AN ABSTRACT OF THE THESIS OF

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Weedy rye (Secale spp.) is a weed in the winter-wheat- growing regions in the Pacific Northwest and surrounding regions. Ethiazin (4-amino-6-(1,1-dimethylethyl)-3- (ehtylthio)-1,2,4-triazine-5 (4H)-one) has shown selective control of weedy rye in the cultivar 'Stephens', (Triticum aestivum). Field, greenhouse, and outdoor pot experiments were conducted to determine factors influencing selectivity.

Field studies were conducted in eastern Oregon in 1985-86 to determine the optimum timing and rate to apply ethiazin for weedy rye control, and also to see if the addition of metribuzin would increase rye control while reducing the ethiazin rate. Stephens wheat tolerated the herbicide treatments at all locations. Optimum timing for application was the 2-3 leaf stage of rye for two of the locations. Application at the 1-2 leaf stage was most effective at the remaining location. Rye control was enhanced with increasing ethiazin rate. The addition of metribuzin enhanced rye control at a lower rate of ethiazin. Wheat grain yields, above ground biomass, and culm number of wheat increased with increasing rye control.

Greenhouse and outdoor pot studies were conducted in Pendleton and Corvallis, Oregon, through 1985-87, to identify factors influencing this selectivity. Uptake experiments indicated that rye is more sensitive to ethiazin through root uptake than through foliar uptake. In time-of-application studies conducted outdoors, best control was at the one-, two- , and three-leaf stage of rye. Control was lower at preemergence and the four-leaf stage. Depth of seeding did not affect sensitivity of rye to ethiazin.

Immersing roots of wheat and rye seedings into ethiazin solution at various concentrations showed Stephens to be 13 times more tolerant than cereal rye to ethiazin. This indicates that selectivity between wheat and rye seen in the field is primarily due to physiological differences. From a management standpoint, this is greatly preferable to selectivity based on differences in retention on the foliage, rooting depth, crown depth, and other morphological factors.

Weedy rye appears to be taxonomically different from the cultivated species (Secale cereale). Wild and weedy rye were equally sensitive to ethiazin when tested in a solution bioassay.

Factors Affecting Selective Weedy Rye (Secale sp.) Control in Winter Wheat with the Herbicide Ethiazin

by

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FACTORS AFFECTING THE SELECTIVE CONTROL OF WEEDY RYE (<u>SECALE</u> SP.) IN WINTER WHEAT WITH THE HERBICIDE ETHIAZIN

INTRODUCTION

Weedy rye (*Secale* sp.) is a major weed problem in the Pacific Northwest where most cropland is used for production of winter annual cereals (Rydrych 1985). Infestations also are found in northern California and Nevada (Suneson 1969), east into Utah (Dewey 1969) and the Colorado plains (Zimdahl 1986), and also in the dryland cereal areas of Montana (Fay 1986) and Wyoming (Whitson 1986).

Weedy rye escaped from both cultivated fields and an introduced hybrid between *S. cereale* and *S. montanum* (Suneson 1969) and now volunteers freely because it shatters readily at maturity, which is earlier than in most winter annual cereals (Martin et al. 1967). Weedy rye infestation is greatest where rainfall patterns favor winter cereals, as in the intermountain regions of central and eastern Oregon with only 200 to 400 ml of rainfall per year. Weedy rye is not a problem in areas such as the Willamette Valley of western Oregon and higher elevations where sufficient rainfall allows for crop rotation.

An experimental use herbicide, ethiazin, has controlled weedy rye in winter wheat experimentally. Therefore, greenhouse and field experiments were conducted with ethiazin to determine the selectivity factors for weedy rye control in winter wheat. The objectives of these studies were to determine if physiological differences between species, time of application, mode of uptake, and depth of seeding were important in the control of rye with ethiazin. The seed used for these experiments was a cultivated source, and after reviewing the literature and conducting interviews, it was determined that using this source of rye may not have been representative of the wild, weedy population. Therefore, sensitivity of cultivated and weedy rye were compared in root solution bioassays.

Studies on the origin and cytogenetics of weedy rye species (Khush 1963, Suneson 1969) and interviews with cereal breeders (Vogel 1986, Metzger 1986) from the Pacific Northwest have provided considerable insight about the weedy rye population dynamics in the west. An interesting finding was that another *Secale* species had been introduced into the Pacific Northwest, *Secale montanum* (Hitchcock 1971). A successful cross between *Secale cereale* and *Secale montanum* had escaped (Suneson 1969) and now uncertainty about the taxonomy of the weedy rye exists.

CHAPTER ONE

Literature Review

Weedy rye (*Secale sp.*) populations in idle areas such as roadsides, fencerows, and canyon walls are quite common in the Pacific Northwest. These serve as sources of infestation for cereal production areas. This weedy rye has become an economic problem where agricultural production is limited to winter cereals.

In the past two decades, weedy rye has infested an increasing amount of dryland cereal acreage while also reaching the status of a noxious weed in Oregon. Currently, the weedy species is often referred to as *S. cereale*. Reputable plant breeders in the Pacific Northwest (Dr. Robert Metzger, Dr. Orville Vogel, and Dr. Steve Broich) have suggested that identifying weedy rye as *S. cereale* may be misinformative. Evidence in the literature substantiates these scientists' viewpoints on the weedy population of volunteer rye.

Aggressive, sporadic populations of the weedy rye form were reported by Suneson (1969) in the northeastern mountain counties of California and adjacent areas of Oregon and Nevada. There is strong evidence that the weedy rye that infests dryland areas today is of the same origin (Suneson 1969). He indicates the existing population of weedy rye in the western United States is the result of an introduced interspecific hybrid between *S. cereale* and *S. montanum*. Thus, associated with the above misinformation, there is an interesting and informative narrative on the development of volunteer rye as a weed in the PNW, which will be the focus of the following discussion.

Suneson (1969) is the only author who published information on the development of the weedy rye population in the northwestern United States; however, the Secale genus has been studied extensively by many cytogeneticists, plant breeders, and paleobotanists to determine the origin of cultivated rye. The purpose of this review is not to discuss the origin of cultivated rye in detail, but rather to describe the population of weedy rye in the western United States. A list of references will be provided for future reference on the origin and background of the Secale genus (see Appendix C).

The rapid spread of the volunteer rye may be the result of few reliable control methods and/or the unwillingness of growers to utilize the existing control methods. In any case, the control methods currently being practiced will be analyzed, including the deficiency of reliable selective chemical treatments. Ethiazin (Tycor) is an experimental herbicide that has shown selective control of annual grass in winter wheat. The physical characteristics, usages, and research conducted on the compound will be discussed.

Taxonomic Description of Weedy Rye

Before describing the population of weedy rye in the western United States, a taxonomic description should be provided. The weedy rye of today seems to have resulted from an introduction from a wild cross of *S. cereal* x *S. montanum* whose characters introgressed into natural populations of cultivated rye (*S. cereale*) (Suneson 1969). The definition of introgression states that the recipient species (*S. cereale*) does not lose it's taxonomic integrity after several backcrossing, thus weedy rye should be taxonomically similar to cultivated rye except for a few characters. Therefore, it is generally accepted that describing the taxonomic characters of S. cereale will suffice for this discussion. The characters that have changed through the introgression will be mentioned.

Weedy rye is a cross-pollinated winter annual. Its stems are solitary or tufted, erect and stand 35 to 300 cm tall (Davis). Suneson reported the weedy populations to be within that range at approximately 200 cm. The stems are smooth and glabrous except that below the spike they are weakly or densely pilose. Leaf sheaths are villous. The leaf blades are 4-12 cm broad, glabrous, with the margins smooth.

The rachis of S. cereale is tough and does not disarticulate at maturity (Davis). Suneson (1969) reported that weedy rye has a fragile rachis, which correlates well with the personal observation of the senior author (1985-86). Davis reports that S. montanum has a brittle rachis character. This may be one character that has been introgressed into the weedy rye.

Development of Weedy Rye in the Pacific Northwest

Weed problems are often the result of an escaped species that has been brought in as beneficial vegetation. An example of this is Johnsongrass (Sorghum halepense), which was introduced in the southern United States as a forage species (Ross 1985). Similarly, cultivated rye (S. cereale) escaped after being brought into the PNW (Vogel 1986). It was grown as a crop where climate and soil conditions made it more feasible to grow than wheat, and is still grown today. With the advent of adaptable wheat varieties, these poorer areas were converted to wheat production and volunteer rye became a problem.

This was one population that Dr. Orville Vogel of Washington State University indicated was a problem. There was, however, an additional, more vigorous population which had developed through an apparent cross between S. cereale and S. montanum that had escaped as a crop that was thought to be Michel's grass (Suneson 1969).

Michel's grass was reported to be an apparent hybrid grass from a cross between winter wheat and a wild rye (Elymus condensatus) that was developed by Professor C. A. Michel at the University of Idaho in 1932 (Young 1941). Suneson and others at the time questioned the pedigree of the release (Suneson 1969) and identified Michel's grass to actually be a form of rye. Seed from this grass had been widely distributed in the western region by growers around Paul, Idaho in 1938 and 1939 (Suneson 1969).

One wonders how this mistaken release materialized. Dr. Robert Metzger, formerly of Oregon State University, and Dr. Orville Vogel, formerly of Washington State University, discussed the origin of wild weedy rye in the Pacific Northwest. The following are non-documented personal notes taken from Dr. Metzger regarding a conversation he had with Dr. Vogel on the subject.

Dr. Robert Metzger:

"These notes describe the source of wild rye populations in Washington, Oregon, Idaho, and other areas throughout the North American continent. The following events occurred in more or less chronological order.

Dr. Ed Shafer, Head of Agronomy, Washington State College, was studying the cross of S. cereale and S. montanum (perennial).

Dr. Michel, a cereal breeder from Idaho, was attempting to produce crosses of Haploid wheat and Elymus giganteus.

Dr. Florell, USDA cereals, Idaho, requested seed of Dr. Shafer's Secale crosses. He wanted to study chromosome associations.

Ed Gaines asked Dr. Vogel to obtain seed from Shafer's crosses (stored in boxes, Shafer was away at the moment) and give to Florell. Shafer and Gaines were using a common storage area with different boxes.

Florell planted seeds at Idaho University and used what he needed for his study. Due to brittle rachis, much seed fell on the ground.

The following year, Michel planted seeds to be what he thought wheat x *Elymus* cross in the same area. He had the summer crew rogue out the volunteer Secale, but the plants in the rows were left because he insisted they represented crosses of wheat x *Elymus*. He reported he had succeeded in obtaining the wheat x *Elymus* cross at the Western Section of American Society of Agronomy held at Pendleton, Oregon in either 1934 or 1935. Vogel tried to convince him that it was a Secale cross, but he would not listen.

Seeds of the wheat x *Elymus*, which was really *S. cereale* x *S. montanum* cross, were increased (one farmer grew fifty acres). These were sold far and wide to farmers throughout the west (four pound lots) and they escaped from cultivation and now 46 years later (1980), have become established as a wild rye population throughout the Northwest. Their common origin accounts for the similarity in variation within and between populations. Most of the perennial types have been lost from the wild stands.

This information was obtained by telephone from O. Vogel during my visit to Pullman, Washington."

The above information is remarkably similar to Suneson's account of the release of Michel's grass. In fact, Suneson had personal communication with Dr. Vogel and they were in agreement that the origin of weedy rye is from Michel's grass (Suneson 1969). The only discrepancy found in the conversation was that the reported cross of Michel's grass was reported by Young (1941) to be wheat x *Elymus condensatus*, instead of *E. giganteus*. Although the above information has not been documented, it is thought to support the description of the weedy population as described by Suneson.

To support the claims of this mistaken introduction further, Hitchcock (1971) reported the introduction of *S. montanum* from southwestern Asia, which had escaped and persisted along the roadsides around the Experiment Station at Pullman Washington. The first edition of his "Manual of the Grasses of the United States" was published in 1935, which coincides with the time of the reported escape of "Michel's grass".

The wild population as described by Suneson has gone through changes since its release. Suneson's studies were confined to the areas of northern California and adjoining counties of Oregon and Nevada. He studied the weedy rye populations periodically through travel survey from 1937 to 1969. He estimated that the densities and areas of establishment had doubled from 1964 to 1969.

Introductions of Michel's grass were recorded in the Fall River area of California in 1938. However, the existing population is not of direct progeny from the Michel's grass cross. Even though Michel's grass was distributed throughout the western United States, it had trouble establishing itself because of its low winter hardiness.

It did, however, survive well enough to interact with the existing populations of cultivated rye (*S. cereale*) in the Fall River region, where rye was the only suitable crop. As Suneson describes, "the population has probably developed from an introduced, interspecific hybrid subjected to recurrent introgression from the many diverse cultivars of rye long extant in the region." Introgression is the transfer of a germ plasm between species following hybridization and several series of backcrossing, transferring specific features of one species to another without changing the recipient's taxonomic integrity (Briggs and Knowles 1977). In this case the recipient is the cultivated rye (*S. cereale*)

It is because of the brittle rachis character that Dr. Robert Metzger suggested that weedy rye not be referred to as *S. cereale*. Zoherty (1971) describes non-brittle weedy forms of weedy *S. cereale* that occur in Anatolia (Turkey), northern Iran, northern Iraq, and northern Syria. This correlates well with the information obtained from Dr. Orville Vogel through personal communication. He indicated that the cultivated rye in the region volunteered, not by brittle rachis shattering, but rather through loose glumes which allow seed to fall freely. Suneson (1969) states that the weedy rye characteristically bears fragile spikes. Personal observation of rye infestations near Pendleton, Oregon found completely fragile spikes that left the ground literally covered with spikelets with the glumes intact (Figure 1.1). In addition, the spike of weedy rye looks morphologically different than cultivated rye (Figure 1.2). Thus, it is my opinion that cultivated and weedy rye are not the same.

To support the above discussion on the development of weedy rye in the PNW, there is one other reference that identifies the S. cereale x S. montanum interaction. Zoherty (1971) reports that completely brittle rye forms are found on the Anatolian plateau as members of the hybrid between the non-brittle annual type (S. cereale) and the fragile, perennial type (S. montanum). He characterizes these populations as "hybrid swarms" between the two species. Thus, the weedy rye populations of the PNW may be a form of "hybrid swarms" that originated from the escaped Michel's grass.

In his discussion Suneson wondered why the successful establishment of weedy rye was only in the Fall River area after a very wide American distribution. The first reason he gave for the lack of spread is the poor winter hardiness of Michel's grass. In addition, the distribution was primarily in wheat-growing regions providing minimal opportunity for introgression to take place. In the Fall River area cultivated rye is a widely-grown crop, thus maximizing introgression of Michel's grass and cultivated forms (Suneson, 1969). He describes the Fall River area as the "center of origin" of weedy rye in California.

Figure 1.1 Photograph illustrating the shattering characteristics of weedy rye (*Secale* sp.).

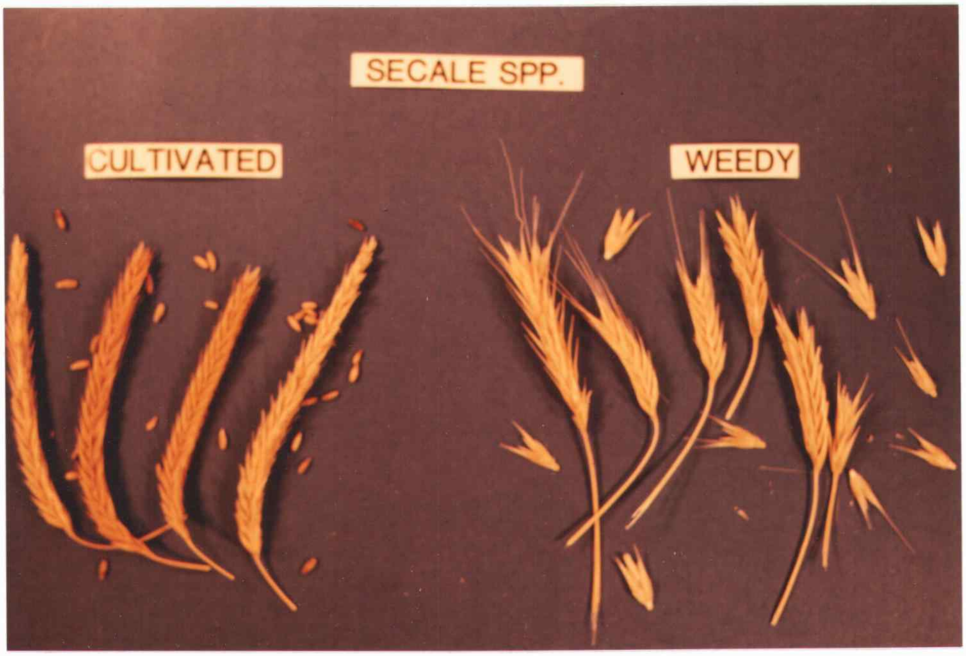

Figure 1.2. Photograph illustrating the morphological differences in spike between weedy rye (*Secale* sp.) and cultivated rye (*Secale cereale*).

It may be that the Fall River area was the "center of origin" for the entire western United States. Since rye is a cross-pollinated species, new genetic combinations may have allowed weedy rye to establish itself in other areas that were previously less suitable. Suneson (1969) indicates that some components of the population are now winter hardy and are capable of survival in many colder parts of the west. This, in addition to the fact that weedy rye spreads profusely along highways, have allowed establishment in other regions of the west, which may be the cause of over 1,000,000 acres of dryland cereal production becoming infested with this weed in Oregon, Idaho, and Washington.

At the time Suneson published his paper (1969), he was uncertain about whether or not the weedy rye stand found in these other areas of the west would become weeds. It is now evident that weedy rye has established itself as a predominant weed in the dryland regions of the northwestern United States. This is a classical example of mistaken plant introduction becoming a severe economic setback for the agricultural community. Now that the weed has established itself there have been numerous control measures practiced in attempting to control weedy rye.

Current Control Measures

Because the literature on the control of weedy rye is limited, much of the following will include information gathered from a survey conducted to determine the scope of infestation of weedy rye (Chapter 2). Many growers have been able to keep the weedy rye population in check by diligently utilizing the control measures available. If the weedy rye population is left unchecked, the result may be a very heavy infestation.

Control measures used include a combination of cultural, chemical, and mechanical methods. The cultural methods practiced are rotation into spring grains or other crops such as peas. This interrupts the winter annual life cycle of weedy rye; however, annual rainfall under 11-12 inches limit this practice because production is largely limited to winter cereals.

Fallowing is another cultural method practice, but annual fallow is not considered to be totally effective. Two-year fallowing is considered to be highly effective when seed production is prevented. Two-year fallowing also helps to control plants that originate from dormant seeds, which Suneson (1969) indicates the weedy rye possesses.

The mechanical measures taken include tillage operations during fallow periods, hand removal, mowing, grazing, and harvesting for hay.

Chemical control methods reported included glyphosate applied post emergence with a ropewick, carpet roller, or handwick. This has been used in accordance to the Section 18 "emergency" label granted, which has not been renewed and a permanent label is pending (Blank 1987). Chemical fallow also is practiced in drier areas (Rydrych 1985). Soil active and foliar applied herbicides have been proven effective in aiding the conventional fallow methods in controlling both annual broadleaves and grasses.

Selective chemical control measures are lacking in the above listing of control practices. Ethiazin (Tycor) has shown selective control of weedy rye and many other annual grasses and broadleaves in winter wheat. The next section of this review will discuss this compound in detail.

Ethiazin Characteristics

Ethiazin is the ethyl-thio analog of metribuzin, both asymmetrical triazine herbicides. Ethiazin has a water solubility of 315 ppm and is formulated as a wettable powder and dry flowable. As with any herbicide, caution should be taken in using this herbicide, but its LD_{50} is greater than 2000 mg/kg in both dermal and oral toxicities.

A broad-spectrum herbicide, ethiazin has the potential to control many grasses and broadleaf weeds in both winter and spring cereals. It is a photosynthetic inhibitor that is primarily taken up by the roots, but it also has a degree of foliar activity (Mobay Chemical Corporation 1984).

Much research has been conducted on this herbicide since there are few selective herbicides on winter annual grasses in winter cereals. Bromus tectorum is the primary winter annual grassy weed problem in winter wheat. Many trials have been conducted in the western United States to study the effects of ethiazin on Bromus tectorum.

Selective weedy rye control has been reported by researchers in the Pacific Northwest (Rydrych 1986, Lish 1985, Joplin 1986). Sporadic control results from the lack of rainfall, which is needed for the activation of this chemical (Mobay Chemical Corporation 1984). Similar results are presented in this thesis. Photodecomposition may have some role in this also, which is being studied in detail at Oregon State University (Peek 1987).

Varietal tolerance has been good when the suitable varieties are grown. There are dramatic differences in tolerance between wheat varieties (Valverde 1987). Upon registration of this material, varietal restrictions will have to be stipulated on the label.

CHAPTER TWO

Survey of Volunteer Rye Infestation

INTRODUCTION

Surveys have been conducted to determine the distribution and severity of various weed species (Southern Weed Science Society 1980, Lee 1986, Dunn 1979). No such information for weedy cereal rye (*Secale* sp.) was found in the literature. Therefore, to fill this information gap, a survey was conducted to determine the scope of infestation in the Pacific Northwest.

MATERIALS AND METHODS

The survey included Oregon, Idaho, and Washington. Extension agents of all counties were contacted by memorandum with an inquiry format (Appendix A). The extension directors (E. Smith, H. Guenthner, O. Young) from Oregon, Idaho, and Washington, respectively, were contacted to gain approval for such a survey.

Questions for the survey (Appendix A) were formulated to determine the general scope of the problem. The questionnaire was kept simple and concise in order to receive maximum, prompt response.

On 17 July 1986, the memorandums and enclosed questionnaires were sent out. Upon arrival of the responses, they were indexed according to state. The information was tallied and a map of infested areas was prepared.

RESULTS AND DISCUSSION

Scope of the problem. The response to the survey was good, as 86 % of the questionnaires were returned. Responses indicated that a considerable infestation of weedy rye occurs in these states, and in the areas where the problem exists, growers are showing concern. An estimated total of over 1,052,000 acres was reported. Of these acres, approximately 8 % are irrigated. Sources of infestation include roadsides, fencerows, hills, and contaminated seed sources. Figure 2.1 shows the areas of infestation and the seriousness associated with the area. Entire acreages are not infested, but designated regions indicate the relative potential of the problem.

Crops infested. Crops that were reported as being infested included small grains, primarily winter annuals such as winter wheat, barley, and oats. Few respondents mentioned it as a problem in spring grains, grass seed, alfalfa, potatoes, or tree nurseries. Non-crop areas such as rangeland and pastures also were reported to have rye as a problem. Refer to Figure 2.2 for a complete listing.

Control measures. The control methods reported in the survey are listed in Table 2.1. The percentages listed in Table 2.1 are percentages of the total number of counties with a rye problem. Roguing was reported by the respondents to be the control method most widely used. Other methods listed indicate the drastic measures undertaken to control this problem (e.g. haying badly infested fields). In addition, classical preventative weed control measures such as seed certification rejection and spraying waste areas were reported.

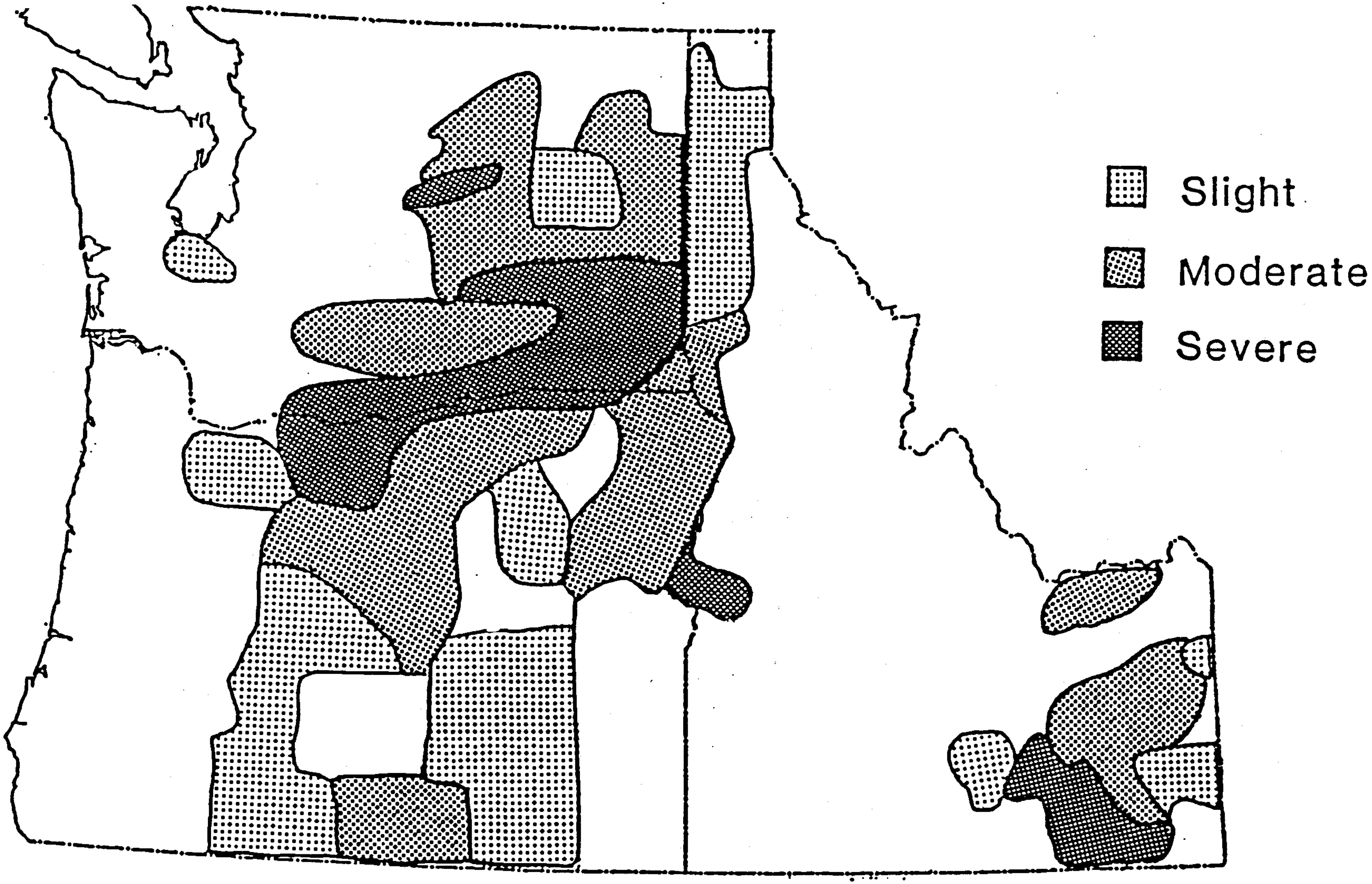

Figure 2.1. Distribution of weedy rye (*Secale* sp.) in the Pacific Northwest.

Table 2.1. Questionnaire with the tallied information from the survey sent out to all Northwest extension agents.

1. Is weedy cereal rye a problem in your county or has it been in the past?

   Yes_44%_ No_41%_

2. If so, which crops are infested?

   winter wheat
   winter barley
   winter oats
   rangeland
   grasslands
   spring barley
   potatoes
   grass seed
   spring wheat
   alfalfa
   pastures

3. What is your estimate of the number of acres infested?

	Dryland		Irrigated
Oregon	267,250	Oregon	48,700
Washington	459,660	Washington	14,100
Idaho	223,200	Idaho	39,600
Total	950,110	Total	102,400

4. Of these acres, would you rate this as being:

   Slight_____ Moderate_____ Severe_____ (see Figure 2.1)

5. If you have a problem in your county, which are the general locations? (see Table 2.1)

6. What control measures are currently being practiced?

   _63%_ Rotation
   _52%_ Ropewick
   _60%_ Fallow

   Other:
   - roguing (31%)
   - spraying waste areas
   - carpet roller
   - handwick
   - reject contaminated certified seed
   - spring tillage
   - spring cropping
   - haying badly infested fields
   - chemical fallow under no-till

7. Are growers in your area concerned about weedy rye, and do they ask questions about its control?

   Yes_33%_ No_39%_

Respondent____________________

State/county____________________

Miscellaneous information. In addition to the information requested, a few respondents reported uses of rye in their areas. First, it is used as a cover crop to help reduce wind erosion in the winter. It also may be used for ground cover in forest land restoration to prevent water erosion. Rye is grown for seed where rainfall is limited and it also is used for alkali soil rehabilitation programs.

CHAPTER THREE

Field Experiments to Test Ethiazin and Ethiazin- Metribuzin Combination Treatment at Various Timings and Rates

INTRODUCTION

Three field trials were established in the Pendleton area of the Columbia Basin in the fall of 1985. Objectives of the field trials were to a) determine the effects of application timing for selective rye control in winter wheat and b) determine if the addition of metribuzin to ethiazin could reduce the rate of ethiazin and still produce similar results. Three sites were established in order to obtain a broader representation of the control patterns in the production areas, and also to insure that data could be obtained, even if one or more trials were abandoned because of uncontrollable conditions.

MATERIALS AND METHODS

The first experiment was established on the Columbia Basin Agricultural Research Station near Pendleton, Oregon. The soil was a Walla Walla silt loam soil with 1.9% organic matter, pH 6.5, and cation exchange capacity of 16.4 meq/100 g. The soil contained 31 % sand, 52% silt, and 17% clay. Site preparation included addition of 67.2 kg/ha nitrogen, stubble mulch tillage operation, and overseeding with commercial *S. cereale* at 72 kg/ha. Stephens winter wheat was planted on 24 September 1985, into 36-cm rows at 78 kg/ha with an eight-row deepfurrow drill at a depth of 3.8 to 5.1 cm.

A split-plot design was used with five replications. The main plots consisted of timing (pre, 1-2 leaf, 2-3 leaf) and subplots were combination treatments of ethiazin and metribuzin (Table 2.1). The preemergence treatments were made on 25 September 1985, 1-2 leaf on 18 October 1985, and 2- 3 leaf on 26 January 1986. Two treatments were added to the 2-3 leaf application, 2.2/.14 and 3.4/0.0 kg/ha ethiazin and metribuzin, respectively (Table 3.1). The herbicide treatments were applied in 225 L of water per hectare with a bicycle-wheel plot sprayer set at 207 kPa. The rye at 2-3 leaf stage had one tiller.

Table 3.1. Treatment list for the on-station and offstation sites.

Rate (ethiazin/metribuzin) (kg/ha)
0.0/.14
1.7/0.0
0.8/.07
0.8/.14
1.1/.07
1.1/.14
1.7/.07
1.7/.14
2.2/.14*
3.4/0.0*
hand weeded check
weedy check

* Applied only to the 3-4 leaf stage

Visual evaluations for percent injury were made on 3 May and 15 July 1986. Above-ground biomass of both wheat and rye was determined within a 53-cm-sq. area in selected plots on 3 May 1986. The samples were oven dried at 70 C for 24 h, and dry weights were determined. Culms of both wheat and rye were counted in the same area on 17 July 1986. On 28 July, two rows were harvested with a small plot combine to determine wheat grain yield. Since rye and wheat seed are similar in size and weight, all rye plants had been removed from the harvest area with a hand sickle to avoid contamination of wheat samples.

The data collected were subjected to an analysis of variance. Percentage data from the visual evaluations were analyzed after transformation to arcsin of square root of percentage. The data from the 2-3 leaf applications were analyzed separately since they were not included in the other timings.

Peterson. The Peterson trial was initiated on a farmer cooperator's field located near the north fork of Juniper Canyon where a natural population of Secale sp. occurred. The soil type was a Ritzville silt loam with a 1.1 percent O.M., pH 7.0, and cation exchange capacity of 11.5 meq/100g. This soil contained 31% sand, 52% silt, and 17% clay. Sulfur and nitrogen were applied broadcast prior to planting at 11 and 50 kg/ha, respectively. Stubble mulch was used as a tillage practice. No additional rye was overseeded, as the natural infestation was sufficient. Stephens winter wheat was seeded at 67 kg/ha in 36-cm rows at a depth of 5.1 to 6.3 cm on 27 September 1985. The experimental design was the same as the trial on the experiment station except the subplot size was reduced to 2.4 by 4.5 meters. Preemergence treatments were made on 29 September 1985, 1-leaf on 18 October 1985, and 2-leaf on 25 January 1986. The rye at 1- leaf was actually .5 to 1.5 leaf and wheat was at 3.5 leaf to 1 tiller. The rye at the 2-leaf stage was at 2-to 3-leaf and wheat was at 5-leaf and 2.5-tiller. Spraying operations were the same as at the experiment station trial.

Data collected for this trial consisted of visual evaluation of rye and wheat injury. The evaluations were made on 20 April and 25 May 1986. These data also were subjected to the arcsin transformation of the square root of percentage prior to analysis. Wheat yield was not determined in this trial because of severe planting skips caused by heavy plant residues on the soil surface at planting time, causing the planter to plug periodically. Thus, yield data would have been extremely variable.

Duff. The third trial was established on a site located a mile northeast of Pendleton on another cooperator's field where a natural population of *Secale* sp. exists. The soil was a Walla Walla silt loam with similar characteristics as the soil on the experiment station. Soil sampling and subsequent analysis of this soil were not conducted.

Fifty kg/ha of nitrogen in the form of anhydrous ammonia was applied in the fall prior to planting. Field preparation operations were discing in the spring, using a field cultivator in the fall, followed by a rodweeder prior to planting. Glyphosate and Ultrasolve were applied for field bindweed (*Convolvulus arvensis*) control in the spring, 1985. A row of additional rye was overseeded after planting to supplement natural stands and to insure a stand in each plot. Stephens winter wheat was planted on 26 October 1985 with a standard 18-cm drill at a rate of 95 kg/ha.

The experimental design was the same as the previous two trials, except the subplot size was reduced to 2.4 by 4.5 meters. Preemergence treatments were made 7 November 1985, 1- 2 leaf on 8 February 1986, and 3-4 leaf on 27 March 1986. Both wheat and rye were at the 1.5 leaf stage at the second application and the rye was at the 3.5 to 4.0 leaf and wheat at the 3.0-3.5 leaf, 1 tiller stage at the third application. Spraying operations were the same as the previous sites.

Data collected for this trial consisted of visual ratings for percent injury to rye. Two evaluations were taken on 25 May 1986 and 9 July 1986. The data were subjected to arcsin transformations of the square root percentage prior to analysis. No yields were taken from this site because a heavy snowfall before emergence, which lasted for two months, caused stands to be highly erratic.

RESULTS AND DISCUSSION

EXPERIMENT STATION

Visual Ratings. Visual evaluations showed selective control of rye with combination treatments of ethiazin and metribuzin. Stephens winter wheat was not visibly injured from any treatment, thus no analysis was conducted on the wheat ratings.

Table 3.2. Percent injury ratings of *Secale cereale* when treated at three dates with various rates or ethiazin and metribuzin. Pendleton Station trial.[a]

	Timing		
Rate	Pre	1-2 leaf	2-3 Leaf
		Injury	
0.0/0.14	0	0	3
0.8/0.07	7	26	54
0.8/0.14	0	7	48
1.1/0.07	4	31	59
1.1/0.14	7	18	66
1.7/0.00	5	41	66
1.7/0.07	11	34	76
1.7/0.14	28	47	81*
2.0/0.14	--	--	89*
3.0/0.00	--	--	95*

[a] Ethiazin 1.7 kg/ha considered a standard treatment. Ratings with * were significantly different from that treatment (5%).

The optimum timing for application of ethiazin in this trial was at the 2-3 leaf stage. Very little rye was controlled by the preemergence treatments. One to 2-leaf application of treatments were not as effective as 2-3 leaf- stage applications, which were approaching commercial control (Table 3.2). This may be because the rye population at the time of the 1-2 leaf application had not not fully emerged as with the 2-3 leaf stage.

The addition of metribuzin to ethiazin enhanced rye control. Combination treatment of ethiazin and metribuzin at 1.1/.1 and 1.1/.14 kg/ha controlled rye equally to that of ethiazin alone at 1.7 kg/ha (Table 3.2). Combination treatments of 1.7/.1 and 1.7/.14 kg/ha showed considerably better rye control. This was especially pronounced at the 2- 3 leaf stage.

These results are similar to the timing experiments grown outside at Pendleton and Corvallis where early postemergence applications controlled rye better than preemergence. However, more preemergence activity was evident in the potted experiments than in the field. This could be attributed to the roots of the plants being confined in the pots in which herbicide concentration was greater. In addition, the pots were often heavily watered. Ethiazin, which is partially water soluble, may have been more readily taken up by the plants than under drier conditions in the field. In other greenhouse studies, postemergence applications of ethiazin were most effective for rye control. This could be due to an additive effect of both soil and foliar uptake of the herbicide (see Tables 4.3 and 4.3).

The increased rates of ethiazin to 2.2/.14 and 3.4/0.0 kg/ha gave 23 and 29% increases in rye control over that of the 1.7/0.0 kg/ha

(Table 3.2). Stephens wheat was undamaged at those rates. These two treatments were added because commercial rye control was not evident at the .5-1.5 leaf stage. The control naturally increased with higher rates of ethiazin over the previous high rates.

Commercial control might have been approached with 1.7/.07 and 1.7/.14 rates of ethiazin and metribuzin with a lower rye density. Overseeding the plot with 78 kg/ha of rye resulted in a very thick stand of rye, which will not always be the case in a natural setting. Results obtained in the Peterson trial may support this hypothesis where higher rye control ratings were recorded at lower rates (Table 3.4).

Biomass harvest. Biomass production of wheat increased with increasing rye control (Figure 3.1). With no control of rye, wheat dry matter production was 45% less than wheat with 90% control of rye. This demonstrates the competitive effects of rye on wheat and if rye is left unchecked, devastating yield reduction from rye competition may occur.

There were significant differences in biomass production between application timings. The 1.7 kg/ha rate at the 1-2 leaf stage resulted in biomass production significantly lower that at the same rate at the 2-3 leaf stage. Wheat dry matter production for the hand-weeded check is significantly lower than that of the best control treatments because they were weeded too late in the season, thus, competition had already taken place.

Culms per unit area. Wheat culm number per unit area increased with improved rye control in a similar fashion to the biomass production. There was an inverse relationship of wheat to rye culms (Figure 3.2). This demonstrates a decrease in competition with increasing rye control. The wheat culm number for the 1.7 kg/ha at the 2-3 leaf stage

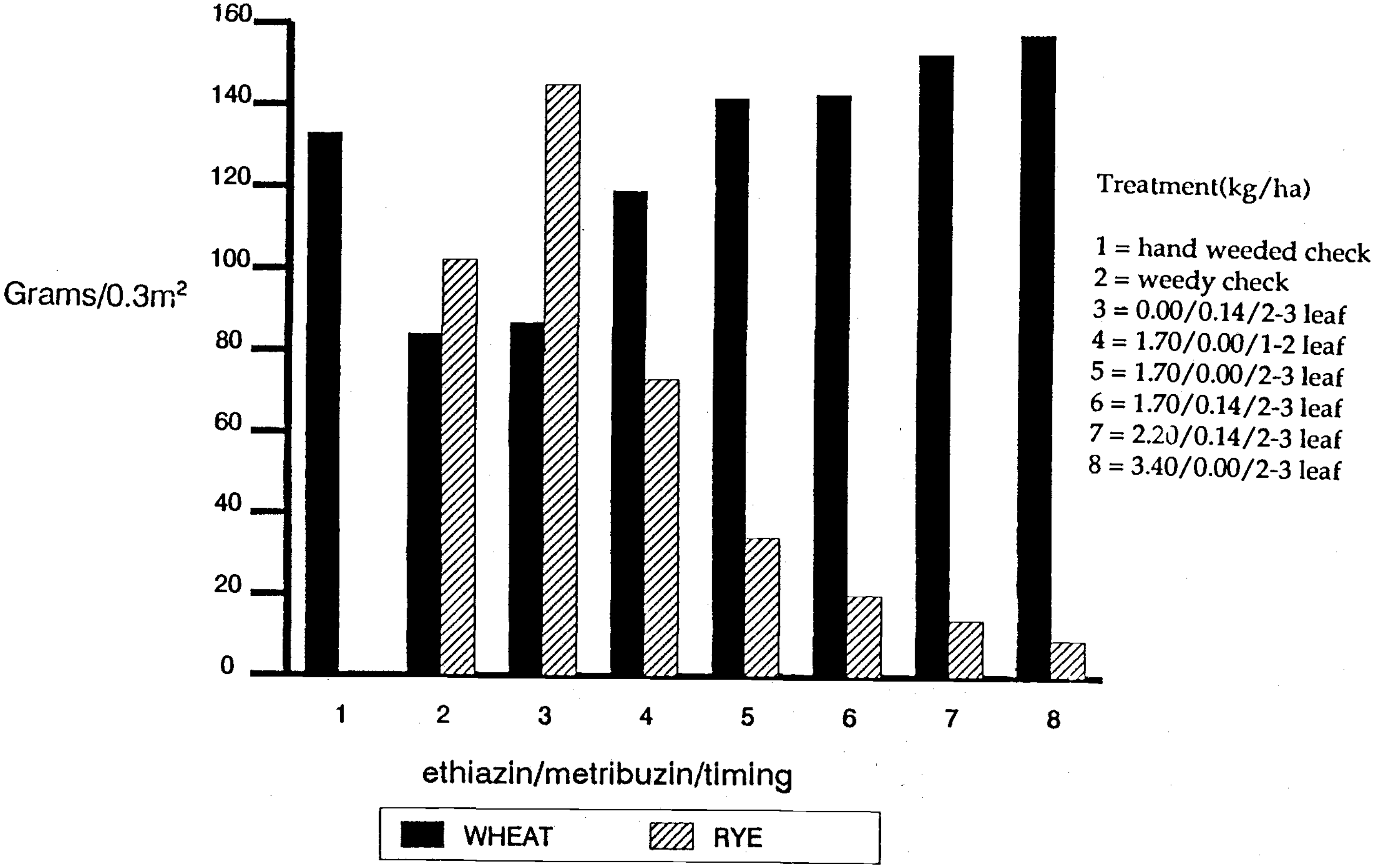

Figure 3.1. Above ground biomass production of wheat and rye.

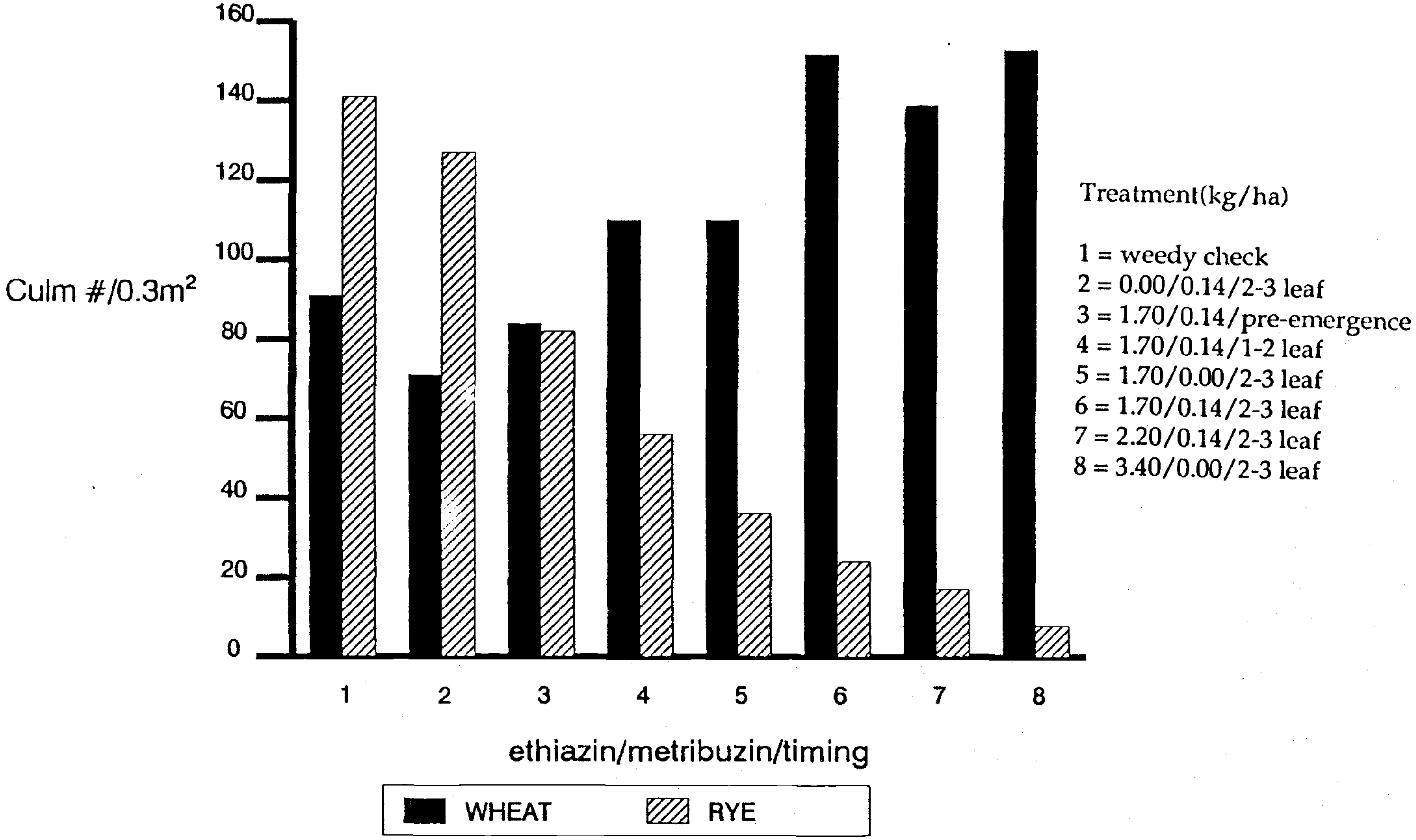

Figure 3.2. Culm # of wheat and rye at various rates and timings.

application was significantly higher than the 1.7 kg/ha for the .5-1.5 leaf stage. The culm number of the hand-weeded check was significantly different at the 5% level from the treatments without rye competition.

Wheat yield. Wheat yields obtained demonstrate the severe economic consequences of poor rye control (Table 3.3). Yields were highest for the 2-3 leaf treatments. With an increase in control of the rye, there was an increase in wheat yields.

Yields from the 2-3 leaf treatments at the rates of ethiazin and metribuzin treatments of 0.8/0.07, 0.8/0.14, 1.1/0.07, and 1.1/0.14 were not different from 1.7 kg/ha of ethiazin alone. Yields for the two highest rates of ethiazin and metribuzin (1.7/0.07, 1.7/0.14) were significantly different from that of 1.7 kg/ha of ethiazin. As with the percent injury ratings (Table 3.2), these yields indicate that the addition of metribuzin enhanced the control of rye, and subsequent yield increases resulted.

Table 3.3. Mean yield of Stephens winter wheat when treated at three dates with various rates of ethiazin and metribuzin. Pendleton Station trial.

Rate	Timing		
	Pre	.5-1.5 leaf	2-3 leaf
		Yield (kg/ha)[a]	
Weeded check	2057	2124	2723
Check	1612	1295	1664*
0.0/.14	1753	1567	1669*
0.8/.07	1895	1995	2898
0.8/.14	1519	2189	3099
1.1/.07	1578	1960	3322
1.1/.14	1639	2011	3496
1.7/0.0	1629	2329	3019
1.7/.07	1578	2323	4077*
1.7/.14	2328	2522	4035*
2.0/.14	----	----	4414*
3.0/0.0	----	----	4087*

[a] Ethiazin at 1.7 kg/ha considered a standard treatment.
Yields with * were significantly different from that treatment (5%).

Table 3.3 also shows the effects of the additional treatments with higher rates added to the two leaf stage. Yield increased as a result of additional herbicide, controlling rye more effectively, resulting in less competition for the wheat.

PETERSON LOCATION

The Peterson trial gave similar results in rye control and wheat selectivity to that of the Station experiment (Table 3.4). Rye control at this site was the best of all sites, which could have resulted from a lower rye density and a different soil type. The lower soil organic matter and less clay content may have resulted in more herbicide in the soil solution. With these soil conditions, the herbicide is more readily available for uptake (Shaw, 1986).

Table 3.4. Percent injury ratings of *Secale* sp. when treated at three dates with various rates or ethiazin and metribuzin. Peterson trial [a].

Rate	Pre	1-2 Leaf	2-3 Leaf
		% Injury	
0.0/0.14	0	0	6
0.8/0.07	2	40	71
0.8/0.14	12	60	67
1.1/0.07	22	51	80
1.1/0.14	23	56	67
1.7/0.00	18	60	70
1.7/0.07	22	70	80
1.7/0.14	31	69	90*
2.0/0.14	--	--	96*
3.0/0.00	--	--	96*

[a] Ethiazin at 1.7 kg/ha considered a standard treatment.
Ethiazin rates to the left, metribuzin to the right.
Injury ratings with * were significantly different from that treatment (5%).

The 2-3 leaf timing also was more effective than other timings at this site. The Peterson rye population was similar to the Station trial at the 1-2 leaf stage, i.e., it may not have been fully emerged. Ethiazin at 0.8 kg/ha in combination with metribuzin at 0.07 and 0.14 kg/ha showed comparable control to ethiazine alone at 1.7 kg/ha. The 1.7/.14 kg/ha of ethiazine/metribuzin at this site gave 10% better control than the station experiment. Again, the additon of metribuzin to the ethiazin combination increased rye control.

Higher rates of ethiazin successfully controlled rye (Table 3.4) while preserving crop safety. However, these higher rates did not control rye significantly better than the 1.7/.14 rate, indicating that lower rates have a higher potential to control rye on these soils.

DUFF LOCATION

Results at the Duff site were different from the other two locations (Table 3.5). In contrast to the other trials, the 1-2 leaf application was the most effective timing for maximum rye control. Preemergence applications controlled rye better than treatments at the 3-4 leaf stage. Preemergence activity may have been enhanced from the immediate snow cover after application, which may have activated the preemergence treatments better.

The loss in activity at the 3-4 leaf stage may be from spraying past the date of effectiveness. Reports have stated that ethiazin is not effective when applied in the spring (Joplin 1986). In the dryland areas of eastern Oregon, most of the rainfall occurs in the winter months. There was only 0.83 inches of rainfall in April, 1986. In addition, the rye might have been too far along in growth, 3.5 to 4.0 leaf and 2-3 tillers, for effective rye control. A weed is susceptible at one stage of its life cycle, but not necessarily at other stages (Ross, 1985). The combination of little rainfall and growth stage may explain the resulting loss in activity at the 3-4 leaf stage.

A rate response was shown for controlling rye at higher rates of the ethiazin/metribuzin combination treatments at the 1-2 leaf applications. These differences were not significant up to the highest rate, but there was a trend toward increasing activity (Table 3.5).

Table 3.5. Percent injury ratings of *Secale* sp. when treated at three dates with various rates or ethiazin and metribuzin. Duff trial.[a]

	Timing		
Rate	Pre	1-Leaf	2-Leaf
0.0/0.14	0	2*	0
0.8/0.07	25	55*	26
0.8/0.14	17	46*	6
1.1/0.07	32	77	17
1.1/0.14	38	65	2
1.7/0.00	51	74	12
1.7/0.07	55	84	19
1.7/0.14	75	81	32

[a] Ethiazin at 1.7 kg/ha considered a standard treatment.
Ethiazin rate to the right, metribuzin to the left.
Injury ratings with * were significantly different than that treatment (5%).

CHAPTER FOUR

Greenhouse Experiments and Outdoor Potted Experiments

INTRODUCTION

An experimental use herbicide, ethiazin, has controlled volunteer rye in winter wheat. Greenhouse experiments were conducted to determine the reasons for this somewhat unusual selectivity. The objectives of these studies were to study (a) physiological differences between species, (b) time of application, (c) mode of uptake, and (d) depth of seeding.

The seed used for these experiments was a cultivated source and after reviewing the literature and conducting interviews, it was determined that using this source of rye may not have been representative of the wild population. Therefore, sensitivity of cultivated and weedy rye was compared in root solution bioassays.

MATERIALS AND METHODS

Greenhouse and outdoor experiments were conducted in Pendleton and Corvallis, Oregon, from the fall of 1985 to the spring of 1987. Time-of-application, mode-of-uptake, and nutrient-solution bioassay experiments were conducted. The rye seed source for these studies was cultivated rye. As previously mentioned, there are taxonomic differences between the cultivated and wild forms, thus, additional bioassays were conducted to determine if the two forms differ physiological in their susceptibility to ethiazin.

Application Timing. Application-timing experiments were established in Pendleton (9 September 1985) and Corvallis (7 October 1986). Both studies were conducted outdoors to obtain natural morphological development. The methods were the same except that wheat and rye were grown in the same pots in Pendleton and in separate pots in Corvallis.

Six hundred g of Walla Walla silt loam was added to 10- by 10-cm plastic pots. Eight seeds each of wheat and rye were planted and covered with 200g of soil. At emergence, plants were thinned to four of each species per pot. Slow- release fertilizer (analysis 10-10-10) was added to each pot. Ethiazin treatments equivalent to 0.0, 1.12, and 2.24 kg/ha were applied in 370 L/ha at 207 kPa pressure. Treatments were applied at preemergence and the 1-, 2-, 3-, and 4-leaf stage of rye. The pots were arranged in a randomized complete block design with four replications. The Pendleton and Corvallis experiments were harvested on 31 March 1986 and 25 February 1987, respectively. Fresh weights were recorded and transformed to the percent of check. Data were subjected to analysis of variance.

Mode of Uptake. Two greenhouse experiments were planted on 17 April 1986 and 25 March 1987 to compare soil and foliar uptake. The second experiment included a soil plus foliar uptake treatment, in addition to the soil alone and foliar alone treatments, included in the first experiment. The greenhouse was kept at 20 C with 14-h daylength. To improve uniformity, seeds of both wheat and rye were pregerminated 24 h before planting to ensure that only viable seeds were used. Number 1 filter paper, 12.5 cm in diameter, was placed in 5.1 cm in diameter round by 25.4- cm deep pots to prevent soil loss. To saturate the soil before planting, the experiment was subirrigated over night. Six seeds of each wheat and rye, with radicles protruding, were planted in pots and covered with 35 g of soil, which left enough volume at the top of the pots for the addition of 2.5 cm of perlite to intercept ethiazin. Water (15 ml) was added over the top daily with a graduated syringe and the pots were subirrigated weekly. At 2 weeks, 5 ml of full strength Number 2 Hoagland's solution was added to each pot to ensure adequate fertility.

Herbicide was applied 1 week after planting, Wheat was at the 1- to 1.25-leaf stage and rye was at the 1.25- to 1.5- leaf stage. Rates of ethiazin were 0.0, 1.12, or 2.8 kg/ha applied in 370 L/ha at 207 kPa. Before the herbicide was applied, perlite was added to pots that were to receive foliage coverage only. In the other treatments, drinking straws (7.5 mm diameter) were placed over the plants and tops of the straws were stapled shut to prevent the herbicide from reaching the foliage. After the herbicide was applied, the perlite was vacuumed off and the straws were removed.

The pots were arranged in a randomized complete block design with five replications. Plants were harvested 35 days after planting and fresh weights were recorded. Data were converted to percent of check and subjected to analysis of variance.

Nutrient Bioassays. Solution bioassays were conducted in the greenhouse in Corvallis in spring 1986 and 1987 to quantify differences in physiologically susceptibility between wheat and rye, and between wild and cultivated rye. This method of treatment eliminated possible differences in sensitivity due to leaf morphology and herbicide retention, depth of rooting, depth of crown formation, etc. The assumption was made that uptake by roots was similar. Greenhouse conditions were the same as in the uptake study.

Seeds of wheat and rye were pregerminated in paper towels for 3 days before planting. Coleoptile lengths of wheat ranged from 3 to 4 cm and rye from 2 to 3 cm. One seeding from each species, supported by foam rubber pieces, was transferred to each 50-ml culture tube. Roots were suspended in a solution containing 7 ml of No. 2 Hoagland's solution, and various concentrations of ethiazin (0.0, 0.5, 1.0, 2.5, 5.0, 10.0, 25.0, or 50.0 umol), formulated from technical grade ethyl-metribuzin. The tubes were brought up to 50 ml by adding deionized water with a 30-ml graduated syringe. At each watering, the amount added was recorded to obtain a cumulative water uptake for each species. A randomized complete block design was used with six replications. Plant shoots were harvested 21 days after planting and fresh weights were recorded. The data were transformed to percentage of controls.

The percentage data were subjected to regression analysis for each species and each replication. The herbicide concentrations required for 50% growth reduction (GR_{50}) were estimated from these equations. The technique was the same as that described by Fuerst et al. (1986) for estimating the rate for 50% injury (I_{50}). The GR_{50} values were subjected to analysis of variance to quantify the difference between species in susceptibility to ethiazin.

Samples of weedy rye were collected in the Columbia River basin near Pendleton. Methods and analysis were the same as previously discussed except for lower herbicide concentrations (0.0, 0.125, 0.25, 0.5, 1.0, 2.5, 5.0, or 10.0 umol), and water uptake was not measured.

RESULTS AND DISCUSSION

The results for all experiments clearly showed selective control of rye with ethiazin in 'Stephens' winter wheat. This selectivity pattern may differ between wheat cultivars because studies at Oregon State University have shown differential tolerance to ethiazin between winter wheat cultivars (Valverde et al. 1987).

Application Timing. In both the Pendleton and Corvallis experiments, differences in application timing were evident in both rye control and wheat tolerance (Tables 4.1 and 4.2). In the Pendleton study, rye control was better at all timings than in the Corvallis study, and wheat showed more tolerance. Rye control was less for the Corvallis experiment at the 3- and 4-leaf stages than the Pendleton at the 3- and 4-leaf stages.

Table 4.1. Response of wheat and rye to ethiazin at different rates and timings (Corvallis experiment).

Species	Rate	Timing				
		PE	1L	2L	3L	4L
Wheat	(kg/ha)	% of check				
	1.12	81	79	119	101	84
	2.24	66	59	67	88	73
Rye	1.12	8	9	15	68	76
	2.24	10	2	3	33	47

$LSD_{.05}$ (Species) = 8.9
$LSD_{.05}$ (Rate) = 8.9
$LSD_{.05}$ (Timing) = 14.2

PE - Pre-emergence
1L,2L,3L,4L - 1,2,3,4 - leaf

Table 4.2. Response of wheat and rye to ethiazin at different rates and timings.

Species	Rate	Timing				
		PE	1L	2L	3L	4L
	(kg/ha)	% of check				
Wheat	1.12	130	127	120	130	127
	2.24	144	134	128	144	120
Rye	1.12	5	.01	2	8	45
	2.24	.01	.01	.01	.01	13

$LSD_{.05}$ (Species) = 7.7
$LSD_{.05}$ (Rate) = 7.7
$LSD_{.05}$ (Timing) = 12.2

PE - Pre-emergence
1L,2L,3L,4L - 1,2,3,4-leaf

These application-timing experiments demonstrated the importance of applying ethiazin at the right stage for optimum rye control. In both the Corvallis and Pendleton outdoor pot studies, rye control was 85% or better from the preemergence treatments, and the 1-leaf and 2-leaf stages, with the 3-leaf stage at the Pendleton providing good rye control. Control started to drop off at the 3- and 4-leaf application at Corvallis and 4-leaf at Pendleton experiments. This correlates well with the field experiments in which optimum control was at the 2-3 leaf stage for two of the off station field trials, but control started to drop at the Duff site when the treatments were applied at the 3-4 leaf stage of the rye.

The pot experiments showed differences between locations in rye control at the same growth stages; however, rye control in the Pendleton experiment was better over all stages than in Corvallis. This difference may be explained by the different environmental conditions at the two locations. In the winter of 1985-86, the experimental area in Pendleton was subject to snow cover and severe cold from early November to mid-January. The Corvallis experiment had very wet and mild conditions over the same period, and the better growing conditions may have allowed the rye to withstand the ethiazin.

The lower wheat tolerance shown in the Corvallis experiment also may be related to these environmental conditions. Hatzios and Penner (1982) indicate that environmental factors affect the metabolism of herbicides. Thus, wheat under cloudy conditions may not have been able to metabolize the ethiazin and subsequent injury occurred. The greater increase in growth of the treated wheat in the Pendleton experiment compared to the treatments in the Corvallis experiment is from the two species being grown in the same pot. With the control of the rye, the wheat was without competition that was present in the check treatments.

Mode of Uptake. Uptake of ethiazin for the control of rye was primarily through the soil (Table 4.3). Treatments which included both foliar and soil exposed caused more injury to rye at the highest rate. A decrease in wheat growth was evident; however, the reduction at the higher rate was not statistically significant in experiment 1 (Table 4.3). Wheat tolerance to ethiazin in experiment 2 from foliar uptake was greater than soil and soil plus foliar uptake, indicating more uptake from the soil (Table 4.4).

Table 4.3. Foliar vs. soil uptake of ethyl-metribuzin in wheat and rye. Experiment 1.

Species	Rate	Soil	Foliar
	(kg/ha)	% of check	
Rye	1.70a	63	100
	2.80	13	62
Wheat	1.70	89	95
	2.80	91	87

LSD$_{.05}$ (Rate) = 10.4?
LSD$_{.05}$ (Uptake) = 10.4?
LSD$_{.05}$ (Species) = 10.4

Table 4.4. Foliar vs. soil uptake of ethyl-metribuzin in wheat and rye. Experiment 2. Combination of soil and foliar included.

Species	Rate	Soil	Foliar	Both
	(kg/ha)		% of check	
Rye	1.7	12	40	17
	2.8	3	13	4
Wheat	1.7	71	85	75
	2.8	26	64	32

$LSD_{.05}$(Rate) = 8.7
$LSD_{.05}$(Uptake) = 10.6
$LSD_{.05}$(Species) = 8.7

The results generated from these experiments provided valuable information for applying ethiazin for effective rye control. Field studies indicate optimum control in rye is obtained with early postemergence applications of ethiazin (Rydrych 1986, Thill 1985). Thus, the combination of soil and foliar uptake may be needed for optimum efficacy.

Metribuzin is known to be taken up primarily by the roots, with a small degree of foliar activity (Weed Science Society of America 1983). Peek (1987) has measured a slightly higher octanol-water partition coefficient for ethiazin compared to metribuzin, possibly indicating better foliar absorption properties of ethiazin.

Solution bioassay: Wheat vs. rye (S. cereale). Stephens wheat was more tolerant than rye to ethiazin. The pooled GR_{50} values from both experiments showed wheat to be about 13 times more tolerant (Figure 4.1). Water uptake was less for rye than wheat at the 2.5, 5.0, and 10.0 umol concentrations (Figure 4.2).

Hardcastle (1979) reports that metribuzin activity and selectivity under field conditions are influenced by various soil types, application rates, rainfall after application, and soil organic matter. The same could hold true under field conditions for ethiazin. Solution bio-

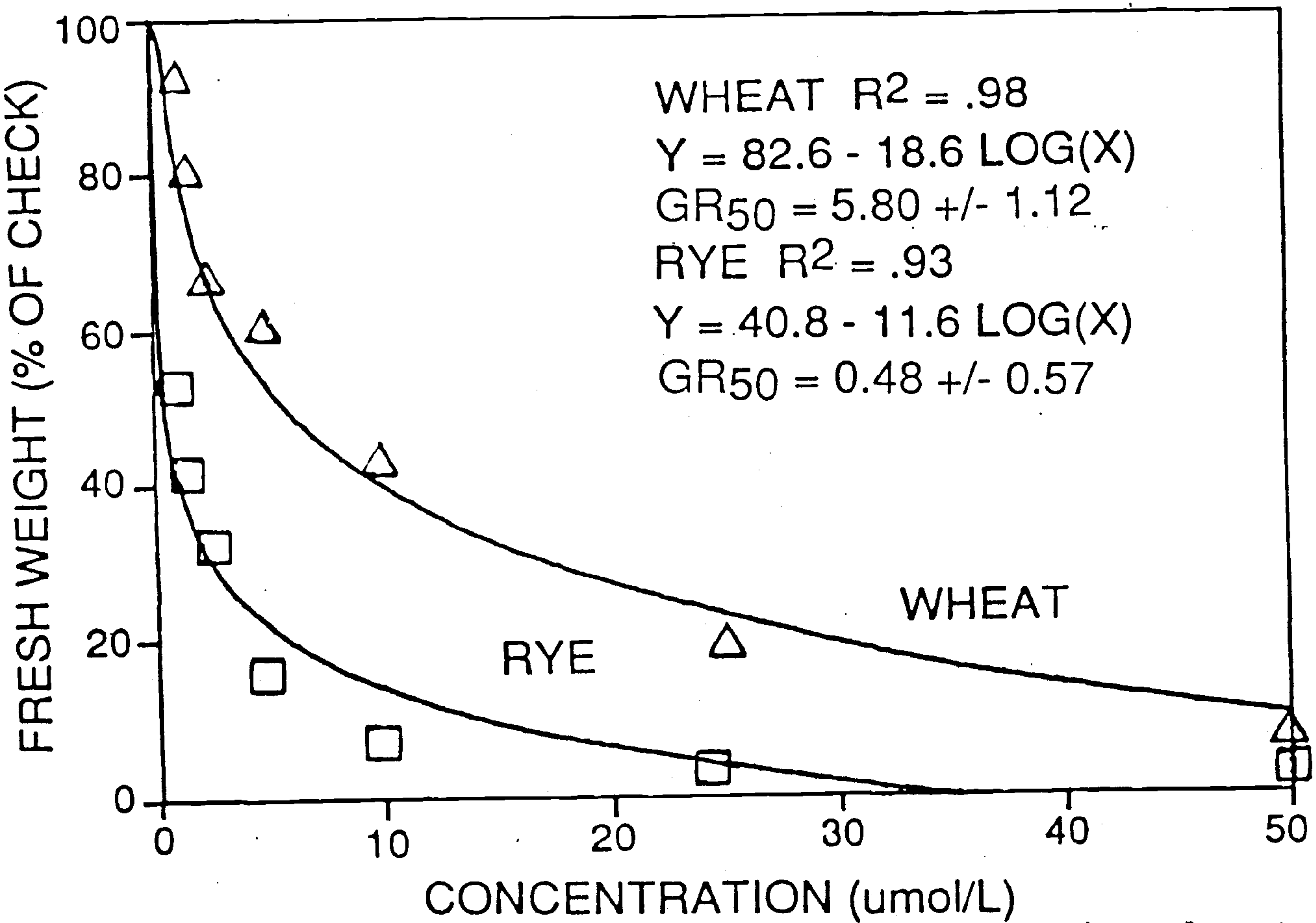

Figure 4.1. Differential response between 'Stephens' winter wheat and cereal rye to ethiazin.

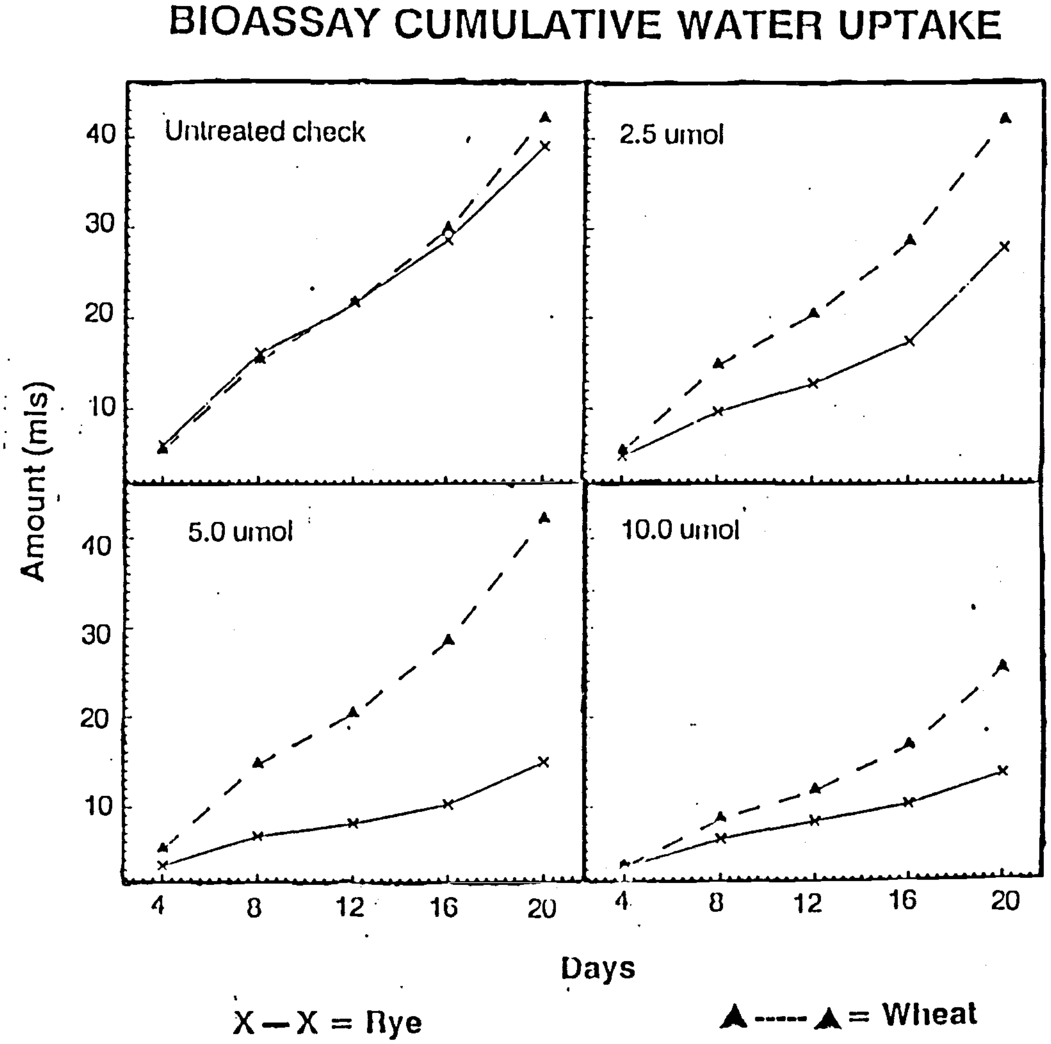

Figure 4.2. Differential water uptake between 'Stephens' winter wheat and cereal rye at various concentrations of ethiazin.

assays, which eliminate the influence of the above factors, are useful tools to quantify physiological tolerance differences between wheat and rye.

The 13 times greater tolerance of Stephens wheat over rye support Rydrych's (1986) findings for the safety of ethiazin on this variety in the field. The mechanism for this selectivity at the cellular level is yet to be discovered; however, these results clearly indicate that the susceptibility difference between the two species observed in the field is largely due to physiological differences and not to differences in uptake.

Solution Bioassay: cultivated vs weedy rye. Cultivated and weedy rye were equally susceptible to ethiazin, as shown by the respective GR_{50}s (Figure 4.3). When this research was initiated, we thought the weedy and cultivated forms of rye were the same species, and they are both still considered by some workers to be S. cereale. However, after we reviewed the literature (Hitchcock 1971, Khush 1963, Suneson 1969) and interviewed local plant breeders (Metzger 1986, Vogel 1986), we found that the wild species differs phenotypically from cultivated rye, and we now believe that interspecific hybridization apparently took place between S. cereale and S. montanum in the wild population (Suneson 1969).

Our studies reported were intended to show that the two seed sources were the same in susceptibility to ethiazin. Because they seem to be identical in susceptiblility to ethiazin (Figure 4.3), results from the research with the cultivated rye seed source should be valid in

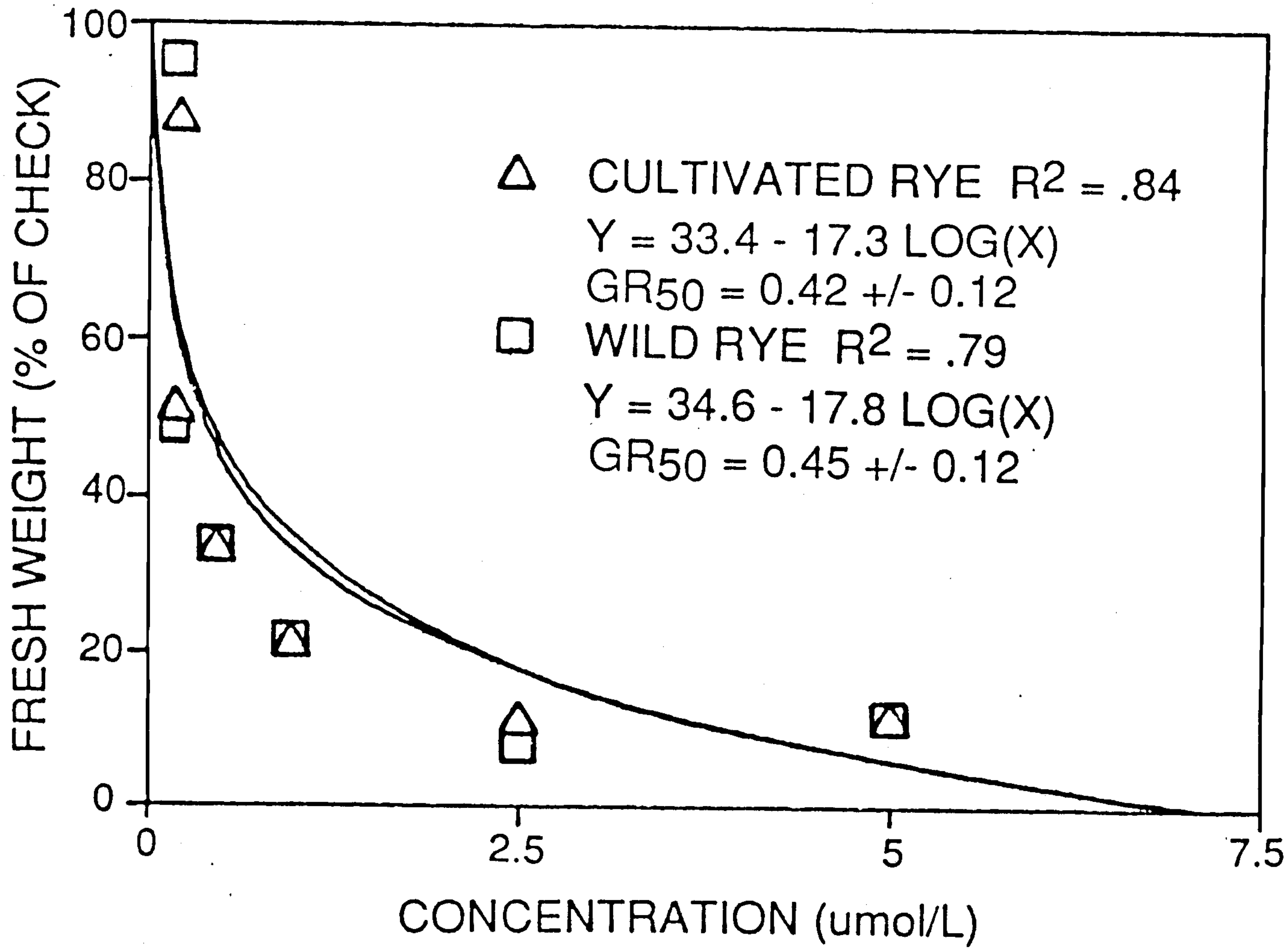

Figure 4.3. Response of cultivated rye vs. wild, weedy rye to ethiazin.

predicting effects on the wild population.

Depth of seeding. The depth from which rye emerged did not influence sensitivity to ethiazin (Appendix Tables 19 and 21).

GENERAL DISCUSSION

Ethiazin shows potential for controlling weedy rye in the dryland winter wheat growing regions of the Pacific Northwest where the variety Stephens is grown. The field and greenhouse studies conducted over the past two years have provided good insight on how to use this product for this purpose.

The most promising discovery associated with this selective control is the physiological selectivity between Stephens wheat and rye. This type of selectivity is preferred because the safety to the crop is much greater than selectivity based on foliar retention, rooting depth, crown depth, and other morphological factors, which often are influenced by environment and, therefore, are less predictable.

In addition to determining the mode of selectivity, other findings on absorption resulted in a better understanding of the application timing of the material. Ethiazin is primarily taken up by the roots, but also has foliar uptake properties. In addition to other mentods for rye control, growers could apply ethiazin early post- emergence for optimum uptake as shown in both the field studies and application timing studies. This timing of application also coincides well with the winter rainfall patterns of the dryland regions. There is a better chance for ethiazin to become activated when it is applied in the fall.

Growers and extension agents often inquire about the price of the material. This information has not been determined, or at least has not been provided to research workers. However, the yield increases obtained because of rye control may offset considerable cost of the material. In the Pendleton study, grain yield increases of 2750 kg/ha were obtained when compared to the untreated check. At $2.50 per bushel this could represent approximately a $230.00/ha increase from control. In addition, a grower can significantly reduce the seed bank within two years to where the rye is no longer a threat, thus the cost may not become a yearly expenditure.

Upon registration of ethiazin, dryland winter wheat growers will have an effective weed control tool against many problem weeds including weedy rye. It is through these studies that satisfactory information was obtained to provide the confidence needed to use this new product.

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APPENDIX A

Columbia Basin
Agricultural
Research Center

Oregon
State
University

Pendleton Station
Box 370
Pendleton, Oregon 97801

(503) 276-5721

July 17, 1986

MEMORANDUM

TO: Pacific Northwest County Extension Agents —Redacted for privac

FROM: Phil Diener, Graduate student, Oregon State University

SUBJECT: INQUIRY: Volunteer cereal rye (Secale cereale), is it a weed problem in your county?

Whether cereal rye is or not a problem, I'm in need of your help to determine the scope of the infestation in the Pacific Northwest. I have contacted each of your extension directors individually, (E. Smith, H. Guenthner, O. Young) from Oregon, Idaho, and Washington respectively, and they have given their approval for such a survey.

I'm a graduate student in Crop Science at Oregon State University majoring in Weed Science, studying under Dr. Arnold Appleby and Don Rydrych, both of whom are on my graduate committee. My thesis project entails the selectivity factors of ethiazine (Tycor or Siege, from Mobay and Dupont respectively) in the early post emergent control of volunteer cereal rye in winter wheat. My research is being conducted in the Columbia Basin at the Columbia Basin Agricultural Research Center near Pendleton, Oregon.

In order to serve the agricultural community effectively, the scope of this weed problem needs to be determined. To date, there hasn't been any information accumulated on the seriousness of volunteer rye in the Northwest. In an effort to fill this information gap, I've decided to contact you, the county agents of the Pacific Northwest, and ask for your help.

All I need from you would be to fill out the enclosed questionnaire. Place it in the enclosed, postage-paid envelope, and promptly mail. Due to the deadline of my thesis being next spring, the urgency of this information is quite substantial.

Thank you for your time and effort, and being part of the volunteer cereal rye inquiry of the Great Northwest.

PD:dl

Enclosure

APPENDIX B

APPENDIX TABLES

Appendix Table 1. Visual injury of *S. cereale* and grain yield of 'Stephens' winter wheat when treated with ethiazin and ethiazin/metribuzin tank mix treatments at various rates and timings. (Pendleton Station Trial)

Treatment[1] (kg/ha)	Timing	% Control R1	R2	R3	R4	R5	Avg	Grain Yield (kg/ha) R1	R2	R3	R4	R5	Avg
Weeded Check	Pre	100	100	100	100	100	100	2745	1107	1796	1586	3053	2057
Check	"	0	0	0	0	0	0	1796	750	2214	1459	1839	1612
0.0/0.14	"	0	0	0	0	0	0	1960	1874	1684	1361	1888	1753
0.8/0.07	"	0	0	0	0	0	0	2263	1695	2237	1687	1594	1895
0.8/0.14	"	10	0	0	10	15	7	2128	801	1834	1491	1341	1519
1.1/0.07	"	0	0	0	20	0	4	1984	1168	1901	1165	1672	1578
1.1/0.14	"	10	10	5	0	10	7	2012	778	1485	1600	2321	1639
1.7/0.00	"	10	0	15	0	0	5	1640	946	1868	1851	1842	1629
1.7/0.07	"	10	15	0	0	30	11	2883	1730	1470	1528	2050	1932
1.7/0.14	"	40	20	25	15	40	28	2941	1695	2710	1672	2624	2328
Weeded Check	1-2 Leaf	100	100	100	100	100	100	2632	2373	1932	1442	2240	2124
Check	"	0	0	0	0	0	0	1465	735	908	1052	2318	1295
0.0/0.14	"	0	0	0	0	0	0	1715	1185	1442	1283	2214	1567
0.8/0.07	"	15	10	0	10	0	7	2018	2123	2485	1643	1701	1960
0.8/0.14	"	30	40	25	15	20	26	2415	1730	1978	2701	2087	2189
1.1/0.07	"	35	45	30	20	25	39	2275	2338	1563	1392	2234	1960
1.1/0.14	"	20	20	15	15	30	20	1626	1790	2145	1926	2566	2011
1.7/0.00	"	40	35	45	40	45	41	2987	1934	2335	1995	2396	2329
1.7/0.07	"	35	30	25	35	40	33	2745	3030	1542	1701	2595	2323
1.7/0.14	"	50	45	80	10	50	47	1384	1958	4705	1280	3287	2522

Appendix Table 1, Cont'd.

Weeded Check	2-3 Leaf	100	100	100	100	100	100	2652	1883	2624	3529	2926	2722
Check	"	0	0	0	0	0	0	1473	2652	1874	1052	1269	1664
0.0/0.14	"	10	5	0	0	0	0	1511	1920	1839	1194	2033	1699
0.8/0.07	"	55	65	60	40	50	54	2647	2831	3552	2419	3039	2897
0.8/0.14	"	40	50	45	50	55	48	2926	3336	3301	2681	3252	3099
1.1/0.07	"	65	70	50	50	60	59	3468	3356	2915	2883	3990	3322
1.1/0.14	"	70	70	75	60	55	66	4062	3070	3650	3460	3238	3496
1.7/0.00	"	75	75	70	40	70	66	2497	2978	4268	2018	3336	3019
1.7/0.07	"	80	75	90	65	70	76	4555	3733	4767	3575	3759	4077
1.7/0.14	"	90	85	80	70	80	81	4152	4639	4019	3731	3630	4034
2.2/0.14	"	95	90	90	85	85	89	4815	4160	3901	4526	4668	4414
3.4/0.00	"	95	95	95	95	95	95	4642	4382	3523	3465	4425	4087

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[1] Ethizain/Metribuzin tank mix.

Appendix Table 2. Analysis of variance of % control of rye in Appendix Table 1 (arcsin transformed).

Source	DF	SS	MS	F
Mainplot	14	28756.26	2054.02	
Replication	4	751.47	187.87	3.82*
Timing	2	27611.95	13805.96	281.15**
Error A	8	392.84	49.11	
Rate	7	18434.95	2633.56	43.53**
Rate X Timing	14	4170.37	297.88	4.92**
Error B	84	5081.44	60.49	
Total	119	56443.03		

*Significant at the 5% level
**Significant at the 1% level

Appendix Table 3. Analysis of variance of % control of rye in Appendix Table 1, 2-3 leaf data (arcsin transformed).

Source	DF	SS	MS	F
Replication	4	570.47	142.62	6.44**
Rate	9	17064.56	1896.06	85.70**
Error	36	796.42	22.12	
Total	49	18431.45		

**Significant at the 1% level

Appendix Table 4. Analysis of Variance of wheat yield in Appendix Table 1.

Source	DF	SS	MS	F
Mainplot	14	52119833.44	3722845.25	
Replication	4	7452921.51	1863230.37	4.09*
Timing	2	41020058.68	20510029.34	44.99**
Error A	8	3646853.25	455856.66	
Rate	9	24980224.91	2775580.54	11.10**
Rate X Timing	18	14810842.25	822824.57	3.29*
Errot B	108	27001590.84	250014.73	

*Significant at the 5% level
**Significant at the 1% level

Appendix Table 5. Analysis of variance of wheat yield in Appendix Table 1, 2-3 leaf data.

Source	DF	SS	MS	F
Replication	4	1737948.90	434487.23	1.78 NS
Rate	11	44002619.40	4000238.12	16.30**
Error	44	10740753.10	244108.03	
Total	59	56481321.40		

NS = Nonsignificant at the 5% level
** = Significant at the 1% level

Appendix Table 6. Visual injury of *Secale* spp. when treated with ethiazin + ethiazin/metribuzin tank mix treatments at various rates and timings (Peterson Trial).

		% control					
Treatment (kg/ha)	Timing	R1	R2	R3	R4	R5	AVG.
Weeded check	Pre	100	100	100	100	100	100
Check	"	0	0	0	0	0	0
0.0/0.14	"	0	0	0	0	0	0
0.8/0.7	"	10	0	0	0	0	2
0.8/0.14	"	20	20	0	0	0	12
1.1/0.07	"	20	45	0	0	45	22
1.1/0.14	"	30	25	10	20	30	23
1.7/0.00	"	40	0	0	0	50	18
1.7/0.07	"	10	20	20	20	40	22
1.1/0.14	"	30	40	40	12	35	31
Weeded Check	1-2 Leaf	100	100	100	100	100	100
Check	"	0	0	0	0	0	0
0.0/0.14	"	0	0	0	0	0	0
0.8/0.07	"	40	40	60	40	20	40
0.8/0.14	"	90	30	20	60	50	60
1.1/0.07	"	75	40	70	50	20	51
1.1/0.14	"	60	50	70	60	40	56
1.7/0.00	"	70	50	60	50	70	60
1.7/0.07	"	85	70	65	70	60	70
1.7/0.14	"	70	60	70	80	80	69
Weeded Check	2-3 Leaf	100	100	100	100	100	100
Check	"	0	0	0	0	0	0
0.0/0.14	"	0	0	0	20	10	6
0.8/0.07	"	85	90	70	50	60	71
0.8/0.14	"	90	60	70	40	75	67
1.1/0.07	"	70	75	80	85	90	80
1.1/0.14	"	60	70	70	65	70	67
1.7/0.00	"	70	60	80	70	70	70
1.7/0.07	"	80	85	70	85	80	80
1.7/0.14	"	95	100	90	85	90	91
2.2/0.14	"	95	98	100	95	95	96
3.0/0.00	"	100	95	100	95	90	96

Appendix Table 7. Analysis of variance for % control of weedy rye in Table 6 (arcsin transformed).

Source	DF	SS	MS	F
Mainplot	14	30983.67	2213.12	
Replication	4	965.91	241.47	0.845 NS
Timing	2	27731.66	13865.83	48.52 **
Error A	8	2286.12	285.76	
Rate	7	26632.10	3804.58	44.17 **
Rate X Timing	14	4165.38	297.53	3.45 **
Error B	84	7234.01	86.12	
Total	119			

NS = Nonsignificant
** = significant at 1% level

Appendix Table 8. Analysis of Variance of % control of weedy rye in Appendix Table 6, 2-3 leaf stage (arcsin transform).

Source	DF	SS	MS	F
Replication	4	98.48	24.62	.33 NS
Rate	9	18771.38	2085.70	27.85 **
Error	36	2702.38	75.07	
Total	49	21572.24		

** = Significant at the 1% level
NS = Nonsignificant at the 5% level

Appendix Table 9. Visual injury of the weedy rye (*Secale spp.*) when treated with ethiazin and ethiazin/metribuzin tank mix treatments at various rates and timings (Duff Trial).

		% control					
Treatment (kg/ha)	Timing	R1	R2	R3	R4	R5	Avg
Weeded Check	Pre	100	100	100	100	100	100
Check	"	0	0	0	0	0	0
0.0/0.14	"	0	0	0	0	0	0
0.8/0.07	"	20	60	10	60	70	25
0.8/0.14	"	5	10	0	40	30	17
1.1/0.07	"	20	60	10	60	70	32
1.1/0.14	"	50	70	0	45	20	38
1.7/0.00	"	30	60	20	80	65	51
1.7/0.07	"	50	40	35	70	80	55
1.7/0.14	"	70	85	50	90	80	75
Weeded Check	1-2 Leaf	100	100	100	100	100	100
Check	"	0	0	0	0	0	0
0.0/0.14	"	0	0	0	0	10	2
0.8/0.07	"	50	50	40	65	70	55
0.8/0.14	"	40	50	65	40	30	46
1.1/0.07	"	85	80	70	85	65	77
1.1/0.14	"	40	60	70	75	80	65
1.7/0.07	"	60	60	80	90	75	84
1.7/0.07	"	60	90	95	70	90	81
1.7/0.14	"	60	90	95	70	90	81
Weeded Check	3-4 Leaf	100	100	100	100	100	100
Check	"	0	0	0	0	0	0
0.0/0.14	"	0	0	0	0	0	0
0.8/0.07	"	25	15	30	40	20	26
0.8/0.14	"	0	0	0	10	20	6
1.1/0.7	"	10	5	0	30	40	17
1.1/0.14	"	10	0	0	0	0	2
1.7/0.00	"	30	0	10	0	20	12
1.7/0.07	"	40	10	15	10	20	19
1.7/0.14	"	30	45	40	15	30	32

Appendix Table 10. Analysis of varience of % control of weedy rye in Appendix Table 9 (arcsin transformed).

Source	DF	SS	MS	F
Mainplot	14	25792.56	1842.32	
Replication	4	1414.34	353.58	1.06 NS
Timing	2	21722.94	10861.47	32.72 **
Error A	8	2655.27	331.91	
Rate	7	27218.54	3888.36	42.19 **
Rate X Timing	14	5248.54	374.89	4.07 **
Error B	84	7740.11	92.14	
Total	119	65999.76		

** = Significant at the 1% level
NS = Nonsignificant at the 5% level

Appendix Table 11. Above ground biomass production of "Stephens" winter wheat and cereal rye when treated with ethiazin and ethiazin/metribuzin tank mix treatments (Pendleton Station Trial).[a]

	grams											
	Wheat						Rye					
Treatment (kh/ha)	R1	R2	R3	R4	R5	AVG	R1	R2	R3	R4	R5	AVG
Weeded Check	170	98	142	117	132	133	0	0	0	0	0	0
Weedy Check	58	75	110	68	106	84	96	108	97	107	103	102
0.0/0.14/2-3 Leaf	86	111	91	51	94	87	133	107	157	179	149	145
1.7/0.0/1-2 Leaf	139	81	126	132	116	119	42	68	114	64	77	73
1.7/0.0/2-3 Leaf	153	147	150	105	158	142	19	45	14	41	48	34
1.7/0.14/2-3 Leaf	171	120	175	125	121	143	18	7	25	36	18	20
2.0/0.14/2-3 Leaf	125	126	221	117	176	153	13	12	11	14	20	14
3.0/0.00/2-3 Leaf	159	127	171	171	164	158	17	9	5	8	7	9

[a] Ethiazin rates to left, metribuzin to the right

Appendix Table 12. Analysis of variance of above ground biomass weights in Appendix Table 11.

Source	DF	SS	MS	F
Replication	4	5060.82	1265.20	2.94 *
Treatments	15	243100.96	16206.73	37.64
Species	1	119799.72	119799.72	278.23
Rate	7	14288.37	2041.20	4.74
Species X Rate	7	109012.85	15573.26	36.17 **
Error	60	25834.93	430.58	
Total	79			

** = Significant at 1% level
 * = Significant a 5% level

Appendix Table 13. Culm number of "Stephens" winter wheat and cereal rye when treated with ethiazin and ethiazin/metribuzin tank mix treatments (Pendleton Station Trial).[1]

	Culm #/30 cm x 30 cm sq											
	Wheat						Rye					
Treatment (kg/ha)	R1	R2	R3	R4	R5	AVG	R1	R2	R3	R4	R5	AVG
Weeded Check	106	113	92	64	76	90	0	0	0	0	0	0
Weedy Check	87	86	92	95	93	91	187	124	148	134	112	141
0.0/0.14/2-3 Leaf	83	77	69	63	67	71	113	156	144	115	111	127
1.7/0.14/Pre	87	65	88	102	76	84	79	82	66	108	74	82
1.7/0.0/1-2 Leaf	112	105	92	113	128	110	32	75	92	65	65	66
1.7/0.14/1-2 Leaf	118	96	108	114	113	110	41	55	44	84	56	56
1.7/0.0/2-3 Leaf	130	153	132	117	140	138	33	26	48	42	33	36
1.7/0.14/2-3 Leaf	185	159	134	145	135	152	19	16	27	43	17	24
2.2/0.14/2-3 Leaf	154	152	147	151	160	153	13	6	4	9	10	8

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[1] Ethiazin rates to the right, metribuzin to the left

Appendix Table 14. Analysis of variance of the culm numbers of wheat and rye in Appendix Table 13.

Source	DF	SS	MS	F
Replication	4	366.74	91.69	0.413 NS
Treatments	19	229087.77	12057.25	54.314
Species	1	82886.41	82886.41	373.379
Rate	9	28781.29	3197.92	14.406
Rate X Species	9	117420.09	13046.67	58.771 **
Error	76	16871.26	221.99	
Total	99			

** = Significant at the 1 % level
NS = Nonsignificant at the 5% level

Appendix Table 15. Fresh shoot weights of "Stephens" winter wheat and cereal rye when subjected to soil or foliar treatments of ethiazin.

	grams					
Treatment	R1	R2	R3	R4	R5	AVG
FR 0.0	2.8	4.4	3.7	4.9	4.0	3.96
FR 1.5	3.8	3.6	3.6	5.2	3.6	3.96
FR 2.5	2.3	2.0	3.2	2.0	2.7	2.44
FW 0.0	3.8	3.6	3.5	3.5	3.7	3.62
FW 1.5	3.4	3.4	3.6	3.0	3.8	3.44
FW 2.5	2.9	2.5	3.4	3.4	3.6	3.16
SR 0.0	3.7	3.7	3.6	5.8	5.3	4.42
SR 1.5	2.3	2.2	2.2	3.6	3.6	2.78
SR 2.5	0.9	0.4	0.3	0.9	0.3	0.56
SW 0.0	3.5	3.7	3.7	2.7	3.4	3.40
SW 1.5	2.6	3.2	2.7	3.9	2.7	3.02
SW 2.5	2.9	3.2	3.1	3.1	3.3	3.12

F=Foliar, S=Soil, R=Rye, W=Wheat, #=Rate of Ethiazin

Appendix Table 16. Analysis of variance of the % of untreated check for the treatments of Appendix Table 15.

Source	DF	SS	MS	F
Replications	4	1189	2973	
Mode of Uptake (Mou)	1	4884	4884	17.78
Species	1	9548	9548	34.75
MOU x Species	1	5290	5290	19.26 **
Rate	1	5336	5336	19.42
MOU x Rate	1	1.60	1.60	0.0058
Species x Rate	1	4000	4000	14.56 **
MOU x Species x Rate	1	260.1	260.1	.9467NS
Residual	28	7693	274.7	

** = Significant at the 1% level
NS = Nonsignificant at the 5% level

Appendix Table 17. Fresh shoot weights of "Stephens" winter wheat and cereal rye when subjected to soil, foliar, or soil plus foliar treatments of ethiazin.

	grams					
Treatment	R1	R2	R3	R4	R5	AVG
FR 0.0	3.7	4.1	4.4	3.4	3.4	3.8
FR 1.5	2.0	2.4	1.4	1.3	0.7	1.5
FR 2.5	1.1	0.9	0.1	0.4	0.1	0.5
FW 0.0	5.2	4.2	4.8	4.7	4.2	4.6
FW 1.5	3.3	3.9	4.8	3.9	3.6	3.9
FW 2.5	1.3	4.2	3.6	3.5	2.0	2.9
SR 0.0	4.4	4.2	3.6	3.4	3.0	3.7
SR 1.5	0.1	1.3	0.5	0.1	0.4	0.5
SR 2.5	0.1	0.1	0.2	0.1	0.1	0.1
SW 0.0	4.7	4.4	5.5	3.8	5.0	4.8
SW 1.5	2.9	3.5	3.2	3.6	3.1	3.3
SW 2.5	1.2	0.2	1.2	2.5	0.5	1.1
BR 0.0	3.6	4.4	3.5	3.2	3.7	3.7
BR 1.5	1.1	0.5	0.6	0.7	0.1	0.6
BR 2.5	0.0	0.1	0.1	0.2	0.1	0.1
BW 0.0	4.5	5.1	3.5	3.4	4.9	4.3
BW 1.5	3.4	4.5	1.8	3.6	2.7	3.2
BW 2.5	0.1	2.1	1.0	0.7	3.4	1.5

F=Foliar, S=Soil, B=Both soil + foliar, R=Rye, W=Wheat, #=Ethiazin rate

Appendix Table 18. Analysis of variance of the % of untreated check for the treatments of Appendix Table 16.

Source	DF	SS	MS	F
Replications	4	2200	550	
Mode of Uptake (MOU)	2	5931	2965	10.59 **
Species	1	28910	28910	103.2
MOU x Species	2	120.9	60.45	.2159
Rate	1	10430	10430	37.24
MOU x Rate	2	57.43	28.72	.1025
Species x Rate	1	1490	19.90	5.321 *
MOU x Species x Rate	2	1288	644.1	2.300NS
Error	44	12310	280.0	

** = Significant at the 1% level
* = Significant at the 5% level
NS = Nonsignificant at the 5% level

Appendix Table 19. Fresh shoot weights of 'Stephens' winter wheat and cereal rye when treated with ethiazin at various planting depths. Experiment 1.

Treatment		grams											
		Wheat						Rye					
Depth (cm)	Rate (kg/ha)	R1	R2	R3	R4	R5	AVG	R1	R2	R3	R4	R5	AVG
1.4	0.0	1.4	1.2	1.3	1.5	1.3	1.3	1.0	1.1	1.1	1.2	1.3	1.1
2.8	0.0	1.6	1.8	1.5	1.7	1.5	1.5	1.1	.13	1.2	1.3	1.6	1.4
5.6	0.0	1.8	1.5	1.6	1.3	1.6	1.6	1.0	1.2	1.3	1.4	1.4	1.3
8.6	0.0	1.5	1.5	.13	1.1	1.4	1.4	1.3	1.1	0.9	1.1	1.1	1.1
11.5	0.0	1.4	0.9	1.0	0.8	0.7	0.7	1.2	0.1	0.0	0.1	0.7	0.4
1.4	2.0	1.5	1.1	1.3	1.4	1.4	1.3	0.6	1.0	1.0	0.13	0.8	0.7
2.8	2.0	1.7	1.5	1.7	1.8	1.7	1.7	1.5	1.3	0.8	1.3	1.2	1.2
5.6	2.0	1.6	1.5	1.4	1.5	1.7	1.5	0.7	1.2	0.8	1.2	1.1	1.0
8.6	2.0	1.7	1.3	1.1	1.3	1.8	1.4	0.9	0.8	0.8	0.7	0.8	0.8
11.5	2.0	0.3	1.1	0.0	0.6	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0

Appendix Table 20. Analysis of variance of fresh shoot weights of Appendix Table 19.

Source	DF	SS	MS	F
Replication	4	0.31	0.08	1.43
Species	1	4.32	4.32	80.39
Rate	1	1.10	1.10	20.45
Depth	4	12.88	3.22	59.95**
Species x Rate	1	0.28	0.28	5.19*
Species x Depth	4	0.06	0.01	0.26NS
Rate x Depth	4	0.52	0.13	2.46NS
Species x Rate X Depth	4	0.26	0.06	1.18
Error	76	4.08	0.05	
Total	99			

** = Significant at the 1% level
 * = Significant at the 5% level
NS = Nonsignificant at the 5% level

Appendix Table 21. Fresh shoot weights of 'Stephens' winter wheat and cereal rye when treated with ethiazin at various planting depths. Experiment 2.

Treatment		grams											
		Wheat						Rye					
Depth (cm)	Rate (kg/ha)	R1	R2	R3	R4	R5	AVG	R1	R2	R3	R4	R5	AVG
1.4	2.5	2.6	2.4	2.1	2.3	2.4	2.4	3.3	2.1	2.9	2.6	2.6	2.7
2.8	2.5	2.2	2.3	2.1	2.0	2.1	2.1	3.0	1.9	3.8	2.5	2.9	2.8
5.6	2.5	2.4	2.8	3.1	1.0	2.6	2.6	2.9	1.7	2.6	2.8	3.7	2.8
8.6	2.5	2.1	2.1	2.4	2.8	2.4	2.4	2.4	2.2	4.7	2.7	2.1	2.8
1.4	2.5	1.8	1.7	1.9	2.1	1.9	1.9	1.0	1.0	0.2	0.2	0.5	0.6
2.8	2.5	1.8	1.7	2.0	2.1	2.1	2.1	1.7	1.1	0.3	0.7	0.8	0.9
5.6	2.5	2.7	2.2	2.4	0.0	2.3	2.3	1.4	0.0	1.2	0.0	1.5	0.8
8.6	2.5	2.3	2.3	2.7	2.5	1.5	1.5	0.8	0.0	2.3	0.04	0.0	0.6

Appendix Table 22. Analysis of variance of fresh shoot weights of Appendix Table 21.

Source	DF	SS	MS	F
Replication	4	4.3	1.08	3.25*
Species	1	3.83	3.83	11.55*
Rate	1	28.87	28.87	87.07*
Depth	3	0.28	0.09	0.28NS
Species x Rate	1	14.11	14.11	42.56**
Species x Depth	3	0.52	0.18	0.53NS
Rate x Depth	3	0.24	0.08	0.24NS
Species x Rate X Depth	3	0.44	0.15	0.44NS
Error	60	19.89	0.33	
Total	79	72.49		

** = Significant at the 1% level
 * = Significant at the 5% level
NS = Nonsignificant at the 5% level

Appendix Table 23. Fresh shoot weights of 'Stephens' winter wheat and cereal rye when grown in nutrient solution treated with various concentrations of ethiazin. (Experiment 1).

Rate	Wheat						Rye					
(mol/l)	R1	R2	R3	R4	R5	R6	R1	R2	R3	R4	R5	R6
0.0	0.46	0.67	0.71	0.65	0.61	0.65	0.67	0.56	0.89	0.78	0.76	1.00
0.5	0.56	0.53	0.64	0.73	0.69	0.46	0.73	0.48	0.69	0.53	0.57	0.46
1.0	0.58	0.63	0.67	0.59	0.63	0.47	0.67	0.56	0.55	0.46	0.26	0.54
2.5	0.52	0.63	0.47	0.61	0.48	0.47	0.65	0.41	0.52	0.49	0.26	0.35
5.0	0.58	0.50	0.53	0.54	0.52	0.62	0.17	0.31	0.44	0.02	0.07	0.03
10.0	0.58	0.48	0.67	0.28	0.26	0125	0.21	0.14	0.02	0.02	0.02	0.03
25.0	0.17	0.24	0.33	0.07	0.08	0.20	0.02	0.01	0106	0.01	0.01	0.01
50.0	0.13	0.05	0.02	0.10	0.01	0.02	0.01	0.01	0.03	0.01	0.02	0.02

Appendix Table 24. Fresh shoot weights of 'Stephens' winter wheat and cereal rye when grown in nutrient solution treated with various concentrations of ethiazin. (Experiment 2).

Rate	Wheat						Rye					
(mol/l)	R1	R2	R3	R4	R5	R6	R1	R2	R3	R4	R5	R6
0.0	0.44	0.45	0.36	0.46	0.47	0.50	0.35	0.37	0.41	0.40	0.48	
0.5	0.16	0.42	0.25	0.46	0.54	0.52	0.05	0.13	0.16	0.15	0.14	
1.0	0.38	0.34	0.13	0.34	0.30	0.25	0.01	0.05	0.03	0.03	0.04	
2.5	0.17	0.25	0.24	0.14	0.27	0.21	0.01	0.01	0.01	0.02	0.01	
5.0	0.13	0.12	0.19	0.04	0.18	0.17	0.01	0.01	0.01	0.01	0.01	
10.0	0.07	0.04	0.06	0.08	0.07	0.01	0.01	0.01	0.01	0.01	0.01	
25.0	0.09	0.06	0.01	0.01	0.09	0.03	0.01	0.01	0.01	0.01	0.01	
5.0	0.01	0.01	0.01	0.01	0.02	0.02	0.01	0.02	0.01	0.01	0.01	

Appendix Table 25. Fresh shoot weights of cultivated rye and two sources of weedy rye when grown in nutrient solution treated with various concentrations of ethiazin.

	R1	R2	R3	R4	R5	R6
Rate (mol/l)	Cultivated					
0.0	.28	.25	.39	.30	.31	.26
0.125	.28	.25	.17	.28	.27	.28
0.25	.05	.14	.24	.19	.20	.15
0.5	.08	.08	.08	.08	.12	.14
1.0	.07	.08	.02	.03	.13	.05
2.5	.04	.06	.01	.01	.04	.01
5.0	.01	.01	.01	.06	.05	.05
10.0	.02	.01	.01	.01	.01	.01
	Duff					
0.0	.29	.32	.34	.34	.27	.19
0.125	.28	.28	.22	.27	.22	.28
0.25	.21	.15	.16	.18	.20	.08
0.5	.07	.03	.26	.26	.08	.05
1.0	.12	.02	.12	.03	.07	.03
2.5	.01	.01	.01	.01	.11	.02
10.0	.01	.01	.01	.01	.02	.01
	Peterson					
0.0	.27	.26	.29	.28	.23	.27
0.125	.25	.31	.26	.28	.22	.22
0.25	.10	.16	.05	.09	.17	.24
0.5	.05	.19	.05	.12	.04	.08
1.0	.01	.03	.11	.10	.05	.05
2.5	.01	.06	.02	.01	.01	.03
5.0	.03	.06	.01	.01	.01	.06
10.0	.01	.02	.01	.02	.01	.04

Appendix Table 26. Fresh weight of 'Stephens' winter wheat and cereal rye when treated with ethiazin at different timings (Pendleton Experiment).

		Grams									
		Wheat					Rye				
Timing	Rate	R1	R2	R3	R4	AVG	R1	R2	R3	R4	AVG
Pre	0.0	3.77	4.92	4.51	3.06	4.06	2.62	2.36	2.80	2.50	2.57
	0.5	4.74	4.04	5.44	3.34	4.39	0.80	2.16	0.26	2.47	1.42
	1.0	5.46	4.72	6.28	5.32	5.49	0.00	0.15	0.19	0.27	0.15
	2.0	6.68	5.53	6.50	5.63	6.08	0.00	0.00	0.00	0.00	0.00
1-leaf	0.0	4.19	4.55	3.60	3.56	3.97	3.98	3.43	2.67	2.90	3.24
	0.5	5.55	6.03	5.44	5.04	5.51	1.12	0.47	0.48	1.36	0.86
	1.0	6.42	3.59	5.59	5.78	5.33	0.00	0.00	0.00	0.00	0.00
	2.0	5.61	5.41	5.46	6.18	5.66	0.00	0.00	0.00	0.00	0.00
2-leaf	0.0	4.86	3.81	3.43	4.03	4.03	2.51	3.11	3.89	2.48	2.99
	0.5	6.17	5.71	5.84	5.41	5.78	1.29	1.57	1.03	0.57	1.11
	1.0	5.98	3.74	4.86	5.75	5.08	0.05	0.00	0.23	0.00	0.07
	2.0	4.71	6.42	4.74	5.72	5.40	0.00	0.00	0.00	0.00	0.00
3-leaf	0.0	4.62	4.32	5.18	5.77	4.85	5.14	4.05	4.21	2.74	4.03
	0.5	7.82	7.46	5.70	6.26	6.86	1.17	1.02	1.31	0.93	1.10
	1.0	6.97	6.41	6.33	2.33	5.51	0.51	0.10	0.43	0.00	0.26
	2.0	5.27	6.26	6.75	6.70	6.12	0.00	0.00	0.00	0.00	0.00
4-leaf	0.0	4.04	3.68	4.53	4.43	4.17	3.27	3.72	3.88	3.51	3.59
	0.5	4.20	3.82	3.83	4.22	4.02	2.55	2.22	3.31	2.44	2.63
	1.0	4.65	5.67	6.05	4.77	5.26	2.24	1.36	1.57	1.06	1.56
	2.0	4.34	4.00	5.00	4.30	4.61	0.55	0.24	0.58	0.93	0.43

Appendix Table 27. Analysis of variance of % of check of fresh weights in Appendix Table 26.

Source	DF	SS	MS	F
Replication	3	1187	395.7	1.34
Species	1	303700	303700	1031
Rate	1	17.03	17.03	0.06
Species x Rate	1	1453	1453	4.93 *
Timing	4	1731	432.9	1.46
Species x Timing	4	4370	1093	3.71 **
Rate x Timing	4	1760	439.9	1.49
Species x Rate x Timing	4	243.6	58.65	0.19 NS
Residual	57	16790	294.6	

** = Significant at the 1% level
 * = Significant at the 5% level
NS = Nonsignificant at the 5% level

Appendix Table 28. Fresh weights of 'Stephens' winter wheat and cereal rye when treated with ethiazin at different timings (Corvallis Experiment).

		Grams									
		Wheat					Rye				
Timing	Rate (kg/ha)	R1	R2	R3	R4	AVG	R1	R2	R3	R4	AVG
Pre	1.12	13.0	9.6	10.1	11.3	11.0	2.9	2.0	3.7	0.6	2.3
	2.24	9.1	7.9	7.4	11.3	8.9	3.5	1.5	3.6	1.3	2.4
1-Leaf	1.12	9.8	11.2	11.1	11.3	10.8	1.8	0.0	4.7	0.0	1.6
	2.24	7.3	11.5	6.7	7.8	8.3	0.0	0.0	0.0	1.0	0.3
2-Leaf	1.12	17.5	13.3	17.5	17.0	16.3	1.1	2.7	1.6	4.5	2.4
	2.24	11.9	7.6	9.9	7.1	9.1	0.0	0.5	1.0	0.4	0.5
3-Leaf	1.12	14.5	8.9	10.3	19.6	13.3	10.9	15.4	10.0	8.7	11.3
	2.24	13.6	10.7	8.8	14.3	11.8	6.6	5.7	4.3	5.9	5.6
4-Leaf	1.2	15.0	11.4	11.9	7.8	11.5	10.5	14.5	5.4	14.3	11.1
	2.24	10.3	10.1	11.9	8.1	10.1	6.7	9.5	8.5	6.6	7.8
Untreated		13.1	19.1	12.8	11.8	14.2	18.9	16.1	18.7	13.5	16.8

Appendix Table 29. Analysis of variance of % of check of fresh weights in Appendix Table 28.

Source	DF	SS	MS	F
Replication	3	5716	1905	4.77 **
Species	1	59670	59670	149.40
Rate	1	7546	7546	18.19 **
Species x Rate	1	171.2	171.2	0.43
Timing	4	16800	4201	10.52
Species x Timing	4	10520	2631	6.58 **
Rate x Timing	4	1558	389.6	0.97
Species x Rate x Timing	4	2722	680.4	1.70
Residual	57	22770	399.4	

** = Significant at the 1% level

APPENDIX C

LIST OF PAPERS COVERING THE SECALE GENUS

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