Dormancy and germination studies of the wild oat (Avena fatua)
by David H Leighty

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:
Seed of the wild oat, Avena fatua, which had been collected from Northwestern states and Canada and then grown at Bozeman, Montana were used in all tests. Twelve strains of wild oats stored in a normal heated room germinated 28 percent more than the same strains stored without heat. Seed which wintered in the soil germinated 25 percent more than seed which wintered on the soil surface. Percent of seed recovered after being buried under sod for one, two, and three years was 59, 34, and 15 percent respectively. In soil under bare ground the comparable figures are 44, 11, and 3 percent. In 1956 and 1957 approximately 100 percent of recovered seed germinated. Seed under continuous light germinated 8 percent more than seed in the dark. Oxygen concentrations of 40, 50, 60, 70, 80, and 90 percent, increased the average germination by 9, 25, 18, 21, 24, and 12 percent respectively. Paper chromatography revealed that non-dormant embryos contain material from various sections of the chromatogram, which inhabits and stimulates Triticum vulgare Coleoptile elongation in about equal proportions. Dormant embryos contain a preponderance of inhibiting material.

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ABSTRACT

Seed of the wild oat, Avena fatua, which had been collected from Northwestern states and Canada and then grown at Bozeman, Montana were used in all tests. Twelve strains of wild oats stored in a normal heated room germinated 28 percent more than the same strains stored without heat. Seed which wintered in the soil germinated 25 percent more than seed which wintered on the soil surface. Percent of seed recovered after being buried under sod for one, two, and three years was 59, 34, and 15 percent respectively. In soil under bare ground the comparable figures are 44, 11, and 3 percent. In 1956 and 1957 approximately 100 percent of recovered seed germinated. Seed under continuous light germinated 8 percent more than seed in the dark. Oxygen concentrations of 40, 50, 60, 70, 80, and 90 percent, increased the average germination by 9, 25, 18, 21, 24, and 12 percent respectively. Paper chromatography revealed that non-dormant embryos contain material from various sections of the chromatogram, which inhibits and stimulates Triticum vulgare coleoptile elongation in about equal proportions. Dormant embryos contain a preponderance of inhibiting material.

INTRODUCTION

Seed of wild oats, Avena fatua, has the ability to remain viable in the soil and not germinate. Wild oats also mature early in comparison to many of the crops with which it grows. These two characteristics make eradication extremely difficult.

Delayed germination or dormancy, could be the result of many factors. Impermeability of seed coat to oxygen or water, inhibiting substances in hull, endosperm, or embryo could be some of the factors involved.

Haun (8) found highly significant increases in germination of dormant seed associated with hulling. He also found that the caryopsis of both dormant and non-dormant seed absorbed more water in the absence of hulls.

The effect of various concentrations of oxygen, storage conditions, and light on germination of wild oat seed is reported herein. The possibility of the presence of germination inhibitors was considered and some preliminary work was done using paper chromatography.

The wide variability of results reported by different investigators could have been caused by using different strains[1] of wild oats. The strains used in these experiments were collected from the Northwestern states and Canada. Many of these strains appeared to breed true, but no attend was made to correlate dormancy with seed phenotypes.

This is a continuation of the work initiated by Haun (8) at Montana State College during the years of 1954 to 1956.

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[1] Wild oat seed collected from each location is considered as a strain.

REVIEW OF LITERATURE

The common wild oat is a noxious weed in many parts of the North American continent, being particularly troublesome in the hard red spring wheat region of Minnesota, the Dakotas, Montana, and Canadian Provinces. The wild oat (22) differs from the cultivated oat in producing taller, more vigorous plants and strongly twisted geniculate awns. The grain has a pronounced sucker mouth at the base, and sometimes a hairy lemma. The mature lemmas may be hairy or non-hairy and yellowish-white, gray, greyish-red, or brownish-black in color.

Wood (23) states that wild oats are inclined to be choosey as to environment. Their preference seems to be for cool, moist soil conditions. This may be observed in at least two ways. First, seldom are wild oats a serious problem in the more arid and hot sections of the northern plains, except where moisture becomes available through irrigation. Second, wild oats are usually more abundant on the lower, damper parts of the field, especially in water runs, than they are on the knolls or southern exposures.

It is known that after fertilization of the oat flower, modifications take place in the tissues enveloping the embryo. Robbins (14) states that before fertilization, the enveloping tissues of the oat seed consist of the following, named successively from the outer to the inner; outer epidermis parenchyma layer, chlorophyll layer, inner epidermis, outer integument, inner integument, and the nucellus. After fertilization, all of these tissues are more or less completely absorbed, with the exception of the outer epidermis and the inner integument. In the mature seed the outer epidermis with remnants of the parenchymatous layer forms the pericarp,

while the inner integument becomes the testa. The pericarp and the testa are fused to form the seed coat.

Robbins (14) concluded, on the basis of his results that delayed germination of the wild oat is due to agencies operating after, and influenced by fertilization. These affect the development or absorption of tissues enveloping the embryo in such a manner as to prevent germination of the seed until after a certain period of after-ripening has elapsed.

The ability of wild oat seed to lie dormant in the soil for a period of years before germinating is the cause of the extreme difficulty experienced in eradication of this weed. Bibbey (3) defined dormancy as "A viable seed not in active growth." One main type of dormancy is primary dormancy. This is caused by some inherent or physiological condition or factor of the seed. It could be physical structure of seed or some material in the seed which prevents germination. Secondary dormancy is the result of unfavorable germination conditions which put seeds into a dormancy, so they will not germinate when shifted to a favorable condition.

Primary dormancy is often overcome with time. A delayed ripening period is present in many varieties of plants. Lutes (13) results suggested that immature seeds of wild oats are more dormant and slower to after-ripen than mature seeds. Johnson (11) found that seed germinability increases progressively from the lower to upper whorls in the panicle. Secondary seeds require a much longer period of after-ripening before germinating. Atwood (2) stated that there is an increase of acidity in the embryo with after-ripening. After-ripening occurs along with drying of the seed, but is independent of the water content, as air dry seed soon

after harvest had lower germination than similar seed the following spring.

Stoa (15) found that machine harvested and threshed wild oats germinated more readily than hand harvested, possibly due to seed coat injury.

In experiments with reduced oxygen concentrations using seared (seed touched with hot object) and unbroken seed, Atwood (2) found that the seed coat, by excluding oxygen, delays germination. Harrington (9) found oxygen relations important in the germination of not after-ripened cereals. He reported that the beneficial effects of mechanical treatments on the seed coats are probably related to an increased oxygen supply to the embryo. He further found 36 percent oxygen had the maximum effect on germination. With higher partial pressures of oxygen, the percentage of germination was about the same, but rate of growth was less. Thornton (16) found that germination of the intact imbibed upper seed of the cocklebur takes place in 20 percent oxygen at a temperature of 30 degrees centigrade or higher. Germination of these seeds at 25 degrees centigrade can be forced by the use of 80 to 100 percent oxygen. Bibbey (3) obtained good germination of wild oat seed under low oxygen and high carbon-dioxide pressure, but germination percenages were higher up to a point with more oxygen.

Johnson (11) in a study of delayed germination of offspring of A. fatua crossedwith A. sativa theorized that germinability is dominant over dormancy, consequently the non-dormant segregates in a hybrid population are first to germinate after maturity. These probably would be killed by any cultural operation or climatic factors unfavorable to the plants. Bibbey (3) states that wild oat seed does not require light for optimum germination. In all of Black and Naylor's (4) experiments with wild oats to date, both

tungsten-filament light and "daylight" fluorescent light have been found to inhibit germination. This would appear to be a true light effect and not one dependent upon increased temperatures, since the heating effect of fluorescent lighting is small. Furthermore, experiments have shown that high temperature does not prevent germination in darkness. Cumming's (5) studies with wild oats obtained from localities in Eastern and Western Canada, and from plants grown under temperature and humidity controlled greenhouse conditions, indicate that light, compared to darkness, decreases the amount of germination in partially dormant seed, but does not decrease the germination of non-dormant seed. Evidence therefore indicates an interaction between levels of dormancy and presence or absence of light. This suggests that under conditions of sufficient moisture, fall cultivation which will bury partially dormant seed may encourage germination, and therefore help to eliminate wild oat infestations. In direct contradiction to Johnson's (11) and Cumming's (5) work, Bibbey (3) and Stoa (15) in separate publications agreed that to shorten dormancy it is best to have the dormant seed on the surface of the soil and not to cultivate until spring.

Toole (19) states that wild oat seed collected from different sections in the Western states showed no significant correlation of sections with germinability. Marked differences in seed characters were found, such as seed size, color, pubescence, etc., but no correlation between seed characters and germinability or dormancy were evident. Lute's (13) results showed that different collections of wild oats may differ in dormancy even after having been grown and harvested under uniform conditions. Her results were supported by Haun (8) who reported large differences in dormancy between

sources. The progeny reacted in the same way.

Housley and Bentley (10) report that it is frequently asserted that 3-Indoleacetic acid (IAA) is either the dominant hormone or the only naturally occurring growth promoter in plants. The only growth promoter other than IAA, isolated from vegetative tissues of higher plants is 3-Indolylaceton itrile (IAN). Alexandra Polyakoff-Mayber et.al. (1), working with lettuce seed, said that natural IAA is not present in dry seeds. It is possible that growth inhibitors present in the dry seeds may be precusors of IAA. Two acidic growth inhibiting substances were the only growth active substances present in dry seeds. These substances apparently disappear when germination proceeds. A variety of other unidentifiable active substances appear during germination.

Stoa (15) found short periods of high temperature comparable to burning stubble tending to break or shorten dormancy. He also found that chilling dry and soaked seeds increased germination slightly. Alternate wetting and drying also increased germination slightly. Johnson (11) found that soaking the seeds in 2 percent KNO_3 for 24 hours produced 64 to 68 percent germination. In water, germination was only 4 percent. Na CNS showed some promise in stimulating germination at concentrations below 1 percent.

Evanari (7), 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. These include unsaturated lactones, akaloids, essential oils, and others. The presence of these compounds has been found to be responsible for the dormancy of seeds of many plants. Some of Black and Naylor's (4) preliminary experiments have shown that an

aqueous extract of wild oat hulls has marked inhibitory properties when tested on lettuce seed. This extract has been chromatographed and it would appear that two inhibitory substances are present, running at different Rf. values. Elliott and Leopold (6), in their investigation 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. Haun (8) attempted the same experiment with wild oats, but in all his tests in which he washed the seeds he obtained a sharp reduction in germination. This could possibly be the result of secondary dormancy due to unfavorable conditions for germination.

Toole (20), reporting the final results of the Duvel buried seed experiment, stated that wild oat seed buried in 1902 at 22 inches germinated 8 percent and at 42 inches 18 percent in 1903. None germinated after 1903. Waldron (21) found that in black alluvial loam soil, wild oats came up through five inches of soil. Seeds buried 7 to 10 inches deep for 20 months were practically dead, and buried 56 months all were dead. Thurston (18) found there was no evidence of induced dormancy in seeds buried at depths down to 20 inches. Plants from seed buried 6 inches deep came up yellow, but recovered and grew into healthy plants. All seeds which had not germinated within 4 years died. No seedlings appeared after 21 months from seeds buried 12 to 20 inches deep. Evidence indicated loss of vitality of the seed with prolonged burying in the soil. Haun (8) found that about 50 percent of the seed of a dormant sample of wild oats germinated or decomposed while buried at four depths in a silt loam soil for one year. Twenty percent of the recovered seeds germinated initially in the laboratory.

MATERIAL AND METHODS

Wild oat seeds were obtained from North Dakota, Idaho, Utah, Colorado, Oregon, Washington, Alberta, and Saskatchewan, Canada. Location and cropping history are reported by Haun (8).

They were grown under irrigation at Bozeman. The progeny from the 1955 crop were planted in 1956, and the progeny from the 1956 crop were planted in 1957. Seed harvested in 1956 and 1957 was used in this study.

Monthly germinations were conducted on damp blotter paper in plastic boxes with lids. A germination cabinet was used with the temperature at approximately twenty degrees centigrade. Germination counts were made after 10 days.

One experiment was designed to study the effect of storage conditions on primary dormancy. Samples of each strain of wild oats were stored in an unheated building and at normal room temperature. Germination tests were conducted on the seed under each method of storing.

Germination of seed which wintered in the soil compared to seed wintering on the surface of the soil was studied. In September of 1956 seed of seven strains were placed in separate flats of soil in the field. In half of the flat seed was mixed with the soil, and in the other half it was left on the soil surface. The flats were covered with wire screen. The seed was recovered in June of 1957.

Haun (8) in 1955 initiated an experiment to determine the length of time wild oat seed will remain viable while buried at different depths in soil, in the field. Material and methods for this experiment are found in his thesis.

Twelve strains were used to test the effect on germination of continuous light as compared to continuous dark.

Germination was carried out in the usual manner except that fluorescent light was provided in one section of the germinating cabinet and all light was excluded from the other section.

The effect of various concentrations of oxygen on germination was determined by placing seed in a bell jar. The seeds were enclosed in blotter paper envelopes arranged so that the envelopes were not touching each other. A measured quantity of water was then placed in the jar and was replaced by oxygen. Knowing the quantity of water present, the concentration of the oxygen could be calculated. Duplicate samples were germinated at normal oxygen concentration adjacent to the bell jar. The size of the bell jar prevented it from being used in the germinator, therefore germination occurred at room temperature.

Paper chromatography was used to isolate substances from wild oat seed embryos. Two strains of wild oats were used. One strain exhibited extreme dormancy while the other germinated readily. An alcoholic extract of each strain was made using 100 embryos. The extract was filtered, dried, and then chromatographed using Whatman Number One filter paper. A solvent composed of butanol, saturated with ammonia and water was allowed to ascend fifteen centimeters past the spot of extract and then air dried. The filter paper was cut into five three-centimeter sections. These were irrigated with twenty milliliters of distilled water into separate Petri dishes. Ten ten-millimeter sections of etiolated Triticum vulgare coleoptiles were added to each dish. They were incubated in darkness for 18

hours after which each coleoptile was measured for elongation. Each analysis was accompanied by two checks; one of distilled water and the other of a dilute concentration of 2,4-D* (.01 normal solution). Results are based on average elongation of the 10 coleoptiles. The first extract was made from air dry embryos. Later, extracts were made of embryos which had imbibed water for 4, 8, 12, 16, 20, and 30 hours. After 30 hours the non-dormant strain was showing signs of germinating. Each separate analysis was repeated 4 times.

Three replicates of one-hundred embryos each, of dormant and non-dormant strains were used to study the affect on germination of various concentrations of IAA**. Fifty milliliters of solution were used and this was areated constantly with compressed air.

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* 2-4-Dichlorophenoxyacetic acid
** Indoleacetic acid

RESULTS

EFFECT OF STORAGE CONDITIONS ON GERMINATION OF WILD OAT SEED

Wild oat seed requires an after ripening period, following harvest, before the seed will germinate. Length of period is determined by inheritance, but may be affected by environmental conditions. To study the effect of storage as related to the length of after-ripening period, 23 strains of wild oat seed were stored under two conditions - an unheated building, and a normal heated room. Germination tests were started in February of 1957 and conducted for the succeeding three months.

The average germination for strains for 4 dates germinated varied from .5 percent to 41 percent after storage, in the unheated condition, with the average for the condition being 25 percent. The average germination after storage at room temperature varied from 3 to 75 percent and averaged 53 percent germination, Table I.

An analysis of variance reveals that storage treatments, dates germinated, and strains were significantly different at the one percent level, Table II. There was a significantly greater number of seeds which germinated after storage under the heated room condition, as compared to the unheated building. The strains also varied significantly in germination. This was expected as germination varied from zero in some strains to 93 percent in others.

The average germination under heated storage was never equal to or less than germination of seed under unheated conditions. Figure 1 shows graphically the average monthly germination under the two storage conditions. There is a distinct difference between the two conditions and

germination was increasing each month.

Table I. Average germination of 23 strains of wild oats stored under two conditions.

Strain No.	Storage		Strain No.	Storage	
	Unheated	Heated		Unheated	Heated
1	28.5	60	15	39	75
2	15	60	16	39	68.5
4	41	70.5	17	36	50.5
5	26	62	18	28.5	55
6	36	61	19	20	59
8	23	58	20	25	59
9	.5	3	21	39	63
10	16.5	35	22A	36.5	70
11	16	31	23	1	15
12	12	31	24	14.5	52
14	35	61	25	18	15
14A	22.5	67	Average	25	53

Table II. Analysis of variance of germination of 23 strains of wild oat seed stored under two conditions and germinated at 4 dates.

Source of variation	DF	MS
Dates germinated	3	6,348 **
Storage treatments	1	37,136 **
Strains	22	1,608 **
Treatment x Strains	22	220
Error*	135	141
Total	183	

* Date germinated x storage treatments plus date germinated x strains plus date germinated x storage treatments x strains.
** Significant at 1 percent level.