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Effects of 2-Chloroethyl-phosphonic Acid (Ethephon) As a Male Gametocide for Induction of Sterility in Wheat and Barley

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To the Graduate Council:

I am submitting herewith a dissertation written by Jacqueline Taylor Martin entitled "Effects of 2-Chloroethyl-phosphonic Acid (Ethephon) As a Male Gametocide for Induction of Sterility in Wheat and Barley." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Plants, Soils, and Insects.

V.H. Reich, Major Professor

We have read this dissertation and recommend its acceptance:

John H. Reynolds, F.F. Bell, J.W. Hilty

Accepted for the Council:
Dixie L. Thompson

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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Vernon H Reich

V. H. Reich, Major Professor

We have read this dissertation and recommend its acceptance:

John H Reynolds

James W. Hilty

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Accepted for the Council:

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Vice Chancellor
Graduate Studies and Research

EFFECTS OF 2-CHLOROETHYLPHOSPHONIC ACID (ETHEPHON) AS A MALE GAMETOCIDE FOR INDUCTION OF STERILITY IN WHEAT AND BARLEY

A Dissertation
Presented for the
Doctor of Philosophy
Degree
The University of Tennessee, Knoxville

Jacqueline Taylor Martin

August 1976

DEDICATED TO

MY SONS

Jeffrey Terence, Ivan Tony,

and Marvin Todd Martin

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ABSTRACT

Exploitation of induced male sterility has now become a potential tool in plant breeding. Ethephon (2-chloroethyl-phosphonic acid) has induced male sterility in winter cultivars of wheat and barley.

The purpose of this research was to further elucidate the response of winter wheat (Triticum aestivum L. em Thell), and winter barley (Hordeum vulgare L.) to foliar application of ethephon.

Ethephon was foliarly sprayed on winter cultivars of wheat and barley which were Arthur and Blueboy, and Barsoy and Volbar respectively, at 0.05, 0.10, and 0.20 and 0.40 percent active ingredient, when plants were in mid-boot and late boot stages in the field study at Knoxville, Tennessee. In the growth room wheat winter cultivars Arthur and Blueboy, and barley winter cultivars Keowee and Harrison were sprayed at 0.02 and 0.05 percent active ingredient at the late boot stage of development.

The most effective level was 0.40 percent ethephon in mid-boot and late boot stages for both cultivars of wheat and barley in the field study.

Concentration, replication, date, cultivar, date X concentration, date X cultivar, concentration X cultivar, date X concentration X cultivar effects were significant for

all variables except seed weight, date headed, and date mature. No overall replication, date X concentration, date X cultivar, and concentration X cultivar effects occurred for seed weight. No overall date X concentration X cultivar effect occurred for date headed. No overall concentration effect occurred for date mature. Concentration and cultivar effects per plant were strongly and positively associated with induction of male sterility.

Clearly female fertility was not impaired to any great extent from ethephon treatments from data obtained from open-pollinated spikes.

Certain beneficial effects, such as reduced height and lodging, were accompanied by reduced yields.

The successful utilization of this technique using ethephon in enhancing production of hybrid plants, however, depends on the economics of hybrid seed production. The results of this research project indicate the induction of male sterility with ethephon in wheat and barley appears feasible.

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CHAPTER I

INTRODUCTION

Barley, *Hordeum vulgare* L., and wheat, *Triticum aestivum* L. em Thell, belong to the naturally self pollinated group of crop plants. A major objective in barley and wheat research has been, and probably will continue to be, improving the performance of cultivars. Breeding procedures for barley and wheat improvement have been restricted by the number of hybridizations a breeder could make. The World Collections of wheat and barley contain much germplasm for resistance to insects and diseases which has not been utilized due to this restriction. To date the wheat and barley cultivars have not been able to capitalize on heterosis.

Emphasis is currently being directed toward the potential use of 2-chloroethylphosphonic acid (ethephon) as a possible gametocide for induction of male sterility in barley and wheat. In order to cross plants of both barley and wheat, in most of the early phases of breeding work, the plant breeder emasculates the floret by removing the anthers before they are mature and protects the spike from pollination by covering it with a small glassine and/or plastic bag. Within a few days he transfers anthers with viable pollen from the selected male parent to the stigma in the emasculated flower. Although this process is effective, it is both time consuming and tedious.

The use of ethephon as a possible gametocide was based on the initial observation that foliar applied liquid ethephon increased the number of pistillate flowers on monoecious cucumbers (Cucumis sativus L.), (11, 15).

Since then, liquid ethephon has been used experimentally as a male gametocide on both wheat (16) and barley (3, 16, 18), and levels of male sterility up to 100 percent have been obtained with no apparent reduction in female fertility (17).

This study was initiated as a preliminary investigation to determine if ethephon could be used as a male gametocide in an applied breeding program. The objectives of this study were to determine what concentrations of ethephon are necessary to induce male sterility and determine what if any side effects are concomitant with the induction of male sterility.

CHAPTER II

LITERATURE REVIEW

Plant breeders have attempted to increase barley and wheat yields of desirable quality grain by improving such characters as stiffness of straw, earliness, shattering, disease resistance, winter hardiness and industrial quality. Achievement of these objectives is often difficult because only one major system of hybridization currently is receiving much attention—the cytoplasmic male sterile-restorer method. This system has several inherent disadvantages centered around the problem of an inadequate restorer system for genetic restoration of fertility in the hybrid in wheat and such a system has not yet been discovered for barley.

Chemical induction of male sterility would provide an additional, workable system that is rapid, flexible, and would not require fertility restoration. The induction of male sterility by chemical means appears to be a possible alternative, because of the problems associated with the present cytoplasmic male sterile-restorer system in wheat.

Initially McMurray and Miller (11) discovered that liquid ethephon foliar applied increased the number of pistillate flowers on monecious cucumbers and could be considered as a possible male gametocide. As many as 19 successive pistillate nodes were observed for the treated monoecious cultivar 'SC 23'.

The most effective concentrations of ethephon were 120, 180, and 240 ppm for these studies. These rates in multiple or single applications resulted with the least shortening of internodes and in the greatest number of continuous female nodes. Significant yield increases were obtained for these monoecious cultivars, 'Model', 'SC23' and 'Chipper'.

Fairey and Stoskopf (5) studied granular ethephon as a gametocide on three winter and six spring wheat cultivars. Using chemical concentrations of 2 to 8, 26.0 to 109.2, and 164 to 822.0 kg/ha. sterility values reached mean values of 65, 71, and 89 percent for the different rate concentrations respectively. Chemical applications were made at three stages of growth development, which included primary tiller emergence, initiation of spikelet primordia on the main culm, and during the early-boot phase. Mean sterility levels rose with increase in the rate of gametocide; it was most effective when applied at the highest rate during reproductive development on the main culm.

Induction of male sterility in wheat with ethephon for both greenhouse and field-grown wheat was attempted by Rowell and Miller (16). Their research demonstrated that plants treated with 500 ppm in the pre-boot and boot stages of development produced significantly fewer seeds per spike compared with untreated spikes. Plants treated with 1000 to

3000 ppm ethephon produced little or no seed set. The chemical concentration from 1000 to 2000 ppm applied at the early, mid- and late boot stages seem to be the most effective level of male sterility. The concentration of ethephon needed to approach 100 percent sterility increased with increasing maturity of the plants. Their results indicate that production of effective male sterility in wheat utilizing ethephon appears feasible, especially since the ovary, style, and stigma of treated plants appeared unaffected. In field-grown 'Nugaines' winter wheat, significant differences between seeds per spike in those spikes allowed only to self-pollinate and those allowed to cross-pollinate with pollinator were shown for all concentrations in the early, mid-, and late boot stages indicating ovary receptiveness. Side effects were minimal except at higher concentrations in which poor spike emergence and plant dwarfing were observed.

Chemical induction of male sterility in wheat and barley with chemicals containing ethephon would be useful, however, only if female fertility was not affected. Previous reports on the chemical induction of male sterility in crop plants have described varying degrees of female sterility which ultimately limited the usefulness of the chemical as a selective gametocide (14). Therefore, Rowell and Miller (17) completed a study to determine the effect of ethephon on female fertility in wheat and to determine if F_1 seed could be produced using chemical male-sterile lines. Female fertility was determined in greenhouse and field-grown chemical male-sterile C-lines of wheat using ethephon as a gametocide. The number of seed per spike and percent of F_1 hybrid seed produced on C-lines did not differ significantly from male-sterile B-lines following hand pollination for both lines in the greenhouse studies. All rates of ethephon resulted in 87 percent or more F_1 seed when treated at pre-, early, mid-, and late boot stages. Outcrossing in the field ranged from 5 to 100 percent. Based on the percent hybrid seed obtained, the optimum stages for field application in 'Nugaines' wheat were pre, early, and midboot at chemical dosages of 1,500 to 3,000 ppm. Sensitivity to ethephon treatment appeared to be greater in the greenhouse than in the field. Under field conditions significant increases in seed set on nonbagged spikes over that of bagged spikes for field grown C-lines were shown. Their observations coupled with the significant occurrence of hybrid seed produced on C-lines grown in the field or in the greenhouse indicate that female fertility was high following chemical sterilization by ethephon.

Other chemicals as possible gametocides for male sterility are maleic hydrazide, dalapon, FW-450, potassium gibberellate, triiodobenzoic acid, dimethylamine salt of trichlorobenzoic acid, napthalene acetic acid, and ethanol and isopropanol series of amine salt of 2,4-D with wheat (14).

Wang and Lund (19) discovered foliar sprays with various rates of an aqueous solution of sodium 1-(p-chlorophenyl) 1, 2-dihydro-4,6-dimethyl-2-oxonicotinate (RH-531) would cause complete male sterility by applying 2,000 and 4,000 ppm RH-531 at the six-leaf stage, 16 days before heading, on 'Larker' spring barley. However, such treatments reduced female fertility by about 60 percent of the control. Seed-set on hand-pollinated spikes might be higher if each spike had been pollinated several times during the fertile stage. Jan, Qualset, and Vogt (9) found that RH-531 did not result in abnormal pollen grain mitosis, and did not find sterility induced by RH-531.

Positive correlations were found between percentage seed-set of bagged spikes and anther length, and between percentage seed-set of bagged spikes and pollen grain carbohydrate content. It appeared that RH-531 inhibited anther growth thus leading to either degeneration of microspores or reduction in carbohydrates in barley pollen grains (19).

Law and Stoskopf (10) reported that to achieve higher and more reliable sterility levels, completeness of foliar coverage experiments were conducted with Paragon barley on 12 potted plants in the growth room. Each plant was sprayed with ethephon at 0.98 or 1.40 kg/ha with a precision sprayer calibrated to deliver the equivalent of 309 and 618 liters/ha of spray solution at a pressure of 2.80 kg/cm^2. An increase in male sterility of less than 10 percent was obtained with the more thorough coverage of the 618 liter/ha spray, indicating that coverage is important but not a limiting factor.

Porter and Wiese (14) used FW 450 during 1958, 1959, and 1960 in the field and greenhouse to evaluate methods for inducing male sterility in wheat. They found the heavier rates caused considerable plant damage, delayed maturity, and decreased plant height. However, none of the treatments caused an appreciable reduction in fertility or seed set. The FW 450 treatments caused severe damage to spring wheat at all stages of growth and severe to moderately severe damage to winter wheat. Only a trace of sterility appeared to be associated with FW 450 treatments applied to winter wheat and injury to spring wheat was so severe as to preclude its evaluation as a gametocide.

Chopra, Jain and Swaminathan (4) used maleic hydrazide (MH-30), which was obtained from the U.S. Rubber Company, as MH-30 (formulation containing 30 percent active ingredient.) They used 50, 100, 250, and 500 parts per million to thirty-seven day old wheat plants treated by spraying and discovered that 250 ppm and 100 ppm were fairly effective in causing pollen sterility. They also used F.W. 450, TIBA, nucleic acid, thymine and uracil, and stated these were not too effective to produce abortion of pollen grains, because the fertility was also approximately the same percentages found in the controls.

CHAPTER III

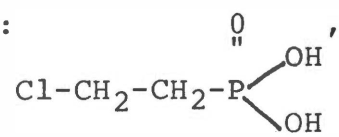
MATERIALS AND METHODS

I. PLANT MATERIALS

Four cultivars of barley, and two of wheat were chosen as plant materials for this study. The cultivars represent cultivars grown in the Soft Red Winter wheat region of the United States within the past ten years. Each cultivar has some outstanding features as noted in the following descriptions. Barsoy barley is an early-maturing, rough-awned variety with good straw strength, as well as good yields (6). Harrison barley is a medium-tall, rough-awned variety with good standing ability. It has good resistance to powdery mildew, leaf rust, scald, and some resistance to net blotch. Harrison is not acid tolerance and performs best at a soil pH of 6.0 or above (7). Keowee barley was selected from the Davis X Hudson cross at Clemson University. Keowee is a six-rowed winter barley with moderate winter hardiness and semiprostrate seedling growth. It has medium-length awns and is medium-late in maturity. This variety has performed well in the Tennessee variety test for several years (6). Volbar barley is a winter-hardy, six rowed, tall, rough-awned variety with maturity similar to Harrison. Volbar has yielded well in the Tennessee variety test and has resisted lodging. Volbar has slight tolerance to Barley Yellow Dwarf Virus disease (6). The two cultivars of wheat selected do possess some notable features too, because Arthur is a very early, winter-hardy, soft red winter variety with good straw strength. Arthur has good test weight and is resistant to certain races of powdery mildew, and moderately resistant to leaf rust, stem rust, and loose smut. Arthur has been relatively free of disease for the past two years in the Tennessee variety test (6). Blueboy is a semi-dwarf wheat with good yielding ability and low test weight. It has excellent standing ability and is variable in plant height with a blue color before ripening (7).

II. GAMETOCIDE

All tests were conducted using ethephon (2-chloroethyl-phosphonic acid) with a structural formula:



a molecular weight of 144.5, and EPA Reg. No. 264-267 AA. Liquid material of 21.3 percent active ingredient was used for all tests.

According to Amchem scientists (1) ethephon is a general plant growth regulator with ethylene responses in plants for fruit ripening, abscission, flower induction and breaking apical dominance. Ethephon releases ethylene to plant tissues as its mechanism of action, and is easily washed off foliage, translocated, as well as a compound which is degraded to naturally occurring substances (8).

III. FIELD EVALUATION

Winter cultivars of barley and wheat were fall planted October 24, 1975 at the Plant Sciences Field Research Laboratory (Knoxville Cotton Farm) Knoxville, Tennessee, on Decatur and Emory silt loam. Plots were ranged in a randomized complete block design with five replications. Plots consisted of four rows eight feet long and one foot apart seeded at the rate of 120 pounds/acre. The amount of fertilizer used consisted of 400 pounds/acre of 6-12-12 before planting and 100 pounds/acre of ammnonium nitrate (34.5 pounds of nitrogen) top dressed on February 17, 1976.

Treatments consisted of two growth stages, midboot and late boot, five chemical concentrations, 0, 0.05, 0.10, 0.20, and 0.40 percent ethephon, and four cultivars, Volbar and Barsoy barley and Arthur and Blueboy wheat. Plants were considered at midboot when the spike was approximately 8 cm from emergence, and late boot when the sheath was slightly swollen until spike was just exposed. The treatments were arranged as a 2 X 5 X 4 factorial. All treatments were applied and data collected from center two rows of each plot.

Six ml of Tween 20 (Polyoxyethylene Sorbitan Monolaurate), a wetting agent, were added to each of the chemical concentrations in 2500 ml of water to aid in keeping the material on the foliage. Plants were foliar sprayed with a hand sprayer at 30 psi of pressure until runoff (approximately 336 ml per square meter) when the majority of culms in the two center rows of each plot were at the appropriate developmental growth stage.

In each plot estimates of sterility were made from randomly selected spikes which were covered with a glassine bag in spike emergence. In addition two unbagged spikes were randomly selected from the center rows of each plot to estimate the amount of cross pollination occurring. Date headed was recorded as days after April 1, and date mature was recorded as days after May 1. Plant height and lodging were recorded the day of harvest. The center two rows of each plot were cut, threshed and weight of grain recorded on June 16, 1976.

IV. GROWTH ROOM EVALUATION

The seeds from four cultivars, Blueboy and Arthur wheat, and Harrison and Keowee barley were vernalized at 0° C from June 23 to July 23, 1975. Forty-eight four-inch pots were filled with a potting mixture of 36 parts soil: 24 parts peat: 18 parts sand; subsequently four vernalized seedlings were planted in each pot on July 23, 1975.

Plants were grown in the growth room maintained at a 16 hour daylength and an 8-hour dark cycle with a temperature of approximately 27° C, and the plants were watered every

40 hours. On August 6, 1975 all seedlings were thinned to one per pot. Male fertile plants were treated at 1 growth stage (late boot), and plants were considered in this stage when the sheath was slightly swollen until the spike was just exposed. Two chemical concentrations of ethephon were used, 0.02 and 0.05 percent active ingredient. Pots were arranged in a completely randomized block design with three replications. Two-thirds of four cultivars were sprayed when the majority of major culms reached the appropriate growth stage and those clums at the desired stage of growth were tagged for harvest. Ethephon in water without a surfactant was foliar applied (approximately 10 ml per pot). Spikes were harvested on October 31, 1975.

V. STATISTICAL ANALYSES

The IBM 360/65 computer located in the University of Tennessee Computer Center, Stokley Management Center, Knoxville, Tennessee, was used to compute the statistical analyses. The Statistical Analysis System (SAS) was used to analyze the variables. These are as follows: date headed, date mature, plant height, lodging, percent sterility of bagged spikes, percent sterility of open-pollinated spikes, yield and 100-seed weight. The IBM 360/65 computer was used again for analyses of variance for a randomized complete block design (RCB) for the variations, differences, and interactions of five replications, two dates, five concentrations, and four cultivars for the eight variables mentioned above at levels of significance of 1 percent and 5 percent for the field study. Duncan's New Multiple Range Test was used for mean separation where analyses of variance were calculated for each variable.

The analysis of variance for a completely randomized design (CRD) was used to determine the variations, differences, and interactions of three replications, one date, three concentrations, and four cultivars in the growth room experiment. The experiment was analyzed for mean percent induced sterility.

CHAPTER IV

RESULTS

I. MALE STERILITY FROM FIELD RESEARCH

The gametocide ethephon was applied at the mid- and late boot stages of winter cultivars of wheat and barley which showed an influence on the induction of male sterility. The data from the field were particularly well suited for determining the relationships among sterility, plant height, yield, lodging, and seed weight because the cultivars in this study varied for these factors.

The data on sterility for different cultivars are given in Table 1 with different concentrations of ethephon during the 1976 field study. Arthur sprayed with 0.20 and 0.40 percent ethephon at the mid-boot stage had a mean sterility of 57.1 and 68.8 percent respectively. At the late boot stage higher ethephon concentrations only reached a mean of 44.4 percent sterility for the same cultivar.

The cultivar Blueboy showed similar trends as Arthur; however, it had a higher mean sterility of 71.0 and 58.9 percent for concentrations of .40 and .20 percent respectively (Table 1). The application of 0.05 percent was most effective yielding 61.6 percent sterility as compared to the control of only 31.0 percent. Female sterility was not

Table 1. Sterility of wheat and barley cultivars treated with ethephon at different stages of development for 1976 field study.

Stage of Development		Mid-boot		Late boot	
Cultivar	Concentration	Sterility of bagged spikes	Sterility of un-bagged spikes	Sterility of bagged spikes	Sterility of open pollin-ated spikes
		%			
Arthur	.00	35.4	38.0	24.5	26.8
	.05	31.0	37.1	23.1	17.4
	.10	30.5	22.8	41.4	29.9
	.20	57.1	29.1	35.8	29.6
	.40	68.8	35.8	44.4	27.1
Blueboy	.00	31.0	16.4	54.8	27.5
	.05	61.6	25.6	37.8	25.2
	.10	28.6	18.9	56.6	20.6
	.20	58.9	16.7	45.4	21.2
	.40	71.0	43.8	73.6	20.5
Barsoy	.00	60.1	34.1	64.6	39.9
	.05	34.1	16.9	55.3	36.7
	.10	40.7	37.0	55.2	35.1
	.20	45.3	42.8	60.9	38.8
	.40	56.4	56.7	46.8	62.7
Volbar	.00	28.6	25.9	38.3	28.5
	.05	28.2	39.5	42.1	19.7
	.10	30.0	20.3	30.6	19.8
	.20	40.5	35.0	33.8	20.8
	.40	44.2	24.2	50.9	33.3

impaired, because there was a decrease in sterility of treated open pollinated spikes due to outcrossing (Tables 1 and 2).

In all experiments reported in this study the rate of application of liquid ethephon had a prevailing influence on the induction of male sterility in wheat. Levels of male sterility obtained were more effective at .20 and .40 percent at mid-boot, and .10 and .40 percent at late boot (Table 1, p. 17). The least effective concentration was .05 percent for both stages of development for all cultivars.

The cultivar Barsoy was not sensitive to any of the concentrations of ethephon in mid-boot because its sterility means were less than that of the control and that trend continued also for late boot (Table 1, p. 17).

Levels of male sterility were improved for Volbar which had higher levels of sterility than the control for rates .20 and .40 percent with means of 40.5 and 44.2 percent respectively for mid-boot (Table 1, p. 17). In late boot Volbar had a mean sterility of 51.0 percent for the rate of 0.40 percent (Table 1, p. 17).

According to the results of Duncan's New Multiple Range Test (Table 2), only the 0.40 percent concentration of ethephon was significantly different across all cultivars and both stages of application.

Considerable differences in sterility were observed

Table 2. Ethephon concentration means for eight measured variables from the 1976 field study.

Variable	Yield[1]	Lodging[1]	Plant Height[1]	Date Headed[1]	Date Mature[1]	100-Seed Weight	Sterility Bagged Spikes[1]	Sterility Open-pollinated Spikes[2]
	gm/plot	(%)	(cm)	(days after April 1)	(days after May 1)	(gm)	(%)	(%)
Concentration								
.00	659[a]	51[a]	103.7[a]	24[d]	34.9[a]	4.0	42.2[b]	29.6[b]
.05	579[b]	18[b]	85.6[b]	26[cd]	35.1[a]	4.0	41.6[b]	27.3[b]
.10	508[c]	15[b]	81.3[c]	27[b]	34.6[a]	3.8	39.6[b]	25.6[b]
.20	401[d]	26[b]	81.3[c]	28[b]	34.8[a]	3.8	47.2[b]	29.2[b]
.40	298[c]	9[c]	79.0[d]	30[a]	35.3[a]	3.8	57.0[a]	37.9[a]

[1]Means within this column followed by the same letter are not significantly different at the 0.01 percent level of probability according to Duncan's New Multiple Range Test.

[2]Means within this column followed by the same letter are not significantly different at the 0.05 percent level of probability according to Duncan's New Multiple Range Test.

between Arthur and Blueboy, as well as Barsoy and Volbar (Figures 1 and 2).

Although 100 percent sterility was not achieved in any of the cultivars, but there were rates that could be considered as effective. The most effective rates for Arthur in mid-boot were 0.20 percent for a mean of 57.1 percent sterility with a range of 24.2-88.6, and 0.40 percent for a mean of 68.8 percent sterility with a range of 60.0 to 74.3 compared to the control of 35.4 percent mean sterility with a range of 27.5 to 47.3 (Table 3).

The most effective rates for Blueboy in mid-boot were 0.05 percent for a mean of 61.6 percent sterility with a range of 45.5 to 83.0, and 0.40 percent for a mean of 71.0 percent sterility with a range of 14.0 to 99.1 compared to the control for a mean of 31.1 percent sterility with a range of 19.7 to 47.2 (Table 3).

The most effective rate for Blueboy in late boot was 0.40 percent for a mean of 73.6 percent sterility with a range of 35.7 to 96.4 compared to the control of 54.9 percent mean sterility with a range of 23.8 to 76.7 (Table 4).

The most effective rate for Arthur in late boot was 0.40 percent for a mean of 44.5 percent sterility with a range of 27.4 to 41.2 compared to the control with a mean of 24.5 percent sterility with a range of 7.7 to 37.2 (Table 4).

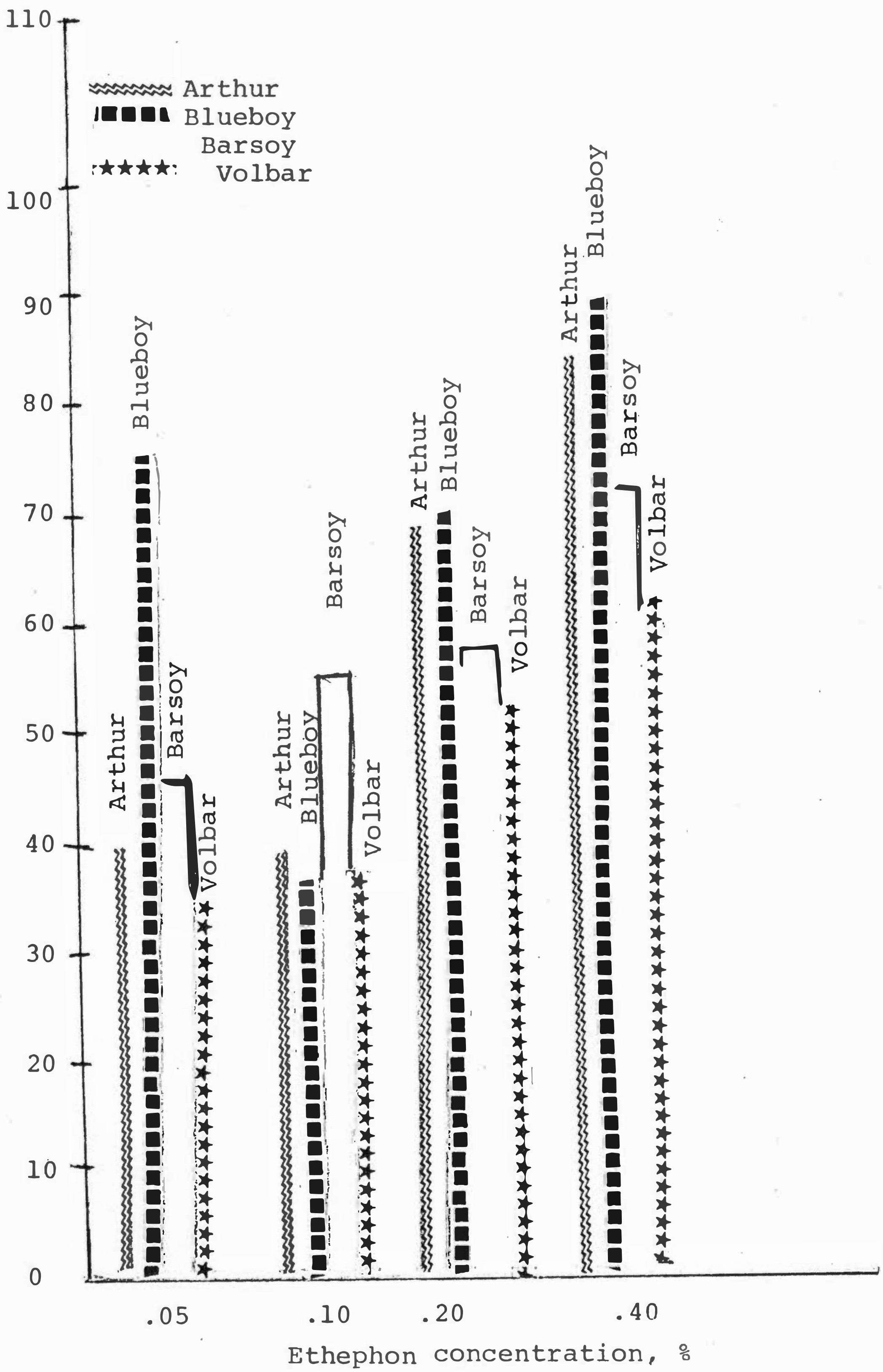


Figure 1. Effect of ethephon on sterility of cultivars in mid-boot (1976 field study).

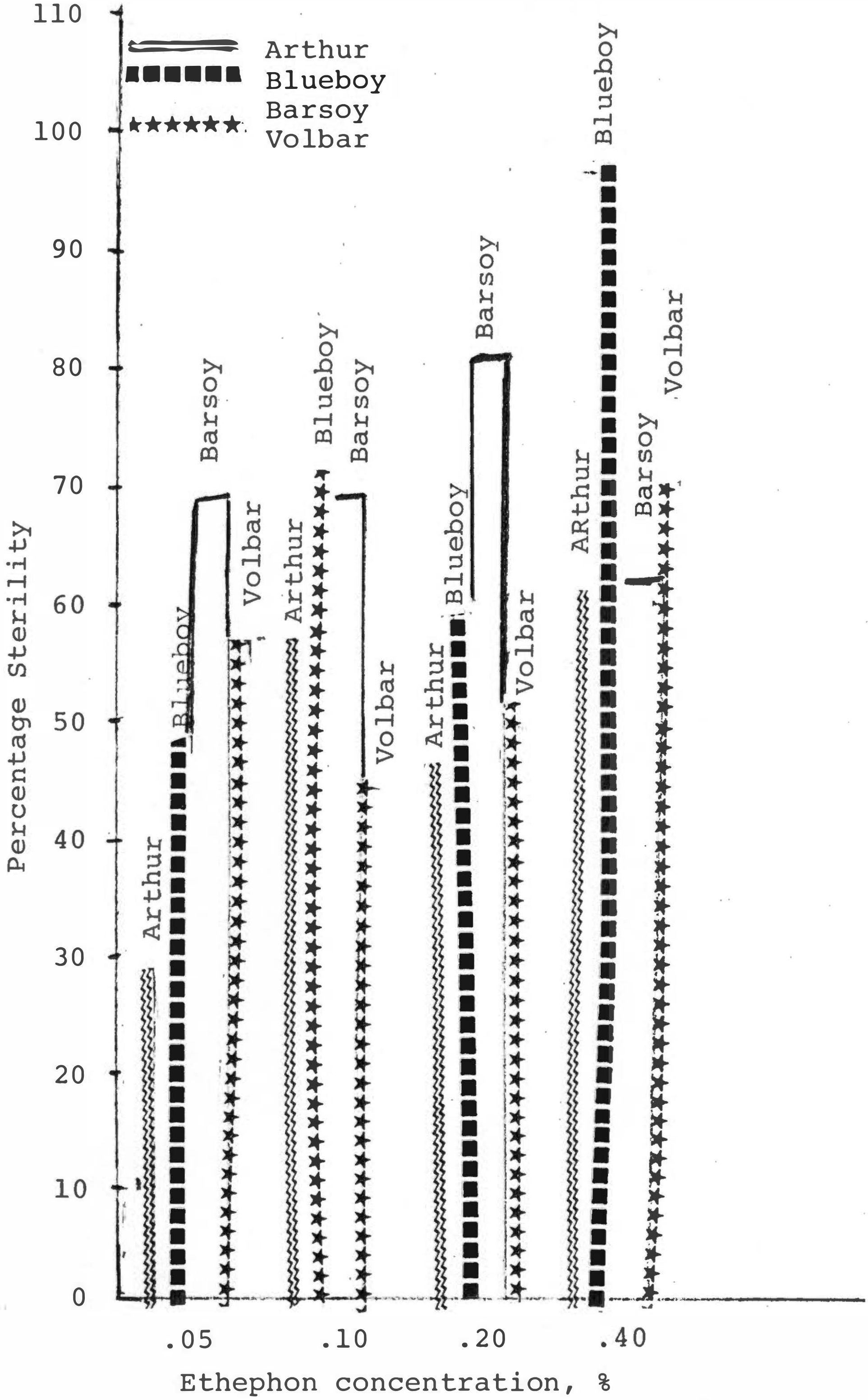


Figure 2. Effect of ethephon on sterility of cultivars in late boot (1976 field study).

Table 3. A comparison between bagged and open pollinated levels of male sterility in mid-boot of Arthur and Blueboy Cultivars of wheat (1976 field study).

Cultivar	Rate %	Bagged Sterility (Bs), % Mean	Bagged Sterility (Bs), % Range	Open Pollinated Sterility (Os), % Mean	Open Pollinated Sterility (Os), % Range	Difference (Bs-Os) %
Arthur	.05	31.0	27.5 - 47.3	37.1	28.6 - 42.7	-5.7
	.10	30.6	19.9 - 45.1	22.8	2.5 - 42.1	7.8
	.20	57.1	24.2 - 88.6	29.1	12.3 - 43.8	28.0
	.40	68.8	60.0 - 74.3	35.8	11.6 - 59.6	33.0
Mean		46.8		37.2		15.6
STD. DEV.		5.2		10.2		
Blueboy	.05	61.6	45.5 - 83.0	25.6	10.3 - 42.5	36.0
	.10	28.6	4.0 - 44.2	18.9	7.3 - 25.7	9.7
	.20	58.9	34.5 - 88.1	16.7	10.3 - 24.3	42.2
	.40	71.0	14.0 - 99.1	43.8	2.6 - 84.8	27.2
Mean		55.0		26.3		28.7
STD. Dev.		21.4		16.0		

Table 4. A comparison between bagged and open pollinated levels of male sterility in late boot of Arthur and Blueboy cultivars of wheat (1976 field study).

Cultivar	Rate %	Bagged Sterility (Bs), % Mean	Bagged Sterility (Bs), % Range	Open Pollinated Sterility (Os), % Mean	Open Pollinated Sterility (Os), % Range	Difference (Bs-Os) %
Arthur	.05	23.1	12.5-35.9	17.4	2.7-69.9	5.7
	.10	41.5	26.7 - 55.3	29.9	11.4 - 28.0	14.6
	.20	35.9	22.1 - 48.9	29.6	3.5 - 37.1	6.3
	.40	44.5	27.4 - 51.2	27.1	2.7 - 56.7	17.4
Mean		36.3		26.0		11.0
STD. DEV.		19.7		10.2		
Blueboy	.05	37.8	35.7 - 96.4	25.2	2.7 - 56.7	12.6
	.10	56.7	34.0 - 81.3	20.9	11.4 - 28.0	35.8
	.20	45.4	15.6 - 76.4	21.2	3.5 - 37.1	24.2
	.40	73.6	23.2 - 82.4	20.5	2.7 - 69.9	53.1
Mean		53.4		22.0		21.4
STD DEV.						

Barsoy was not too sensitive to any of the concentrations in mid-boot as indicated by the higher mean of the control (Table 1, p. 17).

The most effective rate for Volbar in mid-boot was 0.40 percent for a mean of 44.2 percent sterility with a range of 28.6 to 81.0 compared to the control with a mean of 28.6 percent with a range of 20.5 to 40.0 (Table 5).

Again for late boot Barsoy was not sensitive to any of the rates because the control had a higher mean sterility. The most effective rate for Volbar in late boot was 0.40 percent for a mean of 50.9 percent sterility with a range of 30.1 to 81.9 (Table 6).

The greatest difference between sterility in bagged and open pollinated spikes occurred in mid-boot for Arthur was 33.0 percent at the 0.40 percent rate, and for Blueboy it was 42.2 percent at the 0.20 percent rate (Table 3, p. 23). At the late boot stage of development for Arthur it was 17.4 percent at the 0.40 percent rate, and for Blueboy it was 53.1 percent at the 0.40 percent rate (Table 4, p. 24).

The greatest difference between sterility of bagged and open pollinated sterility in mid-boot for Barsoy was 17.2 percent at the rate of 0.05 percent (Table 5) and late boot was 22.1 percent at the rate of 0.20 percent (Table 6). For Volbar in mid-boot, it was 20.0 percent at the rate of 0.40 percent (Table 5), and 22.4 percent at the rate of 0.05 percent for late boot (Table 6).

Table 5. A comparison between bagged and open pollinated levels of male sterility in mid-boot of Barsoy and Volbar cultivars of barley (1976 field study).

Cultivar	Rate	Bagged Sterility(Bs),%		Open Pollinated		Difference (Bs-Os) %
	%	Mean	Range	Mean	Range	
Barsoy	.05	34.1	12.2 - 62.2	16.9	5.0 - 30.3	17.2
	.10	40.7	32.2 - 48.8	37.4	19.8 - 56.9	3.3
	.20	45.3	36.1 - 60.0	42.8	36.3 - 50.0	2.5
	.40	56.4	28.9 - 81.0	50.7	28.6 - 78.7	5.7
Mean		44.1		37.0		7.2
STD. DEV.		14.0		16.1		
Volbar	.05	28.2	19.5 - 33.6	35.5	27.4 - 57.0	-7.3
	.10	30.0	26.1 - 34.8	20.4	9.2 - 28.3	9.6
	.20	40.6	13.4 - 64.2	35.0	29.3 - 48.1	5.6
	.40	44.2	26.2 - 76.8	24.2	18.1 - 50.1	20.0
Mean		35.6		28.9		7.0
STD. DEV.		13.9		11.8		

Table 6. A comparison between bagged and open pollinated levels of male sterility in late boot of Barsoy and Volbar cultivars of Barley (1976 field study).

Cultivar	Rate %	Bagged Sterility(Bs),% Mean	Bagged Sterility(Bs),% Range	Open Pollinated Mean	Open Pollinated Range	Difference (Bs-Os) %
Barsoy	.05	55.3	34.6 - 84.6	36.7	25.0 - 45.7	19.0
	.10	55.2	42.3 - 65.0	35.1	15.4 - 69.5	20.1
	.20	60.9	23.1 - 91.3	38.8	21.3 - 59.7	22.1
	.40	46.8	34.4 - 67.0	62.7	38.6 - 78.8	-15.9
Mean		54.7		43.3		11.3
STD. DEV.		17.1		15.1		
Volbar	.05	42.1	14.9 - 84.9	19.7	8.4 - 30.7	22.4
	.10	30.7	22.9 - 39.4	19.8	17.5 - 25.0	10.9
	.20	33.8	15.9 - 62.4	20.8	7.7 - 33.8	13.0
	.40	51.0	30.1 - 81.9	33.3	14.8 - 67.5	17.7
Mean		39.4		23.4		16.0
STD. DEV.		18.3		10.9		

According to the analysis of variance (Table 7) significant differences were observed among concentrations and cultivars for both bagged and open pollinated spikes. For bagged spikes the interactions date X concentration and date X cultivar were also significant.

Plant Height

The reductions in plant height were used as a measure of physiological and morphological changes. The data pertaining to plant height with the results of statistical analysis are presented in Table 8. The overall average effects on height due to different concentrations of ethephon and due to varietal differences are in Tables 2 (p. 19) and 9.

As regards to the overall differences due to ethephon treatments, the height values decrease with increasing ethephon concentrations (Tables 2, p. 19, and 8). Differences with respect to plant height were observed among varieties and also among ethephon treatments; these differences and also those due to interaction between varieties and ethephon treatments were statistically significant at 1 percent and 5 percent levels (Table 7). All four of the cultivars were sensitive to ethephon, but Barsoy.

Comparing late boot stage with mid-boot stage Volbar showed less differences in plant height than the other three

Table 7. Mean squares for measured variables (1976 field study).

Source of Variation	DF	Yield (gm) Per Plot)	Lodging (%)	Plant Height (cm)	Date Headed (Days After April 1)	Date Mature (Days After May 1)	100-Seed Weight (gm)	Sterility Bagged Spikes (%)	Sterility Open Pollinated Spikes (%)
Replication	4	114632	3969	1101.1	28.68	29.39	0.09	666.96	32.90
Date	1	539241**	3160*	959.3*	114.01*	2.40	0.56	144.50	161.10
Concentration	4	819358**	11788**	4446.4*	219.54**	2.79	0.60	2254.38**	921.50*
Date X Conc	4	95423**	879	252.8**	22.99*	39.19	0.03	736.36*	111.43
Cultivar	3	194619**	13510**	1629.0**	2562.18**	2452.87**	4.84**	3298.00**	2555.51**
Conc X Cult	12	33730	2040*	139.3*	25.22	24.44	0.01	530.53	323.37
Date X Cult	3	15858	2936**	45.2	16.66	24.11	0.24	931.35*	349.41
DateXConcXCult	12	27781	618		4.34	25.38	0.41	518.60	388.79

*Indicates significant at 0.05 percent level of probability.

**Indicates significant at 0.01 percent level of probability.

Table 8. Plant height and lodging for wheat and barley cultivars treated with ethephon at different stages of development (1976 field study).

Stage of Development		Mid-boot		Late boot	
Cultivar	Concentration (%)	Plant Height (cm)	Lodging (%)	Plant Height (cm)	Lodging (%)
Arthur	.0	101.1	55	98.6	45
	.05	87.4	26	83.8	14
	.10	81.8	23	83.8	17
	.20	73.2	28	85.4	45
	.40	67.1	0	85.4	24
Blueboy	.0	102.1	0	101.1	4
	.05	81.3	0	88.4	0
	.10	79.3	0	81.8	0
	.20	78.8	0	79.8	0
	.40	68.1	0	73.2	0
Barsoy	.0	110.8	100	102.1	78
	.05	75.7	0	77.7	4
	.10	70.6	0	77.7	0
	.20	70.1	0	77.7	3
	.40	69.6	0	74.7	0
Volbar	.0	109.2	60	105.2	66
	.05	86.4	22	100.6	77
	.10	84.3	32	91.0	48
	.20	87.4	16	97.6	40
	.40	85.4	6	91.5	34

Table 9. Means for cultivars for eight measured variables (1976 field study).

Variable	Yield (gm per plot)	Lodging (%)	Plant Height (cm)	Date Headed (days after Apr. 1)	Date Mature (days after May 1)	100-Seed Weight (gm)	Sterility Bagged (%)	Sterility Open-Pollinated Spikes (%)
Cultivars								
Arthur	416.4	25.3	76.2	28.7	38.3	4.1	51.9	31.1
Blueboy	406.4	0.4	84.8	35.0	41.0	3.8	51.9	24.1
Barsoy	423.4	18.5	72.2	18.3	24.7	3.4	39.5	40.9
Volbar	497.8	40.1	84.9	31.0	34.3	4.1	36.7	26.6

cultivars, indicating it was less sensitive to ethephon treatments (Table 8, p. 30).

As ethephon caused an influence on induction of sterility its mechanism of action of releasing ethylene to plant tissues which speeded up the process of aging, therefore, decreasing plant height as observed by comparing sterility percentages for Arthur which has 68.8 percent at the 0.40 percent rate (Table 1, p. 17) and 44.4 percent at the 0.40 percent rate (Table 1, p. 17) with its greatest plant height decrease at the same rate (Table 8, p. 30); Blueboy had 71.0 and 73.6 percent sterility for the same rates (Table 1, p. 17) with its greatest decrease in height at the same rate (Table 8, p. 30); barley cultivars showed similar trends at the same rate for mid-boot (Table 1, p. 17) but variations for Barsoy in late boot (Table 1, p. 17) and it was not reversed for Volbar (Table 1, p. 17).

However, in looking at mean yield and mean seed weight (Table 10), then comparing these variables with the mean plant height (Table 8, p. 30), the trend is for them to decrease simultaneously. The most important influence of a decrease in plant height (Table 8, p. 30) was a very noticable decrease in lodging for all cultivars (Table 8, p. 30). However, all plant heights were significantly (Table 2, p. 19) different except at concentrations 0.10 and 0.20 percent.

Table 10. Yield and 100-seed weight for wheat and barley cultivars treated with ethephon at different stages of development (1976 field study).

Stage of Development Cultivar	Concentration (%)	Mid-Boot Yield (gm per plot)	Mid-Boot 100-seed weight (gm)	Late-Boot Yield (gm per plot)	Late-Boot 100-seed weight (gm)
Arthur	.0	563	4.3	647	4.4
	.05	594	4.2	534	4.1
	.10	462	4.2	482	3.8
	.20	282	3.9	496	4.5
	.40	181	3.9	419	3.7
Blueboy	.0	613	3.9	648	4.4
	.05	391	3.7	592	4.2
	.10	566	3.7	357	3.8
	.20	274	3.8	355	3.7
	.40	188	4.1	242	3.9
Barsoy	.0	685	3.2	681	3.7
	.05	582	3.7	692	3.3
	.10	409	3.3	576	3.6
	.20	304	3.3	553	3.0
	.40	152	3.2	321	3.5
Volbar	.0	690	4.1	748	3.8
	.05	548	4.2	696	4.2
	.10	635	3.9	573	4.2
	.20	308	3.9	636	4.0
	.40	308	3.9	567	4.1

Lodging

All ethephon treatments were effective in reducing lodging (Table 8, p. 30). Even the lowest rate of 0.05 percent reduced lodging to zero when applied at mid-boot stage for Barsoy (Table 8, p. 30). Ethephon prevented Barsoy from any lodging, although the control had 100 percent (Table 8, p. 30). The results of the analysis of variance showed significant differences for some interactions (Table 7, p. 29) with the greatest variation for concentration. There were two cultivars without any lodging due to ethephon treatments, and they were Blueboy for late boot stage as well as Barsoy for the mid-boot stage (Table 8, p. 30).

Application of the 0.05 percent rate at late boot was effective in reducing lodging to zero without reducing yield, especially in Barsoy (Table 10, p. 33). A reduction in lodging did not reduce the effectiveness of male sterility being induced as shown by Blueboy with a high percent of 71.0 in mid-boot at the rate of 0.40 percent and no lodging (Table 1, p. 17). Similar trends were shown in the other three cultivars (Tables 1, p. 30, and 8, p. 30). A level of one percent significance was observed in lodging means among the ethephon rates of 0.05, 0.10 and 0.20 with 0.40 percent (Table 2, p. 19). This reduction in lodging was probably due to the reduction in plant height.

Yield

The mean values of yield (Table 10, p. 33) and analysis of variance (Table 7, p. 29) show that mean yields were affected by ethephon treatments. The results of the analysis of variance show that the differences between the interactions alone are significant at a level of one percent (Tables 2, p. 19, and 7, p. 29).

Table 10 (p. 33) shows the mean yield was affected less at the lowest concentration with Barsoy having a higher mean yield of 692 gm as compared to the control with a mean yield of 681 gm. However, all cultivars showed a decrease in yield for the higher concentrations (Table 10, p. 33), and concentration was significant at the 1 percent level (Table 8, p. 30).

As mean sterility percent increased (Table 1, p. 17), mean lodging percent decreased (Table 8, p. 30), mean plant height decrease (Table 8, p. 30), mean seed weight decrease (Table 10, p. 33) and it can be noted a decrease in mean yield occurred too (Table 10, p. 33). The highest mean yield for mid-boot with 0.05 percent rate was Arthur with 594 gm (Table 10, p. 33), however, for Blueboy, Barsoy, and Volbar in late boot, their yields were 592, 692, and 696 gm respectively.

Seed Weight

No significant differences in 100-seed weight were observed due to ethephon treatments. In certain cases with high sterility there was a trend toward the improvement in the weight of the grains perhaps due to fewer seeds per spike. Arthur had a higher seed weight than the control for late boot with the rate of 0.20 percent for 4.5 gm. (Table 10, p. 33). Blueboy exceeded the control which was 3.9 at the rate of 0.40 percent for 4.1 gm (Table 10, p. 33). Barsoy was far superior to the control which was 3.2 gm for mid-boot with mean yields at rate 0.05 percent for 3.7, rates 0.10 and 0.20 percent for 3.3 gm each, and same as control for rate 0.40 percent (Table 10, p. 33).

Results of the analysis of variance (Table 7, p. 29) showed that the only difference among cultivars was significant. Results of Duncan's New Multiple Range Test are shown in Table 2, p. 19.

This increase in seed weight in the ethephon treated cultivars was due to better filled grains than those in the untreated plants. It was also observed that the grains from the ethephon treated plants resulted in increased uniformity and heavier seeds.

Blueboy showed a tremendous increase in male sterility over the control at the same rate and stage for its superior increase in seed weight (Tables 1, p. 17, and 10, p. 33). Table 7, p. 29, shows the only significant difference was due to cultivar, and this was to be expected due to the cultivars of two different species of wheat and barley.

Days to Heading

A comparison of the means for the four cultivars at the different concentrations showed an increase in days until date headed (Table 11). The analysis of variance (Table 7, p. 29) showed significant differences for concentration, date, date X concentration, and cultivar, and these means were significantly different (Table 7, p. 29). The lateness in heading was much greater at the rate of 0.40 percent, especially for Barsoy with 9 days more than the control, and Volbar showed an increase of almost 10 days (Table 7, p. 29). An increase in days to heading did not affect the induction of male sterility by comparing the means of Blueboy and Arthur (Table 1, p. 17).

Days to Maturity

According to the analysis of variance (Table 7, p. 29) the concentration of ethephon had no significant effect on days to maturity. The greatest significance was shown for cultivar (Table 7, p. 29). Observing the means of the cultivars for different concentrations of ethephon no set trend was noted (Table 7, p. 29). The cultivar Barsoy was the only one with days decreasing and this was shown in late boot (Table 11). No significant differences in date mature means (Table 2, p. 19) were observed.

Table 11. Date headed and date mature for wheat and barley cultivars treated with ethephon at different stages of development (1976 field study).

Stage of Development Cultivar	Concentration%	Mid-boot Date headed[1]	 Date mature[2]	Late boot Date headed[1]	 Date Mature[2]
Arthur	.0	25.4	35.8	26.0	39.4
	.05	26.8	38.6	27.0	38.4
	.10	27.6	38.8	25.8	40.0
	.20	32.8	38.6	27.8	38.2
	.40	32.8	35.6	29.0	38.4
Blueboy	.0	32.4	39.2	31.8	42.2
	.05	33.4	43.4	33.2	42.0
	.10	33.6	31.0	33.6	43.8
	.20	35.0	41.4	34.0	40.2
	.40	35.8	42.6	35.2	43.8
Barsoy	.0	12.0	24.6	13.4	27.6
	.05	15.8	24.6	16.4	25.0
	.10	18.2	25.0	18.0	24.4
	.20	19.4	24.0	17.8	24.6
	.40	21.0	24.6	19.4	25.0
Volbar	.0	26.2	35.0	26.8	35.0
	.05	29.8	36.4	25.2	32.4
	.10	32.4	37.2	30.2	36.8
	.20	32.8	36.2	27.0	34.8
	.40	37.4	34.4	32.8	37.8

1) Number of days after April 1.

2) Number of days after May 1.

II. MALE STERILITY FROM GROWTH ROOM RESEARCH

The data from these cultivars were particularly well suited for determining the relationships between induced male sterility with the gametocide ethephon. Blueboy and Arthur sprayed with ethephon obtained a mean sterility of 79.1 and 75.4 percent in late boot with 0.02 percent active ingredient respectively. However, Arthur was more effective sprayed with 0.05 percent at the same stage of development for a mean of 91.2 percent, and Blueboy showed a decrease with a mean of 71.7 percent of induced male sterility (Table 12 and Fig. 3).

Harrison and Keowee barley cultivars showed similar trends with a mean sterility sprayed with 0.02 percent for 50.1 and 99.1 percent respectively. Keowee was more sensitive at the 0.02 and 0.05 percent, but this variety did obtain a mean of 86.8 percent at the 0.05 percent rate. Harrison showed a considerable increase to 89.9 percent at 0.05 percent (Table 12 and Fig. 3).

All four cultivars showed the effectiveness of these lower rates in the growth room. The mean sterility of the control showed a range from 0 to 15.4 percent (Table 12). Keowee showed almost 100 percent sterility with a concentration of 0.02 percent (Table 12 and Fig. 3).

The data pertaining to sterility together with the results of statistical analyses are presented in Table 13.

Table 12. Induction of male sterility in winter cultivars of wheat and barley in late boot (1975 growth room study).

Cultivar	Concentration,%	Mean Sterility,%
Blueboy	.00	00.0
	.02	79.1
	.05	71.7
Arthur	.00	15.4
	.02	75.4
	.05	91.2
Harrison	.00	1.8
	.02	50.1
	.05	89.9
Keowee	.00	14.3
	.02	99.1
	.05	86.8

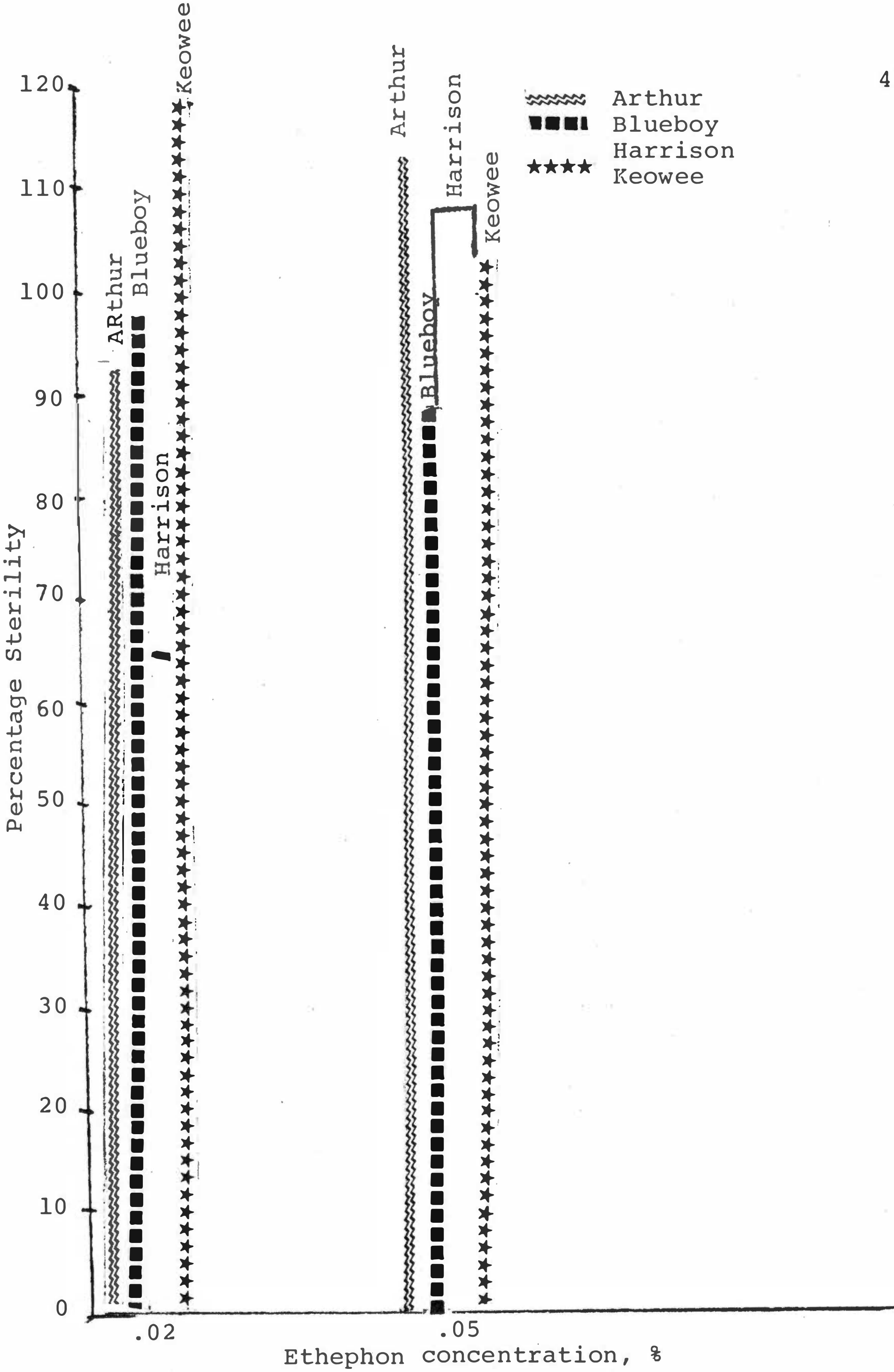


Figure 3. Effect of ethephon on sterility of cultivars in late boot (1975 growth room study).

Table 13. Analysis of Variance for Percent Sterility for 1975 growth room study.

Source of Variation	DF	MS
Total	45	646.16
Among Treatment	11	52345.6
Among Level	2	16342.2
Among Variety	3	294.3
Level X Variety	6	90372.4
Error	32	17085.2

*Significant at 5 percent level.

The relative individual varietal responses to each of the concentrations of ethephon are shown in Fig. 3 (p. 41). No differences with respect to chemically induced sterility were observed among the cultivars and also among chemical treatments; these differences as also those due to the interactions between varieties and treatments were found to be statistically non-significant at the 5 percent level (Table 13, p. 42). The failure to find any statistically significant difference among the control and two rates of ethephon application is perhaps due to the high variability within treatments. Thus only trends can be noted from this experiment.

CHAPTER V

DISCUSSION

A level of natural sterility does exist in all cultivars. Natural sterility determined in the field cultivars used in this study was in agreement with the literature (13). In the absence of ethephon treatment a mean of 35.4 percent for Arthur and a mean of 31.0 percent sterility for Blueboy was observed when treated in mid-boot. In late boot, Arthur overall mean for male sterility decreased to 24.5 percent, and Blueboy overall mean for male sterility increased to 54.8 percent (Table 1, p. 17).

The barley cultivars showed upward trends for the field study because Barsoy had a mean of 60.1 percent and Volbar had a mean of 28.6 percent in mid-boot. In late boot of development Barsoy had a mean of 64.6 percent and Volbar had a mean of 38.3 percent (Table 1, p. 17).

The trends in the growth room for natural sterility were just the opposite of those observed in the field study. The highest mean sterility for wheat cultivars was 15.4 percent and for barley cultivars the highest mean was 14.3 percent (Table 12, p. 40).

The data from this research indicate that ethephon can be effective to induce male sterility chemically with the selection of the proper concentrations applied at various stages of development of the cultivars.

It appears that the effective concentration of ethephon will vary with the application, stage of development, and cultivar. The most effective concentrations and stages of development for these cultivars were as follows:

In the growth room Blueboy was most sensitive to a concentration of 0.02 percent and Arthur was 0.05 percent; the barley cultivars Harrison was 0.05 percent and Keowee was 0.02 percent, and these findings were similar to Rowell and Miller (16).

In the field study Blueboy was most sensitive to a concentration of 0.40 percent and Arthur for the same rate in the mid-boot stage of development; the same rate was true for both cultivars in late boot; and for the barley cultivars only Volbar was sensitive at any of the concentrations with the most effective in late boot at 0.40 percent, and these findings were similar to those of similar previously reported studies (2, 3, 5, 10, 16, 17, 18).

All ethephon treatments were effective in reducing plant height and thus reducing lodging. Generally yields were reduced along with seed weight. There was a significant difference among rates of application, stages of application, and a significant rate X stage X cultivar interaction.

Consequently care must be exercised in using ethephon as a male gametocide to choose the proper concentration for the cultivar to be sterilized.

Treatment of the cultivars Blueboy in the field reached 71.0 percent sterility compared to 31.1 percent for control in the field, and Keowee reached 99.1 percent in the growth room compared to 14.3 percent for the control, therefore, a trend toward almost 100 percent sterility is possible with exact concentration and precise stage of development for cultivars.

In spite of the great amount of research already done on chemically induced and natural sterility, our present knowledge with the use of a chemical male gametocide is rather scanty. A better understanding of the mechanism of action and the nature of the induced sterility is of utmost importance of induced sterility to plant breeding problems in the Southeastern United States. From the work already reported by several authors (2, 3, 5, 10, 11, 15, 16, 17, 18) it has become clear that ethephon can work as a male gametocide.

For a complete analysis of the gametocide ethephon and its effects, more information is needed than was available from the research completed in this project. In the light of these results, it can be concluded that ethephon is capable of bringing about a selective abortion of pollen grains in wheat and barley without reducing the seed-setting capacity to any great extent (17).

First, in order to evaluate the effectiveness of any gametocide for inducing pollen sterility, to be useful in the commercial production of hybrid seeds in barley and wheat for plant breeding in the Southeast, the following criteria should be fulfilled: (1) there should be no undue hazards either to plant or man; (2) the precise dosage when applied at a definite stage of growth in the life cycle of the plant should give consistently reproducible results; (3) the treatment should cause only pollen abortion and not affect ovule fertility; and (4) the method of application should be easy and economical.

Therefore, more research is needed for selective abortion of pollen because none of the treatments tried gave complete pollen sterility coupled with complete ovular fertility. It does appear highly possible if one only considers the numerous instances of male sterility occurring among plants in nature without associated ovule sterility which indicate that it may be possible to reproduce this situation artifically. However, the exact and precise mechanisms are not known.

A follow-up study should be conducted to see if it is possible to take advantage of the dwarfing effect due to a reduction in plant height, which would allow closer spacing and higher populations and consequently with the possibility of higher yields per hectare.

We must not overlook the method of application, although, hand foliar sprayers are effective, easier methods may need to be worked out if the results are to be put to practical use.

Even though aqueous ethephon has the practical use as an applied selective male gametocide and probably has more potential than most compounds tested to date, I still feel additional research is needed to know how long the effects of a treatment would last, to know the precise treatment, and the stage of development of plants when application is to be made and the external conditions of application should be defined. These variations need to be known because there may be differences in absorption by the leaf area and the atmospheric conditions. Further studies should be conducted in conjunction with different rates of ethephon with an antidwarfing compound.

The results from this study indicate that ethephon could be used in a plant breeding program to develop breeding populations from which selection can be made. The breeder should be able to recognize the individual plants which resulted from selfing rather than crossing. Unless further refinements are made in the techniques, however, hybridization for genetic studies should still be performed by the conventional method of emasculation and hand transfer of pollen to ensure 100 percent crossed seeds.

CHAPTER VI

SUMMARY AND CONCLUSIONS

In order to elicit information regarding the effect of liquid ethephon on wheat and barley, and also to determine if different cultivars show a differential response to this chemical as a potential male gametocide, plants of six cultivars, two wheat (Arthur and Blueboy) and four barley (Barsoy, Volbar, Harrison, and Keowee), cultivars were treated in mid-boot and late boot stages of development for the field study and only late boot for the growth room study. The four cultivars in the field study were treated with five concentrations of ethephon: 0, 0.05, 0.10, 0.20 and 0.40 percent active ingredient. The four cultivars in the growth room were treated with only three concentrations of ethephon: 0, 0.02, and 0.05 percent active ingredient.

The most effective level was 0.40 percent active ingredient in mid-boot and late boot stages for both cultivars of wheat and barley for the field study. Sterility of the cultivar Blueboy in the field study reached 71.0 percent compared to 31.1 percent for the control and Keowee reached 99.1 percent in the growth room compared to 14.3 percent for the control.

The cultivar Barsoy was not sensitive to any of the concentrations in either mid-boot or late boot because its sterility means were less than those of the controls. The overall mean sterility for Volbar was slightly more than 50 percent for both mid-boot and late boot stages. Arthur had a high mean sterility of 91.2 percent in the growth room and 68.8 percent in mid-boot in the field study.

All ethephon treatments were effective in reducing plant height and thus reducing lodging. Generally yields were reduced along with seed weight.

Concentration, replication, date, cultivar, date X concentration, date X cultivar, concentration X cultivar, date X concentration X cultivar effects were significant for all variables except seed weight, date headed, and date mature. No overall replication, date X concentration, date X cultivar, and concentration X cultivar effects occurred for seed weight. No overall date X concentration X cultivar effect occurred for date headed. No overall concentration effect occurred for date mature. There was a significant difference among rates of application, stages of application, and a significant rate X stage X cultivar interaction. Concentration and cultivar effects per plant were strongly and positively associated with induction of male sterility.

It can, therefore, be concluded that definite research should continue in order to gain evidence on rates that maximize sterility or anther retardation without adverse morphological, physiological, and histological effects on different cultivars of wheat and barley in the Southeast and on the mechanism of action causing male sterility.

Although there are probably some differences with regard to ethephon permeability through the covering of the spikes in the different cultivars used in this study which would explain some of their differential response to ethephon and to prevent higher male sterility to occur. However, the genetic diversity in thise cultivars used in this study is assumed to be mainly responsible for their differential response to ethephon as a male gametocide.

LITERATURE CITED

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1. Amchem Products, Inc., 1965. Ambler, Pennsylvania.

2. Bennett, Michael D. and W. Glyn Hughes, 1972. Additional Mitosis in Wheat Pollen Induced by Ethrel. Nature 240: 566-568.

3. Brown, C. M. and E. B. Earley. 1973. Response of One Winter Wheat and Two Spring Oat Varieties to Foliar Applications of 2-Chloroethylphosphonic acid (Ethephon). Agron. J. 65: 829-832.

4. Chopra, V. L., S. K. Jain, and M. S. Swaminanthan. 1960. Studies on the Chemical Induction of Pollen Sterility in Some Crop Plants. Indian J. Genetics and Plant Breeding 20:188-199.

5. Fairey, D. T. and N. C. Stoskopf. 1975. Effects of Granular Ethephon on Male Sterility in Wheat. Crop Science 15: 29-32.

6. Graves, Charles R. 1976. 1975 Performance of Field Crop Varieties. The University of Tennessee Agriculture Experiment Station. Bulletin 551. p. 9-10.

7. ________. 1971. 1970 Performance of Field Crop Varieties. The University of Tennessee Agriculture Experiment Station. Bulletin 474. p. 7-8.

8. Herbicide Handbook. 1967. Weed Science Society of America.

9. Jan, C. C., C. O. Qualset, and H. E. Vogt. 1974. Chemical Induction of Sterility in Wheat. Euphytica 23: 78-85.

10. Law, J. and N. C. Stoskopf. 1973. Further Observations on Ethephon (Ethrel) As A Tool For Developing Hybrid Cereals. Can. J. Plant Sci. 53: 765-766.

11. McMurrary, A. L. and C. H. Miller. 1969. The Effect of 2-Chloroethanephosphonic Acid (Ethrel) on the Sex Expression and Yields of Cucumis sativus. J. Amer. Soc. Hort. Sci. 94: 400-402.

12. Mohan, Ram H. Y. and P. N. Rustagi. 1966. Phytogametocidal Compounds. Sci. Cult. 32: 286-291.

13. Poehlman, John Milton. 1959. Breeding Field Crops. Holt, Rinehart and Winston, Inc. New York.

14. Porter, Kenneth B., and Allen F. Wiese. 1961. Evaluation of Certain Chemicals As Selective Gametocides For Wheat. Crop. Sci. 1: 381-382.

15. Robinson, R. W., S. Shannon, and M. D. Delagaurdia. 1969. Regulation of Sex Expression in the Cucumber. Bio. Sci.:19-2: 141-142.

16. Rowell, P. L. and D. G. Miller. 1971. Induction of Male Sterility in Wheat with 2-Chloroethylphosphonic Acid (Ethrel). Crop Sci. 11: 629-631.

17. ________, and ________. 1974. Effect of 2-Chloroethylphosphonic Acid (Ethephon) on Female Fertility of Two Wheat Varieties. Crop Sci. 14: 31-34.

18. Stoskopf, N. C. and J. Law. 1972. Some Observations on Ethrel As A Tool For Developing Hybrid Cereals. Can. J. Plant Sci. 52: 680-683.

19. Wang, R. C. and Steve Lund. 1975. Studies on Male Sterility in Barley Induced by Sodium 1-(p-Chlorophenyl) 1, 2-Dihydro-4,6-Dimethyl-2-Oconicotinate. Crop Sci. 15: 550-553.

VITA

I discovered America in Tuscaloosa, Alabama to the parents of Mr. and Mrs. Moses Esther Taylor. Grade school through high school was completed in the Alabama Public Schools.

My educational experience started at Stillman College, Tuscaloosa, Alabama, with a major in Biology for the B.S. degree, and completed the M.S. in Natural Sciences from The University of Oklahoma, Norman, Oklahoma in August, 1969. Upon completion of my graduate work at The University of Oklahoma, I returned to the Tuscaloosa City School System as a Science/Resource Supervisor. The summer of 1969 was the beginning of my college teaching career at Stillman College in Biology and Physical Science. I was selected as a Leader in The Personnel Leadership Conference at Michigan State University, East Lansing, Michigan to teach the New Science Curricula during the summer of 1971. To satisfy two needs, one of interest, and additional money I became the Staff Meteorologist/Announcer part-time for Channel 33, WCFT-TV, Tuscaloosa, Alabama in 1972. During the month of February, 1973, I was selected as an Assistant Professor of Biology and Physical Science at Lane College, Jackson, Tennessee. Realizing the need for additional knowledge, and to meet the doctoral requirement for college teaching, therefore, on September 23, 1974, I entered as a graduate student in The Department of Plant and Soil Science at The University of Tennessee, Knoxville, Tennessee, to earn the Ph.D.