Dormancy and germination studies of the wild oat (Avena fatua)
by Carl R Haun

A THESIS Submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of Master of Science in Agronomy
Montana State University

Abstract:
Samples of Avena fatua seed were collected from several areas In the western states and Canada* Seed of these samples germinated at intervals over a period of several months exhibited wide variability in degree of dormancy and after-ripening* Progeny of the original samples suggested the possibility that dormancy and germination characteristics might be heritable* About 50% of the seed of a dormant sample of wild oats decomposed while buried at four depths in a silt loam soil* 20% of the recovered seed germinated in the laboratory* No significant differences were evident in germination percentages of seed from different whorls in the panicle, but primary seed germinated significantly higher than secondary or tertiary seed* Highly significant increases in germination of dormant seed were obtained from hulling and from puncturing the seed, with the greatest increases resulting from removal of the hulls* Washing wild oat seed in running tap water caused a progressive decrease in the percentage of germination over a 48-hour period* A sample of seed having a high degree of dormancy showed no effect on germination after washing for 24 hours* No evidence of a water soluble inhibitor was found* Covering hulled seed with the detached hulls from dormant wild oat seeds caused no apparent difference in germination* Loosening the hulls of moderately dormant seed appeared to cause some increase in germination# It was found that the caryopses of both dormant and non-dormant seed absorbed more water with the hulls removed than with the hulls intact* The most dormant type of seed seemed to show the greatest difference in moisture absorption* Seed presoaked 8 and 14 hours in the sulfhydryl-containing compounds glutathione, dithiopropanol, and thioglycollate produced no increase in the germination percentages such as that found in Avena sativa by Elliott and Leopold (5), but instead, resulted in almost complete supression of germination, as did soaking in distilled water for the same lengths of time* Presoaking seed in solutions of another sulfhydryl compound, cysteine, for four hours produced no differences in germination in a moderately dormant sample of seed, except a decrease at the IO-^-M concentration, but caused decreases in germination at all concentrations in a highly dormant sample*

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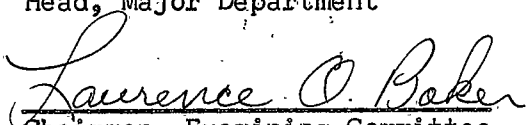
Approved:

Head, Major Department



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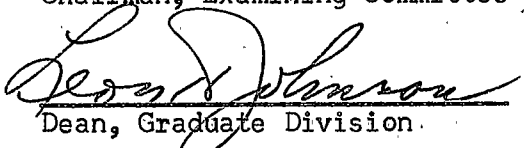

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ABSTRACT

Samples of Avena fatua seed were collected from several areas in the western states and Canada. Seed of these samples germinated at intervals over a period of several months exhibited wide variability in degree of dormancy and after-ripening. Progeny of the original samples suggested the possibility that dormancy and germination characteristics might be heritable.

About 50% of the seed of a dormant sample of wild oats decomposed while buried at four depths in a silt loam soil. 20% of the recovered seed germinated in the laboratory.

No significant differences were evident in germination percentages of seed from different whorls in the panicle, but primary seed germinated significantly higher than secondary or tertiary seed.

Highly significant increases in germination of dormant seed were obtained from hulling and from puncturing the seed, with the greatest increases resulting from removal of the hulls.

Washing wild oat seed in running tap water caused a progressive decrease in the percentage of germination over a 48-hour period. A sample of seed having a high degree of dormancy showed no effect on germination after washing for 24 hours. No evidence of a water soluble inhibitor was found.

Covering hulled seed with the detached hulls from dormant wild oat seeds caused no apparent difference in germination. Loosening the hulls of moderately dormant seed appeared to cause some increase in germination.

It was found that the caryopses of both dormant and non-dormant seed absorbed more water with the hulls removed than with the hulls intact. The most dormant type of seed seemed to show the greatest difference in moisture absorption.

Seed presoaked 8 and 14 hours in the sulfhydryl-containing compounds glutathione, dithiopropanol, and thioglycollate produced no increase in the germination percentages such as that found in Avena sativa by Elliott and Leopold (5), but instead, resulted in almost complete supression of germination, as did soaking in distilled water for the same lengths of time. Presoaking seed in solutions of another sulfhydryl compound, cysteine, for four hours produced no differences in germination in a moderately dormant sample of seed, except a decrease at the 10^{-1}M concentration, but caused decreases in germination at all concentrations in a highly dormant sample.

INTRODUCTION

Dormancy in the seed of Avena fatua, and the ability of the seed to remain viable in the soil for comparatively long periods of time before germinating, are characteristics which add to the difficulties of controlling this weed. Eradication is especially troublesome in the cereal grain crops, where selective herbicides have not yet proven successful.

Delayed germination, caused by such factors as impermeability of the seed coat to oxygen or water, inhibiting substances, mechanical restriction of the embryo, or immaturity of the embryo, has been found in the seed of many plant species. Investigators have found the agencies responsible for dormancy in a number of types of seeds, such as hard seed coats in legumes, acetaldehyde in unripe corn and pea seeds, and lactones in tomato juice; this has led to the development of means of breaking dormancy, such as scarifying legume seeds, drying unripe corn and pea seeds, and fermenting the pulp of tomatoes from the seed, and others.

Preliminary tests have indicated that delayed germination in wild oats is caused, at least partially, by some effect of the hulls. The studies reported herein have been made with the objective of determining the effect of the hulls on germination; whether the hulls have an impermeability to water or oxygen, whether there is an inhibitor present in the hulls, such as has been found in A. sativa, whether the seed coat has some impermeability, or whether dormancy is the result of a combination of factors.

As an additional aid in the evaluation of the problem, strains of wild oats from several regions have been used in these trials, and experi-

ments have been done relative to the longevity of the seed at various depths in the soil, germination of primary and secondary seed from different parts of the panicle, and the emergence of seedlings from several depths of planting in soil.

REVIEW OF LITERATURE

Lindsay (8) has divided the Avena fatua group into the subspecies fatua, cultiformis, septentrionalis, and meridionalis on the basis of morphological seed characters; he further subdivided the subspecies fatua into the varieties pilosissima, glabrata, intermedia, and vilis by a classification of the color and pubescence of the lemma. Subspecies fatua was found to be the most prevalent in western Canada, with the variety glabrata the rarest. Thurston (13) has differentiated A. ludoviciana from A. fatua by its prostrate growth, winter habit, and the fact that only the primary seed has an abscission scar, while the scar is present on all three seed of A. fatua. Derscheid (4) stated that Thurston has classified some 70 strains of wild oats, mostly A. fatua and A. ludoviciana. Toole and Coffman (15) collected wild oat seed from several states and observed marked differences in such characters as size, color, pubescence, etc., but were unable to correlate them with dormancy and germination.

Bibbey (2) defined dormancy as, "A viable seed not in active growth."; he divides dormancy into several categories, including environmental (quiescence), inherent, primary, and secondary dormancy. Thurston (11) concluded that dormancy in A. fatua develops after fertilization of the ovules, and depends upon the genetic constitution of the embryo. Johnson (7) observed that primary seed germinability increased progressively from the basal to the apical whorl in the panicle, and that secondary seeds required a much longer period of after-ripening before becoming readily germinable. Stoa, et al. (9) tested wild oat seed in 1949, 1950, and 1952 and found a progressive increase in germinability from 1 to 6%, 7 to 10

days after harvest, to 97%, 21 months after harvest. They also found that machine-harvested and -threshed seed germinated more readily than seed harvested by hand, which led them to the conclusion that seed-coat injury might be responsible for the increased germination. Crocker (3) observed that seeds of A. fatua germinated 8% in 30 days with seed coats unbroken, while those with seed coats broken germinated 96% in the same period. Atwood (1) pricked wild oat seeds with a needle and obtained 95 to 100% germination, although unpricked seeds germinated only 35 to 64% by December of the year harvested. Investigations with reduced oxygen concentrations with seared and unbroken seed indicated that germination was delayed by exclusion of oxygen by the seed coat, and that after-ripening seemed to consist of an increase in permeability of the seed coat to oxygen, a rise in embryo acidity, and increased water-absorbing power of the embryo. Bibbey (2) obtained good germination of A. fatua under low oxygen and high carbon dioxide pressures, but germination percentages were higher, up to a point, with more oxygen. He also found evidence that light was not essential for optimum germination of wild oats. Thornton (10) concluded that dormancy in A. fatua has its inception in the accumulation of intermediate products of anaerobic respiration that act as germination inhibitors because the oxidation system has been temporarily impaired by a lack of oxygen. Products such as acetaldehyde, polypeptids, and reducing sugars accumulate in small quantities and the removal of the seed coat tends to dilute the inhibiting substances by allowing greater water absorption.

Waldron (16) found that wild oat seed buried at 7 to 10 inches in black alluvial soil were nearly all dead after 20 months, and that no via-

ble seed remained after 56 months. Zade (17) planted A. fatua seed at various depths and concluded that 5 to 10 cm was more favorable for germination than any other depth down to 30 cm, where germination ceased. Thurston (12) found that seeds which had not germinated within four years at depths down to 20 inches were dead, and that seeds buried 12 to 20 inches deep produced no seedlings in 21 months. Toole and Brown (14) recovered A. fatua seed buried at 22 and 42 inches for one year and they germinated 8%, and 18%, respectively; seeds buried at these depths for two or more years were no longer viable.

Evanari (6), in his work on germination inhibitors, has identified a number of compounds produced by plants which inhibit the germination of their own or other plant seeds, including unsaturated lactones, alkaloids, essential oils, and others. The presence of these compounds has been found to be responsible for the dormancy of seeds of many plants. Elliott and Leopold (5), in their investigations of the seed of A. sativa, variety Victory, have demonstrated a water-soluble inhibitor in the hulls, which appears to be a high molecular weight protein. This substance could be washed out of the hulls with water, and inhibited the activity of alpha and beta amylase on starch. Their experiments indicated that its action in inhibiting germination was due to the inactiviation of sulfhydryl groups needed by amylase, and that such sulfhydryl reactivators as glutathione and dithiopropanol were able to counteract the inhibition and effect a large increase in germination when the seeds were soaked in solutions of these compounds before being germinated.

MATERIALS AND METHODS

Wild oat (Avena fatua) seed samples were obtained from North Dakota, Idaho, Utah, Colorado, Oregon, Washington, Montana, and Alberta, and Saskatchewan, Canada in 1954. Seed of these samples was used in various tests during the balance of 1954, and early 1955. In the spring of 1955, seed from each sample was planted in the field for seed increase. The progeny were used in investigations, along with some of the 1954 seed, during the fall and winter of 1955, and the spring of 1956. Seed used for the studies was selected on the basis of degree of dormancy. No attempt was made to correlate dormancy with seed phenotypes, although there were marked differences in seed size, lemma color, and pubescence among the various samples. Seed from both irrigated and dryland areas were represented in the collection.

Germination tests conducted from the fall of 1954 to the summer of 1955 were in moist paper towels in germination cabinets at 15 to 18 degrees C. New facilities became available, and from the fall of 1955 germination was in petri dishes on damp blotter paper in a germination cabinet at approximately 20 degrees C.

In the test in which the seed was washed in attempting to determine whether or not a water-soluble inhibitor was present in the hulls or seed, tap water at approximately 8 degrees C. was used. In a preliminary trial, tap water at about 25 degrees C. was used. Soaking of seed, as a check in the tests where the treatments consisted of soaking in solutions of various sulfhydryl compounds, was in distilled water at room temperature.

Hulling and puncturing of seed was done by hand. Field plantings

were in Bozeman silt loam soil.

Germination tests were made with 300 seeds of each sample (three subsamples of 100 seeds each) per treatment, except in the periodic germination of seed from each sample, where 100 seeds per sample were used, and in the germination of primary, secondary, and tertiary seed from different locations in the panicle, where two replications of 100 seeds each were used for each type of seed from each whorl. In the field, three replications of 100 seeds each were used in each location at each depth for the depth of burial trial, and for depth of planting, four 100-seed replications were used for each seed sample at each depth.

RESULTS

GERMINATION CHARACTERISTICS OF SEVERAL SAMPLES OF WILD OAT SEED

Seed of each 1954 sample was germinated periodically from August, 1954 to October, 1955; considerable variation was noted in the degree of dormancy and progressive after-ripening among the samples. Samples number 9, 11, and 12 had especially low in germination and seemed to after-ripen more slowly than any of the other samples tested. Sample number 24 exhibited very little dormancy and had reached maximum germination by February, 1955. With the exception of samples number 8, 18, and 22, none of the other 1954 samples approached maximum germination until October, 1955. Table I lists the various seed samples, their places of origin, and the dates received. Germination percentages for each sample on the different dates is shown in Table II from the date each seed lot was first available.

Progeny of the original samples of seed were not germinated in the manner of the 1954 seed, but several samples were germinated in the course of the trials made during 1955 and 1956 and it appeared that the progeny generally followed the pattern of the parents in the degree of dormancy and progress of after-ripening. Progeny of samples number 9 and 12 showed somewhat the same high degree of dormancy as the parent seed, and the progeny of sample number 24 was readily germinable, as had been the parent stock. Progeny of sample number 11 was exceptional in that it did not exhibit the high degree of dormancy of its parent seed. In general, it appears that the dormancy and germination characteristics of Avena fatua, while quite variable in different strains, is due to the genetic constitu-

tion of the particular variety and is heritable, even though there may be some variation when grown under different environmental conditions. Comparative germination data for some of the progeny samples and parent seed is shown in Table III. Due to the low germination of samples number 9 and 12, the supply of progeny seed was exhausted and further tests with them had to be discontinued. Additional stocks of seed of these samples were obtained from Moscow, Idaho and Stavely, Alberta in the spring of 1956 and seed from these was used in some of the tests.

Table I. History of wild oat seed samples used in this study.

Sample Number	Geographical Origin	Irrigated or Dryland	Cropping History	Date Collected
1	Bozeman, Mont.	Irrig.	Barley	8/17/54
2	" "	"	Seed peas	8/17/54
3	Moccasin, Mont.	Dryland	Oats	8/3/54
4	Fairfield, Mont.	Irrig.	Barley	8/9/54
5	Choteau, Mont.	Dryland	Winter wheat	8/10/54
6	Valier, Mont.	Irrig.	Barley	8/10/54
7	Bozeman, Mont.	"	Barley	Fall, 1952
8	Williston, N. D.	Dryland	Fallow	Fall, 1954
9	Moscow, Idaho	"	Wheat	Sept., 1954
10	Logan, Utah	?	?	Fall, 1953
11	Stavely, Alberta	Dryland	Wheat	9/11/54
12	La Combe, Alberta	"	Wheat	Fall, 1954
14	Fargo, N. D.	"	Wheat	Fall, 1952
15	Lake County, Mont.	Irrig.	Barley	Fall, 1954
16	Creston, Mont.	Dryland	Wheat	Fall, 1954
17	Pullman, Wash.	Irrig.	Peas	Fall, 1954
18	Bozeman, Mont.	"	Peas	Fall, 1954
19	Regina, Sask.	Dryland	Wheat	Fall, 1954
20	Creston, Mont.	Irrig.	Oats	Fall, 1954
21	Creston, Mont.	Dryland	Wheat	Fall, 1954
22	Fort Collins, Colo.	?	?	Fall, 1954
23	Corvallis, Ore.	?	?	Fall, 1954
24	Logan, Utah	?	?	Fall, 1954
25	Chester, Mont.	?	?	Fall, 1952

Table II. Germination percentages of wild oat samples on various dates.

Sample Number and Year Collected		1954					1955			
		8/30	9/30	10/29	12/4	12/30	2/3	3/2	5/12	10/13
1	1954	0	8	59	73	87	86	64	66	99
2	"	26	41	69	72	82	84	37	83	96
3	"	17	18	48	43	44	53	29	34	86
4	"	28	36	47	31	80	93	44	77	--
5	"	27	52	56	59	75	90	58	72	97
6	"	14	28	30	20	69	79	46	57	83
7	1952	98	--	--	--	--	--	--	--	--
8	1954	--	64	85	97	94	--	--	93	97
9	"	--	1	0	1	0	1	0	3	24
10	1953	--	98	97	96	--	--	--	99	97
11	1954	--	2	1	4	2	32	21	50	91
12	"	--	--	0	2	2	8	2	4	--
14	1952	--	--	--	--	--	--	--	95	97
15	1954	--	--	--	10	49	73	68	73	--
16	"	--	--	--	75	62	72	75	86	--
17	"	--	--	--	73	60	91	62	81	97
18	"	--	--	--	73	55	94	92	94	100
19	"	--	--	--	43	47	71	62	77	93
20	"	--	--	--	--	22	67	66	83	99
21	"	--	--	--	--	25	71	84	86	91
22	"	--	--	--	--	43	79	58	59	96
23	"	--	--	--	--	2	36	36	41	87
24	"	--	--	--	--	80	98	99	95	99
25	1952	--	--	--	--	--	--	--	84	97

Table III. Germination of 1955 progeny and 1954 parent seed for several samples of wild oats.

Seed Sample	November		December		January		February		March		April	
	1954	1955	1954	1955	1955	1956	1955	1956	1955	1956	1955	1956
	Par.	Pro.	Par.	Pro.	Par.	Pro.	Par.	Pro.	Par.	Pro.	Par.	Pro.
	Percent Germination											
1					87	22						
3									29	63	34	64
9	0	2	1	8	0	3	1	9				
11	0	39	4	64								
12					2	16			2	5	4	4
18					75	64	90	62	58	48		
19			43	21								
24									99	93		

LONGEVITY OF BURIED SEED

An experiment was deisgned to determine the length of time wild oat seed will remain viable while buried at different depths in soil in the field. Seed of sample number 9, germinating less than 10%, was used in this trial. In November, 1954 one hundred seeds were mixed with soil and placed in each of 120 lumite plastic screen bags. Four bags were placed in each of 15 holes dug in grass sod, and 15 holes in bare soil at depths of 2, 6, 12, and 18 inches, one bag at each depth. The turf was replaced over the holes in sod, and the following spring, oats were seeded in the bare soil. The soil in the area is Bozeman silt loam. It was planned to excavate the seed from three holes under each cropping condition at intervals of one year for the five following years, and attempt to germinate the recovered seed.

In November, 1955 the 24 bags of seed were removed from three holes under each cropping condition, the undecomposed seed separated from the soil in the bags and placed in a germination cabinet for seven days. The percent of undecomposed seed recovered, and the germination percentages are shown in Table IV and an analysis of variance in Table IV (a). The same data is presented graphically in Figure 1. Undecomposed seed recovered from the holes under sod is consistently greater than those under oats and an analysis of variance indicates that the difference is highly significant; however, the differences in seed recovered from the different depths is non-significant. It will be interesting to see whether this holds true for the seed recovered during the subsequent four years of this test. Decomposition of seed appears to be partly due to germination of

some of the seed, especially at the 2 and 6 inch depths. At any rate, there were sufficient viable seeds at all depths to have reinfested a field with wild oats if they had been plowed up at the end of one year. Also, there may have been dormant seed among the seed which failed to germinate and this seed could still germinate at some future time.

Table IV. Germination of wild oat seed buried under grass sod and under annual cropping at four depths for one year in Bozeman silt loam soil, and percent of undecomposed seed recovered.

Depth of Burial	2"		6"		12"		18"	
Seed Buried Under	Sod	Oats	Sod	Oats	Sod	Oats	Sod	Oats
			Percent of Seed Recovered					
	57	46	61	50	61	42	57	40
			Percent Germination on Seed Recovered Basis					
	6	21	30	18	23	25	24	31
			Percent Germination on Seed Buried Basis					
	3	8	18	8	14	10	13	12

Table IV (a). Analysis of variance of undecomposed wild oat seed recovered.

Source of variation	D. F.	M. S.
Replications	2	14
Depth buried	3	47
Cropping condition	1	1276**
Depth buried x Cropping cond.	3	25
Error	14	128
Total	23	

**Significant at 1% level.

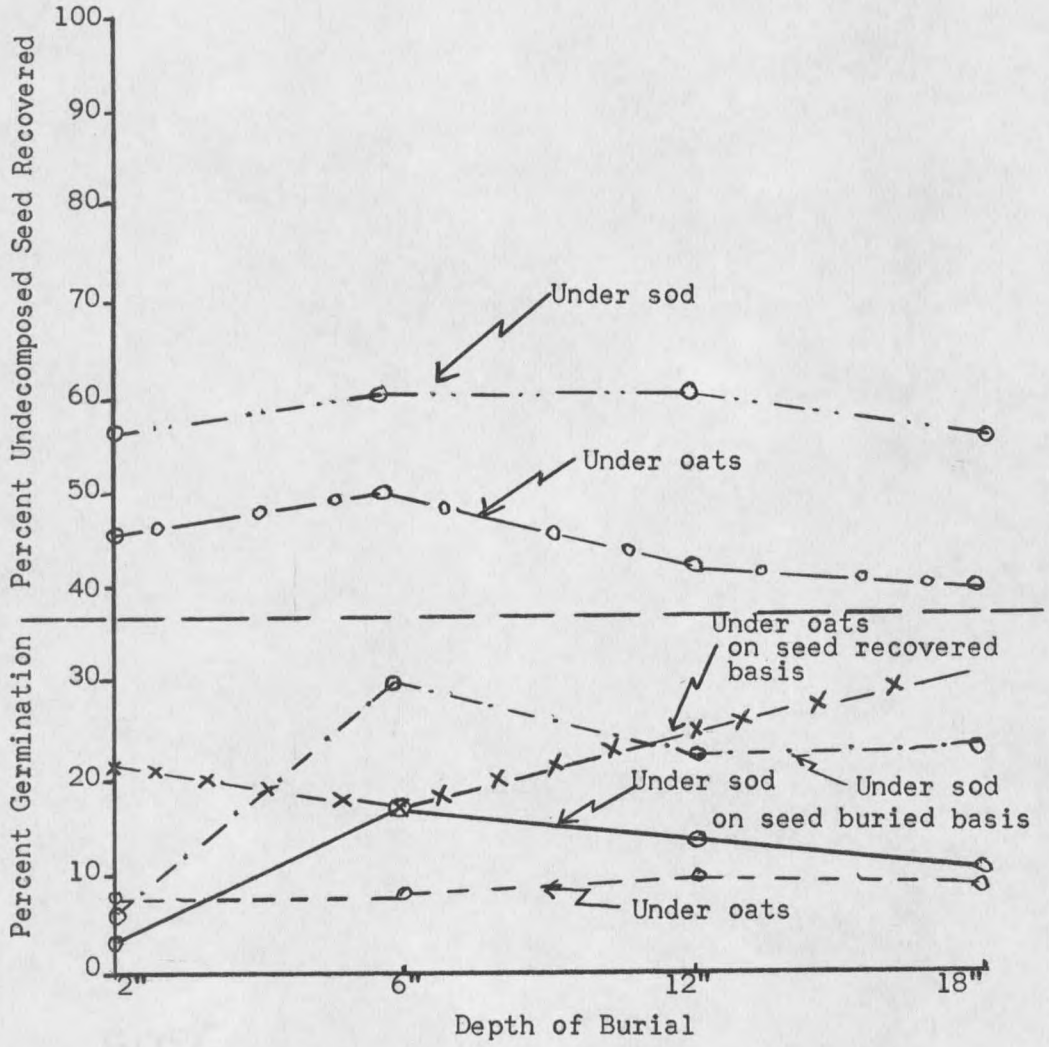

Figure 1. Percent germination and percent of seeds undecomposed after burial in soil for one year.

DEPTH OF PLANTING

Wild oats were planted in the field in a trial to determine the percentage of emergence of seedlings from seed planted at six different depths in soil. One hundred seeds for each of four replications of each of samples number 10, Logan, Utah, and number 22, Fort Collins, Colo., were planted at 2, 4, 6, 8, 10, and 12 inches in Bozeman silt loam soil in June, 1955. The plots were in a randomized complete block design. In July, when the plants were 8 to 10 inches high, they were dug up and counted. The greatest percentage of emergence was from the 2, and 4 inch depths, a considerable number of plants came up from 6 inches, very few from 8, and 10 inches, and none from 12 inches. An analysis of variance indicated a highly significant difference in emergence between the two seed samples, as well as a highly significant interaction between depth of planting and seed samples. These differences appear to be due to the fact that sample number 22 had higher percentages of emergence from the 2, 4, and 6 inch depths than did sample number 10. Both of these samples germinated over 95% in the laboratory, prior to planting. Percent emergence from the different depths is shown in Table V with an analysis of variance in Table V (a). Differences in emergence are presented graphically in Figure 2.

Table V. Emergence of plants from seed of two samples of wild oat seed planted at six depths in Bozeman silt loam soil.

Depth Planted	Seed Sample #10 Percent Emergence	Seed Sample #22 Percent Emergence
2"	66	82
4"	49	81
6"	27	48
8"	2	3
10"	3	3
12"	0	0

Table V (a). Analysis of variance of emergence of two samples of wild oats planted at six depths.

Source of variance	D. F.	M. S.
Replications	3	144
Depth of planting	5	8887**
Seed samples	1	1740**
Seed samples x depth	5	342**
Error	33	85
Total	47	

**Significant at 1% level

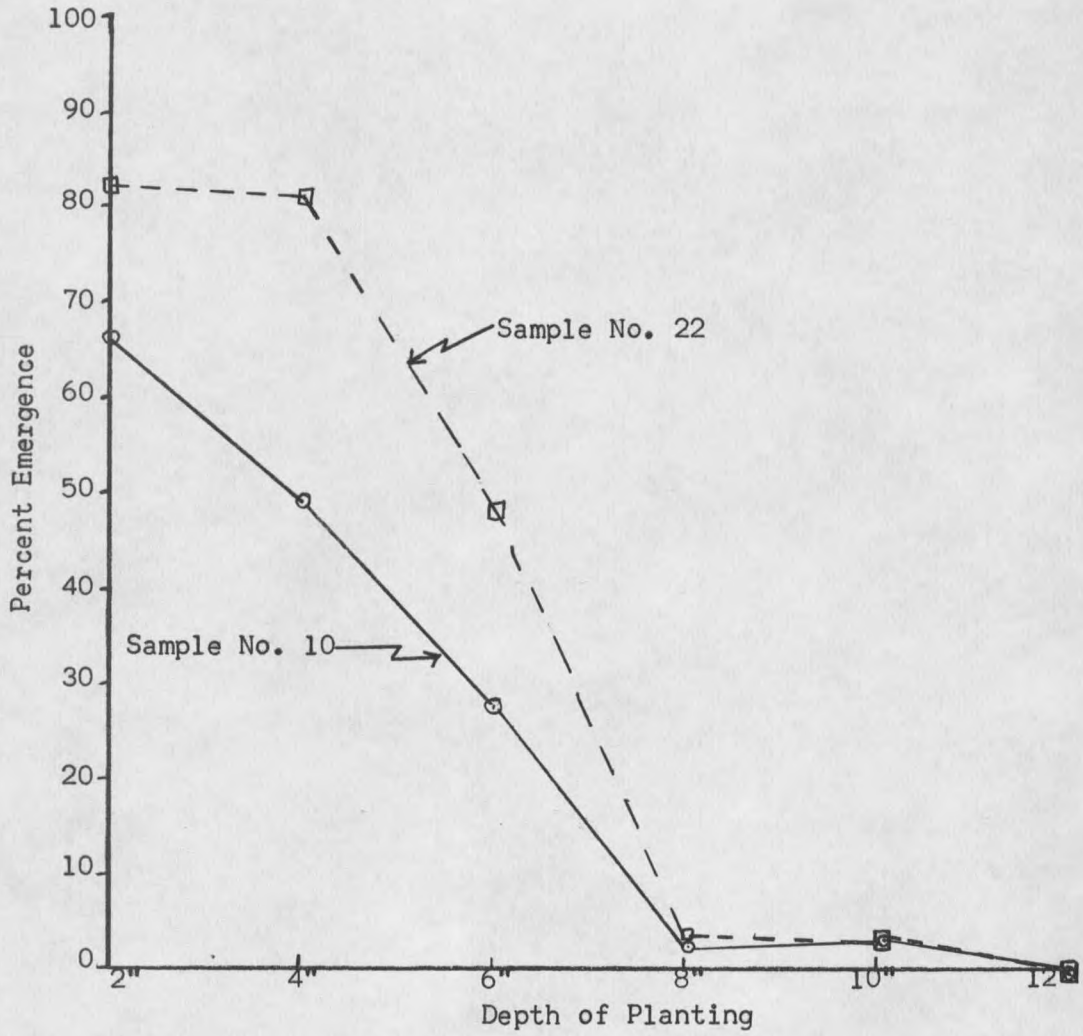

Figure 2. Emergence of seedlings from two samples of wild oat seed planted at six depths in Bozeman silt loam soil.

GERMINATION OF PRIMARY, SECONDARY, AND TERTIARY SEED FROM DIFFERENT WHORLS IN THE PANICLE

In the fall of 1954, basal, second, third, and apical whorls were clipped from wild oat plants in a field in the Bozeman area, and placed in separate bags. One hundred seeds of each seed type from each whorl for each of two replications were placed in the germination cabinet for seven days in a test to determine any differences between types of seed and position in the panicle. The seed used in the trial appeared to be mature seed. An analysis of variance indicated highly significant differences between seed types, with primary seed having the highest percent germination, and tertiary seed the lowest. There were no significant differences in germination between whorls, nor was the whorl times seed type interaction significant.

The seed on a wild oat plant at a given time generally represents various stages of maturity, with the most mature seed usually in the apical portion of the panicle. The results obtained in a test of this kind would probably vary with the time at which the seed was collected, as well as with the particular strain of wild oats from which the seed was harvested. Table VI shows the germination percentages of the three types of seed in the four shorls and Table VI (a) the analysis of variance. Figure 3 presents the data in graphical form, with whorls plotted against germination percentage for the three types of seed.

Table VI. Percent germination of wild oats by position of seed in the panicle and in the spikelet.

Whorl	Seed Position		
	Primary	Secondary	Tertiary
	Percent Germination		
Basal	78	26	14
Secondary	73	9	2
Tertiary	37	32	13
Apical	54	26	4

Table VI (a). Analysis of variance of germination of wild oats by position of seed in the panicle and in the spikelet.

Source of variation	D. F.	M. S.
Replications	1	641
Whorls	3	210
Seed position in spikelet	2	5760**
Whorls x position in spikelet	6	381
Error	11	384

**Significant at 1% level.

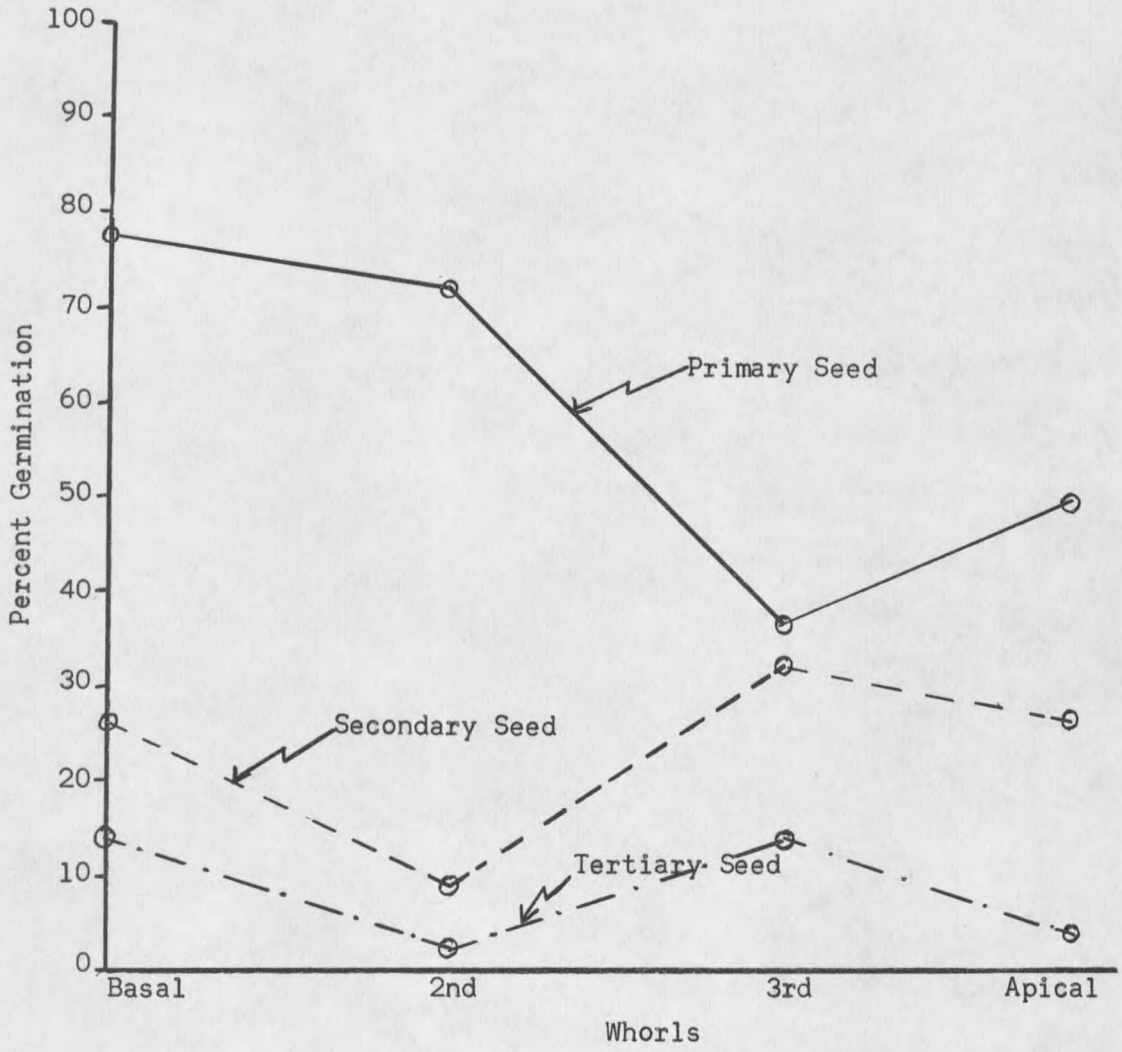

Figure 3. Germination of primary, secondary, and tertiary wild oat seed from different whorls in the panicle.

EFFECTS OF REMOVING THE HULLS AND PUNCTURING THE SEED COATS ON GERMINATION

Crocker (3), and Atwood (1) found that there was an increase in the germination of dormant wild oat seed when the seed coats were seared, or punctured with a needle. Preliminary tests have indicated that removal of the hulls also increases germination in dormant seed. An experiment was designed to evaluate the effects of hulling and puncturing seed on the germination of dormant wild oat seed. Seed of sample number 9, germinating less than 10%, sample number 11, germinating less than 50%, and sample number 12, germinating less than 20%, were used in this test. The treatments consisted of hulling and puncturing seed in both the endosperm and embryo areas, and puncturing without removal of the hulls. The effects of these treatments on germination were compared to the germination of seeds with hulls removed, but not punctured, and with intact seed. Three hundred seeds (3 subsamples of 100 seeds each) of each sample were used for each treatment.

An analysis of variance, Table VII (a), showed highly significant differences due to treatment, between seed samples, and for the interaction of treatment times seed sample. In nearly every case, the greatest increase in germination was exhibited where the hulls had been removed without pricking the seed coats. In the treatments involving both hulling and puncturing, whether in the endosperm or embryo, there was very little increase over the seeds with the hulls removed without puncturing. Puncturing unhulled seed appeared to cause increased germination, but to a lesser degree than the removal of the hulls. The less dormant samples,

number 11 and 12, approached maximum germination with removal of the hulls, while sample number 9 reached only about 50% germination. This might be interpreted as an additional indication that there are variations in the dormant condition in different strains of wild oats. It seems reasonable to assume that the changes that have taken place in the seed at different stages of after-ripening affect the response of the seed to these treatments. Germination percentages are shown in Table VII, with an analysis of variance, Table VII (a).

Table VII. Effects of hulling and puncturing the endosperm and embryo on the germination of dormant wild oat seed.

			Seed Sample		
			#9	#11	#12
Hull Treatment	Endosperm Treatment	Embryo Treatment	Percent Germination		
Removed	Punctured	None	38	99	92
None	Punctured	None	5	89	57
Removed	None	Punctured	41	99	93
None	None	Punctured	27	86	52
Removed	None	None	51	97	89
None (Check)	None	None	1	35	14

Table VII (a). Analysis of variance for germination of seed hulled and punctured in the endosperm and embryo.

Source of variation	D. F.	M. S.
Seed treatment	5	5319**
Seed sample	2	15378**
Treatment x seed sample	10	352**
Error	36	82
Total	53	

**Significant at 1% level.

WATER ABSORPTION IN THE CARYOPSIS OF HULLED AND INTACT SEED

If wild oat hulls delay germination by an impermeability to water which reduces the amount of water imbibed by the caryopses, it should be possible to measure the difference in water uptake by the caryopses of hulled and unhulled dormant seed. At the same time, it might be assumed that the hulls of non-dormant seed would not impede the absorption of water by the caryopses to an extent which would depress germination. Accordingly, seed of samples number 9 and 11 were selected as the dormant type, and sample number 10, germinating more than 95%, as the non-dormant. One hundred seeds of each sample were hulled for each of three replications, and a like number of each sample was left intact. These seeds were placed in moist paper towels in a germination cabinet and left for about 48 hours, at the end of which time the hulls were removed from the intact seed and each lot of seed was weighed. The seeds were allowed to dry at room temperature for one week; the seed was then weighed again. The moisture uptake of the caryopses was calculated on the basis of percent of air-dry weight. An analysis of variance revealed highly significant differences between water absorption of hulled and intact seed, and between seed samples. The caryopses of all samples absorbed more water when hulled than when unhulled, the greatest difference being in sample number 9, and the least difference in sample number 10. It appears that the hulls of dormant seeds are not entirely impermeable to water, but if dilution of inhibiting substances within the caryopsis is the factor, the amount of water necessary may be critical enough to impede the germination process if it is reduced even slightly. On the other hand, the caryopses

of non-dormant seed, which presumably contain no substance inhibitory to germination, may require only enough water for the germination process, so that even though the caryopsis absorbs less water with the hulls intact, there is no interference with germination. Percent water absorption of the caryopses of hulled and unhulled seed of each sample is presented in Table VIII, with an analysis of variance in Table VIII (a).

Table VIII. Water absorption by the caryopses after soaking hulled and unhulled, dormant and non-dormant, wild oat seed.

Condition of Seed During Soaking	Seed Sample		
	#9	#11	#10
	Percent Water Absorption by the Caryopses		
Hulls removed	57	44	47
Hulls intact	34	26	34

Table VIII (a). Analysis of variance for percent water absorption by the caryopses after soaking hulled and unhulled seed of dormant and non-dormant wild oats.

Source of variation	D. F.	M. S.
Condition of seed	1	1489**
Seed sample	2	148**
Condition of seed x seed sample	2	41
Error	12	30
Total	17	

**Significant at 1% level.

EFFECTS OF THE HULLS OF DORMANT SEED ON THE GERMINATION OF WILD OATS

This experiment was deisgned to evaluate further the effects of the hulls of dormant seed on germination. As in previous tests, 300 seeds of each sample were used in three subsamples for each treatment. Seed of dormant 1954 samples number 9, 11, and 12 was chosen for the trial. One treatment consisted of separating the hull from the caryopsis and pushing the caryopsis back into the hull -- in effect, loosening the hull around the seed. In another treatment, hulled seed was covered with hulls removed from dormant seed before being placed in the germination cabinet. The third treatment consisted of germinating hulled seed, as in a previous test.

An analysis of variance showed highly significant differences between treatments, and between seed samples, but no significance for interaction. Loosening hulls appeared to produce some increase in germination in samples number 11 and 12. Covering the hulled seed with hulls from dormant seed had no apparent effect on germination. As before, removal of the hulls resulted in definite increases in germination in all three samples. Under these conditions there is still no definite evidence of an inhibitor in the hull, but the results seem to give more support to the possibility that an impermeability of the hull to oxygen or water, or both, is responsible for its effect on germination. Table IX shows the germination percentages of the three samples of seed for the treatments used in this test, together with an analysis of variance in Table IX (a).

Table IX. Effects of the hulls of dormant wild oat seed on germination.

Seed Treatment	Seed Sample #9	#11	#12
	Percent Germination		
Hulls loosened	5	64	20
Hulls removed, caryopses covered with hulls	43	88	65
Hulls removed	46	87	71
Intact seed (check)	3	34	7

Table IX (a). Analysis of variance for germination of wild oat seeds with hulls loosened, hulls removed, and hulls removed and caryopses covered with hulls from dormant seed.

Source of variation	D. F.	M. S.
Treatment	3	6309**
Seed sample	2	6022**
Treatment x seed sample	6	174
Error	24	178
Total	35	

**Significant at 1% level.

AN EXPERIMENT TO INVESTIGATE THE POSSIBILITY OF A WATER-SOLUBLE INHIBITOR IN THE HULL OR SEED OF AVENA FATUA

Elliott and Leopold (5) found evidence of a water-soluble inhibitor in the hull of dormant Avena sativa seed and were able to demonstrate increased germination after washing seed continuously in tap water. Seed removed from the water after about 8 hours germinated at more than 90%, and seed removed and germinated at intervals therafter continued to germinate at that rate. An experiment was performed to determine whether a similar inhibitor is present in the hulls of wild oats. A quantity of seed of sample number 9 (1955), germinating less than 10%, and of sample number 18 (1955), germinating less than 80%, was placed in beakers so that it was washed continuously by running tap water at about 8 degrees C. At intervals during the next 48 hours 300 seeds (subsamples of 100 seeds each) of each sample were removed from the water and placed in the germination cabinet. Unfortunately, the supply of seed of sample number 9 was exhausted at the end of the first 24 hours so that only sample number 18 was used during the second 24-hour period.

There was no apparent effect of the washing on sample number 9 during the 24-hour period. Unwashed seed germinated 9%, and the washed seed germinated from 6 to 9% at intervals during the washing. Sample number 18 germinated 63% unwashed, 55% at the end of 24 hours, and 22% at the end of the 48 hours of the test. In another test, seed was washed in tap water at about 25 degrees C. and germinated at 24 and 48 hours only. There was a depression of germination in this trial also. If there was a water-soluble inhibitor in the hulls of these samples of seed, it clearly did

not react in the manner of the inhibitor in A. sativa. If it is true that products of anaerobic respiration within the seed are responsible for delayed germination, it may be that immersion in water, by reducing available oxygen, may result in a secondary dormancy. It would seem that more work with the washing of seed will be necessary before any definite conclusions can be drawn. A graphic presentation of the percent germination of the seed after the various lengths of time of washing is shown in Figure 4, with a regression line.

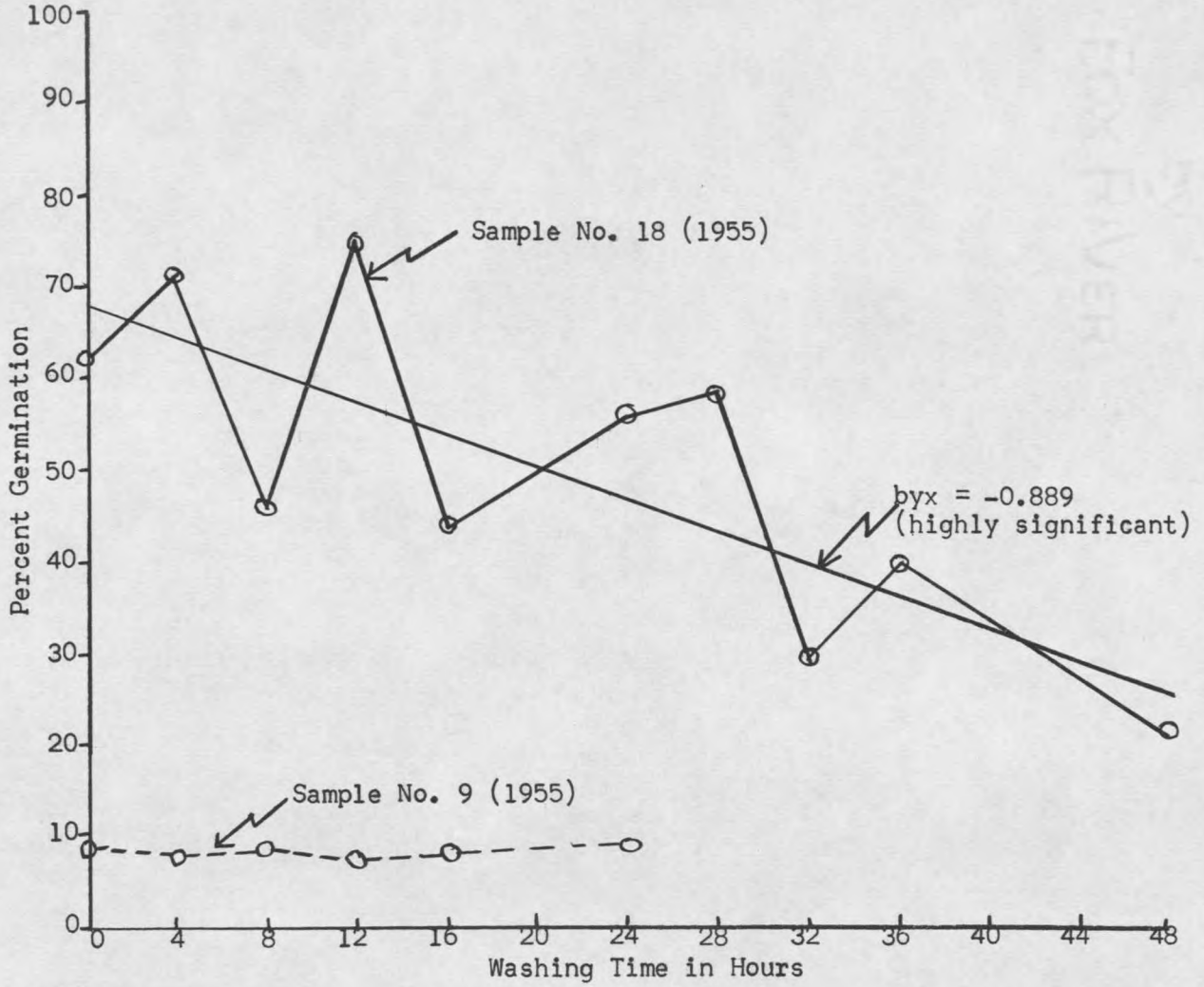

Figure 4. Effects of washing two samples of wild oat seed 24 and 48 hours in tap water at 8 degrees C.