The effects of foliar applied gibberellic acid3 on the dormancy of wild oat seeds
by Howard Francis Bowman

A thesis submitted in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE
in AGRONOMY
Montana State University
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Abstract:
These studies were conducted to determine if foliar applied gibberellic acidg (GA3) could reduce seed
dormancy of wild oats. Gibberellic acid3 gave the most reduction in seed dormancy when foliar
applied at 160 ppm at the five-leaf stage of growth. When applied to wild oat plants at the first, second,
and third weeks after heading no reduction in dormancy occurred. A 100% reduction of seed dormancy
was not obtained for any rate of applied GA3. Seedling vigor was increased significantly when 160
ppm GA3 was applied at the five-leaf stage of growth by increasing radicle and coleoptile elongation.
The activity of extracted aqueous gibberellic substances increased as the rate of foliar applied GA3
increased, when applied at the five-leaf stage. It was concluded that foliar applied GA3 alone will not
completely overcome seed dormancy in wild oats, but will increase seedling vigor.
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Date: May 19, 1975
THE EFFECTS OF FOLIAR APPLIED GIBBERELLIC ACID$_3$ ON THE DORMANCY OF WILD OAT SEEDS

by

HOWARD FRANCIS BOWMAN

A thesis submitted in partial fulfillment of the requirements for the degree of

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in

AGRONOMY

Approved:

[Signatures of committee members]

MONTANA STATE UNIVERSITY
Bozeman, Montana

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# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>LIST OF TABLES</td>
<td>vi</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>vii</td>
</tr>
<tr>
<td>INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>LITERATURE REVIEW</td>
<td>3</td>
</tr>
<tr>
<td>Economic Loss Due to Wild Oats</td>
<td>3</td>
</tr>
<tr>
<td>Dormancy of Wild Oats</td>
<td>4</td>
</tr>
<tr>
<td>The Effects of Growth Hormones on Germination</td>
<td>6</td>
</tr>
<tr>
<td>The Foliar Application of Materials to Wild Oat Leaves</td>
<td>8</td>
</tr>
<tr>
<td>Determination of Gibberellin Activity</td>
<td>9</td>
</tr>
<tr>
<td>Use of the Bioassay to Measure Quantities of Gibberellins</td>
<td>9</td>
</tr>
<tr>
<td>GENERAL MATERIALS AND METHODS</td>
<td>11</td>
</tr>
<tr>
<td>RESULTS AND DISCUSSIONS</td>
<td>13</td>
</tr>
<tr>
<td>Screening of Plant Hormones and Chemicals</td>
<td>13</td>
</tr>
<tr>
<td>Materials and Methods</td>
<td>13</td>
</tr>
<tr>
<td>Results and Discussions</td>
<td>14</td>
</tr>
<tr>
<td>Foliar Application of Gibberellic Acid, to Wild Oat, Spring Wheat, Barley and Cultivated Oat Plants</td>
<td>16</td>
</tr>
<tr>
<td>Materials and Methods</td>
<td>16</td>
</tr>
<tr>
<td>Results and Discussions</td>
<td>17</td>
</tr>
<tr>
<td>Continued Foliar Application of Gibberellic Acid&lt;sub&gt;3&lt;/sub&gt;, to Wild Oats, Spring Wheat, Barley and Cultivated Oat Plants</td>
<td>20</td>
</tr>
<tr>
<td>Materials and Methods</td>
<td>20</td>
</tr>
<tr>
<td>Results and Discussions</td>
<td>23</td>
</tr>
<tr>
<td>Effect of Increased Concentrations of Foliar Applied Gibberellic Acid&lt;sub&gt;3&lt;/sub&gt;</td>
<td>27</td>
</tr>
<tr>
<td>Materials and Methods</td>
<td>27</td>
</tr>
<tr>
<td>Results and Discussions</td>
<td>28</td>
</tr>
<tr>
<td>TABLE</td>
<td>Description</td>
</tr>
<tr>
<td>-------</td>
<td>---------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>1.</td>
<td>Field study to evaluate seed dormancy and seedling vigor when GA$_3$ was foliar applied to wild oats at two stages of growth.</td>
</tr>
<tr>
<td>2.</td>
<td>Optical density readings evaluating the gibberellin activity in wild oats seed collected from plants receiving foliar applied GA$_3$.</td>
</tr>
<tr>
<td>3.</td>
<td>Gibberellic Acid$_3$ foliar applied to wild oats at the five leaf stage of growth using four rates.</td>
</tr>
</tbody>
</table>
LIST OF FIGURES

<table>
<thead>
<tr>
<th>FIGURE</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>The Evaluation of Seed Dormancy in Seeds from Wild Oat Plants Receiving Foliar Applied Benzyladenine, Gibberellic Acid$_3$ and Thiourea in a Greenhouse Study. . . . . 15</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Field Study to Evaluate the Effect of Foliar Applied GA$_3$ on Seed Germination of Wheat, Barley, Cultivated Oats and Wild Oats at Four Stages of Plant Growth. . . 18</td>
<td></td>
</tr>
</tbody>
</table>
These studies were conducted to determine if foliar applied gibberellic acid₃ (GA₃) could reduce seed dormancy of wild oats. Gibberellic acid₃ gave the most reduction in seed dormancy when foliar applied at 160 ppm at the five-leaf stage of growth. When applied to wild oat plants at the first, second, and third weeks after heading no reduction in dormancy occurred. A 100% reduction of seed dormancy was not obtained for any rate of applied GA₃. Seedling vigor was increased significantly when 160 ppm GA₃ was applied at the five-leaf stage of growth by increasing radicle and coleoptile elongation. The activity of extracted aqueous gibberellic substances increased as the rate of foliar applied GA₃ increased, when applied at the five-leaf stage. It was concluded that foliar applied GA₃ alone will not completely overcome seed dormancy in wild oats, but will increase seedling vigor.
INTRODUCTION

Wild oats (Avena fatua L.) has become a serious economic weed problem in cereal grains throughout the world. Seed of this weed can remain dormant in the soil for long periods of time as compared to many other seed.

The wild oat matures earlier than most cereal grains and shatters readily. Dormancy and early maturity in wild oats result in a large build up of viable seed in the soil. These characteristics make control of wild oats difficult.

Most state seed laws classify wild oats as a noxious weed and many nations prohibit the import of seed containing wild oats.

Extensive research is being conducted to develop better herbicides to control wild oats during the seedling stages of growth. Another possible method of control would be to eliminate the development of dormant seeds during maturation. If seed dormancy could be prevented in the seeds maturing on the plant, germination could occur when they shatter and fall to the soil. More complete control of wild oats could be accomplished by destroying the new seedlings through winterkill or fall cultivation.

The objective of this research was to determine if a foliar application of a plant hormone or chemical will
prevent dormancy of wild oat seeds, when applied at a given rate and stage of growth.
Economic Loss Due to Wild Oats

Wild oats (Avena fatua L.) has been reported to be adapted to most areas of the world and is found to be one of the most prevalent weed problems in cereal crops (16, 22, 24). Leith (20) assessed Canada's monetary loss due to wild oats at $120 million. In England and Wales 911,250 ha (2 1/4 million acres) of wheat and barley were estimated to be infested with wild oats. This was a 55% increase during the past 6 years (27).

Wild oats has been estimated to have infested 3,062,750 acres of agricultural farmlands in Montana (16) and 28,110,000 acres in the United States (24). Jackson (16) estimated that 75% and 50% of the irrigated and dryland acreages, respectively, in Montana are infested with wild oats.

The presence of wild oats has a distinct economic effect on farm income by reducing the quality and quantity of agricultural products (8, 11, 16, 21). The monetary loss to agricultural income for 1974, nationwide due to wild oats, was estimated at approximately $303 million. The presence of wild oats reduced crop yields, increased dockage and increased cost of production (24).
Crop yields have been drastically reduced due to infestation of wild oats. Wheat yields were reduced 30% due to a wild oat infestation of 100 wild oat plants per square yard. A similar infestation of wild oats reduced barley yields 20% and flax yields 65% (24).

Producers of pedigreed seed in some states are finding their livelihood being jeopardized by wild oats and they cannot supply the quality of seeds demanded by consumers (16).

Wild oats has many genotypes and is adapted to a wide range of environmental conditions (11).

Dormancy of Wild Oats

The causes of dormancy in wild oats have been described by several researchers (1, 7, 34). Generally these causes are characterized as:

1. rudimentary embryos
2. physiologically immature embryos (inactive enzyme systems)
3. requirements of chilling, light or darkness
4. impermeable seed coats
5. presence of germination inhibitors

Andrews (2) has shown that the cause of dormancy in freshly harvested wild oat seeds was inactive enzyme systems. This type of dormancy has been labeled as innate dormancy by
many researchers (36). Innate dormancy is considered to be an inherent characteristic of mature seeds. Germination of seeds innately dormant does not occur until an after-ripening period has passed (7). The innate dormancy is believed to be genetically controlled and various levels arise due to climatic variations during seed development on the plant (36). Sexsmith (29) found wild oat seed produced on plants exposed to low temperature (15.6 °C) in moist soil (approximately 75% available moisture) were from 31 to 100% more dormant than seeds produced on plants grown at a higher temperature (26.7 °C) in drier soil (approximately 25% available moisture). Temperature may have an effect on the amount of certain plant hormones that are translocated to the seeds and retained after maturation (29).

Induced dormancy is also found in wild oat seed and is a condition which depends on the interaction of the seed with the environment. Induced dormancy is due to specific conditions of low light intensity, low oxygen tension, high carbon dioxide tension and/or unfavorable temperature (5). Other researchers term this dormancy as imposed or enforced (34, 36).

Andrews (2) found that dormancy in wild oat seed was due to a block in the production of water soluble sugar
from the endosperm. This block was due to the absence of maltase. He found a second block in the embryo due to inefficient utilization of sugar because of inability to synthesize the 3-nucleotidase enzyme. When gibberellic acid (GA) was added, the production of maltase and 3-nucleotidase enzymes was triggered and germination occurred. Simpson (30) concluded that wild oats contained high concentrations of α and β-amylase, but maltase appeared to be absent. The application of exogenous GA₃ activated or initiated maltase synthesis which provided glucose for germination.

Inhibitors are known to exist in the hull of wild oats (5, 13). These inhibitors could be directly associated with the environmental condition in which the wild oat seeds were grown.

The Effects of Growth Hormones on Germination

The agents believed responsible for the triggering of germination in seeds are classified as plant hormones. The hormones are categorized as auxins, gibberellins, cytokinins, abscisic acid, ethylene, hypothetical florigins and miscellaneous growth substances. Balanced concentrations of certain hormones are required in seeds for germination to
occur (34, 35). Gibberellins found in the embryo of cereal grain are essential to increase the metabolic activity of the aleurone layer which results in the breakdown of stored material of the endosperm (35).

Dormancy was reduced by 61% when wild oat seeds were germinated for one week on filter paper moistened by GA$_3$ in distilled water (15). Dormant lettuce seed requires a brief exposure to red light before it will germinate. Khan (19) soaked lettuce seed in 35 mg/1 of gibberellic acid and exposed a portion of the same lot to red light for 2-3 minutes. Both lots were germinated in the dark and percent germination from the treatments was equal. Therefore, GA has been deemed capable of replacing the red light requirement and has become extensively used for germination of lettuce seed.

Thiourea has also been used to break dormancy in lettuce (32). Dormancy of peach seeds which have an after-ripening period of 10-17 weeks was broken by soaking the pits in thiourea (33). The most uniform germination of peach seeds occurred when thiourea concentrations of 0.5% and 1.0% were used. Higher rates of thiourea have been found to be toxic to germination. The mode of action of thiourea in stimulating germination is not known (3, 15).
N⁶ Benzyladenine (BA), a synthetic cytokinin has been used to overcome the dormancy causing inhibitor in apple seeds. Seeds from three varieties of apples were soaked in a 20 ppm BA solution. Most of the seeds germinated within 10 days and seedling vigor was initially increased as compared to the check. However, these applications of BA caused roots to become long and thin and seedling growth stopped (4).

The Foliar Application of Materials to Wild Oat Leaves

One of the main questions asked when applying herbicide is "At what stage of growth should the herbicide be applied in order to obtain the highest retention?" Hibbett (14) experimented with leaf angle of the wild oat to determine best growth stage for applying herbicide. He applied acid red dye using water as the carrier. After application, the dye was washed from a 5 X 0.5cm leaf section. The sections were taken from leaves which ranged from vertical to a 75° angle from vertical and plant growth stages were 1 to 8 leaves. The five-leaf stage of plant growth had the highest retention of dye measured in ug of dye removed from a given weight of leaf material. Although the leaf angle plays a very important role in spray retention, the leaf axil is
also an important collection point for retention of spray runoff (9, 14).

**Determination of Gibberellin Activity**

**Use of the Bioassay to Measure Quantities of Gibberellins**

Gibberellic acid (GA₃) and other gibberellins enhance the release of reducing substances from barley aleurone layers (25). The quantity of reducing substances released is proportional to the logarithm of gibberellin concentration applied (26). This proportionality has provided a basis for the estimation of gibberellins in plant extracts (10). The use of the barley endosperm has proven the most useful method of measuring gibberellins because the production of α-amylase is one step nearer to the primary site of action of gibberellin. Therefore, measurement of α-amylase activity as a gibberellin bioassay may be less susceptible to non-specific interferences. The direct measurement of the sugars released by α-amylase from the endosperm has proved to be simple, reproducible and insensitive to solvent residues (18).

Aqueous extraction of gibberellins from plant materials is more rapid, produces extracts which are relatively free
of contamination by pigments, and retains gibberellin substances which exist in the protein complex (17).
GENERAL MATERIALS AND METHODS

The seed used in these studies was collected from samples of commercial grain lots being tested for grade at the Montana Seed Laboratory. The lots being tested came from western Montana. All wild oat samples collected were blended to make one composite sample.

All field studies were conducted at the Plant and Soil Science Department field research laboratory in either 1972, 1973 or 1974. These research areas did not receive fertilization or supplemental irrigation.

The field plots in each study consisted of four rows 10 feet long and spaced one foot apart. Each received 10 grams of seed. Four-hundred ml of GA$_3$ were applied to the three plots of each treatment. All material was applied with a walking single wheeled sprayer at 35 psi of air pressure moving two miles per hour. A ten foot boom with five 8001 Tee-jet nozzles was used to apply the treatments. Distilled water was used as the carrying agent for all GA$_3$ treatments. The GA$_3$ used was 90% pure grade 3, and was obtained from Sigma Chemical Company, Saint Louis, Missouri.

At maturity, seed from the treated plants was harvested, cleaned and prepared for testing. Germination tests were conducted using the standard germination test as prescribed for oats by the Association of Official Seed Analysts (28).
with no prechill. Fifty seeds per observation per replication were germinated.

Viability of ungerminated seeds was determined using 0.1% tetrazolium chloride solution (31). To evaluate seedling vigor the coleoptiles and radicles of 30 seeds from each replication were measured each day for 10 days after initiation of germination. Thirty seeds which had initiated germination on the same day were vigor tested.
RESULTS AND DISCUSSIONS

Screening of Plant Hormones and Chemicals

Materials and Methods

This study was conducted in the fall of 1971 in the Montana Agricultural Experiment Station Greenhouse at Montana State University to screen GA₃, benzyladenine and thiourea for reduction of dormancy in wild oats.

Six wild oat seeds were selected at random and planted in eight-inch clay pots containing 25% peat-moss and 75% sand. A total of 28 pots were planted. After the seeds germinated and seedlings were one inch tall plants were thinned to four plants per pot. When seedlings reached the five-leaf stage applications of the treatments began. The treatments applied were GA₃ at 20 and 40 ppm, benzyladenine at 20 ppm, thiourea 10,000 ppm and an untreated check. Treatments were applied at the five-leaf stage, boot, head, and one, two and three weeks after heading. Each of the five treatments were applied to one pot of plants for each stage of plant growth. An atomizer and an aluminum foil shield were used to apply the treatments. The treatments were applied at 40 ml per pot at each of the above mentioned stages of growth.
The benzyladenine (control No. 92) and the thiourea (control No. 8930) were obtained from Nutritional Bio-Chemical Corporation, Cleveland, Ohio. The pots were completely randomized on a greenhouse bench each day to overcome the greenhouse effect. Seeds produced on these plants were germinated for eight days.

Results and Discussions

The application of 40 ppm GA₃ at the five-leaf stage increased germination of the wild oat seed 26% when compared to the check (Figure 1). A 16% increase occurred when plants were treated with 40 ppm GA₃ at the boot stage. An 11, 10, and 9% increase in germination occurred when plants were treated with 40 ppm GA₃ at the head stage and first and second weeks after heading, respectively. No increase in germination occurred when a similar treatment was applied three weeks after heading.

Germination was decreased when wild oat seeds were produced on plants receiving 20 ppm GA₃ (Figure 1). A 38% decrease in germination occurred when GA₃ was applied at the heading stage and a 22% decrease occurred when 20 ppm GA₃ was applied three weeks after heading.

No increase or decrease in germination of wild oat seeds occurred when plants were treated with 20 ppm benzyladenine or 10,000 ppm thiourea when compared to the check (Figure 1).
Figure 1. The Evaluation of Seed Dormancy in Seeds from Wild Oat Plants Receiving Foliar Applied Benzyladenine, Gibberellic Acid$_3$, and Thiourea in a Greenhouse Study.
The results of the greenhouse study indicate that an application of 40 ppm GA$_3$ at the five-leaf stage caused the most increase in wild oat seed germination. This treatment, however, did not overcome dormancy of all seed produced. All other treatments were found to increase dormancy in the seed produced or have no effect on dormancy. An application of 20 ppm GA$_3$ actually increased dormancy 38% over the check. An increase in seed dormancy when applying GA$_3$ has not been reported in the literature reviewed. However, GA is a plant hormone and it may react similarly to auxins when applied at low concentrations inhibit growth (32).

Benzyladenine and thiourea at the concentrations used in the greenhouse experiment had no effect on seed dormancy.

The greatest reduction in seed dormancy with GA$_3$ was obtained when plants were sprayed at the five-leaf stage (Figure 1).

**Foliar Application of Gibberellic Acid$_3$ to Wild Oat, Spring Wheat, Barley and Cultivated Oat Plants**

**Materials and Methods**

A field study was designed to determine if GA$_3$ had any objectionable affects on the germination of cultivated cereals and if seed dormancy in wild oats could be reduced. A split plot design with sub-unit treatments in strips was
used with "Shortana" spring wheat (Triticum aestivum L.), "Shabet" barley ( Hordeum distichum L.), cultivated "Park" oats ( Avena satium L.) and wild oats randomized within each of three replications. The seed of these cultivated varieties was acquired from the Montana Agricultural Experiment Station, Foundation Seed Program.

The treatments consisted of applying GA₃ at four stages of plant growth and an untreated check for each of the three cereals and wild oats. The GA₃ was applied at 40 ppm using 400 ml of solution per treatment (three plots).

The GA₃ was applied as a foliar spray at the following stages: five-leaf, boot, head and one week after heading. Observations of the appearance of the cereal crops during reproductive growth were recorded.

Results and Discussion

Applications of GA₃ to wheat, barley and cultivated oats did not appear to affect seed germination. Seed produced from GA₃ treated cereal plants germinated equal to the untreated checks (Figure 2). GA₃ treated plants were taller than the untreated plants and had a greater tendency to lodge.

Wild oat seed produced from plants treated at the five-leaf stage with 40 ppm GA₃ had a 9% reduction in dormancy
Figure 2. Field Study to Evaluate the Effect of Foliar Applied GA₃ on Seed Germination of Wheat, Barley, Cultivated Oats and Wild Oats at Four Stages of Plant Growth.
compared to the untreated check (Figure 2). A reduction in dormancy of 7% and 5% was observed when GA₃ was applied at the boot and head stage, respectively. Forty ppm GA₃ applied to wild oats one week after heading did not reduce dormancy when compared to the untreated check.

Foliar applied GA₃ at 40 ppm when applied to spring wheat, barley and cultivated oats had no adverse affect on growth or germination of these cereals when applied at four stages of growth. Therefore GA₃ could safely be used as a control measure for wild oats in cereal crops.

The greatest reduction in seed dormancy of wild oats was obtained when 40 ppm GA₃ was foliar applied at the five-leaf stage. The results obtained with foliar applications of 40 ppm of GA₃ at the five-leaf stage in this study agree with those obtained in the greenhouse study for the same rate and stage of application. These studies also show that complete reduction of dormancy was not obtained using 40 ppm GA₃.

Some herbicides are applied at the five-leaf stage of crop growth; therefore, it may be possible to apply GA₃ along with these herbicides. Application of GA₃ at the five-leaf stage of wild oat growth could readily be done by air or ground equipment.
Continued Foliar Application of Gibberellic Acid

Materials and Methods

Data obtained in the previous studies suggest that higher rates of GA₃ may be advantageous in reducing seed dormancy of wild oats.

The field design for this study was a completely randomized block with three replication.

Rates of 0, 40 and 160 ppm GA₃ were applied to wild oat plants at the five-leaf stage and 40 ppm applied at the five-leaf stage and again at the boot stage.

A modified form of the extraction procedure used by Jones (17) for pea seeds was used for extraction of aqueous gibberellins from wild oat seeds. The procedure used is as follows: Five grams of wild oat seed from each treatment was ground in a Hobart Grinder, Model 3440, made by Hobart Manufacturing Company, Troy, Ohio. The ground material was mixed with 10 ml of 80% aqueous methanol and allowed to soak for 24 hours. The debris was removed using Whatman No. 41 ashless filter paper. The filtrate was partitioned twice with 10 ml of petroleum ether to remove pigments and lipids. The methanol was evaporated from the aqueous phase of the methanol extract at room temperature for 24 hours. The aqueous phase was measured and partitioned with an equal
amount of ethyl acetate and then placed under a hood to remove the ethyl acetate. The solution was buffered to a pH of 7.2 with "Tris" buffer and incubated in crude ficin (0.1 g/10 ml of solution) for 8 hours at 19.4°C. The protein was precipitated from the solution with methanol and the solution acidified with 1N-HCL to a pH of 2.5. It was then partitioned three times with ethyl acetate. The remaining aqueous solution was evaluated for gibberellin activity.

The ficin, tech. 4865 was obtained from K & K Laboratories, Inc., Hollywood, California and the Trizma base No. T-1503, reagent grade, Tris (Hydroxymethyl) Aminomethane was obtained from Sigma Chemical Company, Saint Louis, Missouri.

A barley endosperm bioassay was used to determine gibberellin activity of the aqueous solution. Shabet barley seeds (enough for three endosperm per sample) were soaked in 3% hydrogen peroxide for two hours. Seeds were removed from the hydrogen peroxide and soaked overnight in distilled water. The embryo of each seed was removed to obtain endosperm portions of approximately 4 mm for the bioassay test. Three barley endosperms were placed in 5 ml of each aqueous extract and incubated for 24 hours at 38.9°C. After
incubation, endosperms were removed from the aqueous extract which was then evaluated for reducing sugars.

The Anthrone method for carbohydrate evaluation was used to evaluate gibberellin activity or amount of reducing sugars produced.

The procedure used was a modified form of the Methods of Analysts, as outlined by the Association of Official Agricultural Chemists (23) and as described by Yemm (37).

Reagents:
1. Anthrone—2% in ethyl acetate placed in a brown ground glass stoppered bottle (1 gram anthrone per 50 ml ethyl acetate).

2. Concentrated $\text{H}_2\text{SO}_4$ c.o.

Procedure: Pipette 0.5 ml of extract into 180 x 18 mm pyrex test tube. Add 0.5 ml of distilled water. Add 0.5 ml of anthrone reagent, then add 6 ml of concentrated $\text{H}_2\text{SO}_4$, carefully layered into the test tube. Swirl the tube gently, then vigorously.

Three observations were prepared for each treatment. Test tubes were heated in water to a boil and held for three minutes, then air cooled for 20 minutes. Optical density readings were made on a Spectrophotometer, Model
Results and Discussions

Wild oat seeds produced on plants treated at the five-leaf stage with 160 ppm GA₃ or with 40 ppm GA₃ applied at two stages of growth were more rapid in germination than all other treatments (Table I). These treatments had the highest germination after seven days. The germination of seed from the 160 ppm GA₃ treatment was 23% higher than the check. The application of 40 ppm GA₃ at the boot stage, produced seeds which were significantly greater in germination than the check. There was no difference in the germination of the seed produced from plants which were untreated or treated at the five-leaf stage with 40 ppm GA₃.

There were less differences in germination of treated and untreated seeds after 10 days of germination. However, the two treatments of 160 ppm and 40 ppm GA₃ applied twice were significantly greater than the other GA₃ treatments and the check. The untreated check had more dormant seeds remaining after 10 days of germination than the 160 ppm
Table 1. Field study to evaluate seed dormancy and seedling vigor when GA<sub>3</sub> was foliar applied to wild oats at two stages of growth

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Germination 7 days</th>
<th>10 days</th>
<th>Dormant 10 days</th>
<th>Radicle Elongation 10 days</th>
<th>Coleoptile Elongation 10 days</th>
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<tr>
<td>Check</td>
<td>28 a**</td>
<td>71 a</td>
<td>27 a</td>
<td>38 b</td>
<td>113 b</td>
</tr>
<tr>
<td>40 ppm 5 leaf</td>
<td>28 a</td>
<td>70 a</td>
<td>28 a</td>
<td>29 a</td>
<td>89 a</td>
</tr>
<tr>
<td>40 ppm Boot</td>
<td>40 b</td>
<td>70 a</td>
<td>28 a</td>
<td>30 a</td>
<td>99 a</td>
</tr>
<tr>
<td>*80 ppm</td>
<td>49 bc</td>
<td>81 b</td>
<td>19 a</td>
<td>37 b</td>
<td>113 b</td>
</tr>
<tr>
<td>160 ppm 5 leaf</td>
<td>51 c</td>
<td>84 b</td>
<td>15 a</td>
<td>44 c</td>
<td>132 c</td>
</tr>
</tbody>
</table>

*40 ppm applied at the 5 leaf stage and 40 ppm applied at the boot.

**Means within a column followed by the same letter are not significantly different at the 5% level of probability according to Duncan's multiple range test.
GA₃ treatments, but the statistical analysis indicated no significant differences.

Greatest radicle and coleoptile elongation was obtained from the seeds of plants treated at the five-leaf stage with 160 ppm GA₃. Radicle and coleoptile elongation of the check and the 40 ppm GA₃ applied twice was similar. The treatments of 40 ppm GA₃ applied at the five leaf stage and at the boot stage produced the least amount of radicle and coleoptile growth (Table 1).

Approximately 2.5 ml of gibberellin extract was produced from each of the three observations per treatment. The 160 ppm rate of GA₃ applied at the five-leaf stage resulted in the greatest gibberellin activity based on the optical density readings. The 40 ppm GA₃ applied at the boot and 40 ppm applied twice (five-leaf and boot stage) were both equal in gibberellin activity but were significantly more active than the check and the 40 ppm GA₃ applied at the five-leaf stage (Table 2).

Higher concentrations of GA₃ applied as a foliar spray did reduce dormancy when compared to the 40 ppm GA₃ rate used in previous studies. The 160 ppm GA₃ rate improved germination and increased radicle and coleoptile elongation. The untreated check germinated slowly but those seeds which germinated grew rapidly as evidenced by
Table 2. Optical density readings evaluating the gibberellin activity in wild oats seed collected from plants receiving foliar applied GA₃

<table>
<thead>
<tr>
<th>GA₃ Treatments</th>
<th>Replications</th>
<th></th>
<th>2</th>
<th>3</th>
<th>X</th>
</tr>
</thead>
<tbody>
<tr>
<td>Check</td>
<td></td>
<td>.68</td>
<td>.66</td>
<td>.56</td>
<td>.63 a**</td>
</tr>
<tr>
<td>40 ppm five-leaf</td>
<td></td>
<td>.67</td>
<td>.77</td>
<td>.66</td>
<td>.70 a</td>
</tr>
<tr>
<td>40 ppm boot</td>
<td></td>
<td>.69</td>
<td>.98</td>
<td>.85</td>
<td>.84 b</td>
</tr>
<tr>
<td>80 ppm* 5 leaf &amp; boot</td>
<td></td>
<td>.90</td>
<td>.87</td>
<td>.85</td>
<td>.87 bc</td>
</tr>
<tr>
<td>160 ppm 5 leaf</td>
<td></td>
<td>.95</td>
<td>.96</td>
<td>.90</td>
<td>.93 c</td>
</tr>
</tbody>
</table>

*40 ppm applied at the five-leaf stage and 40 ppm applied at the boot stage.

**Means within a column followed by the same letter are not significantly different at the 5% level of probability according to Duncan's multiple range test.
elongation of radicle and coleoptile. The rapid growth of seedlings from the check occurred because seeds which germinated first were the ones measured. Those seeds would have constituted the non-dormant seed portion of the untreated check. Therefore, the level of GA present in those seeds could have been equal to that of seeds from GA$_3$ treated plants.

In comparing the data in Table 1 and Table 2 it was observed that as GA$_3$ rates increased; wild oats seed dormancy decreased, seedling vigor increased, and gibberellin activity increased.

Effect of Increased Concentrations of Foliar Applied Gibberellic Acid$_3$

Materials and Methods

This field study was designed to determine if increased concentrations of GA$_3$ would give more complete reduction of seed dormancy of wild oat.

A randomized complete block design with three replications was used in this study. Rates of 0, 160, 240, 320, and 640 ppm of GA$_3$ were applied to the wild oat plants at the five-leaf stage.
Results and Discussions

Application of 240, 320 and 640 ppm GA$_3$ at the five-leaf stage of growth did not increase germination of wild oat seeds over the 160 ppm treatment previously evaluated (Table 3). However, all four rates increased germination significantly over the check. The check had a significantly greater amount of dormant seed when compared to the four GA$_3$ treatments.

Coleoptile and radicle elongation was not significantly different from the five treatments, including the check. The results of this study corresponds with the reduction of dormancy which occurred in the 1973 field study for the same application rate and stage of growth.

Data from this study and the previous study indicated no advantage to applying GA$_3$ in excess of 160 ppm to reduce seed dormancy. The difference in percent of seed dormancy in Table 1 and Table 3 for all treatments may be attributed to difference in temperature during seed maturation. Similar observations were noted by Sexsmith (29); he found that low temperature increased seed dormancy.

This field study was subjected to considerable stress from lack of moisture, poor germination of wild oats and an infestation of cutworms. The number of plants producing
Table 3. Gibberellic Acid foliar applied to wild oats at the five leaf stage of growth using four rates.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Germination 7 days</th>
<th>Germination 10 days</th>
<th>Dormant 10 days</th>
<th>Mean Radicle Elongation 10 days</th>
<th>Mean Coleoptile Elongation 10 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Check</td>
<td>4.3 a*</td>
<td>4.3 a</td>
<td>88 c</td>
<td>37.1 a</td>
<td>99.9 a</td>
</tr>
<tr>
<td>160 ppm</td>
<td>19.0 b</td>
<td>21.7 b</td>
<td>53 a</td>
<td>59.7 a</td>
<td>141.2 a</td>
</tr>
<tr>
<td>240 ppm</td>
<td>15.3 b</td>
<td>20.3 b</td>
<td>60 a</td>
<td>62.7 a</td>
<td>120.5 a</td>
</tr>
<tr>
<td>320 ppm</td>
<td>17.6 b</td>
<td>20.0 b</td>
<td>52 a</td>
<td>48.1 a</td>
<td>124.8 a</td>
</tr>
<tr>
<td>640 ppm</td>
<td>14.6 b</td>
<td>18.0 b</td>
<td>61 b</td>
<td>38.2 a</td>
<td>101.9 a</td>
</tr>
</tbody>
</table>

*Means within a column followed by the same letter are not significantly different at the 5% level of probability according to Duncan's Multiple range test.
seed and harvested range from five to ten plants per replication. Due to the irregular number of plants harvested among replications, the data collected was variable as indicated by a CV of 42% for radicle elongation.
GENERAL DISCUSSION

These studies indicate that foliar application of GA$_3$ at the five-leaf stage of growth is the best stage of application to reduce seed dormancy in wild oats. Previous studies by Hibbitt (14) indicate that this stage has the highest retention of applied solution. He found that the low contact angle of the five-leaf stage retained more red dye. This stage allows the applied material greater flat surface area to contact and the angle allows runoff spray to flow toward the stem and collect in the leaf axil.

Applications during the boot and head stages of growth resulted in significantly greater reduction of dormancy compared to the check, but were less effective than applications made at the five-leaf stage. These results may have related to the leaf angle at time of application and the age of plant. As plants become older the cuticle becomes thicker; therefore, less spray is absorbed. Also, as plants become older the leaves angle downward at the tips leaving less area to retain spray (14).

Thiourea and benzyladenine had no effect on reduction of dormancy. These results (Figure 1) confirm those obtained by Holm (15). Benzyladenine is known to induce germination in peach, apple and lettuce seeds (14), but
the dormant seeds of the wild oats did not respond to foliar application of 20 ppm.

Forty ppm GA$_3$ applied at the five-leaf stage and again at the boot stage significantly reduced dormancy of the wild oat seeds as compared to the check or 40 ppm applied at the five-leaf stage (Table 1). The 40 ppm applied at the five-leaf stage and again at the boot and the 160 ppm rate were equal and gave the most reduction in seed dormancy of wild oats (Table 1) as compared to the other treatments.

The 160 ppm GA$_3$ rate was equal to higher rates of 240, 320 and 640 ppm. However all GA$_3$ treatments were significantly more effective in reducing seed dormancy than the check (Table 3).

Total reduction of dormancy was not observed in these studies regardless of the treatment. Black (6) observed similar results when he treated wild oat plants which were severed below the node of the youngest leaf when the seeds were in the milk stage. Culms were placed in flasks containing 10, 100 and 1000 ppm of GA$_3$ and allowed to develop mature seeds which germinated 30, 25 and 50% respectively. Even at the higher rates of GA$_3$, the dormancy was not 100% reduced as has been found in these studies using foliar applied GA$_3$. 
The germination of spring wheat, barley and cultivated oats was not affected by the GA$_3$. The noted height increase of these cereals in the second study is additional evidence to indicate that foliar applied GA$_3$ is being taken up by the plants. The higher rates of GA$_3$ were observed to increase gibberellin activity (Table 3). These results correspond to those of Andrews (2) where he found that dormancy in wild oat seeds is due to the inability of the seed to produce soluble sugars. He states that gibberellic acid must be present to trigger the synthesis of soluble sugars and promote germination.

Seedling vigor of many species is related to the increased growth of radicle and coleoptile. The most growth increase noted in both radicle and coleoptile elongation was at the 160 ppm rate of GA$_3$ applied at the five-leaf stage (Table 1). This rate was equal to the 40 ppm rate applied at the five-leaf stage and again at the boot. Both of these treatments increased seedling vigor over other GA$_3$ treatments. The literature suggests that increased growth of the seedling could be the result of increased production of soluble sugars due to increased levels of GA present in the seed (2). If this fact is true then more soluble sugar is available as food for germination.
The gibberellin activity of wild oat seeds increased as the GA$_3$ rates were increased as observed by the optical density readings (Table 3). The increased optical density reading was a measure of the amount of reducing sugar produced from barley endosperms which were incubated in gibberellin extractions obtained from the wild oat seeds. These same results were observed by Paleg (25). Jones (18) showed that optical density at 620 mu will increase or decrease directly proportional to the quantity of sugar present in a mixture. Based on this relationship it appears that increased rates of foliar applied GA$_3$ increased gibberellin activity which resulted in increased elongation of radicles and coleoptiles.
CONCLUSION

The greatest reduction in seed dormancy of wild oats was obtained when a foliar application of 160 ppm of GA$_3$ was applied at the five-leaf stage of growth. This rate also produced the greatest increase in elongation of coleoptile and radicle and had the most gibberellin activity.

The elongation of radicles and coleoptiles and the activity of aqueous gibberellin were increased as the rate of applied GA$_3$ was increased up to 160 ppm. A similar phenomenon occurred in the reduction of seed dormancy. None of the foliar applied rates of GA$_3$ gave 100% reduction in seed dormancy.

Benzyladenine and thiourea did not effect the dormancy of the wild oat seeds even though they are effective in reducing seed dormancy of other species.

Seeds containing higher levels of gibberellin activity may germinate faster and produce seedlings with greater growth vigor.

The door is still open for further research in this area, even though seed dormancy was not totally reduced by any of the rates of GA$_3$ applied or by any of the stages. Combination of different plant hormones may be the answer to 100% reduction in seed dormancy. Another possible
avenue of approach would be plant hormone and chemical combinations that would control dormancy and therefore give the farmer better control of wild oats.

The treating of seeds with GA₃ or further research in foliar applied GA₃ may improve seedling vigor of some cultivated crops and in turn increase yield or enhance crop establishment. The increased radicle elongation observed, due to GA₃, in this study (Table 1) may produce more and stronger roots with greater food reserves in a fall seeded crop. Therefore; increased gibberellin activity may be a factor in the prevention of winterkill.

Research techniques developed in this study may be used to progeny test malt barley breeding lines to determine gibberellin activity which could result in higher malt extracts which would be beneficial to the malting industry.
BIBLIOGRAPHY


Bowman, Howard F

The effects of foliar applied geberellic acid on the dormancy of wild oat seeds