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

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

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HOWARD FRANCIS BOWMAN

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

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ABSTRACT

These studies were conducted to determine if foliar applied gibberellic acid$_3$ (GA_3) could reduce seed dormancy of wild oats. Gibberellic acid$_3$ 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 GA_3. Seedling vigor was increased significantly when 160 ppm GA_3 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 GA_3 increased, when applied at the five-leaf stage. It was concluded that foliar applied GA_3 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.

LITERATURE REVIEW

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 GA_3 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/l 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).

N^6 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 (GA_3) 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 GA_3, 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 GA_3 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 GA_3 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 GA_3 at the boot stage. An 11, 10, and 9% increase in germination occurred when plants were treated with 40 ppm GA_3 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 GA_3 (Figure 1). A 38% decrease in germination occurred when GA_3 was applied at the heading stage and a 22% decrease occurred when 20 ppm GA_3 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).

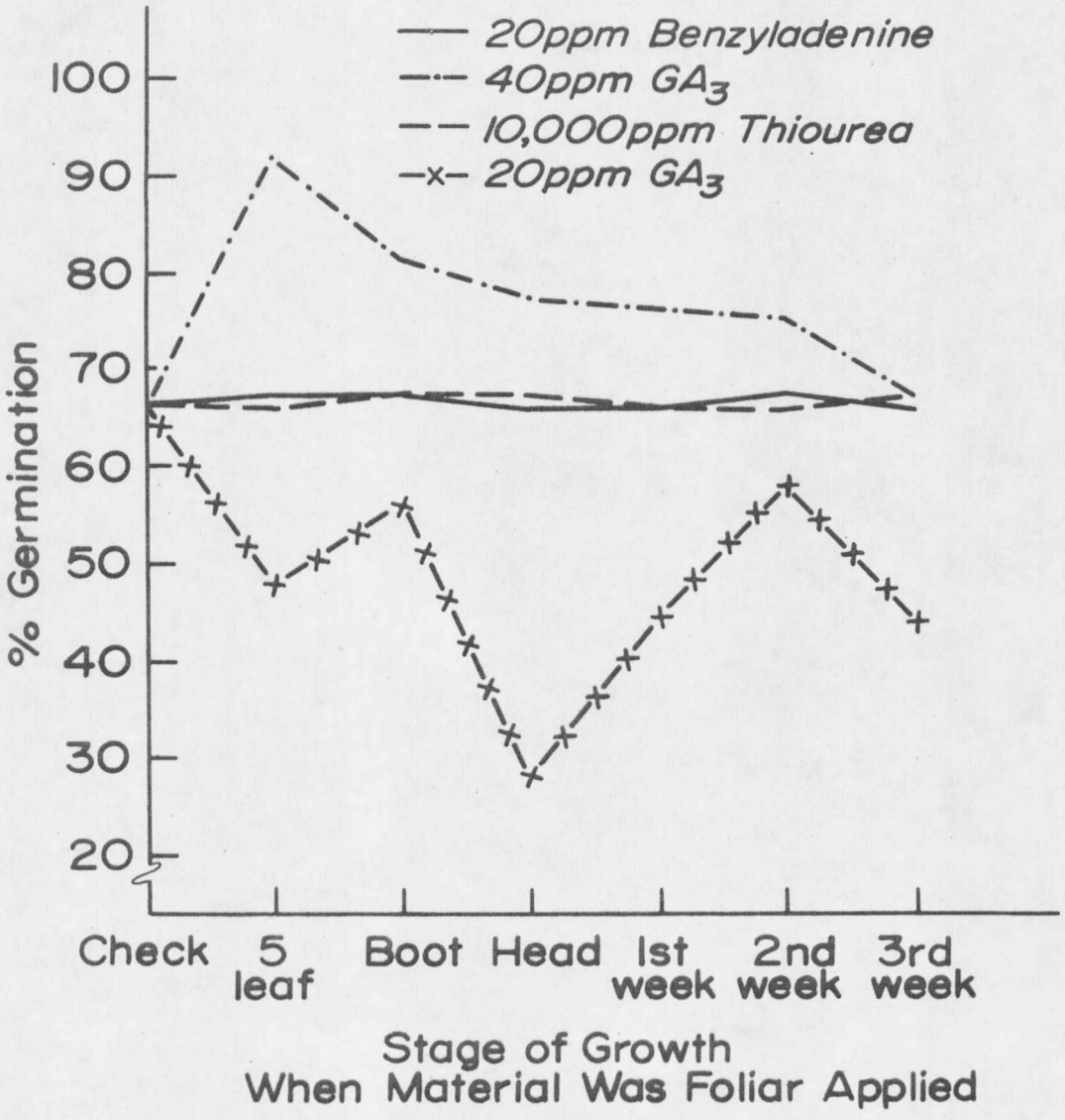

Figure 1. The Evaluation of Seed Dormancy in Seeds from Wild Oat Plants Receiving Foliar Applied Benzyladenine, Gibberellic Acid$_3$ and Thiourea in a Greenhouse Study.

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 GA_3 at four stages of plant growth and an untreated check for each of the three cereals and wild oats. The GA_3 was applied at 40 ppm using 400 ml of solution per treatment (three plots).

The GA_3 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 GA_3 to wheat, barley and cultivated oats did not appear to affect seed germination. Seed produced from GA_3 treated cereal plants germinated equal to the untreated checks (Figure 2). GA_3 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 GA_3 had a 9% reduction in dormancy