric acid and Arasan

Treatment	Fifth day			Total		
	percent normal seedlings	percent abnormal seedlings	percent seeds not germinated	percent normal seedlings	percent abnormal seedlings	percent seeds not germinated
Concentrated sulfuric acid	36.4	5.2	58.4	48.3	13.3	38.4
Arasan	25.6	5.1	69.3	49.2	15.1	35.7
$\bar{X}$	31.0	5.1	63.9	48.7	14.2	37.0
F value for treatment	22.47**	-	18.07**	-	2.65	6.26**
L.S.D. (.05 level)	4.7	-	5.28	-	-	3.0
L.S.D. (.01 level)	6.4	-	7.19	-	-	-
C.V. percent	27.0	45.9	14.9	13.6	29.9	14.6

** Significant at 1 percent level

Table 13. Means for the interaction of treatment and source from the experiment involving Arasan and concentrated sulfuric acid treatment of various sources of seed[4]

Utah source No.	Source of seed	Treatment No.	Fifth day			Total			Percent of seeds affected by fungus
			percent normal seedlings	percent abnormal seedlings	percent seeds not germinated	percent normal seedlings	percent abnormal seedlings	percent seeds not germinated	
3	Superior seed	1	13.2	3.5	83.3	27.8	18.5	53.7	18.8
		2	11.8	3.0	85.2	36.5	19.5	43.7	4.5
4	Aebischer seed	1	82.5	4.5	13.0	84.8	5.2	10.0	0.0
		2	50.0	11.2	38.8	64.2	15.5	20.3	0.0
5	Williams Randolph seed	1	13.2	1.0	85.8	15.8	3.8	80.4	72.5
		2	16.0	2.8	81.2	25.5	10.8	63.7	8.2
6	Ioreed seed	1	25.2	4.0	70.8	38.2	12.0	49.8	19.5
		2	30.8	4.2	65.0	48.8	14.0	37.2	4.2
9	Local seed 1/2 ripe	1	59.2	10.8	30.0	77.0	20.0	3.0	0.0
		2	31.2	6.0	62.8	70.8	16.5	12.7	0.0
10	Local seed 3/4 ripe	1	47.2	9.5	43.3	70.0	20.2	9.8	0.5
		2	29.8	5.5	64.7	74.2	19.0	6.8	0.0
12	Porter Walton Seed Co. Commercial seed	1	13.5	3.2	83.2	24.2	13.5	62.3	37.8
		2	10.0	2.8	87.2	24.0	10.5	65.5	10.2
$\bar{X}$			31.0	5.1	63.9	48.7	14.2	37.07	
F value for source x treatment			6.58**	10.93**	5.33**	5.71**	3.16*	7.61**	
L.S.D. (.05 level)			12.44	3.43	14.02	9.8	6.03	7.94	
L.S.D. (.01 level)			16.92	4.67	19.07	13.33	-	10.81	
C.V. percent			27.0	45.9	14.9	13.6	29.9	14.6	

4. Treatment No. 1: Concentrated sulphuric acid. Treatment No. 2: Arasan

* Significant at 5 percent level
** Significant at 1 percent level

produced a significantly lower percent normal seedlings than the Aebischer by the fifth day but the difference was not significant at the final count. The combined effect of treatment and seed source did not change the relative position of the seed sources. The Aebischer seed and the two local seed lots were high while the Superior, Williams Randolph, and Porter Walton seed were low. The Ioreed seed fell between these 2 groups.

Arasan did not eliminate fungus from the seed lots which were badly affected in the earlier seed source experiment. The Arasan greatly reduced fungal incidence but did not give any appreciable increase in total normal seedlings. There were approximately 10 percent more normal seedlings in the Superior and Williams Randolph and Ioreed seed treated with Arasan than with sulfuric acid. The difference was significant in favor of Arasan with the Ioreed seed only. There was no difference in favor of the Arasan at the fifth day count.

Soaking seed in alcohol and acetone

Table 14 shows the average germination percentages of seed soaked in alcohol for 15 and 30 minutes, in acetone for 15 and 30 minutes, and of seed which had the lemma and palea removed. Note that germination was inhibited or at least slowed down by the 4 soaking treatments. The fifth day count yielded 10.5 percent normal seedlings or less for these 4 treatments. In each case the longer period of soaking gave a slight but not significant increase in percent normal seedlings. Note that there were essentially no abnormal seedlings on the fifth day count.

The raw data show that the majority of seeds germinated between the seventh and tenth days, which is approximately 5 days later than

Table 14. Means for the treatments of the experiment involving treatment of Reed canarygrass seed with alcohol and acetone

Treatment	Fifth day			Total		
	percent normal seedlings	percent abnormal seedlings	percent seeds not germinated	percent normal seedlings	percent abnormal seedlings	percent seeds not germinated
Alcohol 15 minutes	6.0	0.0	94.0	77.0	6.0	17.0
Alcohol 30 minutes	10.5	0.5	89.0	78.5	6.5	15.0
Acetone 15 minutes	4.0	1.0	95.0	76.5	13.0	10.5
Acetone 30 minutes	9.5	1.0	89.5	74.0	11.5	9.5
Remove lemma and palea	52.0	2.0	46.0	91.0	5.5	3.5
$\bar{X}$	16.4	0.9	82.7	79.4	8.5	11.1
F value for treatment	39.99**	-	36.81**	2.16	10.79**	2.23
L.S.D. (.05 level)	12.77	-	13.4	-	8.34	-
C.V. percent	27.3	3.3	5.8	8.0	35.2	44.8

** Significant at 1 percent level

the general pattern of germinating Reed canarygrass seed in earlier experiments. The variation in total abnormal seedlings was largely in the treatment with acetone with little or no difference between the length of soaking. Fungus was not a problem in this experiment.

DISCUSSION

The data in table 3 show that there is very little difference in Reed canarygrass seed yields when one-fourth to three-fourths of the seeds in the panicle are ripe while that in table 2 show that it takes 3 to 5 days for panicles to progress from one-fourth to three-fourths ripe. Since the results of the first experiment involving 16 treatments and 5 maturities show no difference in germination of one-fourth, one-half, and three-fourths ripe seed, it would be desirable to harvest a uniform field of seed in not over 5 days from the time one-fourth of the seed in the panicles is ripe. This is in very close agreement with work reported by Griffith & Harrison (1954).

As reported in the results, only 2 treatments of the 16 used increased germination over the untreated check. Nearly all of the other treatments had no measurable effect on seed germination except Arasan which had an adverse effect.

The results indicate an inhibiting effect of the lemma and palea on germination since removing the lemma and palea and treating seed with concentrated sulfuric acid improved germination. Whether this inhibition is mechanical or chemical is not known. Figure 2 shows definitely more vigorous seedlings resulted from removing the lemma and palea. The difference could be due to chemical inhibition. Germination percentage of seeds treated with sulfuric acid was higher than the check (fifth day) but the seedlings did not appear as vigorous as when the lemma and palea were removed. Improved germination

could be due to increased permeability of the seed after being treated with the acid. Soaking seed in acetone or alcohol did not improve seedling vigor. Actually germination was slowed down several days by this treatment.

It is interesting to note that while treatments and maturities were significantly different the interaction of treatment and maturity did not produce significant differences.

Since none of the treatments resulted in lowered abnormal seedling percentages the problem appears to lie more in getting seed to germinate quickly rather than in getting more of the seedlings to be normal.

Only one treatment resulted in more normal seedlings than the check at the final count. Very few seeds germinated in any of the treatments after 14 days in the germinator. When viewed together the above comments indicate a possibility of slow germination and low germination due to chemical inhibition, poor permeability of lemma and palea and mechanical inhibition by the lemma and palea. Additional work would be necessary to determine specific causes.

Seedlings emerging within 5 days after the start of germination should have a much better chance of survival than seedlings emerging in 10 to 14 days. If the 2 treatments (removal of lemma and palea and soaking in sulfuric acid) will shorten the emergence time under field conditions, stands might be more easily obtained. The increase in number of normal seedlings in this shorter time would increase the possibility of an adequate stand. Field trials in soil where Reed canarygrass would be used should be made to determine if laboratory results will apply to field conditions. If the possible results

justify it, work toward finding the cause of inhibition to germination might be desirable.

The problem of seed maturity was brought up in the review of literature. At the fifth day there was very little difference in the one-fourth, one-half, and three-fourths ripe seed, while green and ripe seed were significantly lower in percent normal seedlings. This picture very readily supports the discussion above of possible chemical or mechanical inhibition of germination. It is possible that the lemma and palea of ripe seed contain chemical compounds not present earlier or in the final ripening process change so that permeability is decreased or become able to mechanically reduce seedling vigor.

Green seed are too immature to produce normal vigorous seedlings.

If seed dormancy causes poor germination, then the usual methods of breaking dormancy failed on Reed canarygrass.

After the behavior of seed of known source and handling was determined it was necessary to compare them with seed from other sources. The Aebischer seed performed very well in comparison to locally collected seed while the Superior seed was definitely inferior. The commercial seed gave low germination and was affected by fungus. It is not known if these samples of seed from other sources were representative, so generalizations cannot be made about them. The Superior seed used did not equal the performance indicated in the literature. If the commercial seed, Ioreed, and Williams Randolph seed were harvested when fully ripe then the germination is within the expected range of the local ripe seed at the fifth day count. These seeds do not remain in the expected range for total germination however.

Fungus was no problem in the first experiment but as shown in table 10 there was an appreciable amount of fungus infection in the Williams Randolph, Ioreed, and Porter Walton commercial seed. Would Arasan reduce this fungus and give an increase in percent normal seedlings? A third experiment was designed to compare these seed sources when treated with Arasan and when treated with concentrated sulfuric acid. The results were in agreement with the second experiment in performance of the various seed sources. Fungus was reduced in varieties that were affected before, but germination was not increased.

As mentioned before, Arasan had an adverse effect on germination of local seed. If this holds true for other sources of Reed canarygrass seed, one would not expect an increase in germination even though fungus were reduced. This is apparently what happened.

There was a remarkable increase in germination of the Aebischer seed treated with sulfuric acid (almost 30 percent) in 5 days. The magnitude of increase was approximately the same in local seed, but seed from other sources did not exhibit this increase.

The last experiment reported was performed to determine if solvent soaking would improve germination. If there is chemical inhibition, it was thought that alcohol or acetone might have a beneficial effect similar to that reported by Anderson et al (1953) with okra seed. Instead of an increase there was a depressing effect on germination of Reed canarygrass seed. Germination was even slower than normal which makes one wonder if there is some chemical relation of acetone and alcohol to the chemical content of the lemma and palea.

SUMMARY AND CONCLUSIONS

Four experiments were designed and performed to determine if Reed canarygrass seed germination could be improved or hastened through seed treatment.

The first experiment involved 16 seed treatments, 5 seed maturity stages and 2 sets of alternating temperatures for germination. By removing the lemma and palea from the seeds germination was both improved (39 percent higher) and hastened materially in comparison with the untreated check. Soaking seed in concentrated sulfuric acid at room temperature hastened and increased germination slightly (12 percent) over the check. Treatment with Arasan and sandpaper scarification had an adverse effect on germination. Sandpaper scarification reduced germination due to seed injury. Seed which were one-fourth, one-half, and three-fourths ripe gave equivalent germination but green and fully ripe seed gave lower germination than the other three stages of seed maturity. Temperature was not a factor though the lower temperature slowed germination slightly.

The second experiment was designed to compare several (5 separate sources plus the 5 seed maturities collected locally) sources of seed. Aebischer seed from Wisconsin gave the highest germination (58 percent) in 5 days with the local seed just below it (37 to 45 percent). Total germination was equivalent for the local seed maturities (one-fourth, one-half, and three-fourths ripe seed) and Aebischer seed (70 to 80 percent). The commercial seed, Superior, Ioreed, and

Williams Randolph seed were inferior to the other sources (5 to 17 percent) with fungus as a major factor.

The third experiment was to determine if reducing fungus would improve germination of previously poorly germinating seed sources. Seed from the 5 outside sources plus 2 local seed maturities were treated with Arasan and with concentrated sulfuric acid. Fungus was reduced in the commercial seed, the Ioreed, Superior, and Williams Randolph seed, but germination was not improved by treatment with Arasan. Treatment with sulfuric acid hastened germination of the Aebischer seed (58 to 80 percent in 5 days) and also the local seed as already noted in the first experiment.

The fourth experiment was to determine if soaking in acetone or alcohol would remove any possible chemical inhibitors in the lemma and palea and thus improve or hasten germination. Locally collected seed was used with 2 different soaking times in alcohol and acetone. Germination was slowed down approximately 5 days and reduced somewhat. Instead of improving germination these treatments had a detrimental effect.

Standard germination procedure in Mangelsdorf germinators was used throughout the experiments except for the pretreatments and the additional temperature used in the first experiment.

Conclusions are:

1. Germination of Reed canarygrass seed can be improved and hastened materially by removal of the flowering lemma and palea from seed.

2. Treatment with concentrated sulfuric acid at room temperature will hasten germination and give a slight increase in normal seedlings.

Soaking time should be determined for each lot of seed involved. Time used in this experiment was 3 minutes. Poor lots of Reed canarygrass seed were not benefited.

3. Seed should be harvested when one-fourth to three-fourths ripe as this range gives higher germination than seed fully ripe. A higher seed yield will probably result when seed are harvested in this range.

4. Sandpaper scarification is too harmful to Reed canarygrass seed to be of value. Lemma and palea removal is more effective and less harmful.

5. Arasan controlled fungus but had an adverse effect on germination of Reed canarygrass.

6. Of the ten sources of Reed canarygrass seed compared the Aebischer seed gave highest fifth day germination counts followed closely by local seed (except green and fully ripe seed). At the final count these sources were statistically the same. Superior, Ioreed, commercial seed from Wisconsin, and Williams Randolph seed were lower in germination percentage than the other sources used.

7. Soaking in acetone and alcohol slowed germination approximately 5 days, though total germination appeared to be unchanged at 21 days.

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