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Title : Response of Wheat (Triticum Aestivum L.) Cultivars and Downy Brome (Bromus tectorum L.) to Metribuzin and Ethyl metribuzin.

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Downy brome (Bromus tectorum L.), a serious grass weed in eastern Oregon can be partially controlled in wheat by metribuzin [4-amino-6-tert-butyl-3-(methylthio)-as triazin -5(4H)-one]. However, cultivars of many crops have been reported to differ in their level of tolerance to metribuzin. This lack of tolerance has led to the investigation of other compounds, such as the ethylthio analog of metribuzin [4-amino-6-tert-butyl-3-(ethylthio)-as-triazin-5(4H)-one], for selective control of downy brome in wheat.

Greenhouse and growth chamber experiments on wheat, growing in soil or nutrient solution showed that:

1) GR50 values for Stephens, Hill 81, Yamhill, and Malcolm in soil were 0.41, 0.23, 0.25, and 0.44 kg/ha, respectively, for metribuzin and 1.89, 1.29, 1.37, and 1.97 kg/ha, respectively, for ethyl metribuzin;
2) GR50 values for these cultivars in nutrient solution were 3.26, 1.17, 1.32, and 3.87 uM, respectively, for metribuzin and 12.69, 7.20, 7.19, and 13.41 uM, respectively, for ethyl metribuzin;
3) Uptake of both herbicides by wheat was through the roots;

4) Cultivars did not show any differences in herbicide absorption from the nutrient solution. Therefore, differences in varietal tolerance may be are due to biochemical or physiological reasons, but are not due to differences in herbicide uptake.

Increased growth at lower concentrations of these herbicides was observed in all cultivars studied. Metribuzin was five times more active than ethyl metribuzin. Both of these herbicides can be applied as an early postemergence treatment at the 3 leaf stage of wheat for effective control of downy brome.

Yield components of the four cultivars were measured in response to metribuzin and ethyl metribuzin at two ecologically different sites. The susceptible cultivars (Hill 81 and Yamhill) showed greater injury in the lighter soils with high pH and lower organic matter content. Visual estimates of crop injury were generally higher than the actual reduction in final yield. Crop injury ratings up to 25% generally did not show a significant reduction in final grain yield. A positive correlation between protein content and concentration of these herbicides was noted.

A study on the joint action of these two herbicides in the field and greenhouse showed that the combination of the two, increased the control of downy brome at lower rates. Their combined action was studied by using Colby's method and isobole method of Tammes. The reaction was calculated as additive. Downy brome was 8, 5, 5, and 9 times more sensitive to metribuzin and 6, 4, 4, and 6, times more sensitive to ethyl metribuzin than were the cultivars Stephens, Hill 81, Yamhill, and Malcolm, respectively. The use of these two herbicides to control downy brome in the cultivars Hill 81 and Yamhill should be avoided unless careful attention is given to soil properties and environmental conditions.

Response of Wheat (Triticum aestivum L.) Cultivars and Downy Brome (Bromus tectorum L.) to Metribuzin and Ethyl Metribuzin.

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DEDICATIONS

I dedicate this humble effort, the fruit of my thoughts, and study, to my affectionate parents, and family members, who inspired me to the higher ideals of life.

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INTRODUCTION

Wheat (Triticum aestivum L.) is a principal food grain of the world population and is grown under a variety of climatic conditions in different parts of the world. It contributes more calories and more protein to the diet of the world's people than any other crop and is grown on 240 million hectares, an area larger than that of any other crop. World trade in wheat exceeds all other grains combined. Wheat production exceeded 537 million tons in 1986 (25).

In spite of many technological advances, the average yield of wheat is much lower than the potential yield of common wheat cultivars. Considerable effort has been directed at increasing wheat production by developing high yielding varieties and using improved agronomic practices. But a trend towards short statured varieties and improved production practices may encourage infestation by weeds, leading to crop losses exceeding 50% depending upon the situation (48).

In eastern Oregon, one of the main weeds associated with winter wheat is downy brome (Bromus tectorum L.). This troublesome weed can be partially controlled by moldboard plowing, but to reduce soil erosion, some farmers have been implementing systems of reduced-or no-tillage production. Generally, implementation of these systems has resulted in decreased crop yields. Poor weed control is often cited as a reason for lower yields under reduced tillage systems. Population of the winter annual grass weed, downy brome, has increased dramatically in response to a change from a conventional to a reduced- or no-tillage system.

One of the few herbicides which even partially controls downy brome in wheat is metribuzin [4-amino-6-tert-butyl-3-(methylthio)-as triazin-5(4H)-one]. But because of differential varietal tolerance and inadequate tolerance to metribuzin on certain soils, other compounds are under investigation for selective downy brome control in wheat. One such compound is the ethylthio analog of metribuzin, BAY SMY 1500, or, DPXR 7910; [4-amino-6-tert-butyl-3-(ethylthio)-as-triazin-5(4H)-one]. Preliminary research indicates that this herbicide is effective as an early postemergence treatment for downy brome in winter wheat.

Although these herbicides offer an effective and economical means of brome control, certain risks such as crop injury, are inherent in their use. Selectivity of herbicides is relative, depending on dosage and time of application. All herbicides are potentially phytotoxic if applied at high enough dosages. It is essential then to know the response to herbicides by cultivars of a specific crop such as wheat.

In recent years, new wheat cultivars, particularly the high-yielding semi-dwarf cultivars, have been introduced to wheat production areas in many countries. These cultivars display their high yielding potential when grown with a proper package of cultural practices. Two major components of management are fertilizers and weed control. In some cases herbicides are an appropriate weed control tool. Response of wheat cultivars to fertilizers has been documented, but their reaction to herbicides has not received as much attention. The occurrence of cultivars susceptible to a particular herbicide may stimulate further study of the biochemical and genetic interactions between plants and herbicides; whereas, tolerant cultivars could lead to improved weed control and increased crop production.

For this study, the response of selected wheat cultivars and an associated weed, downy brome, to metribuzin and the ethylthio analog of metribuzin was tested.

The objectives of this study were to:

1. Evaluate the response of wheat cultivars to metribuzin and ethyl metribuzin.
2. Compare the grain yield and yield components of cultivars in response to herbicides.
3. Develop a growth response curve and GR50 for different varieties.
4. Evaluate the response of downy brome to several rates of these chemicals.
5. Assess the joint action of metribuzin and ethyl metribuzin.
6. Compare the response of winter wheat, growing in soil and nutrient solution, to the herbicides under investigation.

LITERATURE REVIEW

Winter wheat production in Idaho, Oregon, and Washington is ranked among the highest in the United States on a per hectare basis. To obtain maximum productivity, farmers have been using production practices that often result in severe soil erosion. To limit erosion, reduced- or no-tillage practices are being implemented in the Pacific Northwest region of the United States. As no-tillage practices replace conventional tillage, weed populations increase substantially. Downy brome (Bromus tectorum L.), a winter annual grass, is estimated to infest 800,000 ha of small grains in Washington and about 450,000 ha in Oregon and Idaho (43). Downy brome infestations have increased dramatically under reduced- or no-tillage practices that leave seeds closer to the surface (43, 87). Downy brome has up to 100% emergence from depths of less than 5 cm and essentially no emergence from depths greater than 8 cm (23, 43, 47, 87). Conventional deep tillage has provided a measure of control by preventing emergence of most of the downy brome seedlings.

The life cycle of downy brome is similar to that of winter wheat. Downy brome is normally a winter annual which germinates in the fall, overwinters in the vegetative state, and reaches maturity by mid-June (23). Downy brome roots are fine, fibrous, and shallower, than winter wheat roots (104). The roots of downy brome occupy the upper soil space extensively but extend only 15 to 30 cm deep. The shallow root system of downy brome allows it to compete successfully with winter wheat for soil moisture and nutrients. Rydrych (87) reported that in eastern Oregon downy brome densities of 108 and 538 plants per square meter reduced winter wheat yields by 40 and 92%, respectively.

Without selective herbicides, control of downy brome in winter wheat has consisted of deep plowing, as mentioned earlier, or rotation to spring planted crops which allows the use of tillage or herbicides to reduce, or eliminate, the fall-emerged downy brome plants (87). Another system for control is the seeding of winter wheat as late as possible in the fall. This system is not widely accepted since late seeded winter wheat normally yields less than early seeded winter wheat. Biological control of downy brome with insects or pathogens has not been successful.

Herbicides appear to be essential for control of downy brome if reduced tillage systems are to be implemented. Numerous studies have been conducted to examine various herbicides for their efficacy in controlling this weed in winter wheat.

Metribuzin [4-amino-6-tert-butyl-3-(methylthio)-as-triazin-5(4H)-one] is one of the few herbicides that gives partial control of downy brome in winter wheat (3). It also has been used extensively, in combination with other herbicides, during the fallow season in no-till situations (8, 13, 20, 49, 58,59, 62, 64, 86, 105, 110). Metribuzin is an excellent herbicide with a broad spectrum of activity on broadleaf weeds and some grasses. It can be applied preemergence, postemergence, or pre-plant incorporated when mixed with other herbicides. It is used on major crops, such as soybeans, potatoes, tomatoes, cereals, established alfalfa, warm-season grasses, and range and pasture grasses (40). Metribuzin is also often used in no-till wheat, soybeans, corn, and wheat fallow systems (8, 13, 20, 50, 53, 58, 59, 62, 64, 78, 86, 97, 98, 105, 110).

Recently, metribuzin was registered for use on wheat for brome control (69). It is recommended for postemergence use only on cereal crops, but is often used for control of annual weeds in the fallow year in wheat-fallow systems. On fallow land it is sometimes combined with long-residual herbicides such as atrazine (2-chloro-4-ethylamino-6-isopropylamino-s-triazin) or terbutryn [2-(tert-butylamino)-4-(ethylamino)-6-(methylthio)-s-triazin-2-yl amino-2-methylpropionitrile] for control of weeds such as kochia (kochia acoparia L Schard.), tumbling mustered (Sisymbrium altissimum L.), redroot pigweed (Amaranthus retroflexus L.), wild sunflower (Helianthus annuus L.), wild oat (Avena fatua L.), bromes (Bromus sp.), and volunteer wheat (Triticum aestivum L.).

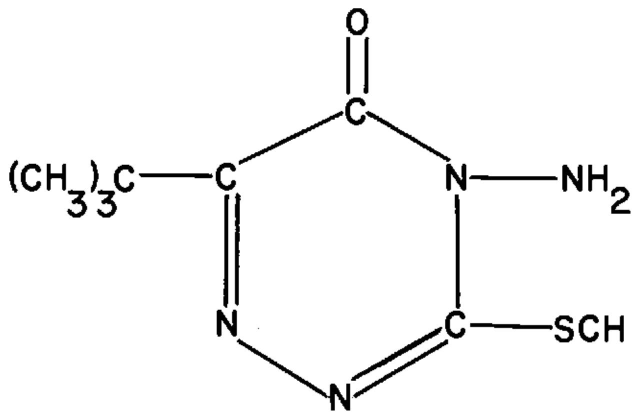
Because of differential varietal tolerance and inadequate tolerance of metribuzin on certain soils, other compounds, such as the ethylthio analog of metribuzin (BAY SMY 1500, or, DPXR 7910) [4-amino-6-tert-butyl-3-(ethylthio)-as-triazin-5(4H)-one] are under investigation for selective control of downy brome in winter wheat.

General Properties of Metribuzin

Metribuzin is a member of the substituted as-triazine family of herbicides that are potent inhibitors of photosynthesis (40). In the United States it is sold as Lexone, by Du Pont, and Sencor, by Mobay. It is formulated as a 75% active ingredient dry flowable and a 4 lb per gallon flowable liquid (40). It is being used as a preemergence and postemergence herbicide for the control of many broadleaf and grass weeds in several crops.

Chemical names for metribuzin are [4-amino-6-tert-butyl-3-(methyl thio)-as-triazin-5(4H)-one] or [4-amino-6-(1,1-dimethylethyl)-3-(methylthio)-1,2,4-triazin-5(4H)-one].

Its structural formula is:



Its empirical formula is: $C_8H_{14}N_4OS$.

It is a white crystalline solid, has a mild odor, and vapor pressure of less than $1*10^{-5}$ mm Hg at 20C. Its solubility at 20C is 45 g/100g in methanol and 1220 ppm in water. The molecular site of action of metribuzin is believed to be identical to that of s-triazines, and has been established to be between the primary and secondary electron acceptor of photosystem II (Q and plastoquinone) (103). The LD50 for male and female rats is 1090 and 1206 mg/kg, respectively.

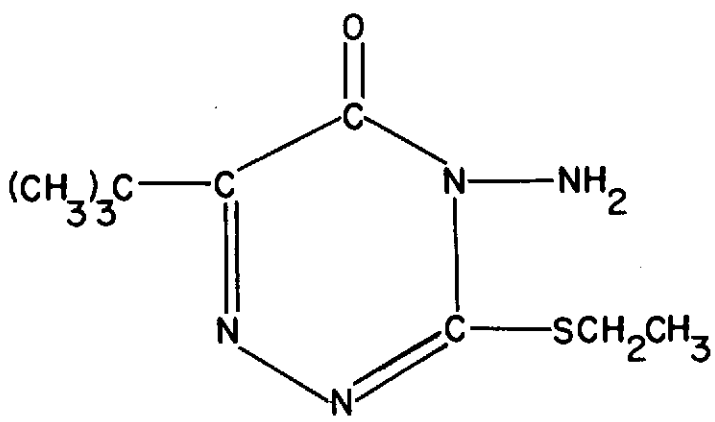
General Properties of Ethyl Metribuzin

BAY SMY 1500 herbicide is the ethylthio analog of metribuzin and is a non symetrical triazine similar to metribuzin. It was discovered by the parent company of Farbenfabriken Bayer GmbH, Lever Kusen, West Germany. In laboratory, greenhouse, and field tests in the U.S, Canada, and Europe the herbicide has shown promise for selective control of Bromus spp; blackgrass

(<u>Alopecurus</u> spp.); <u>Avena</u> spp; and a wide range of other grass and broadleaf weeds in cereal grains.

Its chemical name is: [4-amino-6-tert-butyl-3-(ethylthio)-as-triazin-5(4H)-one]. or [4-amino-6-(1,1-dimethylethyl)-3-(ethylthio)-1,2,4-triazin-5(4H)-one].

Its structural formula is:



Its empirical formula is: $C_9H_{16}N_4OS$.

The acute oral LD50 of the technical material to male and female rats is 2470 and 1280 mg/kg respectively. Its melting point is 95C, and solubility at 20C in water and hexane is 420 and 2500 mg/L, respectively. It also has an initial half life of biological activity that is half that of metribuzin and has less unit activity.

Ethyl metribuzin is a photosynthetic inhibitor with predominant uptake via plant roots. Adequate moisture (rainfall, snow, or irrigation) is required to activate the herbicide following soil or foliar applications.

It is being developed by Du Pont and Mobay in the United States (102).

Metribuzin Behavior in Plants

The major route for uptake of metribuzin is through the roots via osmotic diffusion, but foliar absorption can also occur. Metribuzin absorbed by the roots is translocated upward in the xylem and moves distantly when applied to the base of the leaves. Downward movement in the plant has not been reported (40). It can be considered a systemic herbicide in terms of upward movement. The concentration of metribuzin in treated plants is highest in roots, stems, and leaves and is lowest in fruits and seeds (40).

Its mechanism of action is the inhibition of photosynthesis (5, 40). Pillai et. al. (75) found that it also reduces RNA, DNA, and protein synthesis in the hypocotyl section of soybeans. De Villiers and Van Der Merwe (17) concluded that metribuzin indirectly affects synthesis of RNA, protein, and lipids through its affect on photosynthesis which provides most of the ATP for the synthesis processes. Many of the toxicity symptoms caused by metribuzin are similar to those induced by the s-triazine herbicides. Phatak (73) observed that the most obvious symptoms of metribuzin were localized sunken areas in the leaves which turned chlorotic-necrotic with time. Symptoms were first evident 72 hours after spraying. Injury reached its maximum within 7 to 10 days after treatment. The major routes of detoxification are hydroxylation, oxidation, and conversion to water soluble conjugated products (5, 40). Mangeot et. al. (56) found that tolerance of soybean varieties to metribuzin is due to their ability to rapidly detoxify the herbicide to unidentified metabolites. Tolerance of tomatoes to the herbicide also was found to be due to internal plant metabolism (26).

Factors Influencing Metribuzin Selectivity and Activity

Many factors have been reported to influence the effectiveness, selectivity, and fate of herbicides. Metribuzin was reported to be influenced by factors such as soil type, moisture and rainfall, crop cultivars, cultural practices, interactions with other herbicides, time and method of application, light, and temperature.

Soil Type and Organic Matter.

Soil texture influences the availability of soil-applied herbicides. Mobility of metribuzin was higher in sandy and clay soils than in muck soils (94). In light soils metribuzin moved 6 to 12 cm from the origin, whereas in muck soils it did not move beyond 4 cm from the origin. It was also found that metribuzin persists more in muck soils and leaching was negligible.

Movement in runoff water does not contribute much to the loss of metribuzin but leaching loss can be significant, especially in light textured soils low in organic matter content (67). In laboratory tests, 3.6 inches of water were required to leach metribuzin 1 inch in clay loam. With sandy loam, only 2.2 inches of water moved it 1 inch (40). Coble and Schrader (14) reported that soil organic matter, herbicide rate, and rainfall or irrigation after treatment greatly influenced tolerance of soybean to metribuzin. They also found that, regardless of the rainfall regime, injury was more severe as herbicide rate increased and less severe as organic matter level increased. Savage (89) found that adsorption of metribuzin increases with increasing levels of organic matter in the absence of clay. He also found that its adsorption increases with increasing levels of clay. But metribuzin adsorption decreases significantly when high levels of clay are combined with high levels of organic matter. The addition of clay colloids appears to decrease the adsorptive capacity of the organic fraction. He concluded that the interaction between the two adsorptive compounds resulted from competition between clay and organic matter for sites available for herbicide adsorption. This competition caused a decrease in sites available for herbicide adsorption when clay and organic matter were combined. Weber et. al. (109) found that organic matter affects the performance of metribuzin. Its performance on weeds decreased with increasing organic matter in the soil. But highly water-soluble chemicals are less affected by organic matter than are low water-soluble chemicals.

Findings of Sharon and Stephenson (94) about the behavior and fate of metribuzin in different soils supported previous findings. They reported that metribuzin mobility was inversely correlated with the amount of soil organic matter, and that adsoption of metribuzin was correlated with organic matter and not clay content. They also reported that the addition of $CaCl_2$ increased the adsorption of metribuzin to all soils. Metribuzin was relatively mobile in mineral soils but was immobile in the muck soils. Bioassay studies also indicated that phytotoxicity of metribuzin decreased with increasing organic matter content of the soil. Persistence of herbicidal activity in the field was shown to be dependent on leaching, as well as on microbial degradation.

Murphy et. al. (67) analyzed metribuzin-treated soil from the United States and Canada after the 1973 growing season. Only 7% showed bioassay-detectable residues. High organic matter content and early sampling appeared to be the major factors of bioassay detectable residues.

Microbial Activity.

Metribuzin is degraded by soil microorganisms. The degradation is more rapid on non-autoclaved soils, and soils enriched with glucose than in soils that have been autoclaved or dry for one year (90).

Any soil conditions favoring growth of soil microorganisms will increase the rate of metribuzin breakdown. Breakdown occurs fastest under aerobic conditions in the presence of sunlight (40).

Waggoner, et. al. (106) studied metribuzin degradation in mineral and muck soils under laboratory and field conditions. They reported that degradation metabolites are:

a. DA 6(1,1-dimethylethyl)-3-(methylthio)1,2,4-triazin-5-(4H)-one.

b. DK 4-amino-6(1,1-dimethylethyl)-1,2,4-triazin-3,5(2H,4H)-dione and

c. DADK 6-(1,1-dimethylethyl)-1,2,4-triazin-3,5-(2H,4H)-dione.

Rate of degradation was increased by soil microorganisms, air, and light. The biological activity of metribuzin, and its DA, DK and DADK metabolites, was compared for cucumbers, corn, and cotton under greenhouse conditions. Metabolites were considerably less active than the parent compound, and can be considered biologically insignificant under field conditions.

Soil pH.

Moomaw et. al. (60) found that injury to soybean from metribuzin was greater in soil with pH 7.8 than in soil with pH 6.6. Ladlie et.al. (51) reported that metribuzin degradation by soil microorganisms decreased as the soil pH decreased, but metribuzin mobility increased with increasing concentration and soil pH.

In a separate study, the above authors (52) found that soil pH affected metribuzin availability for plant absorption. Metribuzin applied preemergence resulted in increased phytotoxicity to corn and soybeans, and better control of fall panicum (Panicum dichotomiflorum Michx.) in soils with higher pH.

Increased metribuzin toxicity to soybeans and grass weeds with increasing soil pH was confirmed by Moomaw and Martin (60). They also reported that metribuzin degradation by microorganisms decreased as pH decreased. In low soil pH, metribuzin is bound more tightly and thus becomes less available to soil microorganisms. In high soil pH, metribuzin becomes more available, and leaching increases.

In a study by Ladlie et. al. (51), metribuzin was applied at different rates to sandy clay loam adjusted to various pH levels. Metribuzin at all rates reduced weed and corn population as pH increased. Soybean grown in the greenhouse at the same pH levels gave a similar response.

Rainfall and Soil Moisture.

Moisture in the form of rainfall has been reported to affect metribuzin injury to crops. Under low rainfall conditions, metribuzin had no effect on soybean yield, but metribuzin applied preplant and incorporated under high rainfall caused considerable injury. The observations were made that excessive rainfall following application of metribuzin can cause crop injury by leaching the herbicide into the root zone (37). Excessive rainfall also can result in a failure of the herbicide to control weeds by leaching the herbicide too deep into the soil. These results were supported by Hardcastle (38) and Wax (108). In their independent studies they found that injury to soybean from metribuzin was moderate, even at higher rates, and the injury obtained was mostly associated with rainfall. Under high rainfall, injury to soybeans was less than under low rainfall, and control of deep rooted weeds was better. In another experiment it was concluded that metribuzin applied preemergence in light soils could be less effective on weeds under heavy rainfall conditions. Presumably, the herbicide would leach too deeply (94).

Injury to wheat was also observed. Wheat was almost completely killed when metribuzin was applied postemergence and sprinkler-irrigated, whereas under dryland conditions, using the same rates (4 to 8 oz/A), the herbicide did not cause injury to wheat (63).

Temperature effect on Metribuzin

Temperature was found to affect the fate of metribuzin and its activity on plants. Phatak and Stephenson (73) found that for each increase in temperature from 21C days and 13C nights, to 25C days and 18C nights, to 27C days and 18C nights resulted in increased injury to tomatoes by metribuzin. They suggested that plants low in photosynthate may be highly susceptible to the herbicide because it acts as a photosynthetic inhibitor and would thus limit carbohydrate production.

Fortino (26) reported higher susceptibility to metribuzin by tomatoes less than 10 cm tall growing under high temperature. Moomaw and Martin (61) found that metribuzin injury to soybeans was greater when high rainfall and cooler temperatures occurred following application.

Temperature also has an effect on the degradation of metribuzin in the soil. More rapid degradation was obtained under 30C than under 20C (90). Surface application of metribuzin followed by high temperature and intense light, resulted in the dissipation of the herbicide by volatilization and photodecomposition (91), thus low effectiveness could result.

Light effect on Metribuzin.

The loss of metribuzin from the soil surface was found to be due to photodecomposition and / or volatilization. Savage (91) found that 10 to 12% of metribuzin loss from the soil surface is due to volatility. He also concluded that 30 to 50% of soil surface-applied metribuzin could be lost within 1 to 2 days and that metribuzin exposed to intense sunlight and warm temperature had half-life values of 4 to 5 days.

Pritchard and Warren (76) reported that tomato tolerance to metribuzin was reduced when shading was applied for one day before treatment. The same response was obtained with jimsonweed (Datura stramonium L.) and velvetleaf (Abutilon theophrasti Medik). Three days of shading gave further reduction in tolerance of the three species. Two or 3 days of sunshine were required after 3 days of shading to return tomato to its full tolerance to the postemergence-applied herbicide. Shading was applied before the application of the herbicide. They also found that the rate of metribuzin can be reduced 25% after one day of shading and 45% after 3 days of shading and still control jimsonweed and velvetleaf. In another study they found that a number of days of sunshine equal to the number of days of shading were required to restore the plants to their full tolerance to the herbicide. (77).

Stephenson et. al. (99) reported that low light and cloudy weather increased the susceptibility of tomatoes to metribuzin. They suggested that the tolerance of tomatoes is dependent upon the rate of detoxification by conjugation which can vary, depending on seedling age, cultivar used and the environmental conditions, particularly light, before and after the treatment.

Phatak (73) concluded that plants shaded before and after treatment showed maximum foliar injury. Shading only after treatment caused slightly less injury than shading before treatment. In general, yield decreased as foliage injury increased. From a practical standpoint, Phatak's study indicates that metribuzin injury to potatoes from postemergence applications may be minimized if applications are made during sunny weather.

Rate and Time of Application of Metribuzin

Time of application of metribuzin must be related to growth stage of weeds and crop stage (78). Da Silva and Warren (16) reported that tomatoes became more tolerant to metribuzin as they aged, probably because they had accumulated enough food and were able to detoxify the herbicides.

Early postemergence application of metribuzin to potatoes resulted in taller plants, higher yield, and better weed control than late postemergence applications which resulted in shorter plants, delayed senescence, and lower yield (9).

Eldredge and Lee (20) found that time of application of metribuzin and wheat yield were correlated. Early application, before the crown roots were developed, significantly reduced wheat yield. The yield reduction from early treatment ranged from 60 to 90%, whereas the reduction was only 5 to 25% when metribuzin was applied after the crown roots and the leaf area were well developed.

The most effective stage for application of metribuzin for brome control was when the brome had one to three leaves, and maximum wheat tolerance was found to be when the plant was in full tillering stage with prominent secondary root development (78). The optimum time of application on barley was found to be when the plant was fully tillered and the secondary roots were starting to form (105).

Metribuzin application to alfalfa during active growth is not recommended. Treatment should only be made when alfalfa is dormant (93). On tomato, application to plants less than 10 cm tall could result in severe injury (26). Uniform application, timing, proper rate, stage of growth of crops and weeds, and method of application are all factors influencing metribuzin selectivity and effectiveness.

Metribuzin at a rate of 0.41 kg/ha also reduced wheat yields by 20%. All herbicide applications were made when the winter wheat was in the two to four leaf stage and the downy brome in the three to four leaf stage. A Montana study revealed that metribuzin applications of 0.38, 0.50, and 0.75 kg/ha reduced yield of winter wheat from 60 to 90% in early applications when crown roots were undeveloped (79). Yield reductions of 5 to 25% resulted from late season application of metribuzin.

In an Idaho study in 1983, metribuzin provided 49 to 85% control of downy brome in winter wheat without causing adverse effects to the winter wheat (65). In Oregon metribuzin was the most effective postemergence herbicide tested (88), and in most of the cases metribuzin provided 90% control of downy brome with only slight damage to the winter wheat.

In 1981 at Washington State University, application of metribuzin at rates of 0.5 or 1.0 kg/ha provided downy brome control of 80 to 90% while reducing winter wheat populations 0 to 40%, respectively (33).

Schroeder et.al. (92) conducted greenhouse and field experiments at two locations in Georgia to evaluate the tolerance of several winter wheat cultivars to postemergence applications of metribuzin. The sensitivity to all varieties in the greenhouse was much higher compared to the field. In nutrient solution, differential response of varieties was observed at 0.15 ug/ml concentration of metribuzin. Significant plant injury and yield reductions of wheat cultivars was observed when plants were treated with 0.6 and 1.1 kg/ha of metribuzin in the field. Increased injury was accompanied by higher rainfall and low temperatures subsequent to application.

In Washington state in 1984, metribuzin applied at 0.38 and 0.50 kg/ha reduced winter wheat stands 60 and 70%, respectively, while reducing downy brome infestations by 30 and 50%. The metribuzin was applied to the winter wheat at the one to two leaf stage while downy brome was at the one leaf stage.

These studies suggest that metribuzin is promising for control of downy brome in reduced- or no-tillage winter wheat. However, downy brome control is inconsistent and to have satisfactory control metribuzin must be applied at early growth stages.

Hagood et. al. (37) studied soybean response to metribuzin under weed free conditions. They found that reduced crop vigour at early growth stages was not an adequate indicator of yield response. The data indicated that vigour reduction of less than 30% at early growth stages was tolerated by the crop. Yield was reduced when foliar chlorosis and necrosis persisted.

Differential Crop Tolerance to Metribuzin.

Many researchers reported that crop tolerance to metribuzin is not only due to environmental factors and cultural practices, but to differences between species and cultivars within a species.

Barrentine et. al. (7) reported that differential herbicide detoxification by conjugation may account for the differences in metribuzin injury between sensitive soybean cultivars and tolerant ones. Fedtke (22) also found that tolerant soybean cultivars have a better capacity to detoxify metribuzin in their leaves.

Eastin et. al. (19) concluded that sensitivity of soybeans to metribuzin is dependent on several environmental factors but the response of this crop to metribuzin is also influenced by genotype. They suggested that care be used when choosing a genotype which is to have metribuzin applied for weed control.

Graft and Ogg (35) found that potato cultivars differed significantly in their response to foliar-applied metribuzin and suggested that before metribuzin is used for postemergence weed control in potatoes, the tolerance of the cultivars should be considered.

Stephenson et. al. (99) reported that the tolerance of tomatoes to metribuzin is dependent on the rate of detoxification by conjugation which can vary depending on the seedling age, the cultivar involved, and possibly the environmental conditions.

Callihan et. al. (10), using soil and foliar application on wheat, barley, and oats, found that oats were the most susceptible to metribuzin, and had the smallest range of response among cultivars. Wheat was less susceptible but had the widest range of response among cultivars. Barley was the least susceptible and had a wider range than oats but less than wheat.

Warren and Parish (107), using metribuzin for weed control in wheat and barley, found that barley was more tolerant to metribuzin than wheat. They also found that barley can withstand postemergence applications 14 to 21 days apart and recommended that this practice could be used for better control of wild oats and ryegrass.

A study by Robinson et. al. (82) found crabgrass (Digitaria sanguinalis L. Scop.) to be more tolerant than witchgrass (Panicum capillare L.) to atrazine. Both species absorbed similar amounts of atrazine [2-chloro-4(ethylamino)-6-(isopropylamino)-s-triazin]. The greater sensitivity of witchgrass to atrazine was attributed to increased translocation of atrazine to the shoots and less metabolism of the atrazine to polar metabolites. Other studies have found similar results in that a similar amount of atrazine was absorbed by both sensitive and tolerant species and that the greater the amount of atrazine metabolized the greater the tolerance of that species.

Studies on absorption, translocation, and metabolism of metribuzin by soybean (Glycine max Merr.) and hemp sesbania (Sesbania exaltata L.) were conducted by Hargroder and Rogers (39). They concluded that there were no significant differences in the amount of ^{14}C-metribuzin absorbed from treated nutrient solution by soybean (tolerant) and hemp sesbania (susceptible). When these species were grown in ^{14}C metribuzin treated soil, hemp sesbania's absorbed more herbicide than did soybean. Further study indicated that, this resulted from hemp sesbania shallower root system allowing more uptake of metribuzin. Hemp sesbania appeared to translocate a greater amount of root-absorbed metribuzin from roots to shoots than did soybean. Metabolism studies indicated that more metribuzin degradation occurred in soybean than in hemp sesbania. The major ^{14}C-metribuzin metabolite identified appeared to be the relatively non-phytotoxic deaminated diketo metribuzin [6-(1,1-dimethylethyl)-1,2,4-triazine-3,5(4H)-dione] (DADK) derivative. Unidentified polar metabolites also made up a significant proportion of metabolites present. Metabolites have been identified in the metribuzin pathway and include: a deaminated metribuzin metabolite [6-(1,1-dimethylethyl)-3-methylthio-1,2,4-triazine-5(4H)-one] (DA), DADK, and a diketo metribuzin metabolite [4-amino-6-(1,1-dimethylethyl)-1,2,4-triazine-3,5 92H,4H)-dione] (DK) (54w). These metabolites are termed primary metabolites and are present in varying amounts in metribuzin treated plants. All three metabolites are less phytotoxic to plants than is metribuzin (4). Various polar metabolites have also been identified.

Studies examining differences in metabolism of metribuzin by two soybean cultivars found the tolerant cultivar to be more tolerant to metribuzin than the sensitive cultivar because of its ability to more rapidly detoxify metribuzin to DA, to seven unidentified polar metabolites which remained in the aqueous fraction, and to an insoluble fraction (56).

Studies examining differential tolerance of tomato cultivars to metribuzin found that susceptible and tolerant tomato cultivars similarly root-absorbed and acropetally translocated metribuzin (27). Differential tolerance was related to the rate of detoxification of metribuzin within the tomato leaves, which was approximately two-fold greater in the tolerant cultivar seedling.

No studies have been reported that thoroughly examined the absorption, translocation and metabolism of metribuzin in winter wheat or downy brome. A study in Oklahoma in 1982 indicated that both tolerant and susceptible winter wheat cultivars absorbed similar amounts of metribuzin (24). No differences in photosynthesis or respiration between tolerant or susceptible cultivars was detected in isolated leaf discs. This indicated that differences in metabolism might be present but no studies were conducted to substantiate this. Parrish found cultivar differences in tolerance to metribuzin among various soft white winter wheat cultivars (71).

Soybean cultivars have been reported to range in tolerance to metribuzin from tolerant to susceptible (6, 55). Smith and Wilkinson (96) indicated that the less susceptible variety metabolized more metribuzin in the root and stem tissue than the two more susceptible varieties.

Devlin et. al. (18) determined foliar and root absorption and translocation of metribuzin by downy brome and winter wheat. After a 48-h absorption period, roots of 3 week old downy brome plants had absorbed two times more metribuzin on a total plant fresh weight basis than had roots of winter wheat. The greater tolerance of winter wheat to metribuzin is due, in part, to less root absorption of metribuzin by winter wheat than by downy brome. Roots and foliar absorption and traslocation of ^{14}C metribuzin were determined by Gawronski et.al.(30) in tolerant and susceptible barley cultivars grown in nutrient solution culture under greenhouse conditions. A 50% reduction in growth occured at 0.22 and 0.72 uM metribuzin for susceptible and tolerant varieties respectively. Root absorption of metribuzin by tolerant varieties was about two times more than susceptible varieties, 4 and 8 days after application. Root uptake was positively correlated with water uptake. Root absorption of ^{14}C -5(ring)-metribuzin from hydroponic culture and its subsequent translocation in tolerant and susceptible cultivars were measured by Gawronski et. al. (30). They found that differences in root absorption did not appear to be as important to differential tolerance as did translocation differences. Total absorbed metribuzin was 6 and 7%, 18 and 29%, and 31 and 45% after 1, 4, and 8 days, for tolerant and susceptible varieties respectively. Radioactivity was concentrated in stems, petioles, and leaf veins in the tolerant cultivars, whereas interveinal leaf tissue was the major accumulation site for ^{14}C in the susceptible cultivars. Metribuzin tolerance by tolerant variety is due in part to restricted translocation to the leaf blades.

Runyan and Peeper (84) evaluated the susceptibility of several winter wheat varieties to metribuzin. At the locations where soil had less than 20%

clay content 3/8, 1/2, and 3/4 lb/A rates were used and 1/2, 3/4 and 1.0 lb/A rates were used at the locations where soils had from 20% to over 40% clay content. All treatments were applied at tillering stage. Yield data and visual ratings indicated that some varieties exhibited considerable tolerance to metribuzin, while others were highly susceptible at rates adequate for downy brome control. Runyan et. al. (85) also conducted green house and field experiments to evaluate the differential response of wheat cultivars. They used metribuzin ranging from 0.4 to 1.1 kg/ha as postemergence applications. They observed differences in plant injury among wheat cultivars and a remarkable reduction in yield in different varieties. However, reduction in yield varied in different soil types and under different rainfall situations. Some varieties treated with 0.6 kg/ha of metribuzin showed up to 40% yield reduction as compared to check plots. Higher rates were lethal to all varieties. Greer et. al. (36) found that metribuzin was effective in downy brome control, but not all wheat varieties were tolerant. Control of downy brome varied from 70 to 95% depending on the weather conditions of the season. Injury from metribuzin varied greatly with different varieties of wheat. The average crop injury over several soil types was approximately 10% to the tolerant variety at the medium rate of 3/4 lb ai/A compared with an average of 50% for susceptible varieties.

<u>Interaction of Metribuzin with other Chemicals</u>

Application of chemical mixtures such as herbicides with adjuvants, fertilizers, insecticides or other herbicides are used routinely as part of modern crop management practices. Combined application of selected agrochemicals offers several advantages over the use of a single chemical, including the following:

a. reduced crop production cost, by saving time and labor;
b. increased spectrum of pests controlled or pest control over a longer period;
c. improved crop safety by using minimum doses of selected agrochemicals applied in combinations rather than a high dose of a single chemical;
d. improved pest control under variable weather or soil conditions;
e. reduced crop or soil residues of persistent agrochemicals by using minimum doses of such chemicals; and
f. delayed appearance of weed species resistant to selected herbicides.

However, to ensure the effectiveness and safety of combined application of agrochemicals the potential for adverse chemical interactions must be evaluated. Identification of agrochemicals that interact, can be helpful in preventing problems in crop production. Some terms commonly used to describe the action of combined chemicals are defined as follows;

<u>Interaction</u>: Collective or joint action of chemicals on plant tissues, even when some of these actions do not imply any interactions of the substances involved. In this case considerable modifications in the biological activity of one agrochemical brought about by the prior, simultaneous, or sequential application of another to the same target species and the responses of target species to combined applications of two or more agrochemicals are no longer predictable from the performance of each chemical applied alone.

<u>Synergism</u>: Action of two components of a mixture such that the total effect is greater or more prolonged than the sum of the effects of the two taken

independently.

Addition: Cooperative action, such that the total effect is equal to the sum of the effects of the components taken independently.

Independent Effect: The total effect is equal to the affect of the most active component alone.

Antagonism: The total effect is smaller than the effect of the most active component alone.

Herbicide mixtures are used to broaden the weed control spectrum but when herbicides are mixed with each other, compatibility tests are necessary to determine the physical stability of the mixtures and their selectivity (57).

Metribuzin is often mixed with other herbicides for weed control in many crops. Previous findings reported that metribuzin phytotoxicity and effectiveness can be influenced by other herbicides. Atrazine residues in soil were found to increase metribuzin phytotoxicity to soybeans (33).

Ladlie et.al. (52) found that the addition of trifluralin to metribuzin increased soybean tolerance to metribuzin. Moomaw and Martin (61) confirmed the findings of Ladlie. Ladlie et. al. (52) suggested that trifluralin inhibited root growth of soybeans which resulted in reduced absorption and translocation of metribuzin. The same effect was obtained when using atrazine instead of metribuzin.

Under a no-till system, metribuzin was often tank-mixed with glyphosate, paraquat, alachlor, or chlorsulfuron, for weed control in soybeans, corn and wheat. Its preemergence application with these herbicides often resulted in better weed control. Postemergence applications were also used in combination with bromoxynil (20, 64).

Carter (11) found that combinations of metribuzin with alachlor and trifluralin gave good weed control in soybeans. Metribuzin (0.25 to 0.75 lb/A) and alachlor (1.5 to 2.5 lb/A) applied preemergence to the soil as a tank-mix provided control of 46 weed species i.e. 12 more than alachlor alone and 7 more than metribuzin alone. In addition, crop tolerance was increased because of the reduced application rate of metribuzin.

Jones et.al. (45) studied combinations of trifluralin and metribuzin and found that weed control in soybeans was good to excellent at the rates of 0.5+0.25, 0.75+0.38, and 1.0+0.5 lb/A on light, medium, and heavy soils, respectively. Minor soybean injury was observed at the seedling stage.

Addink et.al. (1) reported that trifluralin and metribuzin combinations did not affect emergence when applied preplant and soil incorporated. That application resulted in increased soybean yield compared to cultivated controls.

Gail et.al. (111) sprayed 25 winter wheat cultivars with metribuzin and its combinations with pendimethalin, 2,4-D, metolachlor, and chlorsulfuron. Differential response of cultivars and a significant reduction in yield was observed as compared to check plots; especially where metribuzin was used alone or in combination with other herbicides. Rainfall within 20 days of metribuzin application lead to significant injury to wheat. Combinations of these chemicals effectively controlled most of the weeds in the area. Trifluralin alone or with metribuzin was evaluated on tomatoes by Hillyer et.al. (41) for weed control, crop tolerance, influence on fruit grade, and yield. Tank-mix or separate applications of trifluralin plus metribuzin gave excellent control of all annual grasses. This control persisted the entire season. Combining trifluralin and metribuzin injured the tomato plants, but less than trifluralin alone. Pagano and Fortino (70) tested metribuzin alone and combined with alachlor or metolachlor applied preemergence to chippewa potatoes for control of specific weeds. The tank-mix of metribuzin plus either grass herbicide offered a better approach to weed control in potatoes.

Ghadiri et. al. (31) tested many herbicides including metribuzin alone and combined with several other herbicides to control annual grass and broadleaf weeds in winter wheat. They observed wheat plant injury and yield reduction at certain levels of these herbicide. None of the treatments affected protein content and volume weight of winter wheat. Treatments that reduced annual grass and broadleaf population by 90% or more were metribuzin + metolachlor @ 0.3+3.0 kg/ha, metribuzin + oryzalin @ 0.3+1.4 kg/ha. and metribuzin + pendimethalin @ 0.3+2.0 kg/ha.

Ethyl Metribuzin:

Shaw et.al. (95) studied the persistence of biologically active metribuzin and its ethylthio analog. They found that degradation of metribuzin at concentrations of 0 to 1 ppm (w/w) a.i. was linear over time with a half life of 8 days at 35C. Initial degradation of the biologically active ethylthio analog was much more rapid than for metribuzin. The initial degradation rate for the ethylthio analog indicated a half life of 4 days at 35C. Soil pH within the range 4.9 to 6.9 had no significant influence on the activity or persistence of either herbicide.

Ratliff and Peeper (80) evaluated BAY SMY 1500 for downy brome control in winter wheat. They applied SMY 1500 in November to 17 winter wheat varieties at 1.5 lb/A. Metribuzin at 0.75 lb/A was also included. At these rates, SMY 1500 was much less toxic to all varieties than was metribuzin. However, varieties differed significantly in their tolerance to these herbicides.

General information about Winter Wheat Cultivars under investigation:

Stephens:

Stephens is a soft white winter wheat developed and released by the Oregon State University Agriculture Experiment Station in 1977. Stephens was developed from a 1965 cross between Nord Desprez and Pullman selection 101. It is adapted to the winter wheat growing areas of the Pacific Northwest and has a superior yield potential under high rainfall or irrigated conditions. Stephens is semi-dwarf statured and has a strong stem. It is early, awned, has large soft white seed, and good quality.

Hill 81:

This cultivar was selected from the progeny of a cross between Yamhill and Hyslop, made in 1968 at the Hyslop Agronomy Farm and was released by Oregon State University Agriculture Experiment Station in 1981. Hill 81 is a high-yielding, midtall semidwarf, soft white wheat with wide adaptability in the Pacific Northwest. It has great promise in the acid soils of Western Oregon as it is more efficient in phosphorus uptake or has a lower phosphorus requirement. Hill 81 emerges rapidly and shows good seedling survival, useful characteristics in summer fallow systems, where strong seedling stands are needed to control soil erosion. Its winterhardeness is good.

Yamhill:

Yamhill is a soft winter wheat cultivar developed and released by Oregon State University Agriculture Experiment Station in 1969. It is a cross between Heines VII and Redmond (alba). It is a midtall variety with white, stiff straw and good resistance to lodging. Yamhill is adapted to the winter wheat growing areas of Western Oregon and Washington. It is medium late, awnless and has soft white seed. The variety is recommended for cultivation on hill side land and low areas having saturated soils during the winter rainfall period. It has only fair winter hardiness and has a strong vernalization requirement. Its unique characteristic is its ability to tolerate wet soils.

Malcolm:

Malcolm is a high-yielding, semidwarf, common soft white wheat released by Oregon State University in 1987. It has had superior yields to those of Stephens and other common varieties. It appears to be best adapted to irrigated areas of Eastern and Central Oregon, but has yielded well in other areas. Its winterhardiness is fair.

CHAPTER ONE

Tolerance of Four Winter Wheat Cultivars to Metribuzin and Ethyl Metribuzin Evaluated in Greenhouse and in Growth chamber.

INTRODUCTION

Metribuzin is currently registered for use in many crops for control of broadleaf and annual grass weeds including downy brome. This could be an effective herbicide in winter wheat production areas where a minimum tillage cropping system is used and downy brome infestation has become high. This is possible only if acceptable cultivar tolerance exists.

Cultivars of several crops have been shown to differ in their response to metribuzin. These include soybean {Glycine max (L.) Merr.} (38, 56), tomato (Lycopersicon esculentum Mill) (99), and potato (Solanum tuberosum L.) (35). Because of differential varietal tolerance (10, 24, 71), it can be applied to a number of cultivars. Because of these varietal limitations and other factors, herbicides such as the ethylthio analog of metribuzin are under investigation for selective downy brome control in winter wheat. The differences in cultivar response of several crops to these chemicals has raised the question of whether wheat cultivars might differ in their tolerance to metribuzin and ethyl metribuzin.

The basis for different level of tolerance in winter wheat cultivars has not been established. Several reports suggest that different levels of herbicide absorption may be a factor in the differential response between tolerant and susceptible species (14, 30, 39). Stephenson et.al. (99) reported that roots of both sensitive and tolerant tomato cultivars absorbed similar amounts of metribuzin. Gawronski et.al. (30) found that a tolerant barley cultivar absorbed more metribuzin from nutrient solution than did a sensitive barley cultivar. Absorption of metribuzin in tomato has been examined by Fortino and Splittstoesser (27), and they reported that a tolerant and a susceptible tomato cultivar absorbed similar amounts of foliar applied metribuzin.

Since ethyl metribuzin is a comparatively recent invention in weed control, its action on winter wheat is not well known. Therefore, several studies were conducted in a greenhouse and growth chamber to measure the effect of metribuzin and ethyl metribuzin on four winter wheat cultivars commonly grown in the Pacific Northwest of USA. The objectives of this research were:

1. Determine whether selected soft white winter wheat cultivars varied in their response to the herbicides under study and whether some cultivars were sufficiently tolerant to permit selective use of these chemicals for downy brome control.
2. Develop growth response curves and evaluate the herbicide concentration needed to reduce growth by 50% of each cultivar under study.
3. Better understand the mode of metribuzin and ethyl metribuzin uptake by plants.
4. Determine if differential absorption of metribuzin and ethyl metribuzin by winter wheat cultivars contributes to the tolerance of these species.

MATERIALS AND METHODS

Winter wheat response trial in greenhouse: An experiment to quantify the differential response of four winter wheat cultivars was established in greenhouse of Oregon State University on May 2, 1986. An experiment with the same treatments and under similar environmental conditions was repeated on July 5, 1986.

Six hundred g of greenhouse soil was added to 10 by 10 cm plastic pots. Seven seeds of each cultivar, taken from a certified source, were planted and then covered with 200g of the same soil. An additional pot of each cultivar per replication was planted to allow selection of the most uniform stand. Water was provided by sub irrigation and sun light was supplemented with inflorescent tube light. At emergence, plants were thinned to four plants per pot of each variety. Slow release fertilizer (analysis 10-10-10), was added to each pot. The experiment consisted of four genetically diverse soft white winter wheat cultivars, Stephens, Hill 81, Yamhill and Malcolm. Treatments were metribuzin and ethyl metribuzin at rates equivalent to 0.07, 0.13, 0.28, 0.56, 0.84 kg/ha and 0.56, 1.12, 1.68, 2.24, and, 2.80 kg/ha respectively. Three weeks after planting irrigation water was drained 24 hours before the herbicide application and treatments were applied with a greenhouse sprayer at 207 Kpa pressure. Water was used as a herbicide carrier at the rate of 300 L/ha. The pots were arranged in a randomized complete block design with a factorial arrangement of treatments and four replications. Visual evaluation of injury to the wheat plants was made 2 weeks after spraying and plants were harvested to determine fresh weight.

The data collected were subjected to regression analysis to quantify the rate of each herbicide required to cause a 50% injury to the plants of each cultivar.

Mechanism of uptake: A study, to determine the uptake of metribuzin and ethyl metribuzin by four winter wheat cultivars, was established in a greenhouse at Oregon State University. The experiment was planted on October 5, 1986 and was repeated on November 25, 1986. The same four cultivars Stephens, Hill 81, Yamhill, and Malcolm, were used as test species during the course of the study. The bottom of the 10 by 10 cm plastic pots was covered with a filter paper to prevent soil loss and pots were filled with 500 g of greenhouse soil. Seven seeds of each cultivar were planted and covered with an additional 150 g of soil with enough room left at the top of the pots for the execution of different treatments. Water was applied with sub irrigation and sun light was supplemented with inflorescent tube light. Slow release fertilizer (analysis 10-10-10) was added to each pot to maintain the soil fertility during the study period. Germinated wheat seedlings were thinned to four to have a uniform stand per pot.

The experiment consisted of three treatments of each herbicide under study. Herbicide rates used for metribuzin and ethyl metribuzin were 0.50 and 2.50 kg/ha respectively, which were proven to cause sufficient wheat injury in earlier experiments and were used to ensure the differences among treatments. Irrigation water was drained 24 hours before the herbicide was sprayed. Treatments included spraying the herbicide on (1) both plant and soil, (2) only the plant, (3) only the soil. Herbicides were applied 2 weeks after planting. Treatments were applied using a greenhouse sprayer at 207 kpa pressure and water at the rate of 300 L/ha. Before the herbicides were applied, a layer of 2.5 cm perlite was added to pots that were to receive foliage coverage of herbicide only. In the other treatment, butter paper bags (used in cereal crossing) were used to cover the seedlings to avoid herbicide contact to the plants. After the application of herbicides perlite was removed immediately with a spoon and butter paper bags were also removed.

The pots were arranged in a randomized complete block design with four replications. Visual observations of injury to the plants were recorded 18 days after treatment and plants were harvested to measure their fresh weight. Data were converted to percentage of check and was subjected to analysis of variance.

Nutrient solution bioassays for GR50 and chemical absorption:

Greater herbicide uptake by roots of sensitive cultivars than tolerant cultivars could explain all or part of the difference in tolerance. If no difference in uptake is measured it could indicate a difference in physical or biochemical activity in the plants.

An experiment to quantify the differences in root uptake among four winter wheat cultivars was conducted in the growth chamber at Oregon State University Corvallis in 1986 and 1987.

The experiment consisted of four genetically diverse soft white winter wheat cultivars, Stephens, Hill 81, Yamhill, and Malcolm, and two herbicides, metribuzin and ethyl metribuzin. Certified seeds of these cultivars were pregerminated in paper towels for 4 days before transplanting. Seeds were put on two layers of paper towel and covered with another paper towel. The towels were rolled carefully so that seed positioning was not disturbed and was put in an upright position. Towel roll was kept moist with distilled water and both ends were kept open to diffuse air to the seeds. Seedlings of uniform coleoptile length were selected for transplanting. One seedling of each species, supported by foam rubber pieces, was transferred to separate 50 ml culture tubes. Roots of each seedling were suspended in a No. 2 Hoagland's solution and various concentrations of herbicides under study.

Eight ml of No. 2 Hoagland's solution was placed in 50 ml culture tubes followed by adding different concentrations of metribuzin and ethyl metribuzin, formulated from technical grade material. Deionized water was added to bring the total liquid to 50 ml in each tube.

Concentrations of metribuzin used in the experiment were 0.05, 0.1, 0.5, 1.0, 2.5, 5, 10., or 25 uM and of ethyl metribuzin were 0.5, 1.0, 2.5, 5, 10, 20, 30, or 50 uM. At each watering, tubes were again filled to the 50 ml mark with a syringe and the amount of water added was recorded to obtain a cumulative water uptake for each species.

The experiment was conducted in a growth chamber with 16 hours of day and 8 hours of night. The day and night temperatures were kept at 20 and 16 C respectively. The experiment was laid out in randomized complete block design with a factorial arrangement of treatments and with six replications.

Visual observations of plant injury were made after 4 weeks of seedlings transplanted in nutrient solution and plant shoots were harvested at the same time to calculate reduction in plant weight. Seedling fresh weight data was recorded in mg. The data so collected were transformed to percentage of control and subjected to analysis of variance to quantify the difference among species in susceptibility to metribuzin and ethyl metribuzin. The data were also subjected to regression analysis for each species. The herbicide concentrations required for 50% crop injury and 50% growth reduction were estimated from these equations.

A herbicide screening technique for wheat: Two experiments were conducted in greenhouse of Oregon State University in April of 1987 to develop a screening technique for winter wheat cultivars in response to metribuzin and ethyl metribuzin. Before conducting the actual experiments, correct amount of herbicide solution needed for best germination of wheat seeds was evaluated by using distilled water. Ten seeds of four winter wheat cultivars, Stephens, Hill 81, Yamhill, and Malcolm were put to germinate on blotting paper in 10 by 10 cm plastic petri dishes. Distilled water of 10, 20, 30, and 40 ml was applied with a 50 ml syringe to each petri dish and then seeds were covered with another piece of blotting paper. Petri dishes were kept at normal room temperature in greenhouse. Experiment was repeated in three replications. Germinated wheat seeds of each cultivar were counted after 7 days and best seed germination of all cultivars i.e 100% was observed in the petri dishes where 20 ml water was applied. Therefore decision was made to use 20 ml of herbicide solution in further studies. In actual experiments same technique of seed germination was adapted as described above except distilled water was replaced with herbicide solution of 2 uM metribuzin and 10 uM ethyl metribuzin concentrations. Actual experiment was repeated twice with three replications each. Data collected were subjected to analysis of variance using randomized complete block design.

RESULTS AND DISCUSSION

Greenhouse experiments to calculate GR50: Winter wheat cultivars Stephens and Malcolm were tolerant to high concentrations of metribuzin and ethyl metribuzin treatments, whereas cultivars Hill 81 and Yamhill were sensitive (Table 1.1). Tolerant varieties were stimulated by either herbicide at the lower rates. High rates of metribuzin and ethyl metribuzin caused leaf burning and stunted growth of test plants. More than 0.56 kg/ha of metribuzin and 2.24 kg/ha of ethyl metribuzin damaged all plants of sensitive cultivars Hill 81 and Yamhill, while severe damage to Stephens and Malcolm was observed at more than 0.84 kg/ha of metribuzin and 2.80 kg/ha of ethyl metribuzin, although not all plants were killed even at the above mentioned rates of herbicides.

Hill 81 was slightly more susceptible than Yamhill, with a GR50 of 0.23 and 0.25 kg/ha for metribuzin and 1.29 and 1.37 kg/ha for ethyl metribuzin respectively. The GR50 values for Stephens and Malcolm cultivars were 0.41 and 0.44 kg/ha for metribuzin and 1.89 and 1.97 kg/ha for ethyl metribuzin respectively (Table 1.2). In case of both the herbicides applied, Malcolm was the most tolerant cultivar followed by Stephens but the difference was small. On the other hand Hill 81 and Yamhill were quite sensitive to metribuzin and ethyl metribuzin and were similar in their reaction to increasing rates of both herbicides. The average increase in fresh weight of plant seedlings treated with lower rates of herbicides was up to 7% in case of Malcolm as compared to the untreated check plants.

Table 1.1. Means of two experiments each with four replications for four winter wheat cultivars treated with metribuzin and ethyl metribuzin in greenhouse.

Herbicide	Rate	Cultivars Stephens	Hill 81	Yamhill	Malcolm
		Visual injury %			
Metribuzin	0.07	0	14	13	0
kg/ha	0.13	14	36	33	13
	0.28	34	79	70	32
	0.56	72	100	98	64
	0.84	96	100	100	90
Ethyl	0.56	0	17	13	0
Metribuzin	1.12	16	36	33	14
kg/ha	1.68	35	79	76	33
	2.24	64	96	93	61
	2.80	92	100	99	88
		Shoot fresh weight % of check			
Metribuzin	0.07	106	96	96	107
kg/ha	0.13	96	61	67	98
	0.28	69	32	37	72
	0.56	37	24	22	43
	0.84	22	19	21	23
Ethyl	0.56	101	89	92	104
Metribuzin	1.12	96	61	65	98
kg/ha	1.68	65	31	33	71
	2.24	64	96	93	61
	2.80	19	18	19	19

Table 1.2. GR50 values for four winter wheat cultivars estimated from greenhouse studies[a].

Herbicide	Cultivars	GR50	
		Visual injury[b]	Fresh weight[c]
		kg/ha	
Metribuzin	Stephens	0.31	0.41
	Hill 81	0.17	0.23
	Yamhill	0.19	0.25
	Malcolm	0.35	0.44
Ethyl Metribuzin	Stephens	1.72	1.89
	Hill 81	1.12	1.29
	Yamhill	1.18	1.37
	Malcolm	1.81	1.97

a) Average of two experiments each with four replications.

b) Predicted from linear regression of visual injury %.

c) Predicted from linear regression of shoot fresh weight expressed as percentage of check plants

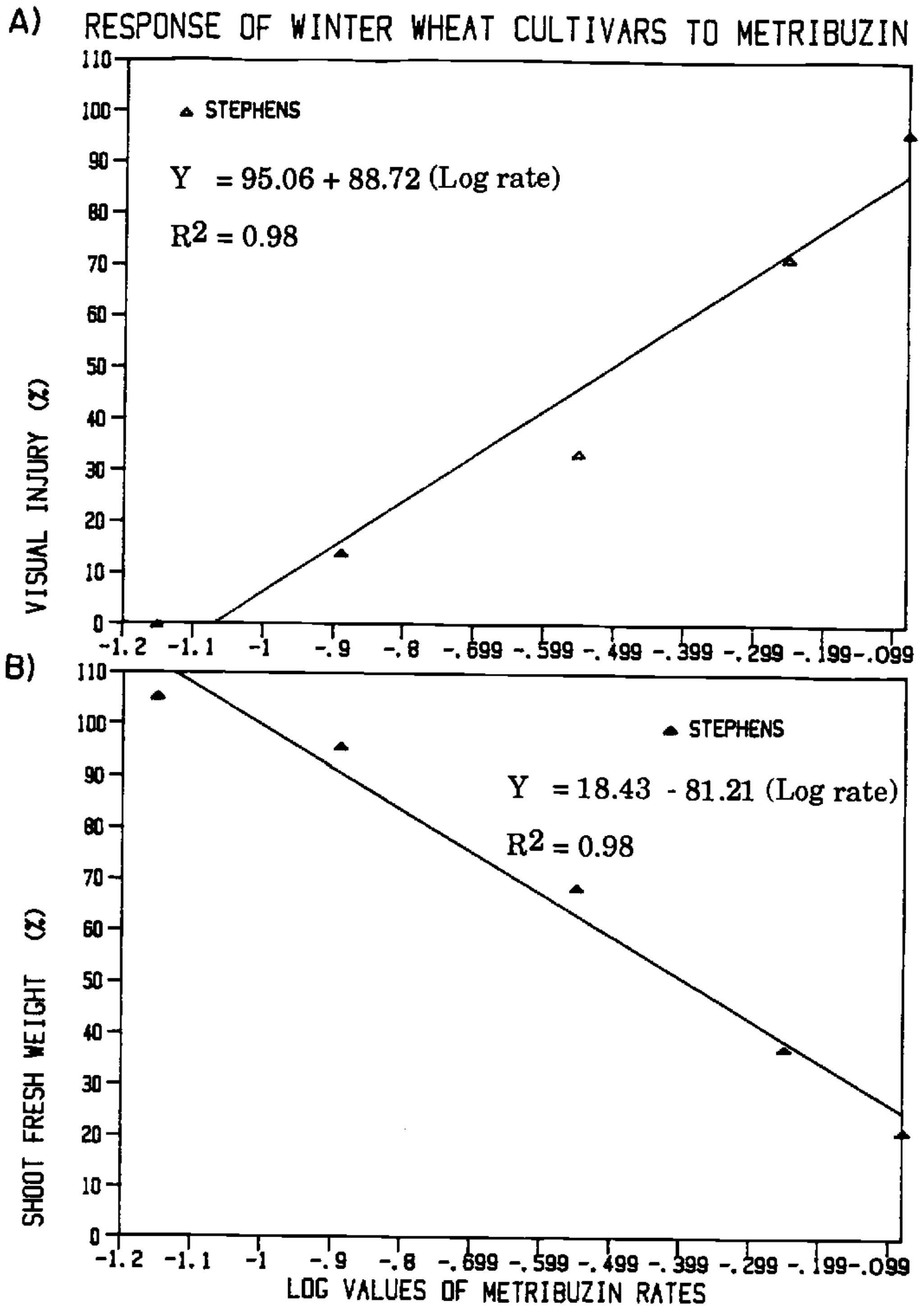


Figure 1.1: Evaluation of GR50 of metribuzin for Stephens winter wheat in greenhouse.
(a) Using data of visual injury (%)
(b) Using data of seedling fresh weight (%)

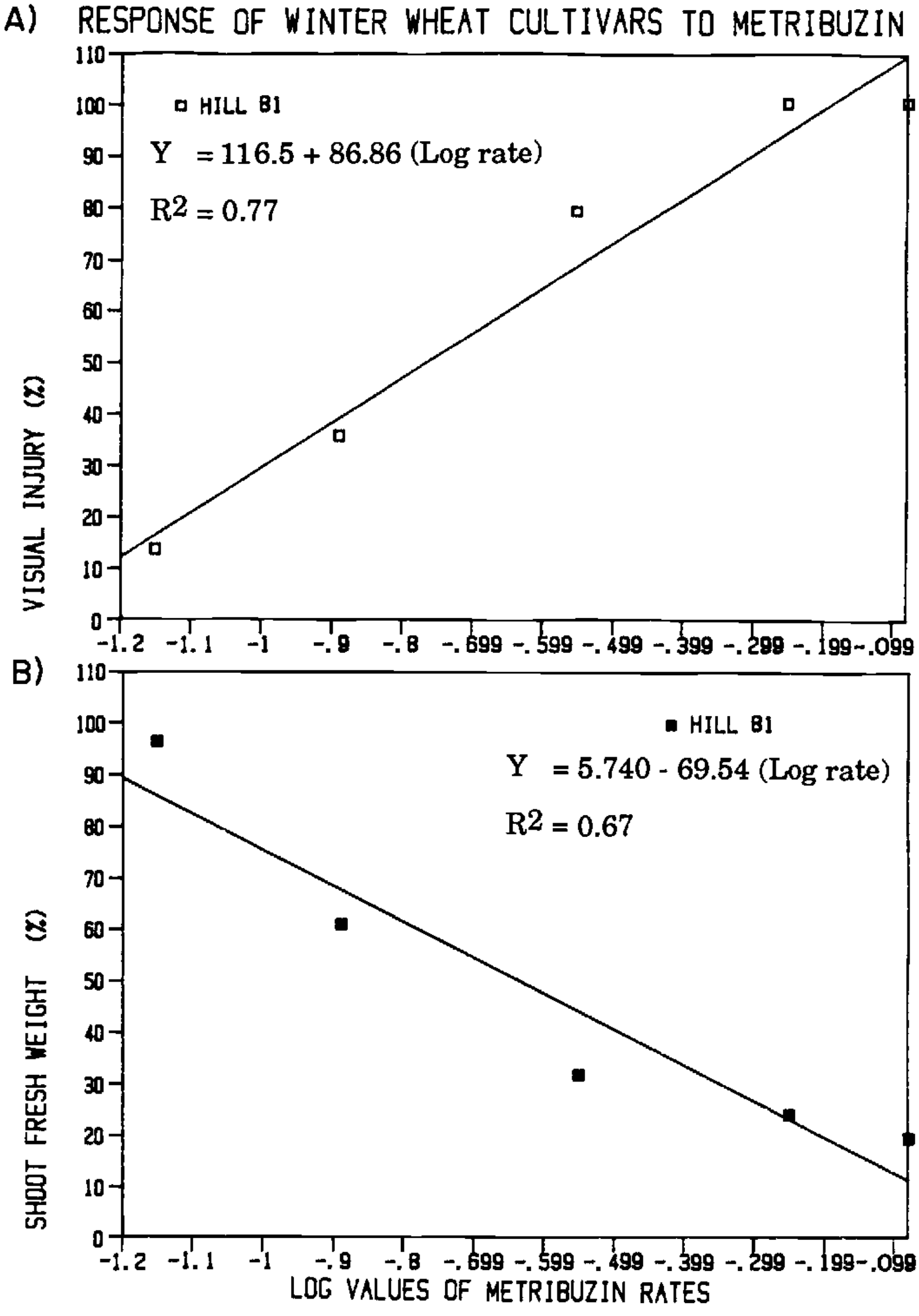


Figure 1.2: Evaluation of GR50 of metribuzin for Hill 81 winter wheat in greenhouse.
(a) Using data of visual injury (%)
(b) Using data of seedling fresh weight (%)

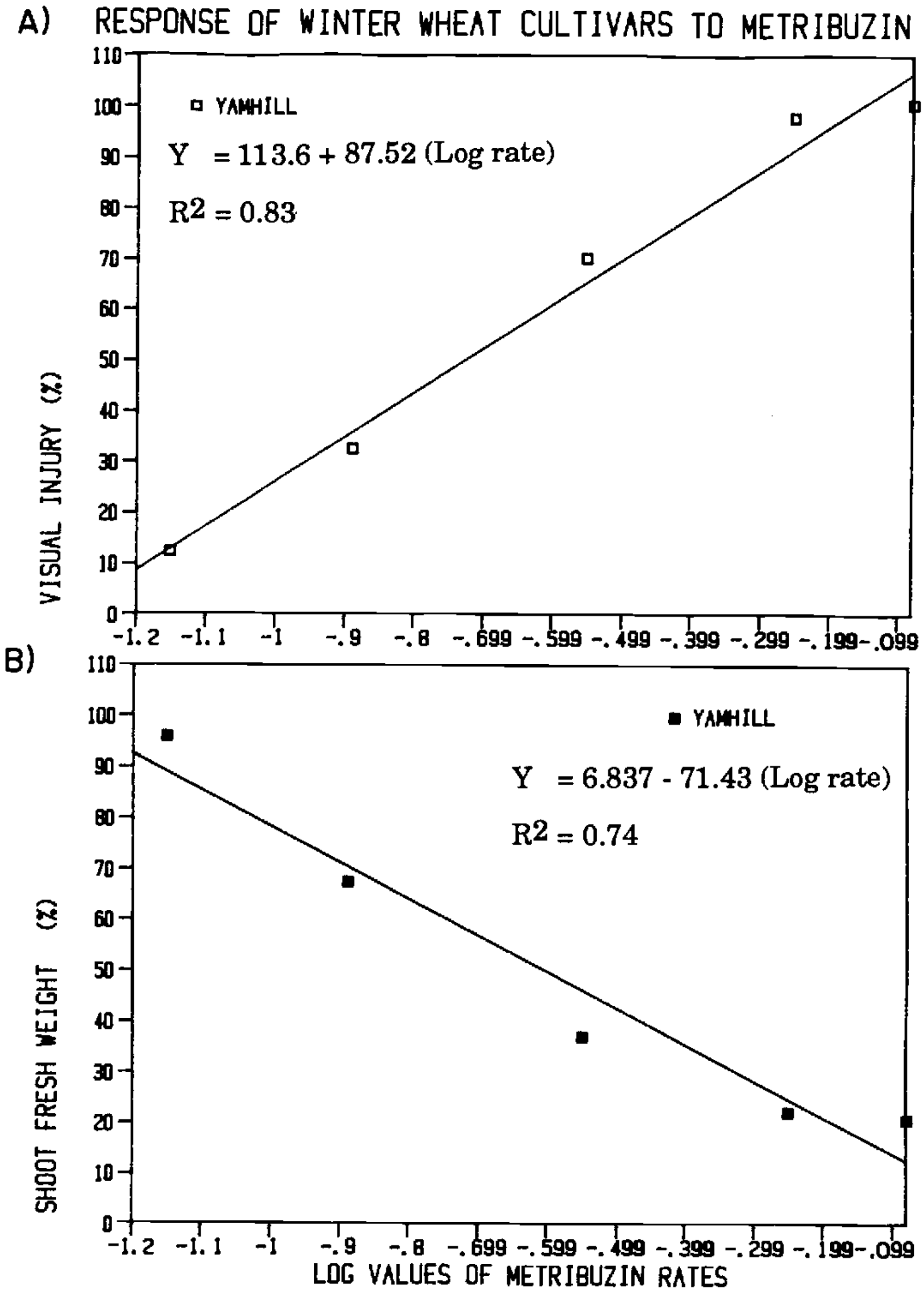


Figure 1.3: Evaluation of GR50 of metribuzin for Yamhill winter wheat in greenhouse.
(a) Using data of visual injury (%)
(b) Using data of seedling fresh weight (%)

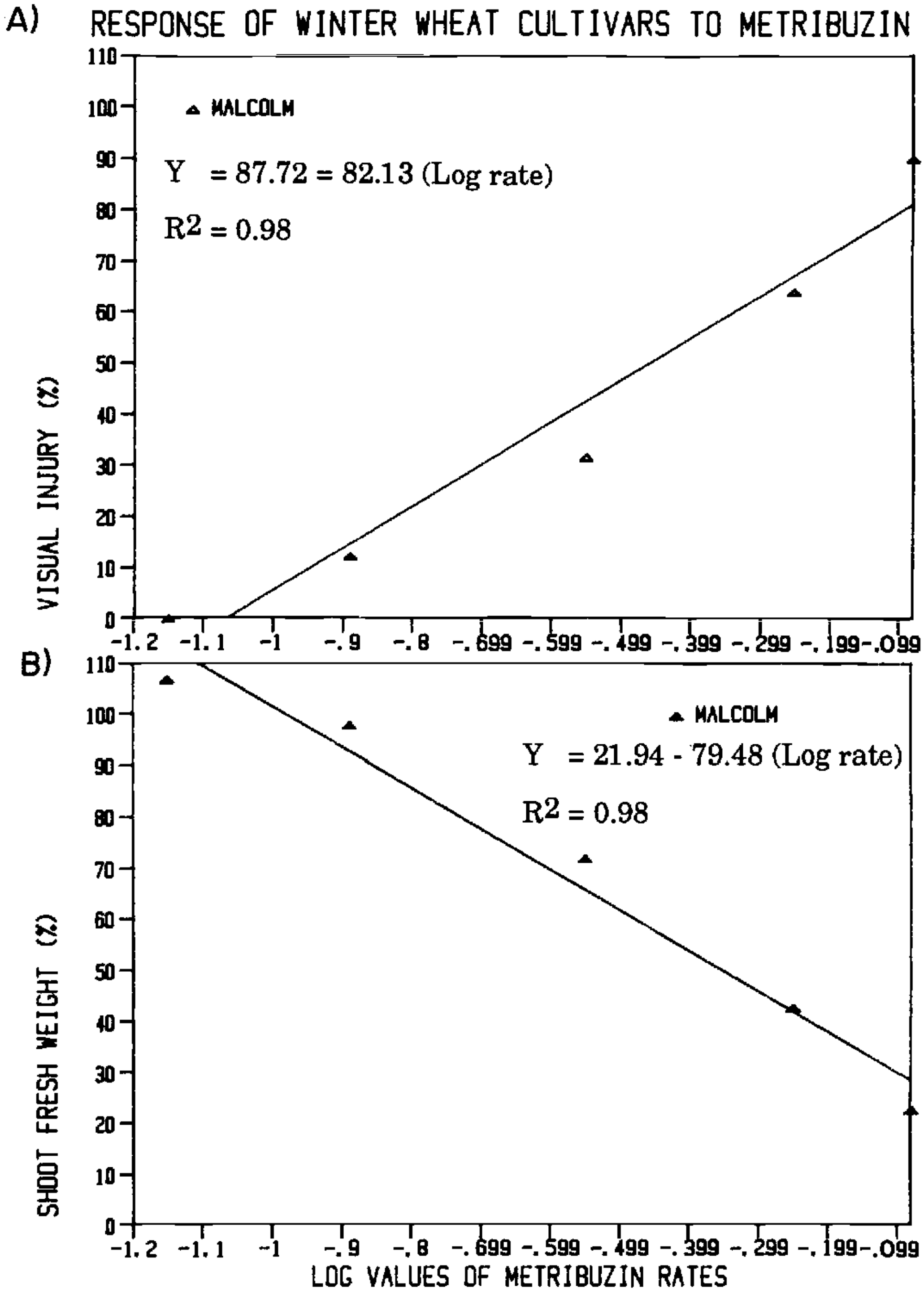


Figure 1.4: Evaluation of GR50 of metribuzin for Malcolm winter wheat in greenhouse.
(a) Using data of visual injury (%)
(b) Using data of seedling fresh weight (%)

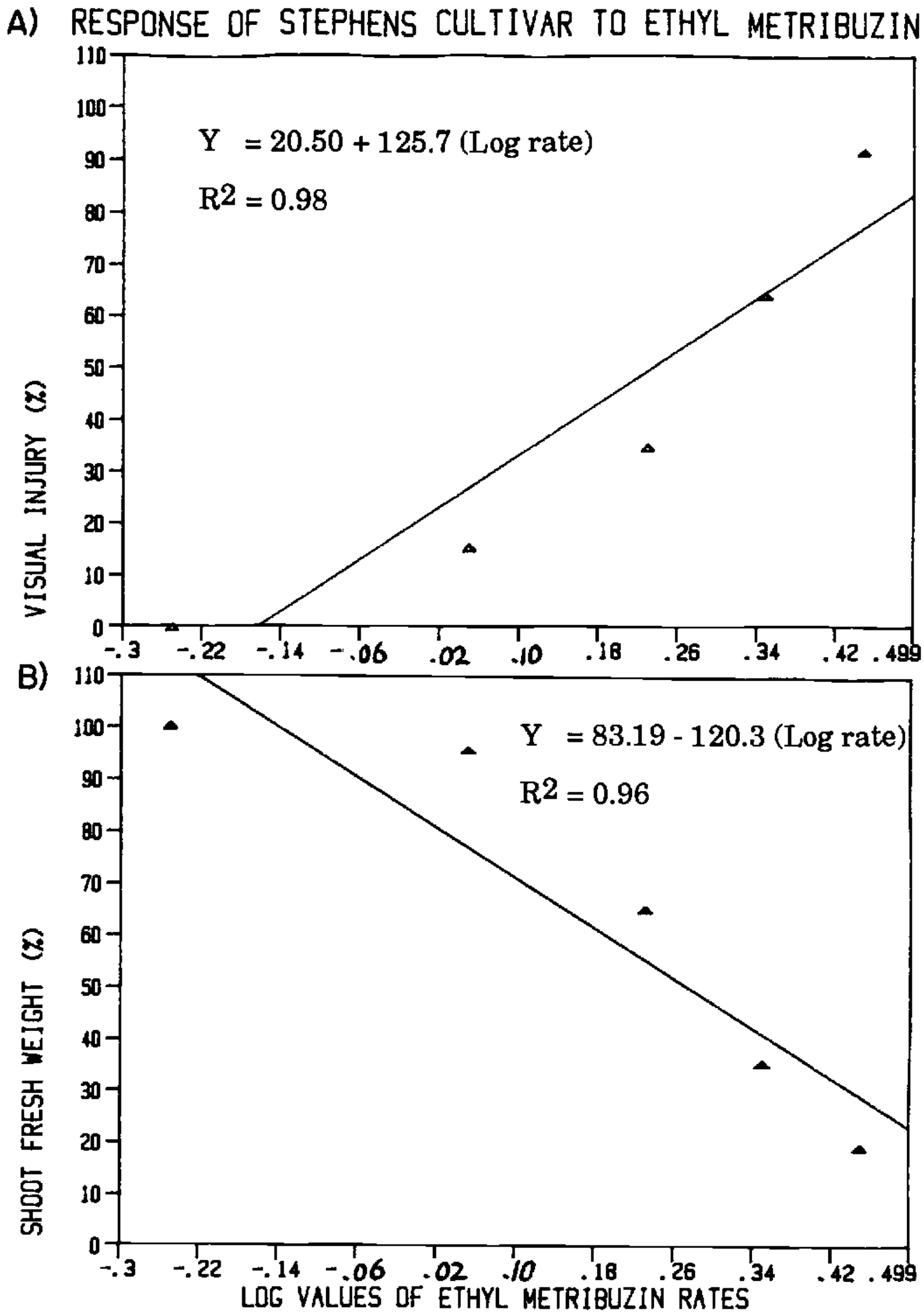


Figure 1.5: Evaluation of GR50 of ethyl metribuzin for Stephens winter wheat in greenhouse.
(a) Using data of visual injury (%)
(b) Using data of seedling fresh weight (%)

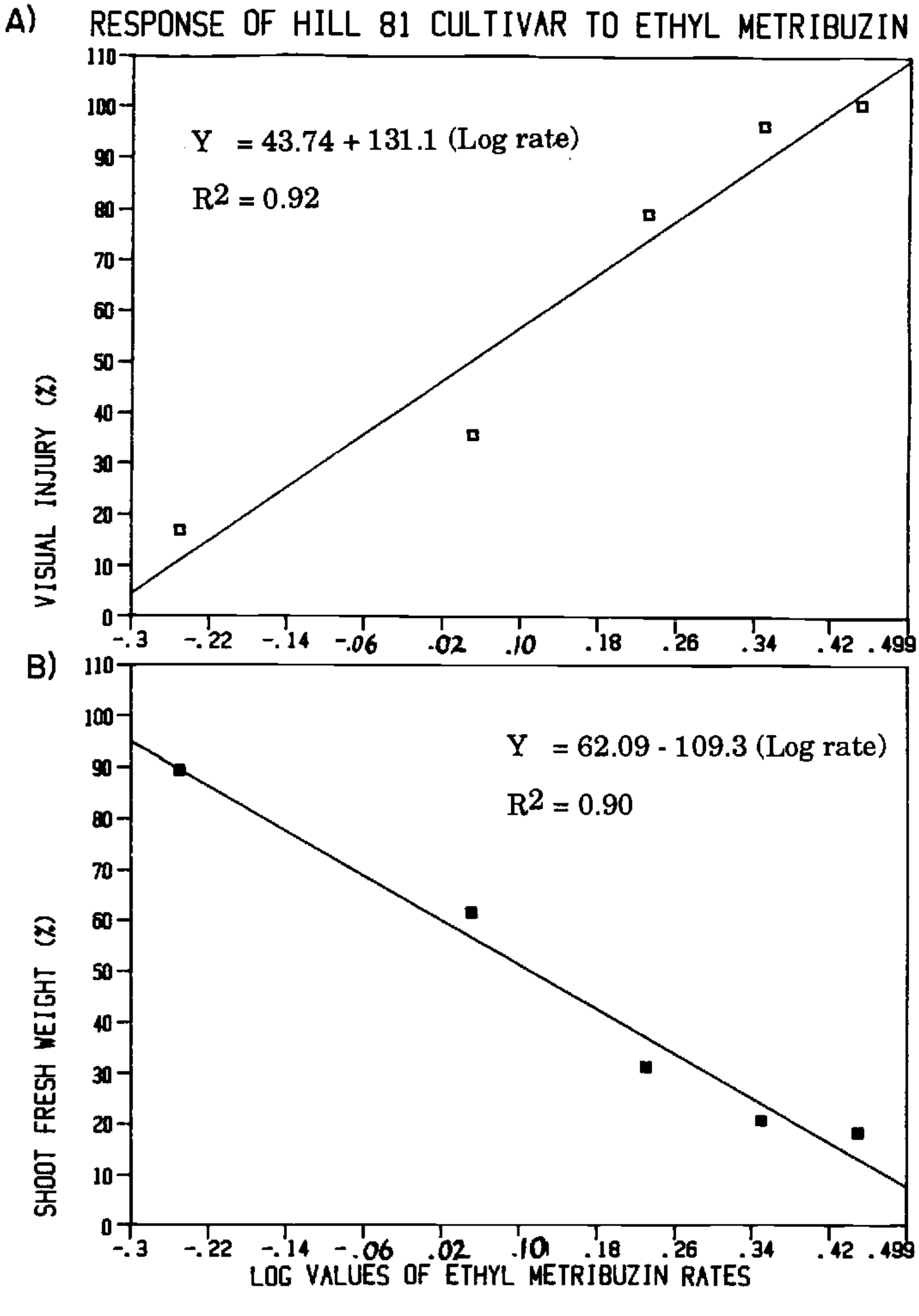


Figure 1.6: Evaluation of GR50 of ethyl metribuzin for Hill 81 winter wheat in greenhouse.
(a) Using data of visual injury (%)
(b) Using data of seedling fresh weight (%)

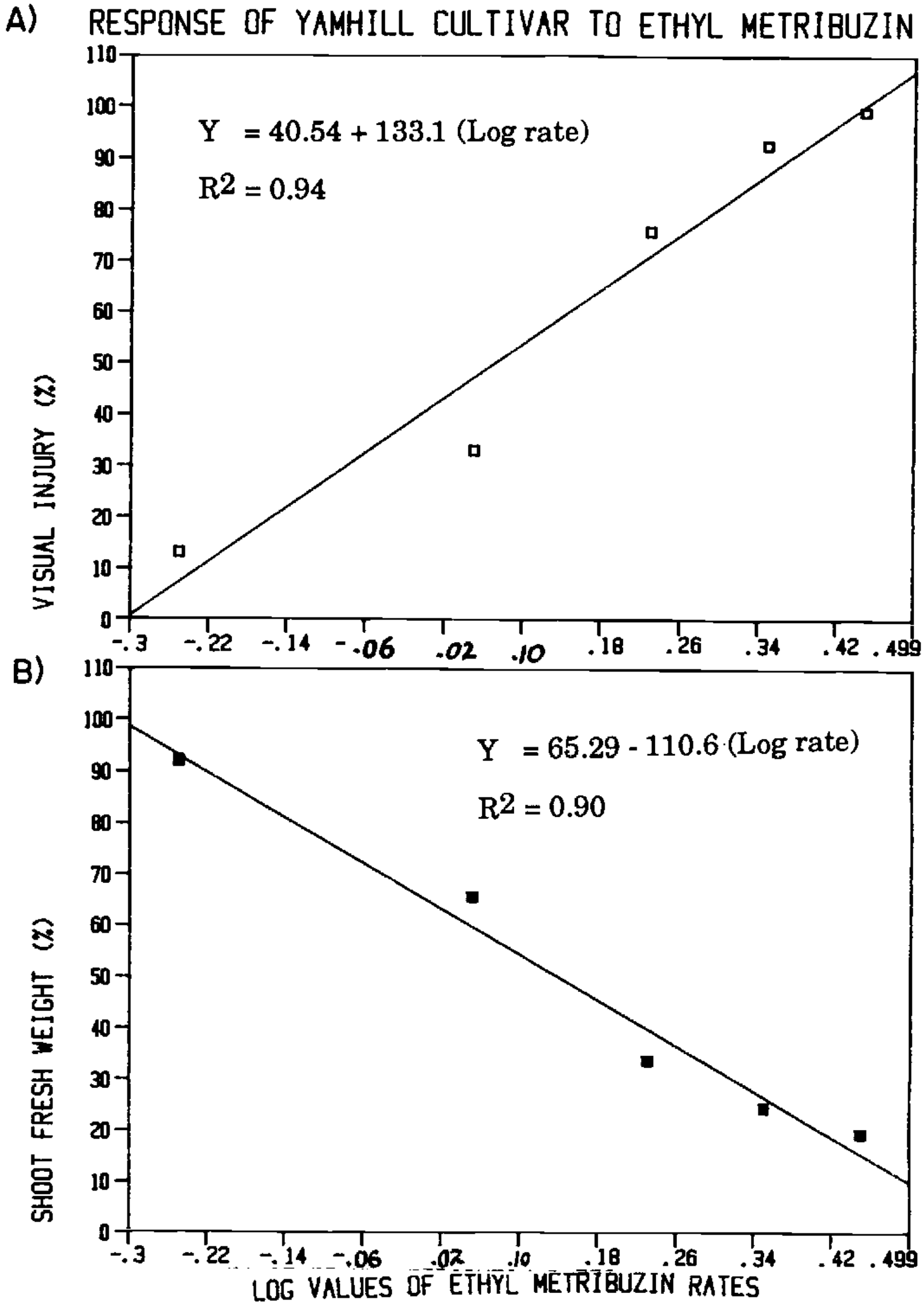


Figure 1.7: Evaluation of GR50 of ethyl metribuzin for Yamhill winter wheat in greenhouse.
(a) Using data of visual injury (%)
(b) Using data of seedling fresh weight (%)

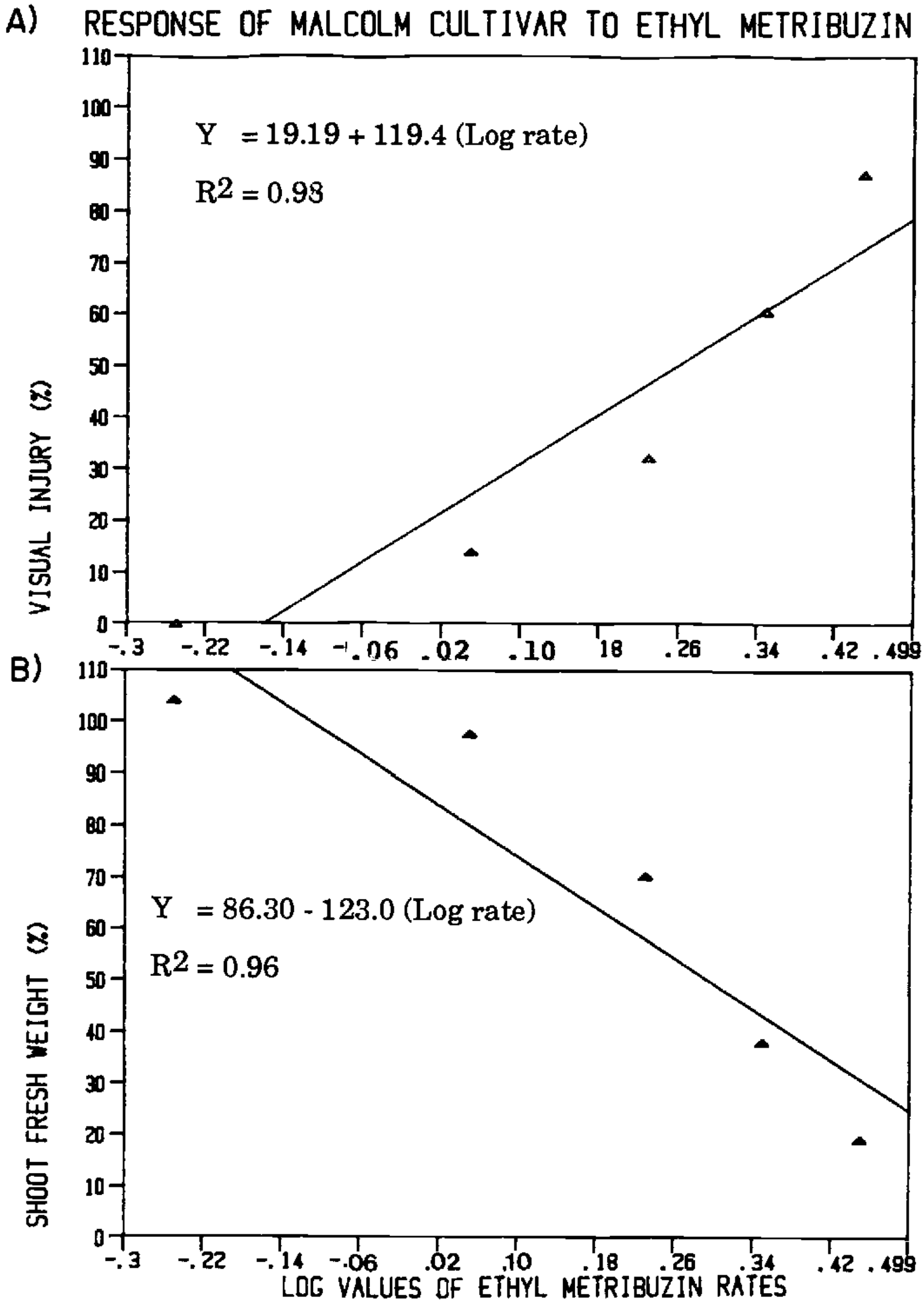


Figure 1.8: Evaluation of GR50 of ethyl metribuzin for Malcolm winter wheat in greenhouse.
(a) Using data of visual injury (%)
(b) Using data of seedling fresh weight (%)

Evaluation of GR50 in nutrient solution : The results presented in Tables 1.3 & 1.4 indicate that none of the cultivars evaluated has complete tolerance to metribuzin and ethyl metribuzin, and cultivars under investigation behaved differently when exposed to different rates of these herbicides. These differences in response were quantified by determining the rate of the two herbicides required to cause 50% growth reduction of plants. Stephens and Malcolm were relatively tolerant to high concentrations of metribuzin and ethyl metribuzin with a GR50 value of 3.26 uM and 3.87 uM, 12.69 uM and 13.41 uM respectively. Hill 81 and Yamhill were sensitive to the herbicides under study. GR50 values for Hill 81 and Yamhill were 1.17uM and 1.32 uM for metribuzin and 7.20 uM and 7.19 uM for ethyl metribuzin respectively (Table 1.5). As is evident from these GR50 figures, cultivars Stephens and Malcolm were approximately twice as tolerant to metribuzin and ethyl metribuzin as susceptible cultivars Hill 81 and Yamhill. Malcolm was observed to be slightly more tolerant to both herbicides than Stephens. However, these differences were non significant. Analysis of the variance of the data shows no significant differences within the cultivars of tolerant group, i.e Stephens and Malcolm, and the cultivars of susceptible group, i.e. Hill 81 and Yamhill, but the differences were highly significant between the tolerant and susceptible groups at 1% level of significance. Metribuzin was approximately five times more toxic than ethyl metribuzin.

These results of varietal behavior and differences in herbicide toxicity were consistent when calculations were made on the basis of visual injury to wheat plants or on the basis of seedling fresh weight. However, as can be seen in Table 1.5 herbicide rates required to cause a 50% growth reduction based on visual assessments were less than rates required to reduce fresh weights by 50%. These results were supported by the findings in chapter two where less reduction in wheat biological and grain yields was recorded than was expected from the observations made of the visible injury to the crop. Moreover, the data presented in Table 1.4 indicate that the lower rates of metribuzin and ethyl metribuzin stimulated the growth of all cultivars under study. Fresh weights of treated plants were up to 10% higher than weights of untreated plants. These results were consistent with results of the field experiment discused in chapter two, in which herbicide rates that did not cause visible injury caused an increase in grain yield and yield components.

Table 1.3. Means of two experiments each with three replications for four winter wheat cultivars established in nutrient solution and treated with metribuzin and ethyl metribuzin in growth chamber.

Herbicide	Rate	Cultivars			
		Stephens	Hill 81	Yamhill	Malcolm
	-- uM --	---------------- Visual injury %			----------------------------
Metribuzin	0.05	0	3	0	0
	0.10	0	23	21	2
	0.50	18	53	51	15
	1.00	34	67	64	27
	2.50	54	88	88	43
	5.00	67	99	99	70
	10.00	88	100	100	87
	25.00	100	100	100	100
Ethyl	0.50	0	8	4	0
Metribuzin	1.00	0	18	21	0
	2.50	6	38	34	0
	5.00	30	65	63	25
	10.00	48	80	84	50
	20.00	70	100	100	72
	30.00	83	100	100	81
	50.00	100	100	100	100

Table 1.4. Means of two experiments each with three replications for four winter wheat cultivars established in nutrient solution and treated with metribuzin and ethyl metribuzin in growth chamber.

Herbicide	Rate	Cultivars			
		Stephens	Hill 81	Yamhill	Malcolm
	-- uM --	------------Shoot fresh weight % of check --------------			
Metribuzin	0.05	108	106	110	105
	0.10	104	90	91	102
	0.50	89	56	60	92
	1.00	72	43	44	80
	2.50	54	31	30	64
	5.00	41	23	25	36
	10.00	24	18	21	29
	25.00	22	21	21	22
Ethyl	0.50	104	105	110	106
Metribuzin	1.00	104	94	92	101
	2.50	97	74	77	100
	5.00	77	44	43	80
	10.00	57	33	34	54
	20.00	39	26	26	37
	30.00	25	25	24	29
	50.00	18	24	20	21

Table 1.5. GR50 values for four winter wheat cultivars estimated from nutrient solution studies in growth chamber[a].

Herbicide	Cultivars	GR50 Visual injury[b]	GR50 Fresh weight[c]
		uM	
Metribuzin	Stephens	1.71	3.26
	Hill 81	0.49	1.17
	Yamhill	0.53	1.32
	Malcolm	1.96	3.87
Ethyl Metribuzin	Stephens	8.64	12.69
	Hill 81	3.37	7.20
	Yamhill	3.46	7.19
	Malcolm	9.04	13.41

a) Average of two experiments each with three replications.

b) Predicted from linear regression of visual injury %.

c) Predicted from linear regression of shoot fresh weight expressed as percentage of check plants

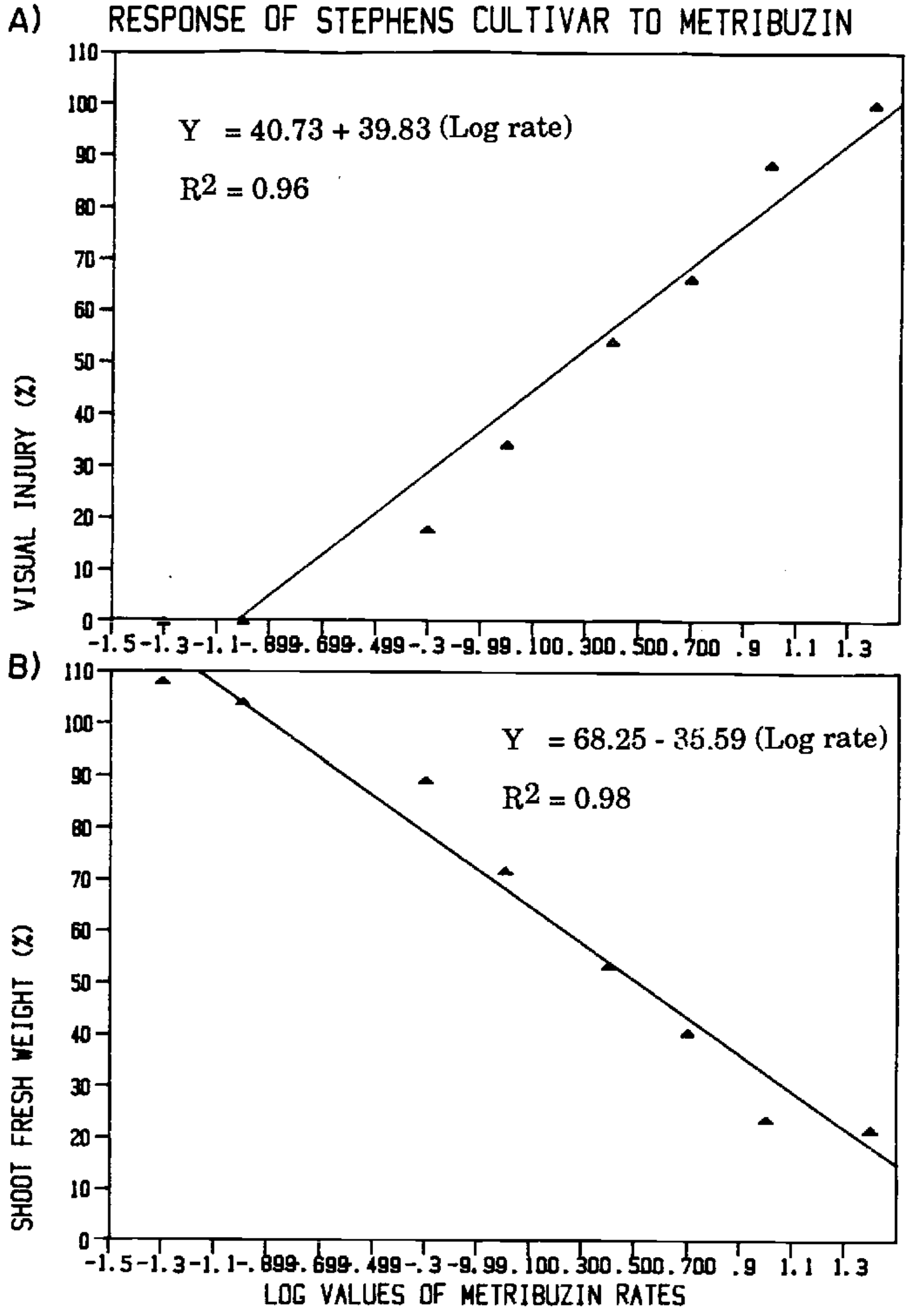


Figure 1.9: Evaluation of GR50 of metribuzin for Stephens winter wheat in nutrient solution.
(a) Using data of visual injury (%)
(b) Using data of seedling fresh weight (%)

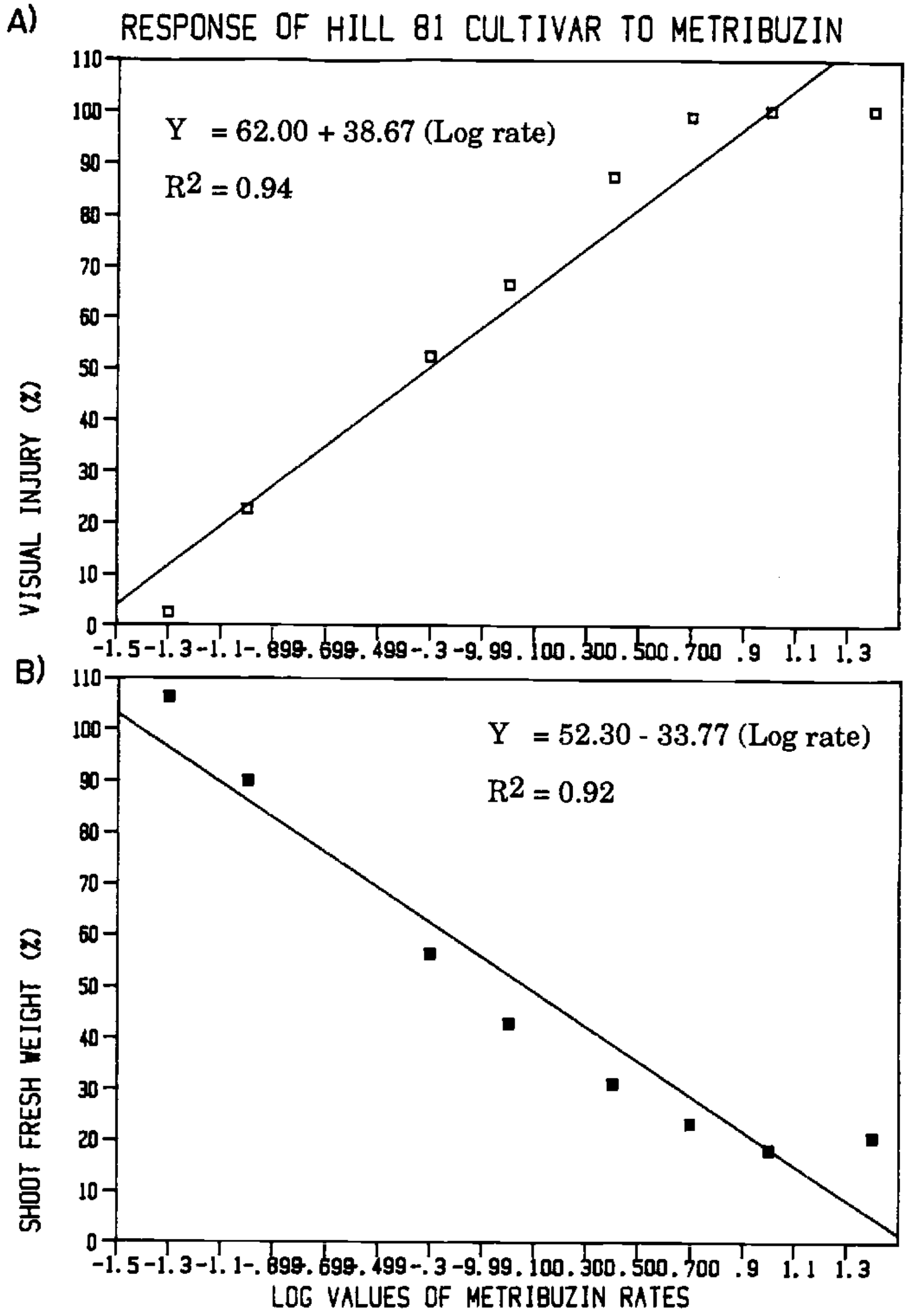


Figure 1.10: Evaluation of GR50 of metribuzin for Hill 81 winter wheat in nutrient solution.
(a) Using data of visual injury (%)
(b) Using data of seedling fresh weight (%)

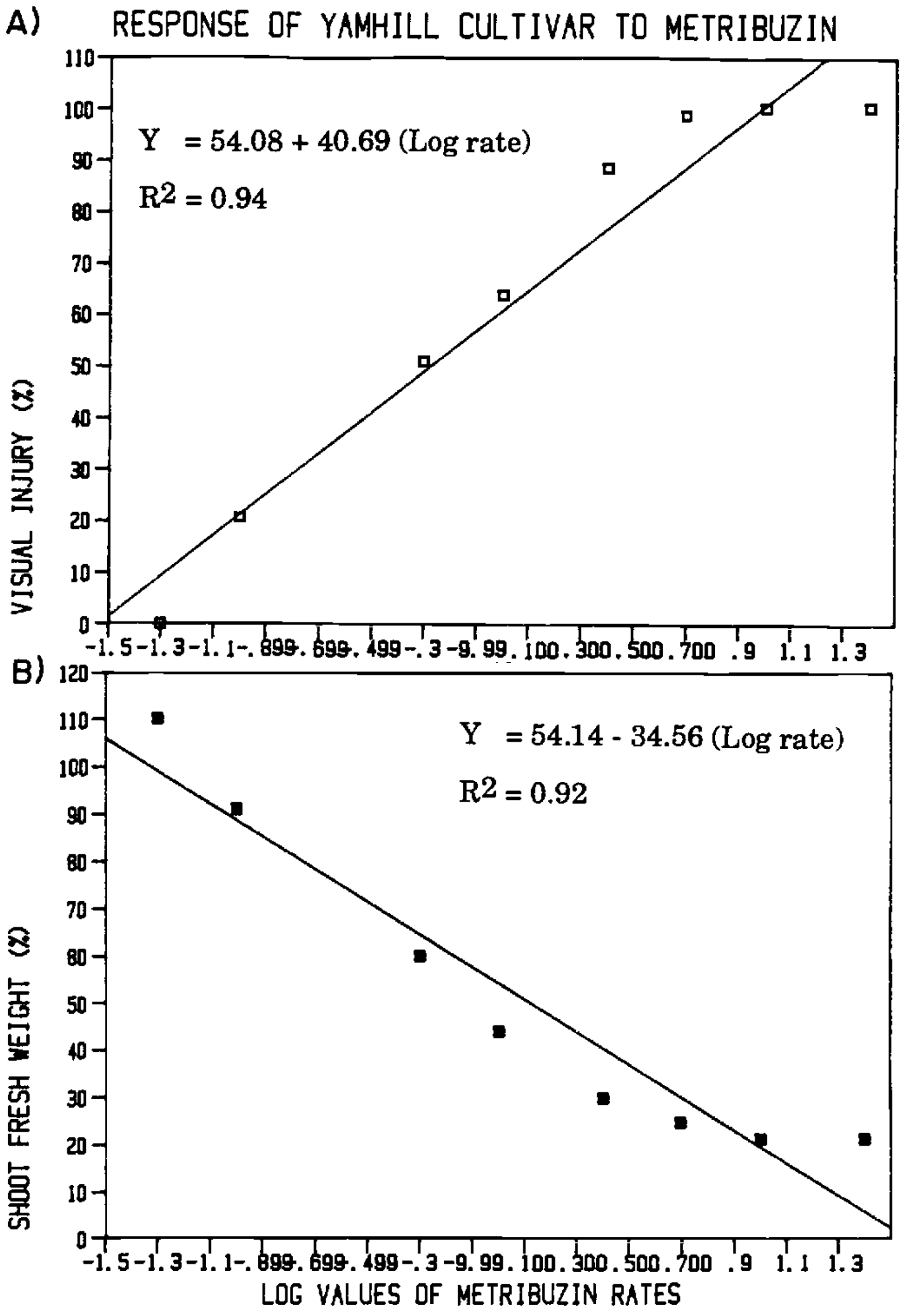


Figure 1.11: Evaluation of GR50 of metribuzin for Yamhill winter wheat in nutrient solution.
(a) Using data of visual injury (%)
(b) Using data of seedling fresh weight (%)

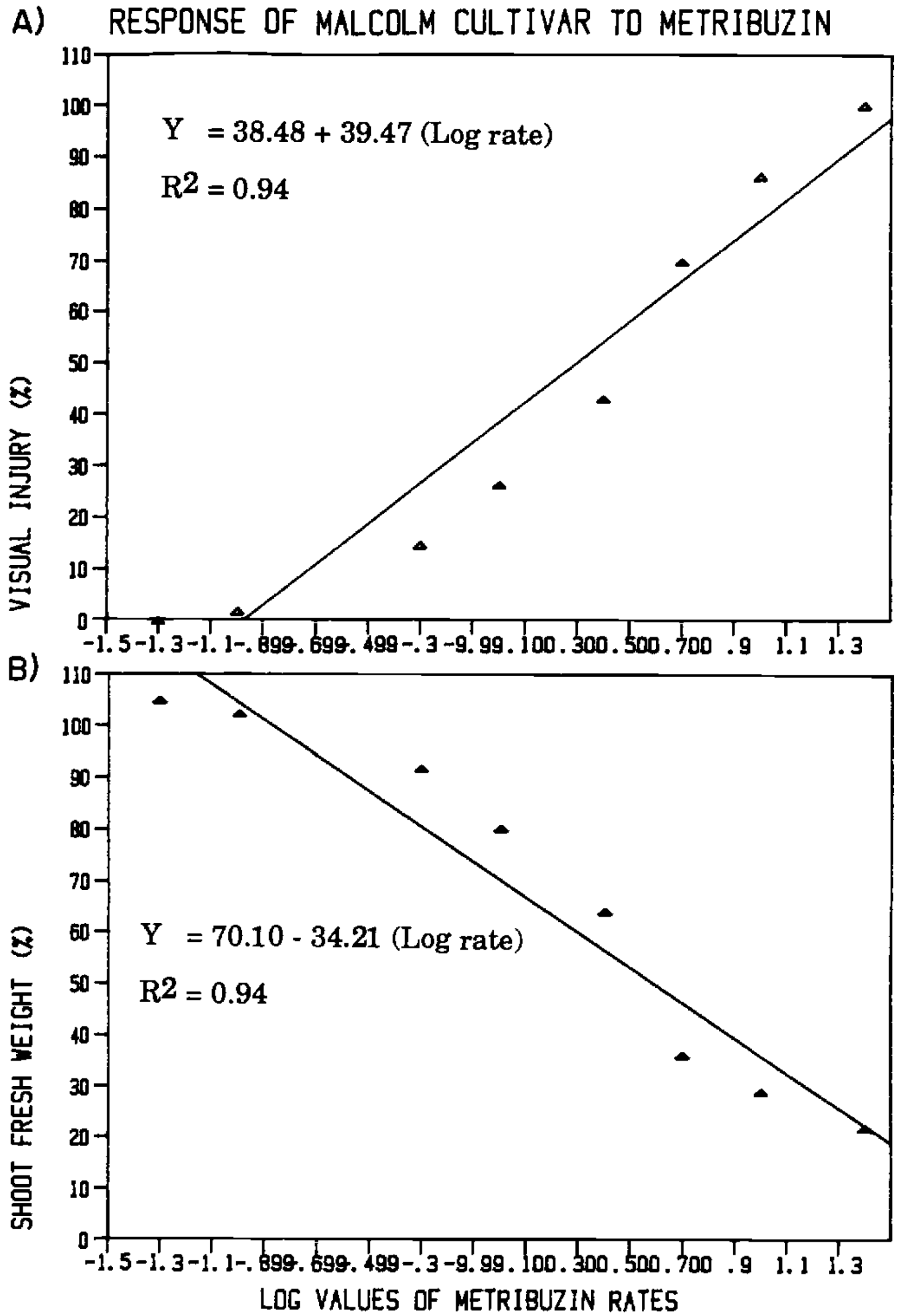


Figure 1.12: Evaluation of GR50 of metribuzin for Malcolm winter wheat in nutrient solution.
(a) Using data of visual injury (%)
(b) Using data of seedling fresh weight (%)

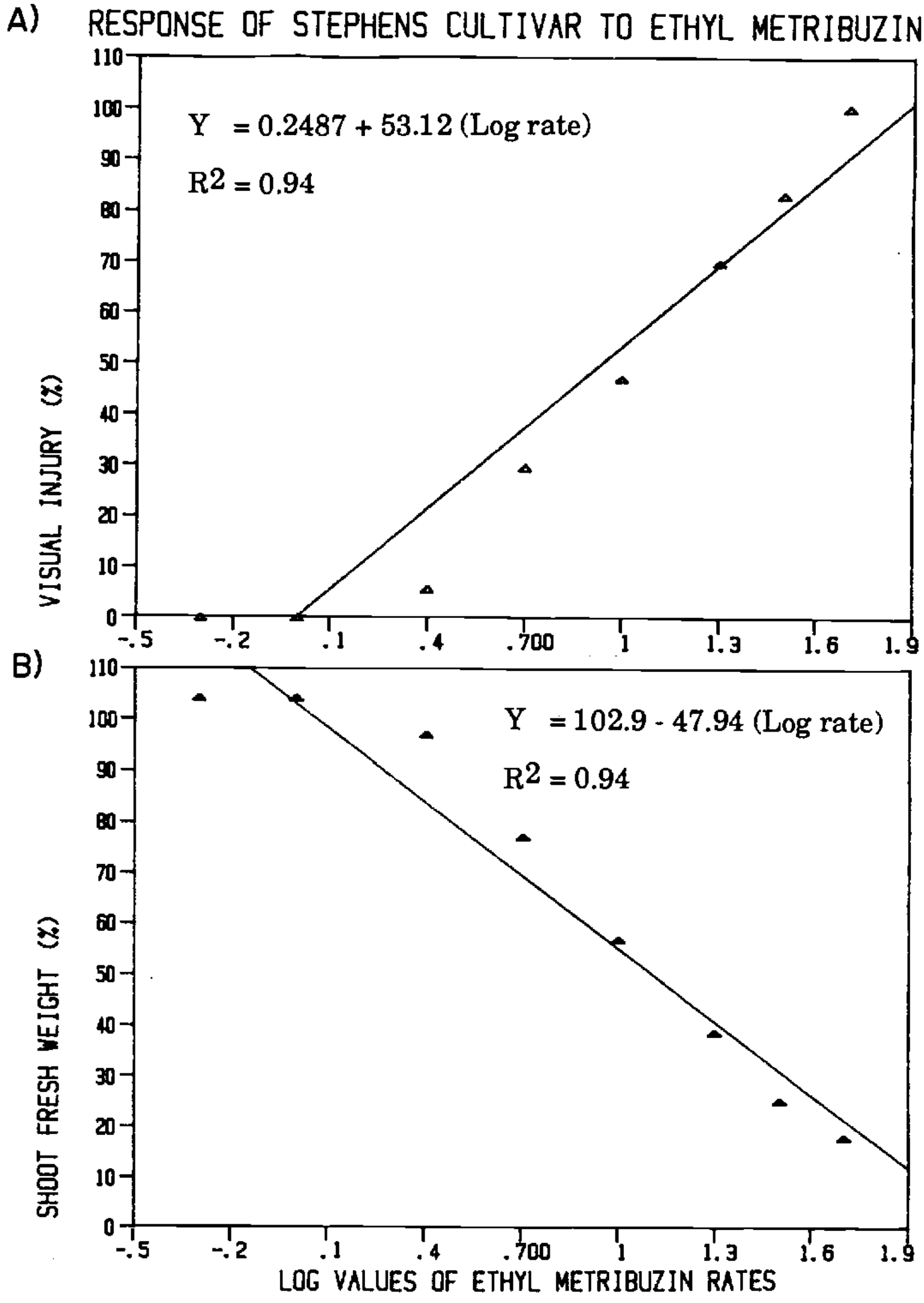


Figure 1.13: Evaluation of GR50 of ethyl metribuzin for Stephens winter wheat in nutrient solution.
(a) Using data of visual injury (%)
(b) Using data of seedling fresh weight (%)

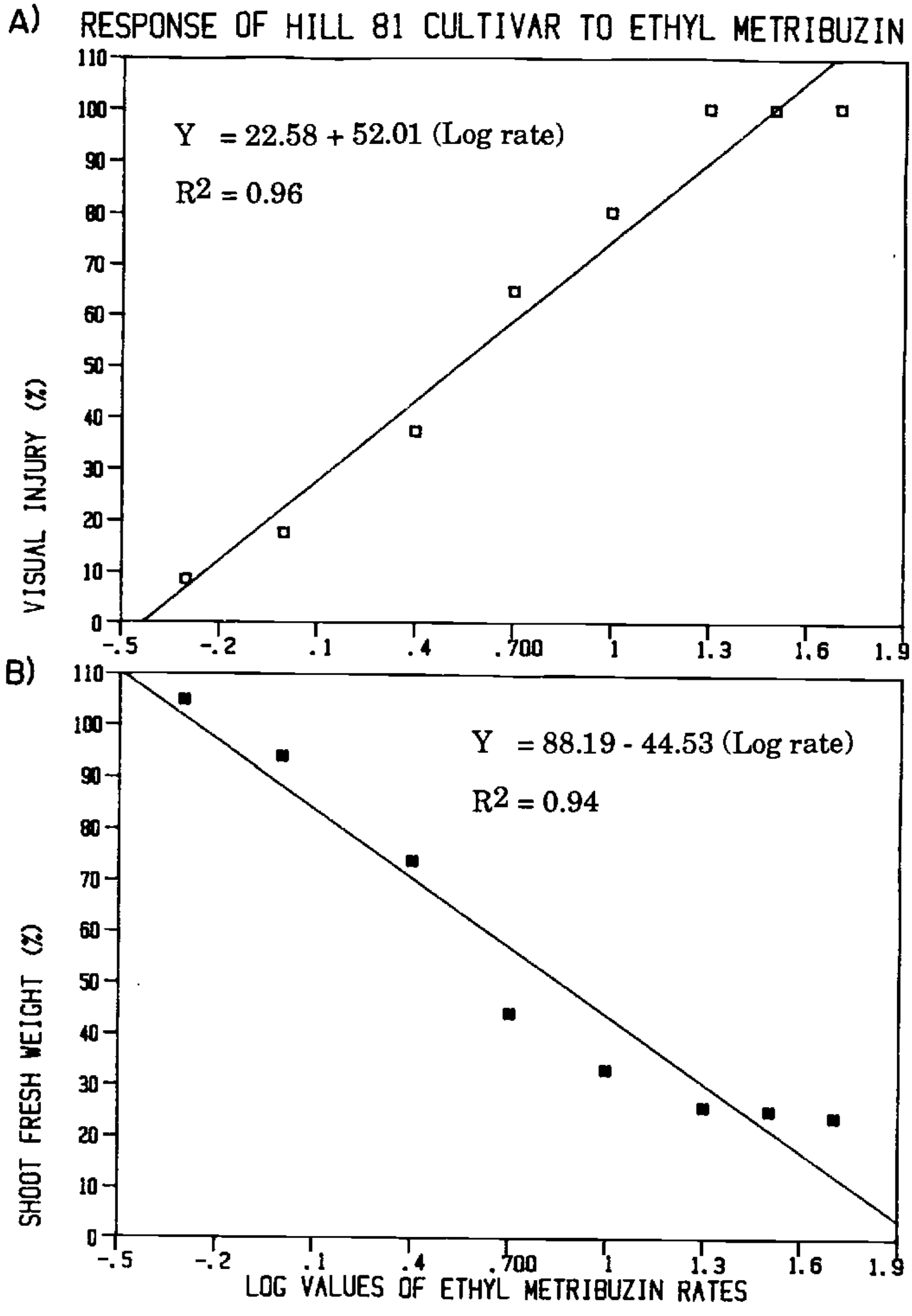


Figure 1.14: Evaluation of GR50 of ethyl metribuzin for Hill 81 winter wheat in nutrient solution.
(a) Using data of visual injury (%)
(b) Using data of seedling fresh weight (%)

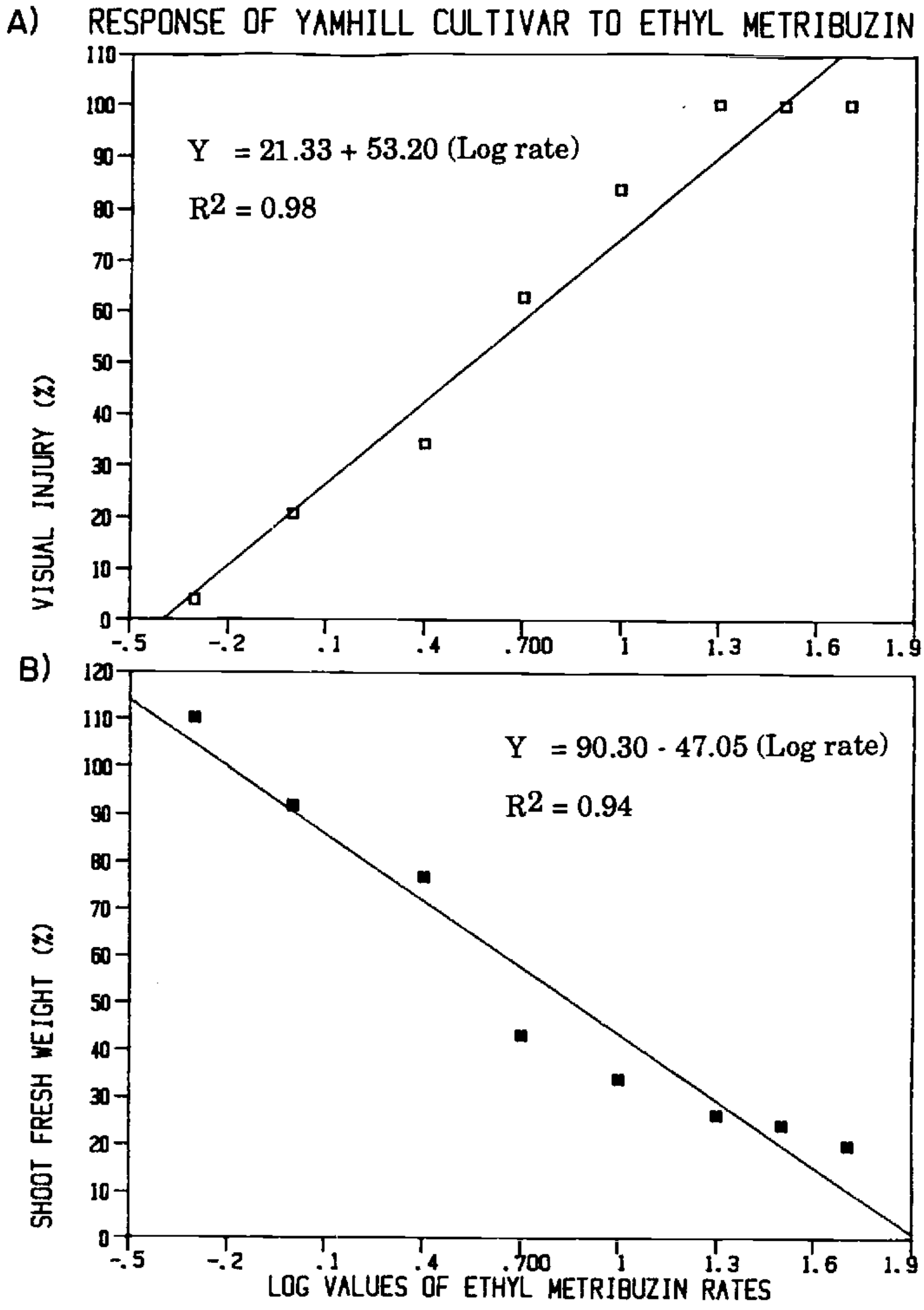


Figure 1.15: Evaluation of GR50 of ethyl metribuzin for Yamhill winter wheat in nutrient solution.
(a) Using data of visual injury (%)
(b) Using data of seedling fresh weight (%)

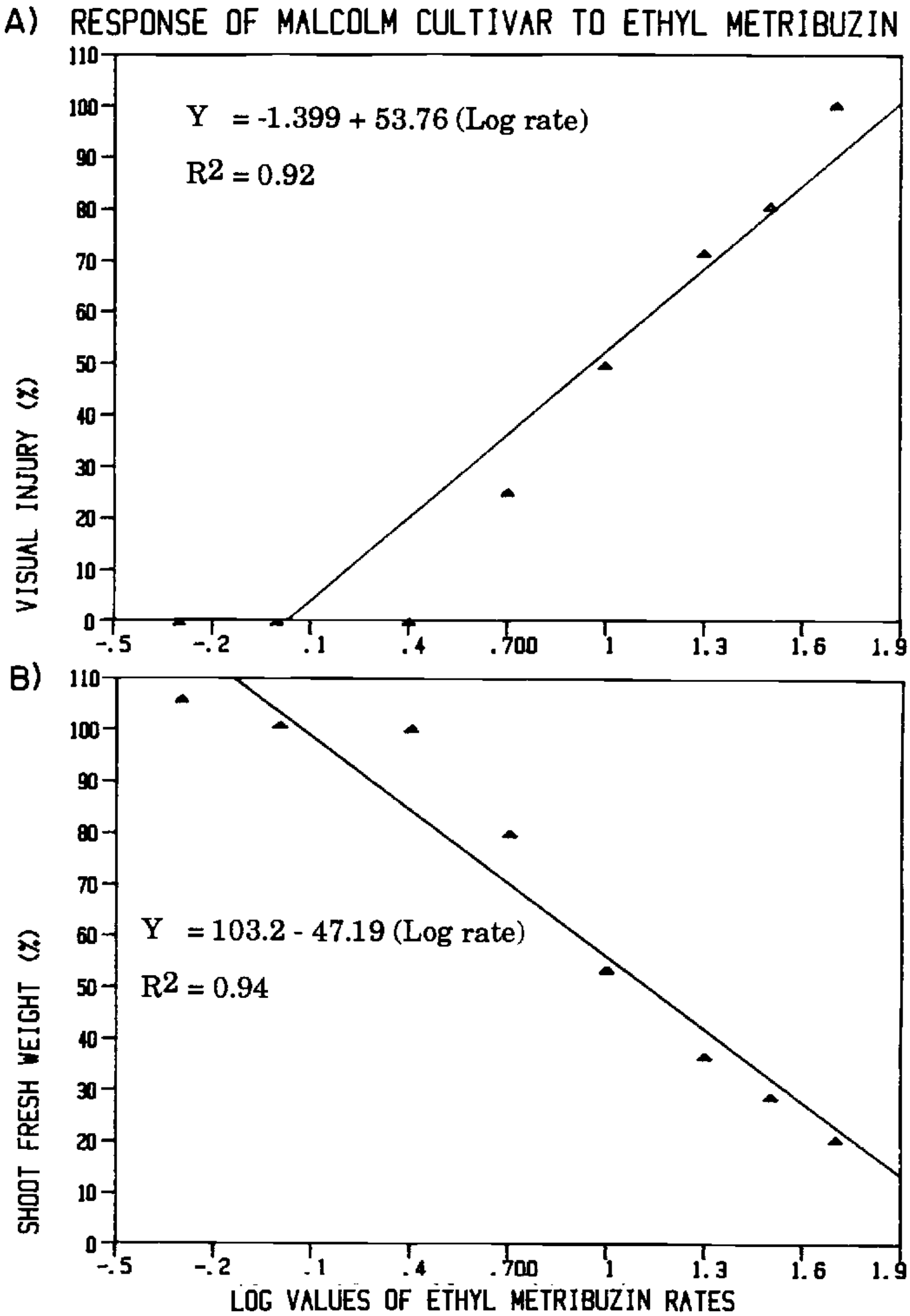


Figure 1.16: Evaluation of GR50 of ethyl metribuzin for Malcolm winter wheat in nutrient solution.
(a) Using data of visual injury (%)
(b) Using data of seedling fresh weight (%)

Mode of herbicide uptake: The data presented in Table 1.6 indicate that uptake of metribuzin and its analog ethyl metribuzin by wheat is through the roots. These results were based on visible injury and reduction in fresh weight of the wheat plants. When the herbicides were applied to the soil only ratings of visible injury were 60, 57, 99, and 100% for Stephens, Malcolm, Hill 81, and Yamhill respectively, in contrast to 4, 3, 14, and 12% injury to the same species where the herbicides were applied only to the foliage. When the herbicides were applied to both the foliage and the soil results were similar to the soil application. These observations on visible injury were consistent with the results recorded for reduction in fresh weight of the above mentioned plants as compared to untreated check plants (Table 1.6).

The results generated in from these experiments provided valuable information for applying metribuzin and ethyl metribuzin for effective control of undesired plants. On the basis of the above results it can be concluded that both the herbicides under investigation are similar in their mode of uptake by plants, i.e., by roots. Therefore, effective control of weeds will depend on the presence of herbicides in the root zone of the weeds. Differences in seeding depth and all other factors related to the movement of the herbicide in the root zone of weeds could have a great impact on efficient weed control.

Table 1.6. Mode of uptake of metribuzin and ethyl metribuzin by winter wheat.

Cultivar	Methods of herbicide application		
	Soil + Foliage	Foliage Only	Soil Only
	-----Plant injury %-----		
Stephens	62 b	4 e	60 bc
Hill 81	100 a	14 d	99 a
Yamhill	100 a	12 d	100 a
Malcolm	60 b	3 e	57 c
	-----Seedling fresh weight % of check-----		
Stephens	48 b	96 a	46 b
Hill 81	22 c	94 a	22 c
Yamhill	15 c	90 a	21 c
Malcolm	46 b	96 a	50 b

a) Each figure is an average of two experiments and each experiment consisted of four replications.

b) Means within a column followed by the same letter are not significantly different at 5% level of significance according to Fisher's protected LSD Test.

c) LSD value at 5% significance level for visible plant injury is 11.93.

d) LSD value at 5% level of significance for seedling fresh weight is 3.33.

Varietal differences in nutrient solution uptake: Root uptake of herbicide by the four winter wheat cultivars was measured by replacing absorbed nutrient solution with water at regular time intervals.

The data presented in Table 1.7 indicate that there were highly significant differences among cultivars in their ability to absorb nutrient solution with different concentrations of metribuzin and ethyl metribuzin. It was noted that an increase in herbicide concentration in nutrient solution resulted in a decrease in uptake by the plants of all cultivars. These differences were more evident at lower rates of herbicide application where tolerant cultivars Stephens and Malcolm seemed to take up more nutrient solution. This is also supported by the data presented in Table 1.4 which indicate that at lower concentrations of the herbicides stimulatory effects (more plant growth) in Stephens and Malcolm were observed. The data in Table 1.7 correlate well with the observations recorded for fresh weight of plants, which can be explained as, at lower concentration of herbicides plant growth was stimulated which resulted more uptake of nutrient solution or may be vise versa, that with the more increase in uptake of nutrient solution more healthy plants were achieved. The increase in nutrient solution uptake recorded was up to 19% of the check plants in Malcolm, 12% in Stephens, 16% in Yamhill, and 4% in Hill 81. The differences in uptake were statistically significant at lower concentrations of herbicides at 1% level of significance but as the systematic injury was increased to the plants of all cultivars with the increase in herbicide concentration, no differences in uptake among cultivars were found. But on overall basis Malcolm uptake recorded was 21%, 25%, and 16% more than Hill 81, Yamhill, and Stephens respectively. Differences in uptake between herbicides were also noted and those plants which were applied with ethyl metribuzin, 10% more uptake of nutrient solution was recorded than those plants which received metribuzin application. This decrease in uptake of nutrient solution in case of metribuzin may be was due to more injury to plants caused by this herbicide. These differences in uptake between metribuzin and ethyl metribuzin were statisticaly different at 1% level of significance.

Table 1.7. Differential uptake of metribuzin and ethyl metribuzin by four winter wheat cultivars in nutrient solution.

		Cultivars			
Herbicide	Rate	Stephens	Hill 81	Yamhill	Malcolm
	-- uM --	absorption % of check			
Metribuzin	0.05	104 a-d	94 cde	103 bcd	108 abc
	0.10	96 cde	87 ef	107 abc	115 ab
	0.50	69 g-k	48 o-t	62 h-p	94 cde
	1.00	45 q-t	50 n-t	49 n-t	61 i-p
	2.50	55 j-s	47 p-t	52 m-t	52 m-t
	5.00	68 g-l	70 g-j	42 s-t	42 rst
	10.00	49 n-t	71 g-j	40 s-t	63 h-o
	25.00	62 h-p	70 g-j	59 i-q	56 k-s
Ethyl Metribuzin	0.50	82 efg	104 abc	116 ab	109 abc
	1.00	112 ab	73 f-i	82 efg	119 a
	2.50	78 fgh	58 i-r	81 efg	95 cde
	5.00	59 i-q	52 m-t	54 k-s	88 def
	10.00	81 efg	69 g-k	64 h-n	105 abc
	20.00	61 i-p	62 h-p	59 i-q	81 efg
	30.00	64 h-n	67 g-m	47 p-t	63 h-o
	50.00	53 l-t	61 i-p	38 t	61 i-p

a) Each figure is an average of two experiments and each experiment consists of three replications.

b) Means within a column followed by the same letter are not significantly different at 5% level of significance according to Fisher's Protected LSD test.

A herbicide screening technique for wheat: The data presented in Table 1.8 indicated very evident differences in seed germination among different wheat cultivars. Malcolm performed best with 100% seed germination and followed by Stephens, Yamhill, and Hill 81 with a seed germination of 99%, 68%, and 40% respectively. These differences in seed germination among different cultivars were statistically significant at 5% level of significance. When Fisher's Protected LSD Test was applied to separate the means of cultivars under investigation, Malcolm and Stephens were found to be similar in their response to herbicides tested. These two cultivars were significantly superior to Yamhill which was also significantly better than Hill 81 in germination performance at 5% significant level. The consistent results in these two experiments indicated that this technique can be used confidently for quick estimation of cultivar response against soil applied herbicides, when ever needed, either before planting or before herbicide spray. If the technique works as well for other herbicides, it would be a valuable, time saving method.

Table 1.8. Germination of seeds of different wheat cultivars in 2 uM of metribuzin and 10 uM of ethyl metribuzin in petridishes.

	Replications						
	Experiment #1			Experiment #2			
Cultivars	I	II	III	I	II	III	Avg
	------------------No. of seeds germinated------------------						
Metribuzin 2 uM							
Stephens	10	10	10	9	10	10	9.8 a
Hill 81	5	5	4	3	5	4	4.3 c
Yamhill	8	7	7	6	6	7	6.8 b
Malcolm	10	10	10	10	10	10	10.0 a
Ethyl Metribuzin 10 uM							
Stephens	10	10	10	10	10	10	10.0 a
Hill 81	2	4	3	4	4	5	3.7 c
Yamhill	6	7	7	6	8	6	6.7 b
Malcolm	10	10	10	10	10	10	10.0 a

Table 1.9: Analysis of variance of Appendix Table 1.8.

SOV	DF	SS	MS	F ratio	
Replications	5	2.17	0.433	1.12	NS
Herbicides	1	0.33	0.333	0.86	NS
Cultivars	3	297.50	99.167	257.10	**
Herb * Cultivar	3	1.17	0.389	1.01	NS
Error	35	13.50	0.386		

a) Means within a column followed by the same letter are not significantly different at 5% level of significance according to Fisher's Protected LSD Test.
b) NS: Non significant at 5% level of significance.
c) ** Highly significant at 1% level of significance.
d) Herb: Herbicides.

CONCLUSIONS

Metribuzin is currently registered for use in many crops, but cultivars of several crops have been reported to differ in their response to this herbicide. Because of these differences in varietal tolerance, metribuzin can be applied to a number of cultivars. Therefore, other herbicides such as the ethylthio analog of metribuzin are under investigation.

The studies were conducted to investigate the acceptable cultivar tolerance of metribuzin and ethyl metribuzin, mode of uptake, and differences in absorption of these herbicides as possible reasons for differential tolerance in wheat cultivars. As a result of experiments conducted on wheat growing in greenhouse soil and in nutrient solution, winter wheat cultivars Stephens and Malcolm were found approximately twice as tolerant to metribuzin and ethyl metribuzin as susceptible cultivars Hill 81 and Yamhill. Metribuzin also was approximately five times more toxic than ethyl metribuzin. Herbicide rates required to cause a 50% growth reduction based on visual assessment were less than rates required to reduce fresh weight by 50%.

Stimulated growth of all cultivars was noted at lower rates of both the herbicides under study, which indicate that at lower concentrations, these herbicides work as plant growth regulators and exert a hormesis effect. These results were consistent with the findings, reported by Wiedman and Appleby (112).

Uptake of metribuzin and ethyl metribuzin was observed to be almost entirely through roots. This information should help growers use either herbicide , or a combination of both, against weeds with roots at different depths than wheat.

Cultivars under study did not show differences in nutrient solution absorption. However, more solution absorption was noted at lower concentrations of herbicides, and with the increase in plant injury at higher herbicide rates, overall absorption was decreased. This indicates that differences in the cultivar's tolerance to metribuzin and ethyl metribuzin is due to physiological differences and not to differences in absorption. Therefore, differences in herbicide metabolism by these cultivars should be studied as a basis for differences in tolerance.

CHAPTER TWO

Influence of Herbicide Injury on the Yield Potential of Winter Wheat Cultivars.

INTRODUCTION

Food security is a fundamental objective for mankind. To sustain the necessary agricultural growth and to achieve this objective, it is essential to overcome the undulations in production. The reduction in agricultural productions is mainly due to weather fluctuations and pest epidemics, which are often inter-related.

Conditions which favor growth of crops often favor the multiplication and spread of weeds because one species cannot utilize all the available resources in a habitat. Unwanted species take advantage of these niches. Hence, weed control is the management of weeds and crops by economically and ecologically sound measures. It is intended to manipulate the ecological niches to allow the utilization, by the crop, of available resources and to prevent other species from competing for those resources.

Potential crop losses and inputs required for weed control vary with crop tolerance to weeds, cropping system, and environmental conditions of the site. The rapid development of selective herbicides has provided a new major field of technology. Although herbicides offer an effective and economical means of weed control, certain risks such as crop injury are inherent in their use. All herbicides are potentially phytotoxic, if applied at high enough dosages.

In recent years, new wheat cultivars, particularly the day length-insensitive, high yielding, semi-dwarf wheat cultivars, have been introduced in many countries. These cultivars display their high yielding potential when associated with a proper package of practices. Two major components of the management practices are fertilizers and weed control. Response of wheat cultivars to fertilizers has been well-documented; however, their reaction to herbicides has not been given enough attention because evaluation of herbicide injury to wheat is difficult for both researchers and growers. This difficulty involves estimating the effect that a given type and degree of injury will have on yield. Often the growers destroy an injured crop and replant. However, recovery can be such that maintaining the original crop would be more economical.

Herbicide injury to wheat is common, depending on the cultivar used, environmental conditions, yield, and other associated factors. In many instances, weed competition makes it difficult to determine how much of the yield loss can be attributed to the herbicide. A generalized relationship between injury level and yield response can be established in weed free experiments by observing the injury patterns which result from application of different rates of herbicide. The primary objective of this research was to correlate the degree of injury by metribuzin and ethyl metribuzin with the yield and major yield contributing components of four winter wheat cultivars under study.

MATERIALS AND METHODS

Two field experiments to investigate the effect of two herbicides on the yield and yield components of four winter wheat cultivars were conducted at the Hyslop experiment station, Corvallis, and Sherman experiment station, Moro during the 1986-87 crop season.

The soil at Hyslop Farm is a Woodburn silt loam (fine silty, mixed, mesic Aquultic Agrixeroll). This soil is moderately well drained. The mechanical analysis of this soil in the Ap horizon (0-18 cm) is 9% sand, 70% silt, and 21% clay with 3% organic matter, pH of 5.4, and cation exchange capacity of about 15.5 meq/100gm. At Sherman experiment station the soil is Walla Walla silt loam. The mechanical analysis of this soil in the Ap horizon (0-30 cm) is 24% sand, 62% silt, and 14% clay, with 1.2% organic matter, pH of 6.6, and cation exchange capacity of about 10.4 meq/100gm. Detailed meteorological data of crop season for both locations is given in Appendix Tables 1 and 2.

The experiment consisted of four genetically diverse soft white winter wheat cultivars, Stephens, Hill 81, Yamhill, and Malcolm, and two herbicides technically known as metribuzin, which is in common use and ethyl metribuzin,a new hope against downy brome in winter wheat.

Commercial products Lexone (75% metribuzin dry flowable) @ 0.22 kg ai/ha, and 0.45 kg ai/ha and Seige (50% ethyl metribuzin dry flowable) @ 1.12 kg ai/ha, 2.24 kg ai/ha were sprayed at early tillering stage of wheat. Water was used as herbicide carrier and a CP3 knapsack sprayer with a four nozzle boom was used for herbicide application.

The experiment was laid out in Randomized Complete Block Design with a factorial arrangement of treatments. The treatments were replicated four times. The crop was sown on a well prepared seed bed in 30 cm and 35 cm apart rows on October 14, 1986 and September 29, 1986 at Hyslop and Moro respectively. Seed rate used was 100 kg/ha or 90 gm per plot at Hyslop and 60 gm per plot at Moro which is standard for the region. Plot size used was 2.1 by 6 m and 1.8 by 6 m at Hyslop and Moro, respectively. Planting was done by an Oyjord planter. At the Hyslop farm, urea fertilizer (46-0-0) was applied at the rate of 100 kg N/ha in a split application; one-half at planting and the other half at a late tillering stage. At Moro, nitrogen fertilizer at the rate of 60 kg N/ha was applied in a single application before planting.

All check plots were kept weed free by hand weeding when and where necessary to avoid confounding possible herbicide injury effects with the effects of weed competition. All other agronomic practices were normal and uniform. A randomly selected unit area of 0.9 by 1 m and 1 by 1 m was harvested at Hyslop and Moro, respectively, by hand to collect data about crop yield and yield components. Data for spikelets per spike, grains per spike, and spike length were recorded from ten spikes randomly selected from each plot.

Observations on the following plant characters were recorded during the course of the study:

1. Visual crop injury level (%): In weed science visual observations provide information about changes in the normal conditions and are a quick indication of how different inputs affect target species in certain situations. This deviation from the normal might be positive or negative but it clearly indicates the behavior of herbicides on weeds or crops without using more complicated methods of measurement. Therefore, visual ratings on crop injury were made 4 weeks following

herbicide application. A scale of 0 to 100 was used with 0 = no injury and 100 = complete kill.

2 . Plant height at maturity: Just prior to harvest the average plant height in each plot was measured in centimeters (cm) as the distance from the soil surface to the tip of the uppermost spikelet, disregarding awns, when present.

3 . Number of productive heads per unit area: All productive tillers in the harvested area were counted.

4 . Spike length:

5 . Number of spikelets per spike:

6 . Number of grains per spike:

7 . 1000 - Grain weight: 1000 kernels were counted from the bulk seed of each plot by using an automatic seed counter. These grains were then weighed and recorded in grams.

8 . Biological yield: Biological yield was determined in gm per unit area and then converted to kg per hectare.

9. Grain yield: Harvested material was threshed, using a Vogel thresher and grain per unit area were weighed in grams and converted to kg per hectare.

10. Harvest Index: harvest index value was calculated by using the following formula.

$$\text{H.I.} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

Biological yield was determined by weighing the whole plant biomass harvested from a unit area and the economic yield was calculated by weighing the grains obtained by threshing the harvested material.

11. Protein content in grain: The percent protein for each sample from the bulk seed used for yield analysis was determined using a Technicon Industrial Systems Infra Alyzer 400.

The data so collected were analysed statistically by using analysis of variance technique, and Fisher's Protected Least Significant Difference (LSD) method in order to test the significance of treatment means.

RESULTS AND DISCUSSIONS

Visual Injury Level: Visible injury to the crop was recorded 4 weeks after the herbicide application and a significant variation in the level of tolerance to the herbicides used was found among the wheat cultivars under investigation. At the Hyslop farm injury levels recorded for Hill 81 and Yamhill were up to 28 and 29% respectively, depending on the rates used, however, Stephens and Malcolm showed no sign of injury (Appendix Table 20). The same varietal behavior was observed in response to both of the chemicals used. Metribuzin @ 0.22 kg/ha and ethyl metribuzin @ 1.2 kg/ha and metribuzin @ 0.45 kg/ha and ethyl metribuzin @ 2.4 kg/ha were approximately equal in toxicity. As the crop matured, the symptoms disappeared and surviving plants made normal growth. The lower rate of metribuzin and ethyl metribuzin used in the experiment was safe for all the cultivars under study because injury level observed was less than 10%.

At Moro, two visual observations were made of crop injury; one prior to snow fall and the second after the snow had melted. Differences were small. Injury to the crop at this location was greater than at Hyslop farm for the same cultivars at the same rates of the chemicals. We were able to place the cultivars under investigation into two categories. Hill 81 and Yamhill were quite sensitive as indicated by injury ratings up to 71 and 84% respectively, while Stephens and Malcolm showed only 21 and 15 % injury, respectively. Stephens and Malcolm were more tolerant to ethyl metribuzin than metribuzin but the margin was small (Appendix Table 24). Statistically there was a highly significant interaction between the herbicides, rates used, and cultivars. At later stages, the crop partially recovered but injury to Hill 81 and Yamhill was so severe that complete recovery was not possible. The severe injury observed at Moro might be due to lighter soils, high soil pH and low temperature prior to herbicide application. These results were quite in accordance with the observations by other researchers (51, 52, 60, 61, 84, 89, 92, 94, 109). Differences in precipitation between the locations might have played a significant role in the level of crop injury, as was observed previously (63, 92, 108). High organic matter at Hyslop farm as compared to Moro also played a role in greater tolerance of the varieties. More crop tolerance in soils with high organic matter might be due to more adsorption of herbicide which reduces the availability of herbicide in the soil solution. Similar results have been reported in the previous studies (14, 89, 94, 109).

Plant height: The height of a plant is a function of both the genetic make up and the environmental conditions. It is common for herbicides to cause reduction in plant height (9). This reduction in height can have both positive and negative effects. Too much depression in plant growth might cause less dry matter production and may decrease grain yield. But more plant height can lead to lodging and more utilization of photosynthates for vegetative growth at the expense of seed yield.

In this experiment plant height was recorded at harvesting time. The data presented in Appendix Tables 26 and 28 reveal that no reduction in plant height was observed. This indicates that crop injury may affect certain plant parts but surviving tillers can attain normal height.

Number of Productive Heads: As seen in Appendix Table 30 the herbicides in the Hyslop experiment did not reduce the number of productive heads at harvest. However, in the Moro experiment the number of productive tillers on Yamhill and Hill 81 cultivars was reduced by 60 and 26% respectively, when counts from the four herbicide treatments were averaged (Appendix

Table 32). The difference in response at the two locations is probably due to the less adsorptive soil at the Moro location. The number of productive tillers corresponded nicely with evaluations of visible injury. At the Moro location, Malcolm cultivar produced approximately the same number of productive heads in the treated plots as in the non-treated plots, but the Stephens cultivar produced an average of 26% more heads in treated plots than in untreated plots. Similar results were recorded at Hyslop, where 7 and 10% more productive heads were counted in case of Stephens and Malcolm cultivars, respectively, with the application of herbicides.

Spike Length: At Hyslop an increase of 13, 11, and 20% in spike length was observed in Stephens, Hill 81 and Yamhill compared to their check treatment but a 10% reduction in spike length was recorded for Malcolm. The same trend was noted at all rates of both herbicides used (Appendix Table 34). At Moro, an increase in spike length was observed in all cultivars under study. Hill 81 led the others with an increase of 26% over untreated plants compared to 12, 9, and 14% increase in spike length for Stephens, Yamhill and Malcolm, respectively (Appendix Table 36).

Number of Spikelets per Spike: Spikelets per spike is an important yield component of wheat. The data presented in Appendix Tables 38 and 40 indicate that there were no statistically significant difference in number of spikelets per spike at 5% level of significance. There are trends in the data that show an increase in number of spikelets per spike in plots treated with the low rates of either herbicide. No trends were apparent as a result of the high rates of the herbicides.

Number of Grains per Spike: Grains per spike has a direct bearing on the final grain yield of wheat and is affected directly by various agronomic practices as well as certain chemicals. In untreated plots at Moro, Stephens and Malcolm produced 50% fewer grains per spike than at Hyslop while this reduction in grains per spike was approximately 25% in Hill 81 and Yamhill at Moro. As is evident from the data in Appendix Tables 42 and 44, a considerable increase in the number of grains per spike was noted among the various treatments when compared to check plots at both locations. However, this increase was statistically non significant at 5% level of significance among the treated plots. At Moro, this increase in grain number was observed in all herbicide treatments. On an average, Hill 81 treated with herbicides produced 33% more grains per spike compared to non treated plants, while Stephens, Yamhill, and Malcolm increased 26, 22, and 21% respectively. At Hyslop, Hill 81 treated with herbicide produced an average of 27% more grains than its check. An increase of 7 and 10% in grain number was also observed in case of Stephens and Yamhill, while Malcolm was affected adversely by the herbicide application and a reduction of 6% in grain number was observed. This decrease was noted at all levels of herbicide application. However, as a general trend, higher rates of both herbicides tended to increase the number of grains per spike. The average increase in grain number was greater at Moro than at Hyslop. The increase might be due to a decrease in number of tillers per unit area in the case of susceptible varieties. This is supported by the fact that the variety which had the most visible injury had the greatest number of grains. This may be due to less partitioning of dry matter towards vegetative growth and more to reproductive growth. Best performance of Hill 81 is also supported by the data presented in Appendix Table 40 in which more spikelets per spike were observed in this cultivar as compared to its check and other varieties under study.

<u>1000 Grain Weight:</u> This is a major agronomic characteristic contributing to the final yield. The analysis of variance of the data presented in Appendix Tables 46 and 48 indicate that all treated plots produced grains with the same weight as their untreated check plots at both locations. However, at Hyslop on the overall performance of cultivars, Hill 81, Yamhill, and Malcolm produced 1, 7, and 1% heavier grains respectively compared to their control plots and a 6% decrease in grain weight was observed in case of Stephens cultivar. At this location, these differences between cultivar grain weight were statistically significant at 1% level. The same trend of increase or decrease in grain weight was observed at Moro. At Moro, Hill 81, Yamhill and Malcolm produced 2, 1, and 1% heavier grains,respectively than their checks and a decrease of 5% in grain weight was observed in case of Stephens cultivar at this location as well. It also is evident from the data that there was a slight decrease in grain weight in response to higher concentrations of herbicides. This decrease was consistent in all cultivars at both locations. However, both herbicides used have the quite similar trend of positive or negative impact on cultivars.

<u>Biological Yield:</u> The data pertaining to biological yield are in Appendix Table 50 and show that based on the average of four replications the four cultivars i.e. Stephens, Hill 81, Yamhill and Malcolm produced 7, 1, 10, and 4% more biomass respectively compared to their check treatment at Hyslop. However, these numbers were not statistically different at the 5% significance level. At Moro, both tolerant varieties Stephens and Malcolm produced 29 and 12% more biological yield compared to their check

treatments, but a reduction in biomass of 3 and 31% was observed for the susceptible varieties Hill 81 and Yamhill, respectively (Appendix Table 52). These differences in biomass were statistically different at the 1% level of significance. At Moro, an increase in biomass of Stephens and Malcolm and reduction of Hill 81 and Yamhill was consistent with the data on visible injury in Appendix Table 24. Injury of up to 70% to Yamhill cultivar was followed by Hill 81 which had an average injury level of 40% in treated plots, while Stephens and Malcolm were unharmed. A strong negative correlation of -0.7 was found in plant injury level and biological yield. This finding is supported by data recorded at Hyslop where no difference in biological yield was measured and initial crop injury levels were low. Higher rates of both herbicides tended to reduce the biological yield as compared to low rates used in the experiments at both locations.

Grain Yield: The final yield of a crop is the function of its individual yield components in response to the applied treatments and other environmental conditions. At Hyslop the grain yield (Appendix Table 54) by different varieties, treated with metribuzin and ethyl metribuzin at two rates indicate that an average increase of 24% in grain yield was produced by Yamhill. While the other cultivars produced approximately the same amount of grain in the treated plots as in untreated plots. In general, the herbicides did not reduce yields. However, a 3% reduction in grain yield was observed for Hill 81. At Hyslop, Yamhill produced more grain than the other cultivars at all rates used of both herbicides. This might be associated with better fulfillment of genetic requirements at this location for that particular variety. It can also be explained that this increase in grain yield of Yamhill was the result of an increase in main yield components such as more spikelets per spike, heavier grains and more biological yield. The harvest index ratio also supports this increase in yield, as can be seen in Appendix Table 58, where treated plots of Yamhill had up to 26 % greater harvest index as compared to its check. That means the ratio of grain production per unit of biological yield is better than other cultivars used in the study, which had the same harvest index as their check.

At Moro, tolerant cultivars Stephens and Malcolm produced 21 and 15% more grain when treated with herbicides as compared to their handweeded check plots while susceptible varieties Hill 81 and Yamhill produced 14 and 39% less respectively compared to their untreated plots (Appendix Table 56).

It is likely that part of the yield difference noted at Moro was due to poor control of downy brome in the check plots. The herbicides controlled weeds in treated plots but handweeding was ineffective in the wheat rows in the check plots. Competition could have masked small effects of herbicides on the tolerant varieties but injury to susceptible varieties was great enough to override the effects of competition. Actual reduction in yield by the herbicides may have been greater than indicated by the data. This is supported by the fact that at Hyslop, all varieties had grain production similar to their check because at this location check plots had fewer weeds than at Moro.

At Moro, reduction in yield of Yamhill (39% average) is attributed to the herbicides and is consistent with the reduction in tillers (65% average) and decrease in biomass production compared to the other three cultivars used in the experiment. Hill 81 was also quite susceptible to the herbicides used as was demonstrated by an average reduction in yield of 14%. This reduction is attributed to the severe crop injury at the early plant growth stage which caused an average loss of 45% of the tillers compared to check. The other yield components of Hill 81 and Yamhill were similar to Stephens and Malcolm.

The observations of economic yield components indicated that initial crop injury beyond a certain level reduced yields but this reduction was primarily due to decrease in productive tillers. Otherwise there was no reduction of other components contributing to crop yield, rather an increase in yield components was observed in all cases. The other observation was that both the rates used in the investigation did not differ in their effects.

The estimation of losses made on the basis of crop injury was usually higher than the actual reduction in yield. Thus visual estimation of injury alone can not be relied on to give an indication of yield reduction. It is therefore necessary to use the actual yield for quantitative measurement of herbicidal injury.

Harvest Index: Harvest index is an indication of grain to straw ratio. At Hyslop, slight reductions of 8, 1, and 5% in harvest index were observed in the case of Stephens, Hill 81 and Malcolm, respectively. However, an increase of 14% was noted in case of Yamhill (Appendix Table 58). The same trend was observed at Moro. At this location, a reduction of harvest index to the extent of 5, 9, and 5% was observed in the case of Stephens, Hill 81 and Yamhill, respectively, while Malcolm had a 2% higher harvest index (Appendix Table 60). However, these differences were not of great importance. The decrease in harvest index at Hyslop is supported by the data in Appendix Tables 52 and 56 which show that biomass of all the cultivars was increased when treated with herbicides but a slight reduction in grain yield was observed in the case of Stephens, Hill 81, and Malcolm. But an increase in harvest index for Yamhill was closely correlated to the increase in grain yield of this cultivar at this location.

Protein Content of Grain: Protein content is a major quality component of grain. The analysis of variance for the data presented in Appendix Table 62 indicated highly significant increase in grain protein content of the cultivars over check plots at Hyslop. On an average, an increase of 8, 10, and 7% was measured for Stephens, Hill 81, and Yamhill, respectively but a 4% reduction in protein content was measured for Malcolm. The increase measured was significantly higher with ethyl metribuzin compared to metribuzin at 5% level of significance. It was also noted that with the increase in herbicide rate, protein content of grain was also increased.

The same trend of varietal reaction to protein was observed at Moro as was noted at Hyslop (Appendix Table 64). On an average, increases of 14, 15, 10, and 4% were recorded for Stephens, Hill 81, Yamhill and Malcolm, respectively. Overall gain in protein was more at Moro than at Hyslop. Hill 81 showed best performance at both locations while Malcolm gained the least. An increase in herbicide rate caused an increase in protein content at this location as well. This increase in protein content by using herbicides is supported by different studies (12, 21, 28, 29, 46).

CONCLUSIONS

With the development of new selective herbicides and the frequent change in commercial wheat cultivars, information on the relative tolerance of wheat cultivars to specific herbicides could help avoid crop injury. Information on relative tolerance of cultivars could also help plant breeders, making hybrid combinations for the development of future varieties, if higher levels of tolerance to specific herbicides are required. The response of four genotypically diverse wheat cultivars (Stephens, Hill 81, Yamhill, and Malcolm) to metribuzin and ethyl metribuzin herbicides was compared under field conditions at two locations (Hyslop and Moro) during the 1986-87 growing season. Grain yield and yield components were considered as a measure of herbicide effects compared to the check plots for each cultivar.

Differential yield responses were found among the four winter wheat cultivars, depending upon the environmental conditions and soil properties of the location. Stephens and Malcolm were classified as tolerant varieties whereas Hill 81 and Yamhill were susceptible. Higher injury to the susceptible varieties was observed in lighter soils with high pH and with less organic matter. The estimation of losses made on the basis of crop injury were generally higher than the actual reduction in yield. Thus, visual estimation of injury alone cannot be relied upon as an indication of potential yield reduction. Reduction in yield was primarily due to a decrease in productive tillers; otherwise there was no effect on other components contributing to crop yield. An increase in yield components was observed in most cases.

At Moro, an average increase of 21 and 15% in grain yield was observed in tolerant varieties Stephens and Malcolm, respectively, as compared to their handweeded check plots. It is likely that part of the yield differences noted at Moro were due to poor control of downy brome within the wheat rows of the check plots. With the application of these herbicides, grain protein content was increased up to 15% in all cultivars at both locations. More increase in protein was measured at Moro, where more crop injury was observed in susceptible cultivars than at Hyslop. This might be is due to more availability of herbicide to the plants. This was also supported by the fact that with the use of higher rates, more increase in protein was noted than at or with lower rates of the same herbicides.

CHAPTER THREE

Evaluation of Herbicide Interaction Between Metribuzin and Ethyl Metribuzin in Downy Brome (Bromus tectorum L.)

INTRODUCTION

Agrochemical mixtures such as herbicides with adjuvants, fertilizers, fungicides, insecticides, nematicides, or other herbicides are used routinely as part of modern pest management practices. Combining selected agrochemicals offers several potential advantages over the use of a single chemical, and some of them are discussed earlier in the review of literature.

However, there are many known instances of modification of the biological activity of one chemical brought about by the prior, simultaneous, or sequential application of another chemical to the same target species. When this occurs, it is commonly referred to as an interaction. This interaction could enhance or reduce the biological activity. To ensure the effectiveness and safety of combined applications of agrochemicals, the potential for adverse chemical interactions must be evaluated. Identification of agrochemicals that interact can help prevent problems in crop production.

Therefore, experiments were conducted: a) to determine the rates of metribuzin and ethyl metribuzin required to cause 50% reduction in growth of downy brome; b) to measure the joint action of the two herbicides, metribuzin and ethyl metribuzin against downy brome, which is a common weed in winter wheat production areas in the northwest of USA; and c) to compare different procedures commonly adapted to study the combined action of herbicides.

MATERIALS AND METHODS

Field experiment: An experiment was conducted in the fall of 1986 at Sherman Experiment Station in Moro, a research facility of Oregon State University in north central Oregon. The objective of the study was to investigate the joint action of two herbicides against downy brome, a common weed of winter wheat in that area. The downy brome seeds were planted on September 29, 1986, with a tractor-mounted drill to ensure a uniform stand of the weed. Row to row distance was 30 cm. Plots were 4.5 m long, and there were six rows of downy brome in each plot. Metribuzin and ethyl metribuzin were sprayed alone and in different combinations with a Geiz Hall knapsack sprayer on November 12, 1986, at the two to three leaf stage of downy brome. The center four rows of each plot were sprayed with a 1.2 m long boom equipped with four 8003 nozzles at 40 psi pressure. Rates of metribuzin and ethyl metribuzin used are in Table 3.1. These treatments were compared with an untreated check. The sprayer was rinsed with water three times after each herbicide application. The treatments were arranged in a randomized complete block design with four replications. Evaluation of visible injury to the plants was made on March 29, 1987. The data collected were subjected to analysis of variance and Colby's method of determining joint action of herbicides.

Greenhouse experiments: After the primary evaluation of metribuzin and ethyl metribuzin rates needed for effective control of downy brome, an investigation was conducted to study the combined action of these herbicides in a greenhouse of Oregon State University in January of 1987.

Six hundred g of greenhouse soil was added to 10 by 10 cm plastic pots and 10 seeds of downy brome were planted in them. These seeds were covered with a thin layer of greenhouse soil and water was provided by sub irrigation. The sunlight was supplemented with inflorescent tube light, and slow release fertilizer (analysis 10-10-10) was added to each pot to maintain the soil fertility. After seed germination, seedlings were thinned to five per pot. Rates of metribuzin and ethyl metribuzin used are mentioned in Table 3.2. Irrigation water was drained 24 hours before the application of the herbicide. Three weeks after planting, treatments were applied with a greenhouse sprayer at 207 Kpa pressure and with a 8002 nozzle. Water was used as a herbicide carrier at a rate of 300 L/ha. The pots were arranged in a randomized complete block design with four replications. The evaluation of visible injury to the plants was made 3 weeks after herbicide application, and plants were harvested to measure the fresh weight of seedlings. A similar experiment with the same treatments was started in February of 1987 to confirm the results of the first experiment.

The data collected were converted to percentage of check and were subjected to regression analysis to quantify the rate of herbicides required to cause a 50% reduction in downy brome vigor. Joint action of these herbicides was evaluated by using Colby's method and isoboles method of Tammes.

<u>Colby's Method:</u>

S. R. Colby introduced a mathematical formula for calculating the expected combined toxicity of herbicide mixtures. This formula was actually a simplification of Gowing's formula which involves several arithmetic operations to convert the data into percent values. Colby's formula is expressed as;

$$E = \frac{X\,Y}{100}$$

Where in our experiments:

X = Growth as a percent of check with herbicide metribuzin at P kg/ha.

Y = Growth as a percent of check with herbicide ethyl metribuzin at Q kg/ha.

E = Expected growth as a percent of check with herbicides metribuzin and ethyl metribuzin at P + Q kg/ha.

After calculating the data with the above mentioned formula results will be interpreted as; when the observed response is greater than expected, the combination is synergistic; when less than expected, it is antagonistic. If the observed and expected responses are equal, the combination is additive.

Isobole method of Tammes: An isobole is a line of equal effects. Points on the curves represent the dosage levels of combinations of chemical A and B required to produce identical, specified growth responses, e.g. 50% of control growth. For an additive response, each chemical can be substituted for the other in linear increments. For a synergistic response the increment level of one chemical substituted for the other is less than expected or, is less than that for the additive response, i.e., smaller total amounts of chemical are required to produce 50% of control growth. For an antagonistic response, the increment level of one chemical substituted for the other is greater than expected, based on an additive response; hence a greater amount of chemical is necessary to produce 50% of control growth.

This method provides information about the existence of an interaction, the nature of the interaction (synergism, antagonism, additive or independent), and the magnitude of deviation.

In these studies GR50 values were established by plotting the percent of seedling fresh weight of downy brome against logarithm of metribuzin and ethyl metribuzin rates to obtain best fit regression equations. Separate regression lines were established for each combination with a fixed rate of metribuzin or ethyl metribuzin. The interpolated values were then plotted graphically. Rates of metribuzin and ethyl metribuzin were transformed to their log values to get more uniform distribution of the data. Calculating GR50 values by regression equation is easier, and may be more practical, because it does not require transformation of data by probit analysis, but does require the plotting of percentage growth against the logarithm of each chemical concentration and interpolation of the values at the 50% growth for graphing the isobole. (A hypothetical picture of expected curves obtained by combined action of herbicides A & B is given in figure 3.0.

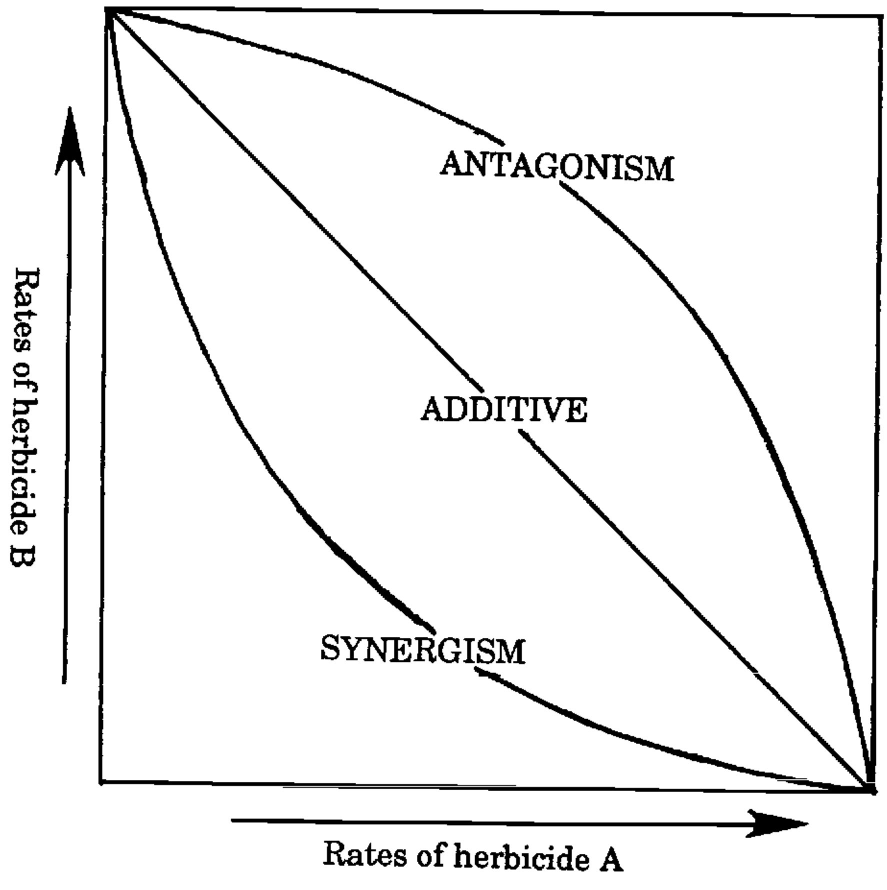


Figure 3.0: A perfect model of curves expected from plotting growth isobole, for combinations of herbicide A & B.

RESULTS AND DISCUSSIONS

Field experiment: The field experiment was analyzed using Colby's method and the response was observed as synergism. Data presented in Table 3.1 indicate that ethyl metribuzin enhances the activity of metribuzin when used in combination to control downy brome. Expected control values were less than observed control of downy brome at all levels of combinations under study. Maximum dosage of metribuzin and ethyl metribuzin used alone was 0.2 kg/ha and 1.00 kg/ha respectively. The control of downy brome was up to 81%, which was less than the control by many combinations of metribuzin and ethyl metribuzin at lower rates (Table 3.1). Complete control of downy brome was observed when 0.15 kg/ha of metribuzin was mixed with 0.75 kg/ha of ethyl metribuzin. However, statistically similar control of downy brome, i.e. 98% and 91%, was noted when 0.15 or 0.10 kg/ha metribuzin was mixed with 0.50 or 0.75 kg/ha of ethyl metribuzin, respectively. Therefore, considering the economics, these two treatments could be more effective and safer than 0.20 kg/ha of metribuzin or 1.00 kg/ha of ethyl metribuzin used alone or in combination at 0.15+0.75 kg/ha, respectively, in soils high in pH and low in organic matter. Of the combinations of herbicides used, the mixtures at moderate rates gave a synergistic response compared to high rates alone or in combination with low rate of the other chemical.

Combinations of metribuzin @ 0.10 and 0.05 kg/ha and ethyl metribuzin @ 0.50 and 0.75 kg/ha gave 86 and 84% downy brome control which was better than using metribuzin @ 0.20 kg/ha or ethyl metribuzin @ 1.00 kg/ha alone. But these differences were not statistically significant at 5% level of significance.

These conclusions seem probable from the data presented in Table 3.1. First, the combination of metribuzin and ethyl metribuzin appeared synergistic on downy brome. This synergism seemed to be greater at moderate concentrations of both herbicides. This might be due to more injury by single herbicide at higher rates which left less opportunity for the other herbicide in combination to show its effects.

Table 3.1. Herbicide interaction studies of metribuzin and ethyl metribuzin at Sherman Experiment Station, Moro with Colby's method. (Field experiment, data in Appendix Table 66)

Treatments		% reduction of growth			
Metri.	E.Metri	Observed		Expected	Interaction
-------- kg/ha --------					
0.20	-.-	81	bcd		
0.15	-.-	70	e		
0.10	-.-	58	f		
0.05	-.-	10	jk		
-.-	1.00	81	bcd		
-.-	0.75	78	cde		
-.-	0.50	21	hi		
-.-	0.25	11	ij		
0.15	0.75	100	a	93	+ 7
0.15	0.50	98	a	76	+ 22
0.15	0.25	76	cde	73	+ 3
0.10	0.75	91	ab	91	+ 0
0.10	0.50	86	bc	67	+ 19
0.10	0.25	73	de	63	+ 10
0.05	0.75	84	bc	80	+ 4
0.05	0.50	44	g	30	+ 14
0.05	0.25	30	h	20	+ 10

a) Each value of downy brome control is an average of four replications
b) Expected values are calculated with Colby's Method of herbicide interaction studies
c) Difference of expected response and observed response with a positive value (+) is an indicative of a synergistic response while a negative value (-) is indicative of an antagonistic response.
d) Means within a column followed by the same letter are not significantly different at 5% level of significance according to Fisher's Protected LSD Test.
e) LSD value at 5% level of significance is 10.20.

Greenhouse experiments: The fresh weights of downy brome seedlings treated with different combinations of metribuzin and ethyl metribuzin were converted to percent of check and are presented in Appendix Table 68. These data were first analysed with Colby's expected response method. The results indicated a synergistic or antagonistic response (Table 3.2) depending on the dosage. Combinations were shown to be synergistic at rates lower than the GR50 for each herbicide when used alone but were antagonistic at higher rates. Therefore, plant responses at extreme herbicide dosage can be exaggerated by this method. Because of the limitations of Colby's method (discussed in conclusions) and inconsistent results, the same data were analysed using the isobole method of Tammes. GR50 values for herbicide interactions, presented in Table 3.5 were graphically interpolated. The results obtained by using this method indicate that the response of downy brome to mixtures of metribuzin and ethyl metribuzin is additive (Figure 3.5).

The data in Appendix Table 68 for percent plant fresh weight were subjected to analysis of variance and highly significant differences were found among treatments. A 10% increase in plant fresh weight was observed at 0.01 kg/ha of metribuzin and 0.05 kg/ha of ethyl metribuzin which indicates that at sub-lethal dosage, both herbicides stimulate growth. These results were supported with a study by Wiedman and Appleby (112). Maximum reduction of 86% in fresh weight was observed when 0.07 kg/ha of metribuzin was mixed with 0.65 kg/ha of ethyl metribuzin, but this treatment was closely followed by many treatments involving herbicide mixtures. But almost all herbicide mixtures gave better control than their use alone at the same dose which is illustrated in Table 3.2 by using Fisher's Protected LSD Test and assigning different letters to each mean value.

Table 3.2. Herbicide interaction studies of metribuzin and ethyl metribuzin using Colby's method. (Greenhouse experiment, data in Appendix Table 68)

Treatments		Fresh weight % of check			
Metri.	E.Metri	Observed		Expected	Interaction
-------- kg/ha --------					
0.01	-.-	110	a		
0.02	-.-	98	b		
0.03	-.-	79	ef		
0.04	-.-	68	g		
0.05	-.-	54	j-m		
0.06	-.-	41	nop		
0.07	-.-	20	uvw		
0.08	-.-	18	vw		
-.-	0.05	110	a		
-.-	0.15	95	bc		
-.-	0.25	63	ghi		
-.-	0.35	52	klm		
-.-	0.45	38	opq		
-.-	0.55	32	qr		
-.-	0.65	21	uvw		
-.-	0.75	19	vw		
0.01	0.05	92	bc	121	+ 30
0.01	0.15	100	b	105	+ 5
0.01	0.25	60	h-k	69	+ 10
0.01	0.35	48	lmn	57	+ 9
0.01	0.45	35	opq	42	+ 6
0.01	0.55	30	q-t	35	+ 6
0.01	0.65	21	uvw	23	+ 2
0.01	0.75	18	vw	21	+ 3
0.02	0.05	88	cd	108	+ 20

Table 3.2 Cont;d.

Table 3.2 Cont,d.

Treatments		Fresh weight % of check			
Metri.	E.Metri	Observed		Expected	Interaction
--------- kg/ha --------					
0.02	0.15	81	de	93	+ 13
0.02	0.25	56	i-l	62	+ 6
0.02	0.35	41	nop	51	+ 10
0.02	0.45	31	qrs	37	+ 6
0.02	0.55	22	t-w	31	+ 9
0.02	0.65	16	vw	20	+ 4
0.02	0.75	16	vw	19	+ 3
0.03	0.05	71	fg	87	+ 16
0.03	0.15	67	gh	75	+ 8
0.03	0.25	46	mn	50	+ 3
0.03	0.35	27	r-u	41	+ 14
0.03	0.45	18	vw	30	+ 12
0.03	0.55	17	vw	25	+ 9
0.03	0.65	16	vw	16	+ 0
0.03	0.75	16	vw	15	- 1
0.04	0.05	60	hij	75	+ 15
0.04	0.15	54	j-m	65	+ 12
0.04	0.25	31	qrs	43	+ 12
0.04	0.35	24	s-v	35	+ 12
0.04	0.45	18	vw	26	+ 8
0.04	0.55	18	vw	22	+ 4
0.04	0.65	17	vw	14	- 3
0.04	0.75	17	vw	13	- 4
0.05	0.05	46	mn	59	+ 13
0.05	0.15	35	pqr	51	+ 17
0.05	0.25	23	s-v	34	+ 11
0.05	0.35	18	vw	28	+ 10
0.05	0.45	17	vw	20	+ 3
0.05	0.55	17	vw	17	+ 0
0.05	0.65	16	vw	11	- 5

Table 3.2 Cont,d.

Table 3.2 Cont.d.

0.05	0.75	15	w	10	- 5
0.06	0.05	43	no	45	+ 2
0.06	0.15	37	opq	39	+ 2
0.06	0.25	21	uvw	26	+ 5
0.06	0.35	16	vw	21	+ 6
0.06	0.45	17	vw	16	- 1
0.06	0.55	17	vw	13	- 4
0.06	0.65	17	vw	8	- 8
0.06	0.75	16	vw	8	- 8
0.07	0.05	21	uvw	21	+ 0
0.07	0.15	20	uvw	19	- 1
0.07	0.25	17	vw	12	- 5
0.07	0.35	18	vw	10	- 8
0.07	0.45	16	vw	7	- 9
0.07	0.55	16	vw	6	- 10
0.07	0.65	14	w	4	- 10
0.07	0.75	16	vw	4	- 12
0.08	0.05	19	uvw	20	+ 1
0.08	0.15	17	vw	17	+ 0
0.08	0.25	16	vw	11	- 5
0.08	0.35	18	vw	9	- 8
0.08	0.45	16	vw	7	- 9
0.08	0.55	17	vw	6	- 11
0.08	0.65	17	vw	4	- 13
0.08	0.75	16	vw	3	- 12

a) Each value of fresh weight is an average of two experiments. (Eight replications)
b) Expected values are calculated with Colby's Method of herbicide interaction studies
c) Difference of expected response and observed response with a positive value (+) is an indicative of a synergistic response while a negative value (-) is indicative of an antagonistic response.
d) Means within a column followed by the same letter are not significantly different at 5% level of significance according to fisher's protected LSD Test.
e) Lsd value at 5% level of significance is 8.17.

Table 3.3. Herbicide interaction studies of metribuzin and ethyl metribuzin using downy brome in greenhouse.

Herbicide	Ethyl metribuzin								
kg/ha	.00	.05	.15	.25	.35	.45	.55	.65	.75
Metribuzin	---------- Control % of check plants ----------								
0.00	0	6	20	51	60	78	82	96	97
0.01	0	12	26	54	65	81	87	98	100
0.02	17	25	33	58	73	83	94	100	100
0.03	38	43	46	67	87	96	100	100	100
0.04	49	53	59	84	94	100	100	100	100
0.05	61	68	80	95	99	100	100	100	100
0.06	71	74	83	96	100	100	100	100	100
0.07	91	96	98	100	100	100	100	100	100
0.08	94	98	100	100	100	100	100	100	100
	---------- Seedling fresh weight % of check plants ----------								
0.00	100	110	95	63	52	38	32	21	19
0.01	110	92	100	60	48	35	30	21	18
0.02	98	88	81	56	41	31	22	16	16
0.03	79	71	67	46	27	18	17	16	16
0.04	68	60	54	31	24	18	18	17	17
0.05	54	46	35	23	18	17	17	16	15
0.06	41	43	37	21	16	17	17	17	16
0.07	20	21	20	17	18	16	16	14	16
0.08	18	19	17	16	18	16	17	17	16

a) Each value is an average of two experiments. (Eight replications)

b) Data for downy brome control % of the check plants is presented in Appendix Table 66.

c) Data for plant fresh weight % of the check plants is presented in Appendix Table 68.

Table 3.4 : Calculations of GR 50 values for evaluating interaction of metribuzin and ethyl metribuzin.

Treatment (kg/ha)	Intercept	Slope	R^2	GR50
	-------- Log values -------			kg/ha
Metribuzin	-92.17	-107.604	0.92	0.05
Ethyl Metribuzin	10.46	-84.225	0.95	0.34
Metribuzin 0.01	12.74	-73.312	0.84	0.31
Metribuzin 0.02	8.11	-69.517	0.92	0.25
Metribuzin 0.03	5.73	-56.605	0.88	0.17
Metribuzin 0.04	7.74	-42.868	0.91	0.10
Metribuzin 0.05	8.87	-28.274	0.95	0.04
Metribuzin 0.06	9.71	-25.790	0.87	0.03
Ethyl Metribuzin 0.05	-67.59	-86.104	0.90	0.04
Ethyl metribuzin 0.15	-84.13	-95.174	0.97	0.04
Ethyl Metribuzin 0.25	-46.22	-56.167	0.93	0.02
Ethyl Metribuzin 0.35	-27.61	-37.833	0.93	0.009
Ethyl Metribuzin 0.45	-11.42	-22.771	0.86	0.002
Ethyl Metribuzin 0.55	-0.59	-13.932	0.82	0.0002

a) Data used for calculating GR50 values is of seedling fresh weight % of check presented in table 3.3. and extracted from Appendix Table 68.

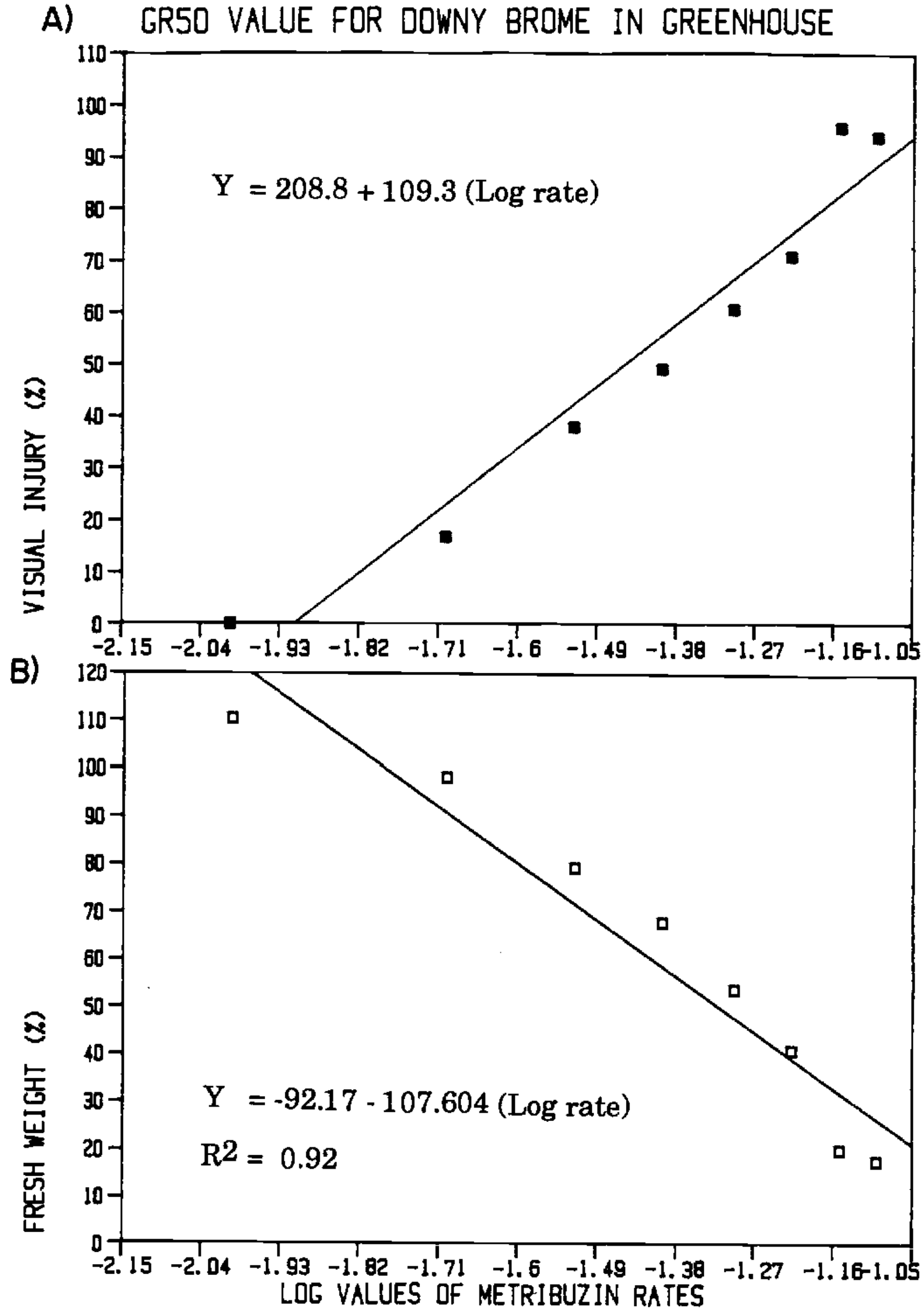


Figure 3.1: Evaluation of GR50 of metribuzin for downy brome in greenhouse.
(a) Using data of visual injury (%)
(b) Using data of seedling fresh weight (%)

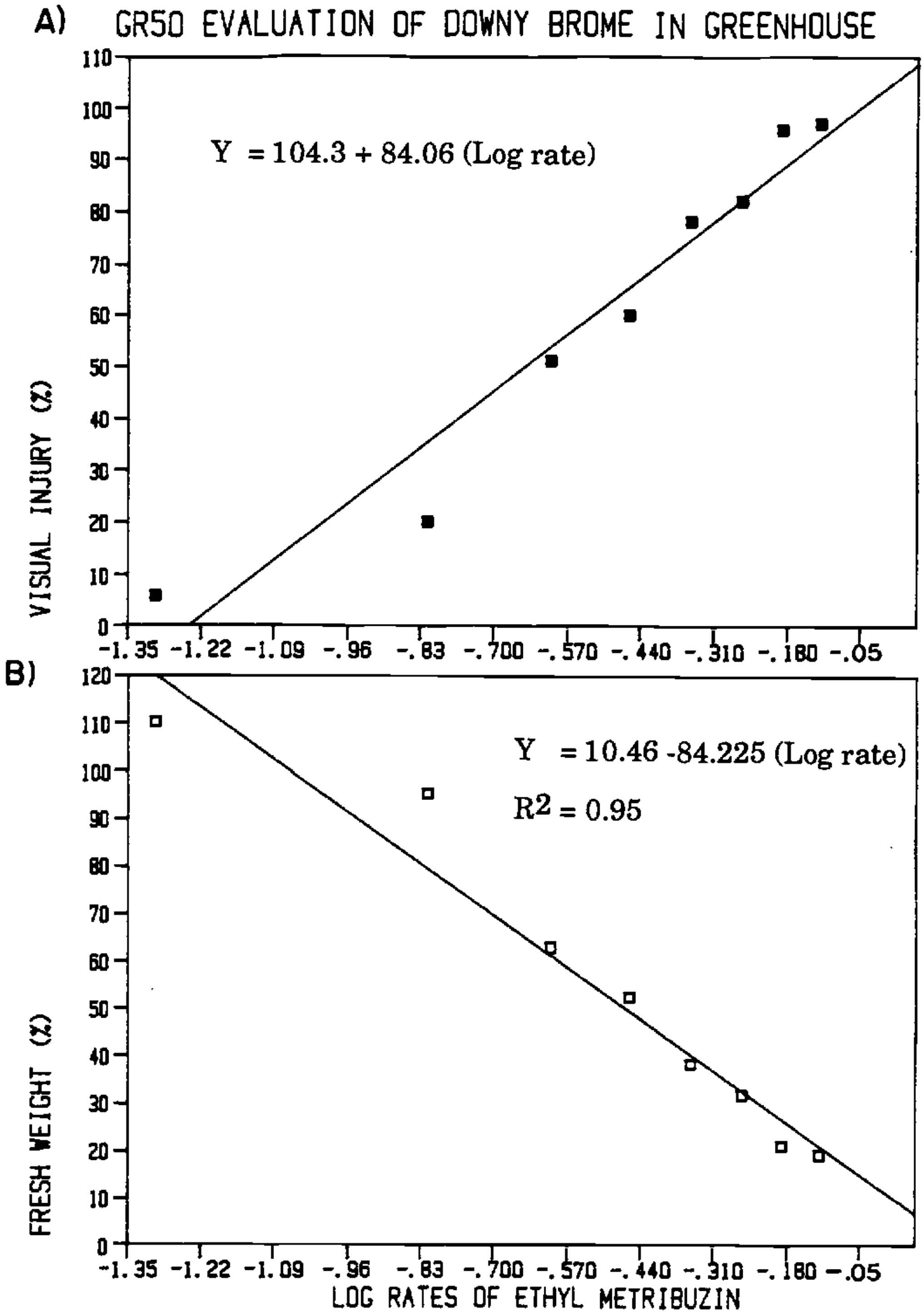


Figure 3.2: Evaluation of GR50 of ethyl metribuzin for downy brome in greenhouse.
(a) Using data of visual injury (%)
(b) Using data of seedling fresh weight (%)

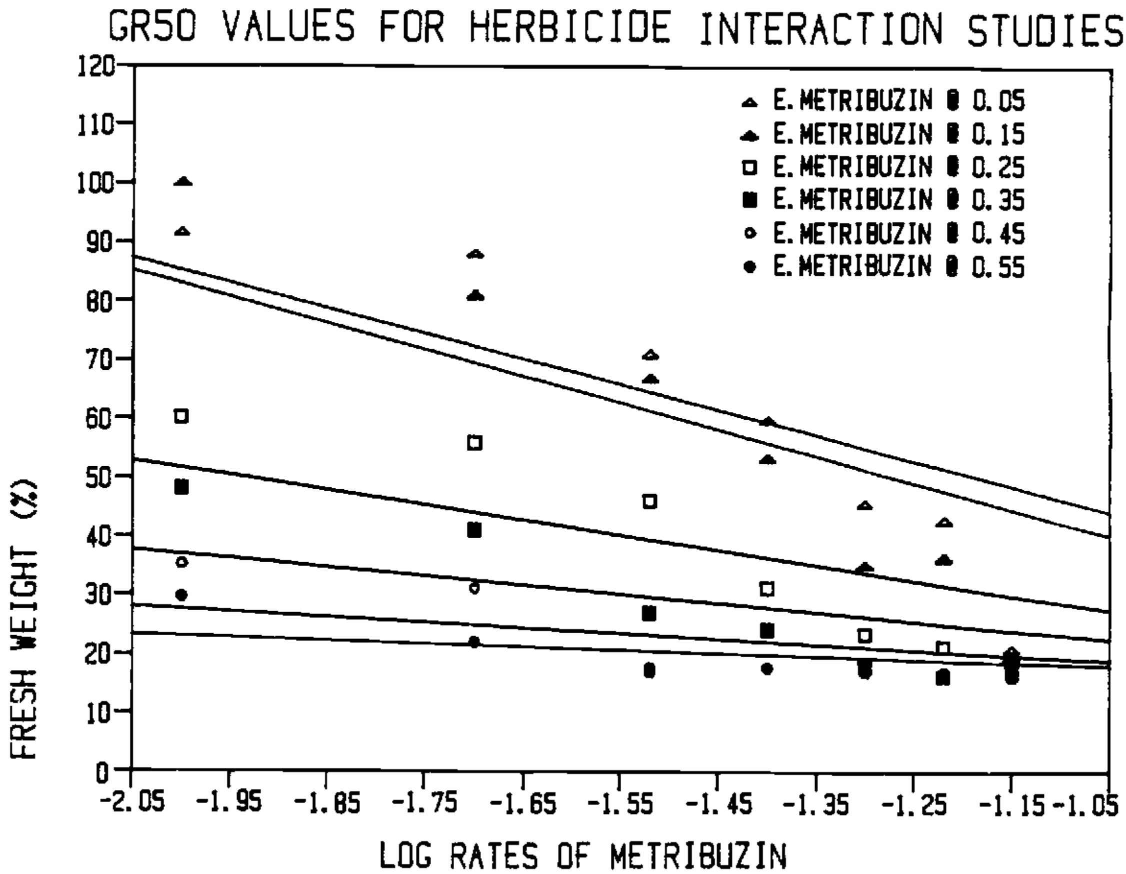


Figure 3.3: Evaluation of GR50 of metribuzin when used in combination with different rates of ethyl metribuzin against downy brome in greenhouse.

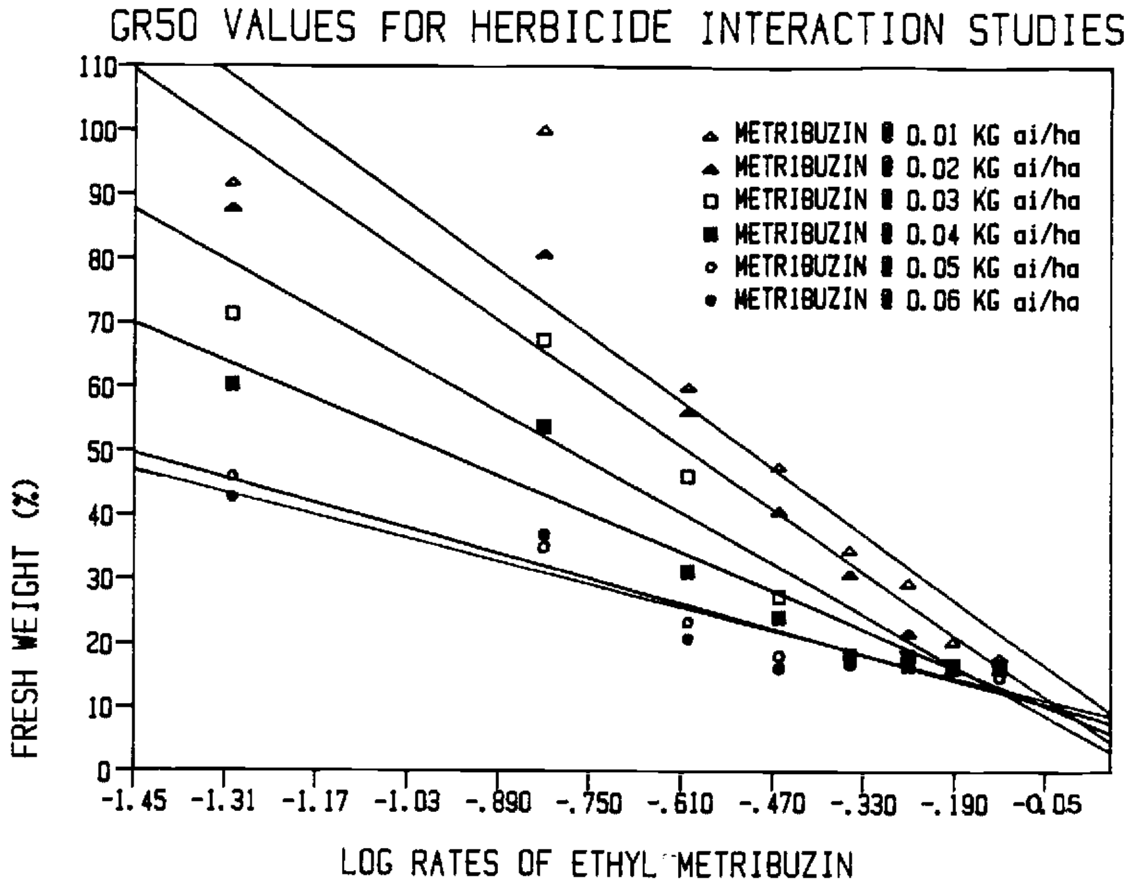


Figure 3.4: Evaluation of GR50 of ethyl metribuzin when used in combination with different rates of metribuzin against downy brome in greenhouse.

Table 3.5. GR50 values used for herbicide interaction studies of metribuzin and ethyl metribuzin with isobole method, using downy brome in greenhouse.

Herbicide kg/ha	Ethyl Metribuzin .00	.05	.15	.25	.35	.45	.55	R^2	GR50
Metribuzin	------------ Fresh weight % of check --------------								
0.00	100	110	95	63	52	38	32	.95	0.34
0.01	110	92	100	60	48	35	30	.84	0.31
0.02	98	88	81	56	41	31	22	.92	0.25
0.03	79	71	67	46	27	18	17	.88	0.17
0.04	68	60	54	31	24	18	18	.91	0.10
0.05	54	46	35	23	18	17	17	.95	0.04
0.06	41	43	37	21	16	17	17	.87	0.03
R^2	.92	.90	.97	.93	.93	.86	.82		
GR50	.05	.04	.04	.02	.009	.002	.0002	kg/ha	

a) Each value is an average of two experiments. (Eight replications)

c) Actual data for plant fresh weight % of the check plants is presented in Appendix Table 68.

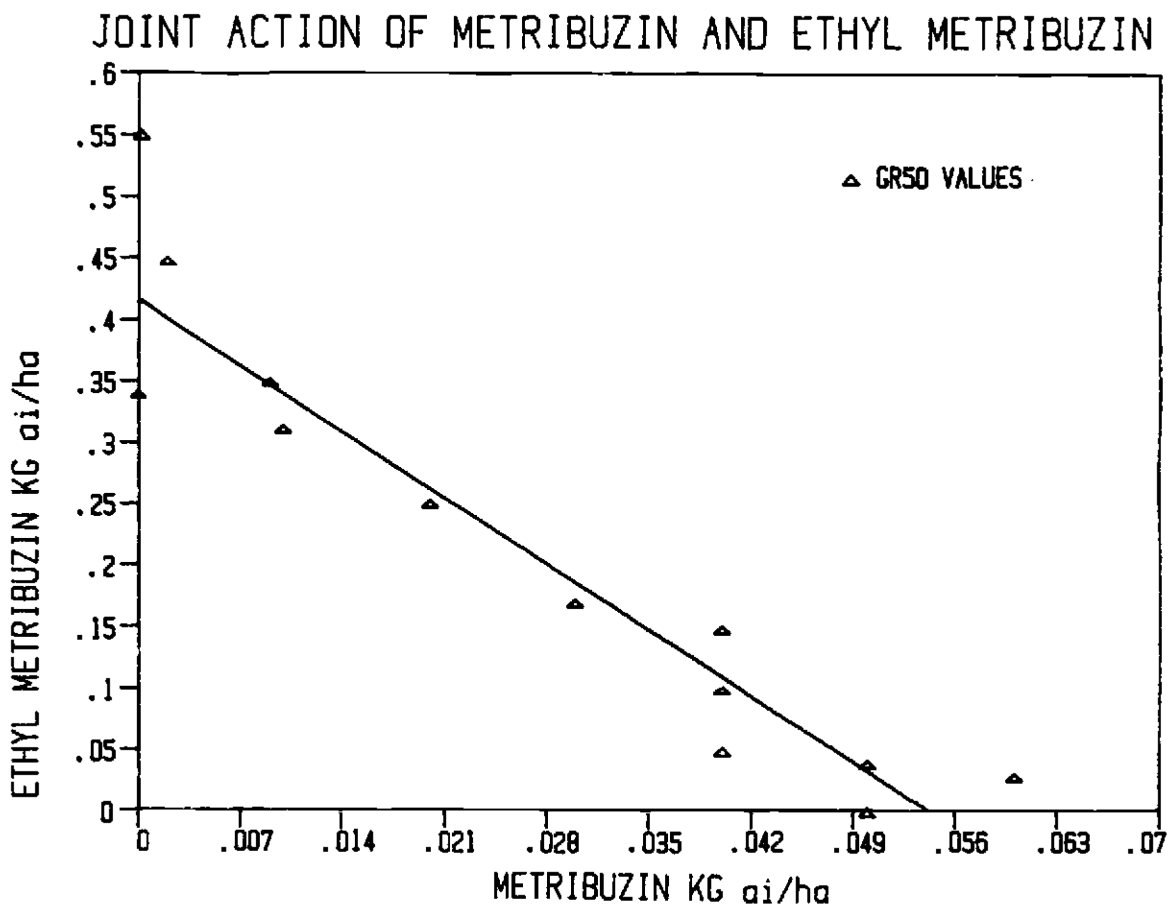


Figure 3.5: Evaluation of combined action of metribuzin and ethyl metribuzin when used together in mixture by using isobole method of Tammes. (Additive response)

CONCLUSIONS

Agrochemical mixtures such as herbicides are used routinely as part of modern pest management practices for different objectives because they behave differently when mixed with each other. Therefore, identification of the nature of interactions between specific herbicides is important to prevent problems in crop production.

One approach to determine herbicide interaction is to use a specific model to describe a response from two or more herbicides. Hence, deviation from the model would indicate an interaction that could be either synergism or antagonism.

Colby's method is an example of this approach and has the added capabilities of producing a calculated product that is indicative of an interaction, its magnitude, and nature. Calculations for this method are simple, whereas other methods require complex procedures. But results obtained by this method cannot be tested for their statistical significance without going into complex procedures. The calculations of expected responses are heavily dependent on observed values for a control and single treatments of each factor. In this method, differences between observed and expected responses are not deviations due to interactions between two or more factors, but they are deviations from the model chosen. This model is less informative as it describes reactions only as synergism or antagonism and fails to describe responses as additive or independent effects of herbicide A and B as was observed in case of the greenhouse experiment (Table 3.2). The formula is most accurate when values of X and Y are near the 50% level since the dose-response curves deviate least from linearity at the 50% level. The inconsistencies of Colby's method were not noted when a response line was plotted using the isobole method, and an additive response was observed. Tammes's method provides information about the existence of an interaction, the nature of the interaction, and the magnitude of deviations. Transformation of herbicide rates to log values helps to get more uniform distribution of data values. Estimation of GR50 values by using the regression method was found easier than other complex procedures such as changing of data values to probit values.

Significant increase in plant injury and a significant reduction in plant fresh weight was observed when metribuzin was mixed with ethyl metribuzin compared to their separate use. Downy brome was found to be 8, 5, 5, and 9 times more sensitive than Stephens, Hill 81, Yamhill, and Malcolm to metribuzin and 6, 4, 4, and 6 times more sensitive than Stephens, Hill 81, Yamhill, and Malcolm cultivars of winter wheat to ethyl metribuzin, respectively. The response of downy brome to different combinations of metribuzin and ethyl metribuzin was observed as additive by using the isobole method of Tammes. This information will offer several potential advantages over the use of a single chemical. This will allow us to use less of these herbicides in different combination, resulting in more effective control of this weed, reduced risk of crop injury, and may be a less expensive treatment. This will also reduce the chances of species becoming resistant and chances of soil persistence will be less as compared to the use of these chemicals alone. However, this all depends upon the type of weed species present, environmental conditions and soil properties of the area.

The additive response of metribuzin and ethyl metribuzin will also reduce the chances of failure to get effective control of weeds. Metribuzin is more water soluble than ethyl metribuzin. In case of low soil moisture at least one will work to kill the weeds or in case of rains if one will leach, the other will be available. Differences in their solubility will also help to control weeds of different rooting depths. Therefore, I hope these results of additive interaction of metribuzin and ethyl metribuzin will help to control downy brome more effectively and more economically.

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APPENDICES

Appendix Table 1. Meteorological Data for the 1986-87 growing season of wheat crop at Sherman Experiment Station, Moro.

Month		Precipitation (Inches)			Temperature (F)
		Total	Normal	Crop year	Average
July	86	0.54	0.21	11.01	63.2
August	86	0.07	0.29	11.08	72.1
September	86	1.52	0.60	1.52	55.7
October	86	0.45	0.93	1.97	51.7
November	86	1.53	1.68	3.50	40.7
December	86	0.78	1.70	4.28	29.4
January	87	1.68	1.64	5.96	29.9
February	87	1.10	1.16	7.06	37.5
March	87	1.54	0.96	8.60	42.6
April	87	0.28	0.75	8.88	51.5
May	87	0.99	0.81	9.87	57.9
June	87	0.29	0.71	10.16	64.2

a) Crop year total starts from September.
b) Precipitation Total is rain of that year.
c) Precipitation Normal is the average of 67 years for that month.

Appendix Table 2. Meteorological Data for the 1986-87 growing season of wheat crop at Hyslop Farm Corvallis.

Month		Precipitation (Inches)			Temperature (F)
		Total	Normal	Crop year	Average
July	86	1.15	0.33	-.-	63.20
August	86	0.00	0.81	-.-	69.75
September	86	3.56	1.48	3.56	59.30
October	86	2.80	3.39	6.36	55.15
November	86	8.62	5.17	14.98	46.95
December	86	3.50	7.77	18.48	39.25
January	87	8.22	7.55	26.70	39.65
February	87	4.50	4.86	31.20	44.10
March	87	3.70	4.63	34.90	47.40
April	87	1.56	2.46	36.46	52.80
May	87	1.40	1.92	37.86	58.15
June	87	0.29	1.20	38.15	63.50

a) Crop year total starts from September.

b) Precipitation Total is Rain of that year.

c) Precipitation Normal is the average of 67 years for that month.

Appendix Table 3. Effect of different rates of metribuzin and ethyl metribuzin on plant injury of four winter wheat cultivars in greenhouse. {(Recorded on a scale of 0 to 100) (Experiment # 1)}

Treatments		Replications			
Herbicide	Variety	I	II	III	IV
Metribuzin 0.07 kg/ha	Stephens	0	0	0	0
	Hill 81	15	20	15	15
	Yamhill	10	15	10	15
	Malcolm	0	0	0	0
Metribuzin 0.13 kg/ha	Stephens	10	15	15	20
	Hill 81	35	45	35	30
	Yamhill	30	30	20	30
	Malcolm	10	20	10	10
Metribuzin 0.28 kg/ha	Stephens	35	35	30	40
	Hill 81	80	90	80	85
	Yamhill	85	70	70	80
	Malcolm	25	30	40	30
Metribuzin 0.56 kg/ha	Stephens	60	70	90	75
	Hill 81	100	100	100	100
	Yamhill	90	95	95	100
	Malcolm	60	75	65	60
Metribuzin 0.84 kg/ha	Stephens	90	100	100	100
	Hill 81	100	100	100	100
	Yamhill	100	100	100	100
	Malcolm	80	90	100	80

Appendix Table 3 Cont'd

Appendix Table 3 Cont'd

Treatments		Replications			
Herbicide	Variety	I	II	III	IV
MEthyl Metribuzin 0.56 kg/ha	Stephens	0	0	0	0
	Hill 81	15	20	15	20
	Yamhill	10	15	15	15
	Malcolm	0	0	0	0
Ethyl Metribuzin 1.12 kg/ha	Stephens	10	20	10	10
	Hill 81	40	35	30	40
	Yamhill	35	40	20	30
	Malcolm	20	10	10	10
Ethyl Metribuzin 1.68 kg/ha	Stephens	40	40	35	30
	Hill 81	70	80	80	90
	Yamhill	90	70	70	75
	Malcolm	35	25	35	25
Ethyl Metribuzin 2.24 kg/ha	Stephens	60	50	50	70
	Hill 81	90	100	100	100
	Yamhill	90	90	100	90
	Malcolm	50	70	60	50
Ethyl Metribuzin 2.80 kG/ha	Stephens	90	100	100	80
	Hill 81	100	100	100	100
	Yamhill	100	100	100	100
	Malcolm	80	100	80	90
Check	Stephens	0	0	0	0
	Hill 81	0	0	0	0
	Yamhill	0	0	0	0
	Malcolm	0	0	0	0

Appendix Table 4. Effect of different rates of metribuzin and ethyl metribuzin on plant injury of four winter wheat cultivars in greenhouse. {(Recorded on a scale of 0 to 100) (Experiment # 2)}

Treatments		Replications				
Herbicide	Variety	I	II	III	IV	Avga
Metribuzin 0.07 kg/ha	Stephens	0	0	0	0	0
	Hill 81	0	10	20	15	14
	Yamhill	20	10	10	10	13
	Malcolm	0	0	0	0	0
Metribuzin 0.13 kg/ha	Stephens	20	15	10	10	14
	Hill 81	35	35	40	30	36
	Yamhill	40	40	35	35	33
	Malcolm	10	10	20	10	13
Metribuzin 0.28 kg/ha	Stephens	40	30	30	30	34
	Hill 81	75	70	75	80	79
	Yamhill	60	60	65	70	70
	Malcolm	25	30	30	45	32
Metribuzin 0.56 kg/ha	Stephens	80	70	70	60	72
	Hill 81	100	100	100	100	100
	Yamhill	100	100	100	100	98
	Malcolm	70	65	60	60	64
Metribuzin 0.84 kg/ha	Stephens	80	100	100	100	96
	Hill 81	100	100	100	100	100
	Yamhill	100	100	100	100	100
	Malcolm	80	90	100	100	90

Appendix Table 4 Cont'd

Appendix Table 4 Cont'd

Treatments		Replications				
Herbicide	Variety	I	II	III	IV	Avg[a]
Ethyl	Stephens	0	0	0	0	0
Metribuzin	Hill 81	20	15	20	10	17
0.56 kg/ha	Yamhill	10	20	10	10	13
	Malcolm	0	0	0	0	0
Ethyl	Stephens	20	20	20	15	16
Metribuzin	Hill 81	40	35	35	30	36
1.12 kg/ha	Yamhill	40	35	35	30	33
	Malcolm	15	15	20	15	14
Ethyl	Stephens	35	35	35	30	35
Metribuzin	Hill 81	80	70	90	70	79
1.68 kg/ha	Yamhill	75	70	70	85	76
	Malcolm	35	30	30	45	33
Ethyl	Stephens	70	70	65	80	64
Metribuzin	Hill 81	90	100	90	100	96
2.24 kg/ha	Yamhill	95	90	100	85	93
	Malcolm	60	55	70	70	61
Ethyl	Stephens	90	90	100	85	92
Metribuzin	Hill 81	100	100	100	100	100
2.80 kg/ha	Yamhill	100	90	100	100	99
	Malcolm	80	80	100	90	88
Check	Stephens	0	0	0	0	0
	Hill 81	0	0	0	0	0
	Yamhill	0	0	0	0	0
	Malcolm	0	0	0	0	0

a) Average values are means of experiment # 1 and Experiment # 2. (Eight replications)

Appendix Table 5. Effect of different rates of metribuzin and ethyl metribuzin on reduction of shoot fresh weight of four winter wheat cultivars in greenhouse. {(expressed as percent of the untreated check plants) (Experiment # 1)}

Treatments		Replications			
Herbicide	Variety	I	II	III	IV
Metribuzin 0.07 kg/ha	Stephens	102	106	100	115
	Hill 81	91	104	97	87
	Yamhill	99	101	88	85
	Malcolm	104	108	115	112
Metribuzin 0.13 kg/ha	Stephens	95	90	105	94
	Hill 81	60	53	65	60
	Yamhill	65	71	68	65
	Malcolm	95	109	88	92
Metribuzin 0.28 kg/ha	Stephens	75	70	72	60
	Hill 81	26	35	29	33
	Yamhill	32	29	44	40
	Malcolm	75	77	64	69
Metribuzin 0.56 kg/ha	Stephens	36	34	38	44
	Hill 81	22	27	23	18
	Yamhill	19	19	20	24
	Malcolm	40	46	41	48
Metribuzin 0.84 kg/ha	Stephens	20	20	24	21
	Hill 81	19	16	24	14
	Yamhill	18	18	20	27
	Malcolm	15	23	29	28

Appendix Table 5 Cont'd

Appendix Table 5 Cont'd

Treatments		Replications			
Herbicide	Variety	I	II	III	IV
Ethyl Metribuzin 0.56 kg/ha	Stephens	102	103	103	98
	Hill 81	82	91	83	101
	Yamhill	89	95	93	93
	Malcolm	101	113	100	98
Ethyl Metribuzin 1.12 kg/ha	Stephens	90	95	93	101
	Hill 81	63	69	67	70
	Yamhill	61	68	62	72
	Malcolm	103	90	100	100
Ethyl Metribuzin 1.68 kg/ha	Stephens	62	60	70	65
	Hill 81	25	32	30	33
	Yamhill	28	38	34	33
	Malcolm	60	67	68	78
Ethyl Metribuzin 2.24 kg/ha	Stephens	30	32	40	39
	Hill 81	23	16	21	20
	Yamhill	23	23	25	25
	Malcolm	45	33	43	32
Ethyl Metribuzin 2.80 kg/ha	Stephens	21	15	23	18
	Hill 81	20	20	17	15
	Yamhill	21	20	15	18
	Malcolm	17	15	20	20
Check	Stephens	100	100	100	100
	Hill 81	100	100	100	100
	Yamhill	100	100	100	100
	Malcolm	100	100	100	100

Appendix Table 6. Effect of different rates of metribuzin and ethyl metribuzin on reduction of shoot fresh weight of four winter wheat cultivars in greenhouse. {(expressed as percent of the untreated check plants) (Experiment # 2)}

Treatments		Replications				
Herbicide	Variety	I	II	III	IV	Avga
Metribuzin 0.07 kg/ha	Stephens	108	103	109	102	106
	Hill 81	87	93	103	108	96
	Yamhill	107	100	89	97	96
	Malcolm	102	100	98	114	107
Metribuzin 0.13 kg/ha	Stephens	90	102	91	94	96
	Hill 81	57	54	70	67	61
	Yamhill	70	65	60	75	67
	Malcolm	102	100	104	91	98
Metribuzin 0.28 kg/ha	Stephens	72	67	69	65	69
	Hill 81	31	29	33	37	32
	Yamhill	38	35	38	40	37
	Malcolm	79	70	72	70	72
Metribuzin 0.56 kg/ha	Stephens	36	39	34	38	37
	Hill 81	27	22	24	27	24
	Yamhill	29	16	22	25	22
	Malcolm	39	49	36	44	43
Metribuzin 0.84 kg/ha	Stephens	27	19	24	18	22
	Hill 81	19	20	25	18	19
	Yamhill	23	17	17	27	21
	Malcolm	20	20	28	18	23

Appendix Table 6 Cont'd

Appendix Table 6 Cont'd

Treatments		Replications				
Herbicide	Variety	I	II	III	IV	Avg[a]
Ethyl Metribuzin 0.56 kg/ha	Stephens	92	100	102	104	101
	Hill 81	95	87	82	92	89
	Yamhill	83	97	100	87	92
	Malcolm	107	104	99	109	104
Ethyl Metribuzin 1.12 kg/ha	Stephens	100	102	88	95	96
	Hill 81	50	53	59	60	61
	Yamhill	55	70	69	65	65
	Malcolm	93	97	95	102	98
Ethyl Metribuzin 1.68 kg/ha	Stephens	72	60	64	70	65
	Hill 81	36	33	25	32	31
	Yamhill	36	32	34	32	33
	Malcolm	75	77	72	68	71
Ethyl Metribuzin 2.24 kg/ha	Stephens	35	38	30	40	36
	Hill 81	18	20	21	25	21
	Yamhill	28	21	21	30	25
	Malcolm	43	38	32	40	38
Ethyl Metribuzin 2.80 kg/ha	Stephens	13	21	25	18	19
	Hill 81	12	20	18	22	18
	Yamhill	22	21	15	23	19
	Malcolm	18	18	24	21	19
Check	Stephens	100	100	100	100	100
	Hill 81	100	100	100	100	100
	Yamhill	100	100	100	100	100
	Malcolm	100	100	100	100	100

a) Average values are means of experiment # 1 and experiment # 2. (Eight replications)

Appendix Table 7. Effect of different concentrations of metribuzin and ethyl metribuzin on plant injury of four winter wheat cultivars established in nutrient solution in growth chamber. {(Recorded on a scale of 0 to 100) (Experiment # 1)}

Treatments		Replications		
Herbicide	Variety	I	II	III
Metribuzin 0.05 uM	Stephens	0	0	0
	Hill 81	15	0	0
	Yamhill	0	0	0
	Malcolm	0	0	0
Metribuzin 0.10 uM	Stephens	0	0	0
	Hill 81	20	20	25
	Yamhill	30	15	20
	Malcolm	0	0	10
Metribuzin 0.50 uM	Stephens	15	20	15
	Hill 81	50	45	50
	Yamhill	45	35	50
	Malcolm	10	15	15
Metribuzin 1.00 uM	Stephens	35	40	30
	Hill 81	75	55	65
	Yamhill	65	60	60
	Malcolm	20	25	30
Metribuzin 2.50 uM	Stephens	45	50	65
	Hill 81	90	90	85
	Yamhill	85	80	100
	Malcolm	35	40	45

Appendix Table 7 cont'd .

Appendix Table 7 Cont'd

Treatments		Replications		
Herbicide	Variety	I	II	III
Metribuzin 5.00 uM	Stephens	65	60	70
	Hill 81	100	100	100
	Yamhill	100	100	95
	Malcolm	70	75	70
Metribuzin 10.00 uM	Stephens	95	85	80
	Hill 81	100	100	100
	Yamhill	100	100	100
	Malcolm	80	90	90
Metribuzin 25.00 uM	Stephens	100	100	100
	Hill 81	100	100	100
	Yamhill	100	100	100
	Malcolm	100	100	100
Ethyl Metribuzin 0.50 uM	Stephens	0	0	0
	Hill 81	20	0	15
	Yamhill	10	0	0
	Malcolm	0	0	0
Ethyl Metribuzin 1.00 uM	Stephens	0	0	0
	Hill 81	10	25	15
	Yamhill	15	25	15
	Malcolm	0	0	0
Ethyl Metribuzin 2.50 uM	Stephens	10	0	15
	Hill 81	35	40	35
	Yamhill	30	35	45
	Malcolm	0	0	0

Appendix Table 7 cont'd .

Appendix Table 7 Cont'd

Treatments		Replications		
Herbicide	Variety	I	II	III
Ethyl	Stephens	30	20	30
Metribuzin	Hill 81	60	60	55
5.00 uM	Yamhill	50	60	70
	Malcolm	20	35	20
Ethyl	Stephens	55	40	45
Metribuzin	Hill 81	80	70	80
10.00 uM	Yamhill	85	80	80
	Malcolm	40	50	50
Ethyl	Stephens	60	65	70
Metribuzin	Hill 81	100	100	100
20.00 uM	Yamhill	100	100	100
	Malcolm	70	70	60
Ethyl	Stephens	75	90	80
Metribuzin	Hill 81	100	100	100
30.00 uM	Yamhill	100	100	100
	Malcolm	70	85	80
Ethyl	Stephens	100	100	100
Metribuzin	Hill 81	100	100	100
50.00 uM	Yamhill	100	100	100
	Malcolm	100	100	100
Check	Stephens	0	0	0
	Hill 81	0	0	0
	Yamhill	0	0	0
	Malcolm	0	0	0

Appendix Table 8. Effect of different concentrations of metribuzin and ethyl metribuzin on plant injury of four winter wheat cultivars established in nutrient solution in growth chamber. {(Recorded on a scale of 0 to 100) (Experiment # 2)}

Treatments		Replications			
Herbicide	Variety	I	II	III	Avg
Metribuzin 0.05 uM	Stephens	0	0	0	0
	Hill 81	0	0	0	3
	Yamhill	0	0	0	0
	Malcolm	0	0	0	0
Metribuzin 0.10 uM	Stephens	0	0	0	0
	Hill 81	25	25	20	23
	Yamhill	20	20	20	21
	Malcolm	0	0	0	2
Metribuzin 0.50 uM	Stephens	25	20	15	18
	Hill 81	60	50	60	53
	Yamhill	65	50	60	51
	Malcolm	20	15	15	15
Metribuzin 1.00 uM	Stephens	35	30	35	34
	Hill 81	70	75	60	67
	Yamhill	70	70	60	64
	Malcolm	30	25	30	27
Metribuzin 2.50 uM	Stephens	50	50	65	54
	Hill 81	80	90	90	88
	Yamhill	90	90	85	88
	Malcolm	55	40	45	43

Appendix Table 8 cont'd

Appendix Table 8 Cont'd

Treatments		Replications			
Herbicide	Variety	I	II	III	Avg
Metribuzin 5.00 uM	Stephens	70	70	65	67
	Hill 81	95	100	100	99
	Yamhill	100	100	100	99
	Malcolm	60	75	70	70
Metribuzin 10.00 uM	Stephens	90	90	90	88
	Hill 81	100	100	100	100
	Yamhill	100	100	100	100
	Malcolm	80	90	90	87
Metribuzin 25.00 uM	Stephens	100	100	100	100
	Hill 81	100	100	100	100
	Yamhill	100	100	100	100
	Malcolm	100	100	100	100
Ethyl Metribuzin 0.50 uM	Stephens	0	0	0	0
	Hill 81	0	15	0	8
	Yamhill	10	0	5	4
	Malcolm	0	0	0	0
Ethyl Metribuzin 1.00 uM	Stephens	0	0	0	0
	Hill 81	25	15	15	18
	Yamhill	30	0	25	21
	Malcolm	0	0	0	0
Ethyl Metribuzin 2.50 uM	Stephens	0	10	0	6
	Hill 81	35	35	45	38
	Yamhill	30	35	30	34
	Malcolm	0	0	0	0

Appendix Table 8 cont'd

Appendix Table 8 Cont'd

Treatments		Replications			
Herbicide	Variety	I	II	III	Avg
Ethyl Metribuzin 5.00 uM	Stephens	40	30	30	30
	Hill 81	85	70	60	65
	Yamhill	70	75	50	63
	Malcolm	25	25	25	25
Ethyl Metribuzin 10.00 uM	Stephens	55	45	45	48
	Hill 81	85	90	75	80
	Yamhill	90	90	80	84
	Malcolm	60	50	50	50
Ethyl Metribuzin 20.00 uM	Stephens	85	70	70	70
	Hill 81	100	100	100	100
	Yamhill	100	100	100	100
	Malcolm	80	80	70	72
Ethyl Metribuzin 30.00 uM	Stephens	100	75	80	83
	Hill 81	100	100	100	100
	Yamhill	100	100	100	100
	Malcolm	85	80	85	81
Ethyl Metribuzin 50.00 uM	Stephens	100	100	100	100
	Hill 81	100	100	100	100
	Yamhill	100	100	100	100
	Malcolm	100	100	100	100
Check	Stephens	0	0	0	0
	Hill 81	0	0	0	0
	Yamhill	0	0	0	0
	Malcolm	0	0	0	0

a) Average values are the means of experiment # 1 and experiment # 2. (Mean of six replications)

Appendix Table 9. Effect of different rates of metribuzin and ethyl metribuzin on seedling weight of four winter wheat cultivars in established in nutrient solution in growth chamber. {(Expressed as percent of the untreated check plants) (Experiment # 1)}

Treatments		Replications		
Herbicide	Variety	I	II	III
Metribuzin 0.05 uM	Stephens	115	104	114
	Hill 81	99	100	101
	Yamhill	108	103	97
	Malcolm	102	97	115
Metribuzin 0.10 uM	Stephens	109	102	112
	Hill 81	88	107	85
	Yamhill	79	110	93
	Malcolm	108	95	96
Metribuzin 0.50 uM	Stephens	95	85	88
	Hill 81	62	58	55
	Yamhill	68	73	58
	Malcolm	97	92	94
Metribuzin 1.00 uM	Stephens	69	65	75
	Hill 81	28	51	43
	Yamhill	44	42	48
	Malcolm	82	86	78
Metribuzin 2.50 uM	Stephens	62	53	52
	Hill 81	27	24	39
	Yamhill	31	32	24
	Malcolm	70	65	67

Appendix Table 9 cont'd .

Appendix Table 9 Cont'd

Treatments		Replications		
Herbicide	Variety	I	II	III
Metribuzin 5.00 uM	Stephens	40	46	41
	Hill 81	25	17	26
	Yamhill	22	27	25
	Malcolm	34	32	36
Metribuzin 10.00 uM	Stephens	17	20	29
	Hill 81	17	12	18
	Yamhill	20	27	21
	Malcolm	25	29	31
Metribuzin 25.00 uM	Stephens	13	23	27
	Hill 81	16	18	18
	Yamhill	17	27	22
	Malcolm	16	24	22
Ethyl Metribuzin 0.50 uM	Stephens	101	113	101
	Hill 81	89	95	100
	Yamhill	95	113	137
	Malcolm	92	104	98
Ethyl Metribuzin 1.00 uM	Stephens	99	109	107
	Hill 81	109	87	93
	Yamhill	104	82	97
	Malcolm	95	102	99
Ethyl Metribuzin 2.50 uM	Stephens	104	100	90
	Hill 81	69	75	80
	Yamhill	78	84	72
	Malcolm	98	101	96

Appendix Table 9 cont'd .

Appendix Table 9 Cont'd

Treatments		Replications		
Herbicide	Variety	I	II	III
Ethyl Metribuzin 5.00 uM	Stephens	76	85	78
	Hill 81	45	41	52
	Yamhill	52	47	39
	Malcolm	82	73	85
Ethyl Metribuzin 10.00 uM	Stephens	50	65	51
	Hill 81	25	38	32
	Yamhill	35	30	35
	Malcolm	49	55	58
Ethyl Metribuzin 20.00 uM	Stephens	40	43	38
	Hill 81	25	30	22
	Yamhill	24	28	26
	Malcolm	35	39	45
Ethyl Metribuzin 30.00 uM	Stephens	21	25	25
	Hill 81	23	26	28
	Yamhill	21	26	29
	Malcolm	27	30	29
Ethyl Metribuzin 50.00 uM	Stephens	15	15	20
	Hill 81	27	22	23
	Yamhill	26	20	17
	Malcolm	19	23	27
Check	Stephens	100	100	100
	Hill 81	100	100	100
	Yamhill	100	100	100
	Malcolm	100	100	100

Appendix Table 10. Effect of different rates of metribuzin and ethyl metribuzin on seedling weight of four winter wheat cultivars established in nutrient solution in growth chamber. {(Expressed as percent of the untreated check plants) (Experiment # 2)}

Treatments		Replications			
Herbicide	Variety	I	II	III	Avg
Metribuzin 0.05 uM	Stephens	108	100	104	108
	Hill 81	114	107	112	106
	Yamhill	112	104	134	110
	Malcolm	102	106	105	105
Metribuzin 0.10 uM	Stephens	100	98	102	104
	Hill 81	83	85	89	90
	Yamhill	88	91	87	91
	Malcolm	102	109	103	102
Metribuzin 0.50 uM	Stephens	83	92	92	89
	Hill 81	52	57	52	56
	Yamhill	50	57	52	60
	Malcolm	86	94	91	92
Metribuzin 1.00 uM	Stephens	72	77	73	72
	Hill 81	42	43	48	43
	Yamhill	40	42	47	44
	Malcolm	76	81	76	80
Metribuzin 2.50 uM	Stephens	57	57	45	54
	Hill 81	35	33	30	31
	Yamhill	28	33	34	30
	Malcolm	55	67	62	64

Appendix Table 10 cont'd

Appendix Table 10 Cont'd

Treatments		Replications			
Herbicide	Variety	I	II	III	Avg
Metribuzin 5.00 uM	Stephens	38	37	41	41
	Hill 81	26	21	23	23
	Yamhill	26	24	24	25
	Malcolm	43	34	37	36
Metribuzin 10.00 uM	Stephens	24	27	25	24
	Hill 81	22	21	16	18
	Yamhill	18	20	22	21
	Malcolm	28	30	28	29
Metribuzin 25.00 uM	Stephens	28	18	20	22
	Hill 81	27	27	17	21
	Yamhill	14	25	20	21
	Malcolm	21	27	19	22
Ethyl Metribuzin 0.50 uM	Stephens	107	98	104	104
	Hill 81	120	110	113	104
	Yamhill	101	100	115	110
	Malcolm	102	131	110	106
Ethyl Metribuzin 1.00 uM	Stephens	103	100	103	104
	Hill 81	92	92	92	94
	Yamhill	83	93	95	92
	Malcolm	103	104	103	101
Ethyl Metribuzin 2.50 uM	Stephens	93	96	100	97
	Hill 81	73	73	73	74
	Yamhill	79	73	78	77
	Malcolm	98	108	100	100

Appendix Table 10 cont'd

Appendix Table 10 Cont'd

Treatments		Replications			
Herbicide	Variety	I	II	III	Avg
Ethyl Metribuzin 5.00 uM	Stephens	68	77	77	77
	Hill 81	38	40	45	44
	Yamhill	40	37	44	43
	Malcolm	80	82	80	80
Ethyl Metribuzin 10.00 uM	Stephens	57	60	57	57
	Hill 81	38	30	32	33
	Yamhill	33	35	33	34
	Malcolm	51	57	55	54
Ethyl Metribuzin 20.00 uM	Stephens	35	38	38	39
	Hill 81	28	26	26	26
	Yamhill	24	26	25	26
	Malcolm	34	33	35	37
Ethyl Metribuzin 30.00 uM	Stephens	23	32	25	25
	Hill 81	24	26	23	25
	Yamhill	21	23	23	24
	Malcolm	32	29	29	29
Ethyl Metribuzin 50.00 uM	Stephens	20	18	18	18
	Hill 81	28	20	23	24
	Yamhill	24	12	20	20
	Malcolm	18	13	23	21
Check	Stephens	100	100	100	100
	Hill 81	100	100	100	100
	Yamhill	100	100	100	100
	Malcolm	100	100	100	100

a) Average values are means of the experiment # 1 and experiment # 2. (Average of six replications)

Appendix Table 11. Evaluation of mode of uptake of metribuzin and ethyl metribuzin by winter wheat in greenhouse. {(Recorded on a scale of 0 to 100) (Experiment # 1)}

Treatments		Replications			
Herbicide	Variety	I	II	III	IV
Metribuzin		--------------- % plant injury -------------------			
Soil + Foliage	Stephens	70	65	70	55
	Hill 81	100	100	100	100
	Yamhill	100	100	100	100
	Malcolm	65	70	65	70
Foliage Only	Stephens	5	5	10	10
	Hill 81	15	10	20	15
	Yamhill	10	10	10	20
	Malcolm	0	0	10	5
Soil Only	Stephens	70	65	60	60
	Hill 81	100	95	100	100
	Yamhill	100	100	100	100
	Malcolm	65	55	70	65
Ethyl Metribuzin					
Soil + Foliage	Stephens	65	55	60	60
	Hill 81	100	100	100	100
	Yamhill	100	100	100	100
	Malcolm	55	50	70	60
Foliage Only	Stephens	5	0	5	5
	Hill 81	15	10	10	20
	Yamhill	15	10	10	10
	Malcolm	0	0	0	5
Soil Only	Stephens	50	65	70	60
	Hill 81	100	100	100	100
	Yamhill	100	100	100	100
	Malcolm	60	60	50	50

Appendix Table 12. Evaluation of mode of uptake of metribuzin and ethyl metribuzin by winter wheat in greenhouse. {(Recorded on a scale of 0 to 100) (Experiment # 2)}

Treatments		Replications				
Herbicide	Variety	I	II	III	IV	Avg
Metribuzin		------------- % plant injury--------------------				
Soil + Foliage	Stephens	45	60	70	70	63
	Hill 81	100	100	100	100	100
	Yamhill	100	100	100	100	100
	Malcolm	50	70	70	55	64
Foliage Only	Stephens	10	0	15	0	7
	Hill 81	15	20	15	10	15
	Yamhill	15	15	10	10	13
	Malcolm	5	0	0	5	3
Soil Only	Stephens	50	50	65	70	61
	Hill 81	100	100	100	100	99
	Yamhill	100	100	100	100	100
	Malcolm	55	50	65	65	61
Ethyl Metribuzin						
Soil + Foliage	Stephens	55	50	70	65	60
	Hill 81	100	100	100	100	100
	Yamhill	100	100	100	100	100
	Malcolm	55	45	60	55	56
Foliage Only	Stephens	0	0	0	0	2
	Hill 81	15	10	10	15	13
	Yamhill	10	5	5	20	11
	Malcolm	0	0	10	0	2
Soil Only	Stephens	45	60	55	65	59
	Hill 81	100	90	100	100	99
	Yamhill	100	100	100	100	100
	Malcolm	40	50	60	50	53

a) Average values are the means of experiment # 1 and experiment # 2. (Eight replications).

Appendix Table 13. Analysis of varience of Appendix Tables 11 & 12 for evaluation of mode of uptake of metribuzin and ethyl metribuzin by winter wheat.

SOV	DF	SS	MS	F.Ratio	
Replications	7	663.41	94.773	4.16	**
Herbicides	1	365.76	365.755	16.04	**
Methods	2	218813.23	109406.641	4798.32	**
Herb * Method	2	1.82	0.911	0.04	N.S
Cultivars	3	42861.85	14287.283	626.61	**
Herb * Cul	3	235.81	78.602	3.45	*
Method * Cul	6	10153.39	1692.231	74.22	**
Herb*Method*Cul	6	166.93	27.821	1.22	N.S
Error	161	3670.96	22.801		

Coefficient of Variation = 8.55%

Herb: Herbicides.
Cul : Cultivars.
Method: Method of herbicide application.
N.S : Non Significant.
* : Significant at 5 % probability level.
** : Significant at 1 % probability level.

Appendix Table 14. Evaluation of mode of uptake of metribuzin and ethyl metribuzin by winter wheat in greenhouse. {(Data recorded as seedling fresh weight) (Experiment # 1)

Treatments		Replications			
Herbicide	Variety	I	II	III	IV
Metribuzin		--------------- % plant injury ------------------			
Soil + Foliage	Stephens	42	56	50	45
	Hill 81	34	16	32	19
	Yamhill	19	23	25	17
	Malcolm	32	80	50	35
Foliage Only	Stephens	97	81	105	87
	Hill 81	96	57	113	119
	Yamhill	65	89	168	78
	Malcolm	68	106	116	70
Soil Only	Stephens	63	52	55	41
	Hill 81	44	20	33	29
	Yamhill	16	38	56	35
	Malcolm	62	73	58	51
Ethyl Metribuzin					
Soil + Foliage	Stephens	85	60	68	51
	Hill 81	36	18	38	17
	Yamhill	20	27	20	30
	Malcolm	39	82	56	48
Foliage Only	Stephens	107	118	96	76
	Hill 81	134	73	107	76
	Yamhill	78	106	85	81
	Malcolm	64	122	89	85
Soil Only	Stephens	62	53	66	42
	Hill 81	28	26	42	25
	Yamhill	28	42	42	18
	Malcolm	43	68	62	49

Appendix Table 15. Evaluation of mode of uptake of metribuzin and ethyl metribuzin by winter wheat in greenhouse. {(Data recorded as seedling fresh weight) (Experiment # 2)

Treatments		Replications				
Herbicide	Variety	I	II	III	IV	Avg
Metribuzin		---------------- % plant injury ----------------				
Soil + Foliage	Stephens	33	41	38	37	43
	Hill 81	14	12	13	24	21
	Yamhill	8	8	8	6	14
	Malcolm	50	37	42	37	45
Foliage Only	Stephens	52	141	100	111	97
	Hill 81	67	67	87	141	93
	Yamhill	72	84	102	85	93
	Malcolm	80	80	124	111	94
Soil Only	Stephens	31	47	38	38	46
	Hill 81	14	13	13	17	23
	Yamhill	11	6	8	7	22
	Malcolm	45	34	39	42	51
Ethyl Metribuzin						
Soil + Foliage	Stephens	32	45	47	32	53
	Hill 81	15	21	29	15	24
	Yamhill	8	6	9	8	16
	Malcolm	49	26	35	41	47
Foliage Only	Stephens	77	104	119	70	96
	Hill 81	89	78	106	90	94
	Yamhill	81	49	131	93	88
	Malcolm	164	71	116	72	98
Soil Only	Stephens	30	41	44	34	47
	Hill 81	13	14	12	13	22
	Yamhill	11	5	9	7	20
	Malcolm	69	28	42	35	50

a) Average values are the means of the experiment # 1 and experiment # 2. (Eight replications).

Appendix Table 16. Analysis of variance of Appendix Tables 14 & 15 for evaluation of mode of uptake of metribuzin and ethyl metribuzin by winter wheat.

SOV	DF	SS	MS	F.Ratio	
Replications	7	11043.40	1577.628	5.40	**
Herbicides	1	44.08	44.083	0.15	N.S
Methods	2	155509.54	77754.771	266.18	**
Herb * Method	2	232.79	116.396	0.40	N.S
Cultivars	3	18763.85	6254.618	21.41	**
Herb * Cul	3	147.88	49.292	0.17	N.S
Method * Cul	6	6034.21	1005.701	3.44	*
Herb*Method*Cul	6	194.12	32.354	0.11	N.S
Error	161	47031.10	292.119		

Coefficient of Variation = 31.69

Herb: Herbicides.
Cul : Cultivars.
Method: Method of herbicide application.
N.S : Non Significant.
* : Significant at 5 % probability level.
** : Significant at 1 % probability level.

Appendix Table 17. Differential uptake of metribuzin and ethyl metribuzin by four winter wheat cultivars in nutrient solution.. {(Expressed as percent of the untreated check plants.) (Experiment # 1)}

Treatments		Replications		
Herbicide	Variety	I	II	III
Metribuzin 0.05 uM	Stephens	114	97	118
	Hill 81	91	93	86
	Yamhill	118	90	79
	Malcolm	94	90	165
Metribuzin 0.10 uM	Stephens	100	84	118
	Hill 81	106	67	90
	Yamhill	107	83	116
	Malcolm	113	73	165
Metribuzin 0.50 uM	Stephens	57	65	79
	Hill 81	41	47	48
	Yamhill	50	41	95
	Malcolm	78	60	159
Metribuzin 1.00 uM	Stephens	34	45	54
	Hill 81	50	57	52
	Yamhill	32	38	95
	Malcolm	44	50	88
Metribuzin 2.50 uM	Stephens	50	47	58
	Hill 81	52	50	34
	Yamhill	71	58	39
	Malcolm	65	39	57

Appendix Table 17 cont'd .

Appendix Table 17 Cont'd

Treatments		Replications		
Herbicide	Variety	I	II	III
Metribuzin 5.00 uM	Stephens	64	53	82
	Hill 81	76	55	73
	Yamhill	55	26	41
	Malcolm	45	41	26
Metribuzin 10.00 uM	Stephens	52	40	48
	Hill 81	82	62	45
	Yamhill	55	33	36
	Malcolm	60	66	65
Metribuzin 25.00 uM	Stephens	46	58	79
	Hill 81	64	74	61
	Yamhill	66	56	57
	Malcolm	55	66	46
Ethyl Metribuzin 0.50 uM	Stephens	80	103	89
	Hill 81	94	107	110
	Yamhill	107	103	163
	Malcolm	88	97	165
Ethyl Metribuzin 1.00 uM	Stephens	120	145	114
	Hill 81	88	60	69
	Yamhill	75	55	111
	Malcolm	106	97	176
Ethyl Metribuzin 2.50 uM	Stephens	74	65	96
	Hill 81	63	40	59
	Yamhill	68	52	105
	Malcolm	66	80	159

.Appendix Table 17 cont'd .

Appendix Table 17 Cont'd

Treatments		Replications		
Herbicide	Variety	I	II	III
Ethyl Metribuzin 5.00 uM	Stephens	40	61	100
	Hill 81	63	37	55
	Yamhill	39	45	74
	Malcolm	88	53	118
Ethyl Metribuzin 10.00 uM	Stephens	48	82	100
	Hill 81	88	69	50
	Yamhill	79	47	70
	Malcolm	110	120	109
Ethyl Metribuzin 20.00 uM	Stephens	64	51	73
	Hill 81	67	57	52
	Yamhill	63	63	61
	Malcolm	98	83	61
Ethyl Metribuzin 30.00 uM	Stephens	52	62	88
	Hill 81	70	60	59
	Yamhill	58	35	41
	Malcolm	60	71	63
Ethyl Metribuzin 50.00 uM	Stephens	48	53	73
	Hill 81	67	60	43
	Yamhill	32	40	41
	Malcolm	53	44	67
Check	Stephens	100	100	100
	Hill 81	100	100	100
	Yamhill	100	100	100
	Malcolm	100	100	100

Appendix Table 18. Differential uptake of metribuzin and ethyl metribuzin by four winter wheat cultivars in nutrient solution. {(Expressed as percent of the untreated check plants)(Experiment # 2)}

Treatments		Replications			
Herbicide	Variety	I	II	III	Avg
Metribuzin 0.05 uM	Stephens	87	89	116	104
	Hill 81	94	103	96	94
	Yamhill	125	100	108	103
	Malcolm	89	108	100	108
Metribuzin 0.10 uM	Stephens	87	89	97	96
	Hill 81	79	93	89	87
	Yamhill	121	104	112	107
	Malcolm	111	115	111	115
Metribuzin 0.50 uM	Stephens	79	61	74	69
	Hill 81	45	47	57	48
	Yamhill	64	57	62	62
	Malcolm	86	92	89	94
Metribuzin 1.00 uM	Stephens	53	39	45	45
	Hill 81	39	47	57	50
	Yamhill	39	43	46	49
	Malcolm	64	58	61	61
Metribuzin 2.50 uM	Stephens	64	53	58	55
	Hill 81	49	45	50	47
	Yamhill	33	50	58	52
	Malcolm	38	55	58	52

Appendix Table 18 cont'd

Appendix Table 18 Cont'd

Treatments		Replications			
Herbicide	Variety	I	II	III	Avg
Metribuzin 5.00 uM	Stephens	73	67	70	68
	Hill 81	71	74	70	70
	Yamhill	40	41	46	42
	Malcolm	49	43	48	42
Metribuzin 10.00 uM	Stephens	52	47	54	49
	Hill 81	91	71	72	71
	Yamhill	31	41	46	40
	Malcolm	56	69	63	63
Metribuzin 25.00 uM	Stephens	66	60	62	62
	Hill 81	80	71	70	70
	Yamhill	58	59	58	59
	Malcolm	53	57	58	56
Ethyl Metribuzin 0.50 uM	Stephens	61	74	87	82
	Hill 81	94	103	118	104
	Yamhill	100	100	123	116
	Malcolm	96	108	100	109
Ethyl Metribuzin 1.00 uM	Stephens	82	100	113	112
	Hill 81	67	73	79	73
	Yamhill	96	75	77	82
	Malcolm	107	119	111	119
Ethyl Metribuzin 2.50 uM	Stephens	76	71	84	78
	Hill 81	61	60	64	58
	Yamhill	100	86	77	81
	Malcolm	86	92	86	95

Appendix Table 18 cont'd

Appendix Table 18 cont'd.

Treatments		Replications			
Herbicide	Variety	I	II	III	Avg
Ethyl Metribuzin 5.00 uM	Stephens	39	58	58	59
	Hill 81	45	47	64	52
	Yamhill	61	50	54	54
	Malcolm	107	81	79	88
Ethyl Metribuzin 10.00 uM	Stephens	93	78	86	81
	Hill 81	71	71	67	69
	Yamhill	52	66	67	64
	Malcolm	80	100	108	105
Ethyl Metribuzin 20.00 uM	Stephens	48	64	64	61
	Hill 81	69	68	61	62
	Yamhill	48	57	63	59
	Malcolm	76	81	88	81
Ethyl Metribuzin 30.00 uM	Stephens	61	62	60	64
	Hill 81	80	68	63	67
	Yamhill	48	48	52	47
	Malcolm	56	67	63	63
Ethyl Metribuzin 50.00 uM	Stephens	39	49	54	53
	Hill 81	74	63	59	61
	Yamhill	33	39	42	38
	Malcolm	69	62	71	61
Check	Stephens	100	100	100	100
	Hill 81	100	100	100	100
	Yamhill	100	100	100	100
	Malcolm	100	100	100	100

a) Average values are the means of experiment # 1 and Experiment # 2. (Average of six replications)

Appendix Table 19. Analysis of variance of Appendix Tables 17 & 18 for differential uptake of metribuzin and ethyl metribuzin by four winter wheat cultivars in nutrient solution.

SOV	DF	SS	MS	F.Ratio	
Replications	5	11742.69	2348.538	12.00	**
Herbicides	1	4160.67	4160.667	21.25	**
Rates	7	117694.25	16813.464	85.88	**
Herb * Rate	7	11070.92	1581.560	8.08	**
Cultivars	3	14991.58	4997.194	25.52	**
Herb * Cul	3	3246.25	1082.083	5.53	**
Rate * Cul	21	22439.00	1068.524	5.46	**
Herb*Rate*Cul	21	12739.00	606.619	3.10	**
Error	315	61673.65	195.789		

Coefficient of Variation = 19.54%

Herb: Herbicides.
Cul : Cultivars.
N.S : Non Significant.
* : Significant at 5 % probability level.
** : Significant at 1 % probability level.

Appendix Table 20. Visual injury of the winter wheat cultivars treated with two rates of metribuzin and ethyl metribuzin at Hyslop.(Expresed in scale from 0-100 as 0 = No injury and 100 = Complete kill of plant)

Treatments		Replications				
Herbicide	Variety	I	II	III	IV	Avg
Metribuzin 0.22 kg/ha	Stephens	0	0	5	5	3
	Hill 81	0	5	10	5	5
	Yamhill	5	10	10	15	10
	Malcolm	0	0	5	5	3
Metribuzin 0.45 kg/ha	Stephens	0	0	5	5	3
	Hill 81	30	35	20	20	26
	Yamhill	25	25	30	35	29
	Malcolm	5	0	5	10	5
Ethyl Metribuzin 1.12 kg/ha	Stephens	0	5	5	5	4
	Hill 81	5	15	5	25	13
	Yamhill	10	10	15	15	13
	Malcolm	0	0	0	15	4
Ethyl Metribuzin 2.24 kg/ha	Stephens	0	5	10	10	6
	Hill 81	20	25	25	40	28
	Yamhill	20	25	25	35	26
	Malcolm	0	5	5	0	3
Check	Stephens	0	0	0	0	0
	Hill 81	0	0	0	0	0
	Yamhill	0	0	0	0	0
	Malcolm	0	0	0	0	0

Appendix Table 21. Analysis of variance of Appendix Table 20. for visual injury of the winter wheat cultivars treated with two rates of metribuzin and ethyl metribuzin at Hyslop.

SOV	DF	SS	MS	F ratio
Replications	3	501.56	167.188	8.49 **
Herbicides	1	39.06	39.063	1.98 N.S
Rates	1	1314.06	1314.063	66.75 **
Herb * Rate	1	39.06	39.063	1.98 N.S
Varieties	3	3620.31	1206.771	61.30 **
Herb * Var	3	64.06	21.354	1.08 N.S
Rate * Var	3	1064.06	354.668	18.02 **
Herb*Rate*Var	3	45.31	15.104	0.77 N.S
Error	45	885.94	19.688	

Coefficient of Variation = 40.00 %

Herb: Herbicides
Var : Varieties
N.S : Non Significant
* : Significant at 5 % probability level.
** : Significant at 1 % probability level.

Appendix Table 22. Visual injury of the winter wheat cultivars treated with two rates of metribuzin and ethyl metribuzin at Moro (expresed in scale from 0-100 as 0 = No Injury and 100 = complete kill of the plant).

Treatments		Replications				
Herbicide	Variety	I	II	III	IV	Avg
Metribuzin 0.22 kg/ha	Stephens	0	10	15	15	10
	Hill 81	30	40	40	30	35
	Yamhill	55	65	65	55	60
	Malcolm	15	20	10	10	14
Metribuzin 0.45 kg/ha	Stephens	15	20	20	5	15
	Hill 81	65	50	50	45	53
	Yamhill	80	70	75	65	73
	Malcolm	35	45	30	45	39
Ethyl Metribuzin 1.12 kg/ha	Stephens	5	0	15	10	8
	Hill 81	30	15	20	5	18
	Yamhill	65	60	50	60	59
	Malcolm	10	15	5	15	11
Ethyl Metribuzin 2.24 kg/ha	Stephens	5	15	10	5	9
	Hill 81	50	65	40	45	50
	Yamhill	70	80	80	75	76
	Malcolm	5	20	5	25	14
Check	Stephens	0	0	0	0	0
	Hill 81	0	0	0	0	0
	Yamhill	0	0	0	0	0
	Malcolm	0	0	0	0	0

Appendix Table 23. Analysis of variance of Appendix Table 22 for visual injury (1) of the winter wheat cultivars with two rates of metribuzin and ethyl metribuzin at Moro.

SOV	DF	SS	MS	F ratio
Replications	3	219.92	73.307	1.43 N.S
Herbicides	1	722.27	722.266	14.06 **
Rates	1	3234.77	3234.766	62.98 **
Herb * Rate	1	9.77	9.766	0.19 N.S
Cultivars	3	30051.17	10017.057	195.o3 **
Herb * Cul	3	516.80	172.266	3.35 *
Rate * Cul	3	960.55	320.182	6.23 **
Herb*Rate*Cul	3	760.55	253.516	4.90 **
Error	45	2311.33	51.363	

Coefficient of Variation = 21.19 %

Herb: Herbicides.
Cul : Cultivars.
N.S : Non Significant.
* : Significant at 5 % probability level.
** : Significant at 1 % probability level.

Appendix Table 24. Visual injury of the winter wheat cultivars treated with two rates of metribuzin and ethyl metribuzin at Moro (Expresed in scale from 0-100 as 0 = No injury and 100 = Complete kill of the plant).

Treatments		Replications				
Herbicide	Variety	I	II	III	IV	Avg
Metribuzin 0.22 kg/ha	Stephens	10	20	10	10	13
	Hill 81	70	50	55	70	61
	Yamhill	75	70	75	65	71
	Malcolm	15	5	10	15	11
Metribuzin 0.45 kg/ha	Stephens	20	25	20	20	21
	Hill 81	80	60	75	75	73
	Yamhill	90	70	75	65	75
	Malcolm	5	20	20	15	15
Ethyl Metribuzin 1.12 kg/ha	Stephens	10	10	10	10	10
	Hill 81	35	35	55	20	36
	Yamhill	85	85	80	60	78
	Malcolm	5	15	5	5	8
Ethyl Metribuzin 2.24 kg/ha	Stephens	5	5	5	5	5
	Hill 81	75	75	65	60	69
	Yamhill	85	90	90	70	85
	Malcolm	10	5	5	5	6
Check	Stephens	0	0	0	0	0
	Hill 81	0	0	0	0	0
	Yamhill	0	0	0	0	0
	Malcolm	0	0	0	0	0

Appendix Table 25. Analysis of variance of Appendix Table 24 for visual injury (2) of the winter wheat cultivars treated with two rates of metribuzin and ethyl metribuzin at Moro.

SOV	DF	SS	MS	F ratio
Replications	3	390.63	130.208	2.38 N.S
Herbicides	1	506.25	506.250	9.26 **
Rates	1	900.00	900.00	16.47 **
Herb * Rate	1	6.25	6.250	0.11 N.S
Cultivars	3	54728.13	18242.708	333.79 **
Herb * Cul	3	1053.13	351.042	6.42 **
Rate * Cul	3	1134.38	378.125	6.92 **
Herb*Rate*Cul	3	665.63	221.875	4.06 *
Error	45	2459.38	54.653	

Coefficient of Variation = 18.63 %

Herb: Herbicides.
Cul : Cultivars.
N.S : Non Significant.
* : Significant at 5 % probability level.
** : Significant at 1 % probability level.

Appendix Table 26. Effect of two rates of metribuzin and ethyl metribuzin on the plant height of four winter wheat cultivars at maturity at Hyslop Farm. (expresed as percent of the check).

Treatments		Replications				
Herbicide	Variety	I	II	III	IV	Avg
Metribuzin 0.22 kg/ha	Stephens	105	105	99	100	102
	Hill 81	86	110	88	106	98
	Yamhill	103	102	111	105	105
	Malcolm	96	89	96	94	94
Metribuzin 0.45 kg/ha	Stephens	104	104	94	99	100
	Hill 81	95	104	97	99	99
	Yamhill	93	92	94	97	94
	Malcolm	106	97	88	91	96
Ethyl Metribuzin 1.12 kg/ha	Stephens	101	103	103	94	100
	Hill 81	98	104	91	103	99
	Yamhill	107	103	111	96	104
	Malcolm	106	100	93	89	97
Ethyl Metribuzin 2.24 kg/ha	Stephens	100	106	96	97	100
	Hill 81	83	106	93	91	93
	Yamhill	92	97	94	90	93
	Malcolm	101	94	96	105	99
Check	Stephens	100	100	100	100	100
	Hill 81	100	100	100	100	100
	Yamhill	100	100	100	100	100
	Malcolm	100	100	100	100	100

Appendix Table 27. Analysis of variance of Appendix Table 26 for effect of two rates of metribuzin and ethyl metribuzin on the plant height of four winter wheat cultivars at maturity at Hyslop.

SOV	DF	SS	MS	F ratio
Replications	3	186.75	62.250	1.77 N.S
Herbicides	1	0.56	0.563	0.02 N.S
Rates	1	162.56	161.563	4.63 N.S
Herb * Rate	1	6.25	6.250	0.18 N.S
Cultivars	3	184.38	61.458	1.75 N.S
Herb * Cul	3	70.31	23.438	0.67 N.S
Rate * Cul	3	373.06	124.354	3.54 *
Herb*Rate*Cul	3	45.13	15.042	0.43 N.S
Error	45	1580.75	35.128	

Coefficient of Variation = 6.03 %

Herb: Herbicides.
Cul : Cultivars.
N.S : Non Significant
* : Significant at 5 % probability level.
** : Significant at 1 % probability level.

Appendix Table 28. Effect of two rates of metribuzin and ethyl metribuzin on the plant height of four winter wheat cultivars at maturity stage at Moro (expresed as percent of the check).

Treatments		Replications				
Herbicide	Variety	I	II	III	IV	Avg
Metribuzin 0.22 kg/ha	Stephens	119	97	103	116	109
	Hill 81	116	112	105	90	106
	Yamhill	99	93	87	89	92
	Malcolm	100	98	99	92	97
Metribuzin 0.45 kg/ha	Stephens	111	101	97	113	106
	Hill 81	98	96	105	99	100
	Yamhill	83	86	90	96	89
	Malcolm	99	88	95	97	95
Ethyl Metribuzin 1.12 kg/ha	Stephens	110	90	99	109	102
	Hill 81	101	99	98	109	102
	Yamhill	89	100	92	102	96
	Malcolm	100	95	105	96	99
Ethyl Metribuzin 2.24 kg/ha	Stephens	104	89	106	99	100
	Hill 81	95	99	98	95	97
	Yamhill	80	91	84	96	88
	Malcolm	96	93	106	80	94
Check	Stephens	100	100	100	100	100
	Hill 81	100	100	100	100	100
	Yamhill	100	100	100	100	100
	Malcolm	100	100	100	100	100

Appendix Table 29. Analysis of variance of Appendix Table 28 for effect of two rates of metribuzin and ethyl metribuzin on the plant height of four winter wheat cultivars at Moro.

SOV	DF	SS	MS	F ratio
Replications	3	175.31	58.438	1.16 N.S
Herbicides	1	64.00	64.000	1.27 N.S
Rates	1	324.00	324.000	6.45 *
Herb * Rate	1	7.56	7.563	0.15 N.S
Cultivars	3	1524.69	508.229	10.12 **
Herb * Cul	3	152.25	50.750	1.01 N.S
Rate * Cul	3	22.25	7.417	0.15 N.S
Herb*Rate*Cul	3	24.69	8.229	0.16 N.S
Error	45	2259.19	50.204	

Coefficient of Variation = 7.27 %

Herb: Herbicides.
Cul : Cultivars.
N.S : Non Significant.
* : Significant at 5 % probability level.
** : Significant at 1 % probability level.

Appendix Table 30. Effect of two rates of metribuzin and ethyl metribuzin on the number of productive tillers of four winter wheat cultivars at Hyslop (expresed as percent of the check).

Treatments		Replications				
Herbicide	Variety	I	II	III	IV	Avg
Metribuzin 0.22 kg/ha	Stephens	119	132	95	95	110
	Hill 81	82	106	80	111	95
	Yamhill	71	104	102	1119	99
	Malcolm	104	97	133	108	111
Metribuzin 0.45 kg/ha	Stephens	123	126	101	99	112
	Hill 81	87	101	95	99	96
	Yamhill	65	81	89	111	87
	Malcolm	110	117	129	119	119
Ethyl Metribuzin 1.12 kg/ha	Stephens	143	128	96	93	115
	Hill 81	95	109	95	102	100
	Yamhill	85	106	109	99	100
	Malcolm	107	116	122	138	121
Ethyl Metribuzin 2.24 kg/ha	Stephens	112	129	87	99	107
	Hill 81	85	95	78	85	86
	Yamhill	75	78	75	97	81
	Malcolm	109	102	112	122	111
Check	Stephens	100	100	100	100	100
	Hill 81	100	100	100	100	100
	Yamhill	100	100	100	100	100
	Malcolm	100	100	100	100	100

Appendix Table 31. Analysis of variance of Appendix Table 30 for effect of two rates of metribuzin and ethyl metribuzin on the number of productive tillers of four winter wheat cultivars at Hyslop.

SOV	DF	SS	MS	F ratio
Replications	3	1051.30	350.432	1.72 N.S
Herbicides	1	11.39	11.391	0.06 N.S
Rates	1	682.52	682.516	3.36 N.S
Herb * Rate	1	606.39	606.391	2.98 N.S
Cultivars	3	6813.92	2271.307	11.18 **
Herb * Cul	3	35.05	11.682	0.06 N.S
Rate * Cul	3	508.17	169.391	0.83 N.S
Herb*Rate*Cul	3	82.30	27.432	0.14 N.S
Error	45	9143.95	203.199	

Coefficient of Variation = 13.84 %

Herb: Herbicides.
Cul : Cultivars.
N.S : Non Significant.
* : Significant at 5 % probability level.
** : Significant at 1 % probability level.

Appendix Table 32. Effect of two rates of metribuzin and ethyl metribuzin on the productive tillers of four winter wheat cultivars at Moro (expresed as percent of the check).

Treatments		Replications				
Herbicide	Variety	I	II	III	IV	Avg
Metribuzin 0.22 kg/ha	Stephens	108	150	114	116	122
	Hill 81	44	54	70	50	55
	Yamhill	40	50	24	53	42
	Malcolm	107	84	91	88	93
Metribuzin 0.45 kg/ha	Stephens	118	121	102	119	115
	Hill 81	51	99	58	93	75
	Yamhill	14	52	29	62	39
	Malcolm	112	65	99	70	87
Ethyl Metribuzin 1.12 kg/ha	Stephens	115	129	92	113	122
	Hill 81	84	60	65	122	83
	Yamhill	49	40	28	55	43
	Malcolm	141	116	127	125	127
Ethyl Metribuzin 2.24 kg/ha	Stephens	131	161	151	149	148
	Hill 81	62	100	92	73	82
	Yamhill	36	36	20	49	35
	Malcolm	111	94	87	85	94
Check	Stephens	100	100	100	100	100
	Hill 81	100	100	100	100	100
	Yamhill	100	100	100	100	100
	Malcolm	100	100	100	100	100

Appendix Table 33. Analysis of variance of Appendix Table 32 for effect of two rates of metribuzin and ethyl metribuzin on the number of productive tillers of four winter wheat cultivars at Moro.

SOV	DF	SS	MS	F ratio
Replications	3	ii73.05	391.016	1.30 N.S
Herbicides	1	2902.52	2902.516	9.68 **
Rates	1	28.89	28.891	0.10 N.S
Herb * Rate	1	112.89	112.891	0.38 N.S
Cultivars	3	66396.05	22132.016	73.79 **
Herb * Cul	3	1224.42	408.141	1.36 N.S
Rate * Cul	3	2338.80	779.599	2.60 N.S
Herb*Rate*Cul	3	2189.30	729.766	2.43 N.S
Error	45	13496.70	299.927	

Coefficient of Variation = 20.36 %

Herb: Herbicides.
Cul : Cultivars.
N.S : Non Significant.
* : Significant at 5 % probability level.
** : Significant at 1 % probability level.

Appendix Table 34. Effect of two rates of metribuzin and ethyl metribuzin on the spike length of four winter wheat cultivars at Hyslop (expresed as percent of the check).

Treatments		Replications				
Herbicide	Variety	I	II	III	IV	Avg
Metribuzin 0.22 kg/ha	Stephens	111	105	90	125	114
	Hill 81	113	110	82	100	105
	Yamhill	133	102	100	133	114
	Malcolm	90	89	82	90	91
Metribuzin 0.45 kg/ha	Stephens	100	104	100	125	121
	Hill 81	113	104	100	122	118
	Yamhill	133	92	129	150	128
	Malcolm	100	100	73	80	88
Ethyl Metribuzin 1.12 kg/ha	Stephens	100	114	100	113	107
	Hill 81	113	100	91	111	104
	Yamhill	133	88	100	150	118
	Malcolm	110	90	82	100	96
Ethyl Metribuzin 2.24 kg/ha	Stephens	122	129	90	100	110
	Hill 81	138	125	91	111	116
	Yamhill	161	88	129	100	121
	Malcolm	100	100	73	100	93
Check	Stephens	100	100	100	100	100
	Hill 81	100	100	100	100	100
	Yamhill	100	100	100	100	100
	Malcolm	100	100	100	100	100

Appendix Table 35. Analysis of variance of Appendix Table 34 for effect of two rates of metribuzin and ethyl metribuzin on the spike length of four winter wheat cultivars at Hyslop.

SOV	DF	SS	MS	F ratio
Replications	3	4770.05	1590.016	5.24 **
Herbicides	1	43.89	43.891	0.14 N.S
Rates	1	606.39	606.391	2.00 N.S
Herb * Rate	1	58.14	58.141	0.19 N.S
Cultivars	3	6934.67	2311.557	7.62 **
Herb * Cul	3	371.80	123.932	0.41 N.S
Rate * Cul	3	497.05	165.682	0.55 N.S
Herb*Rate*Cul	3	79.55	26.516	0.09 N.S
Error	45	13652.70	303.393	

Coefficient of Variation = 16.00 %

Herb: Herbicides.
Cul : Cultivars.
N.S : Non Significant.
* : Significant at 5 % probability level.
** : Significant at 1 % probability level.

Appendix Table 36. Effect of two rates of metribuzin and ethyl metribuzin on the spike length of four winter wheat cultivars at Moro (expresed as percent of the check).

Treatments		Replications				
Herbicide	Variety	I	II	III	IV	Avg
Metribuzin 0.22 kg/ha	Stephens	150	117	100	75	111
	Hill 81	129	150	100	133	128
	Yamhill	117	100	117	100	109
	Malcolm	114	117	117	117	116
Metribuzin 0.45 kg/ha	Stephens	133	150	114	100	124
	Hill 81	129	133	114	117	123
	Yamhill	150	117	100	100	117
	Malcolm	114	117	117	117	116
Ethyl Metribuzin 1.12 kg/ha	Stephens	100	133	114	100	112
	Hill 81	114	133	100	133	120
	Yamhill	100	117	117	71	101
	Malcolm	100	117	117	117	113
Ethyl Metribuzin 2.24 kg/ha	Stephens	100	100	100	100	100
	Hill 81	114	150	114	150	132
	Yamhill	117	117	100	100	109
	Malcolm	86	100	117	133	109
Check	Stephens	100	100	100	100	100
	Hill 81	100	100	100	100	100
	Yamhill	100	100	100	100	100
	Malcolm	100	100	100	100	100

Appendix Table 37. Analysis of variance of Appendix Table 36 for effect of two rates of metribuzin and ethyl metribuzin on the spike length of four winter wheat cultivars at Moro.

SOV	DF	SS	MS	F ratio
Replications	3	1660.13	620.042	2.32 N.S
Herbicides	1	588.06	588.063	2.20 N.S
Rates	1	110.25	110.250	0.41 N.S
Herb * Rate	1	45.56	45.563	0.17 N.S
Cultivars	3	2710.63	903.542	3.38 *
Herb * Cul	3	2927.31	99.104	0.37 N.S
Rate * Cul	3	200.63	66.875	0.25 N.S
Herb*Rate*Cul	3	900.31	300.104	1.12 N.S
Error	45	12032.88	267.397	

Coefficient of Variation = 14.23 %

Herb: Herbicides.
Cul : Cultivars.
N.S : Non Significant.
* : Significant at 5 % probability level.
** : Significant at 1 % probability level.

Appendix Table 38. Effect of two rates of metribuzin and ethyl metribuzin on the number of spikelets per spike of four winter wheat cultivars at Hyslop. (expresed as percent of the check)

Treatments		Replications				
Herbicide	Variety	I	II	III	IV	Avg
Metribuzin 0.22 kg/ha	Stephens	84	106	89	100	95
	Hill 81	132	110	86	84	103
	Yamhill	111	105	121	95	108
	Malcolm	100	105	111	111	107
Metribuzin 0.45 kg/ha	Stephens	100	94	100	106	100
	Hill 81	132	119	110	92	113
	Yamhill	111	105	111	100	107
	Malcolm	100	100	100	105	101
Ethyl Metribuzin 1.12 kg/ha	Stephens	100	100	100	88	97
	Hill 81	111	100	119	88	105
	Yamhill	121	105	111	90	107
	Malcolm	100	105	111	111	107
Ethyl Metribuzin 2.24 kg/ha	Stephens	95	106	100	106	102
	Hill 81	132	124	114	110	118
	Yamhill	111	115	121	100	112
	Malcolm	111	90	105	95	100
Check	Stephens	100	100	100	100	100
	Hill 81	100	100	100	100	100
	Yamhill	100	100	100	100	100
	Malcolm	100	100	100	100	100

Appendix Table 39. Analysis of variance of Appendix Table 38 for effect of two rates of metribuzin and ethyl metribuzin on the number of spikelets per spike of four winter wheat cultivars at Hyslop.

SOV	DF	SS	MS	F ratio
Replications	3	1115.25	371.750	3.64 *
Herbicides	1	39.06	39.063	0.38 N.S
Rates	1	156.25	156.250	1.53 N.S
Herb * Rate	1	14.06	14.063	0.14 N.S
Cultivars	3	1235.88	411.958	4.04 *
Herb * Cul	3	25.06	8.354	0.08 N.S
Rate * Cul	3	642.38	214.125	2.10 N.S
Herb*Rate*Cul	3	33.81	11.271	0.11 N.S
Error	45	4594.25	102.094	

Coefficient of Variation = 9.62 %

Herb: Herbicides.
Cul : Cultivars.
N.S : Non Significant.
* : Significant at 5 % probability level.
** : Significant at 1 % probability level

Appendix Table 40. Effect of two rates of metribuzin and ethyl metribuzin on the number of spikelets per spike of four winter wheat cultivars at Moro (expresed as percent of the check)

Treatments		Replications				
Herbicide	Variety	I	II	III	IV	Avg
Metribuzin 0.22 kg/ha	Stephens	108	133	115	87	111
	Hill 81	111	111	120	119	115
	Yamhill	100	100	112	100	103
	Malcolm	121	133	107	100	115
Metribuzin 0.45 kg/ha	Stephens	108	125	108	113	114
	Hill 81	100	111	120	119	113
	Yamhill	122	111	124	105	116
	Malcolm	129	108	100	100	109
Ethyl Metribuzin 1.12 kg/ha	Stephens	108	100	123	100	108
	Hill 81	94	89	113	113	102
	Yamhill	89	100	112	100	100
	Malcolm	114	108	107	100	107
Ethyl Metribuzin 2.24 kg/ha	Stephens	100	125	115	93	108
	Hill 81	100	122	133	131	122
	Yamhill	117	100	129	116	116
	Malcolm	107	108	114	113	111
Check	Stephens	100	100	100	100	100
	Hill 81	100	100	100	100	100
	Yamhill	100	100	100	100	100
	Malcolm	100	100	100	100	100

Appendix Table 41. Analysis of variance of Appendix Table 40 for effect of two rates of metribuzin and ethyl metribuzin on the number of spikelets per spike of four winter wheat cultivars at Moro.

SOV	DF	SS	MS	F ratio
Replications	3	774.55	258.182	2.17 N.S
Herbicides	1	118.27	118.266	0.99 N.S
Rates	1	500.64	500.641	4.20 *
Herb * Rate	1	252.02	252.016	2.11 N.S
Cultivars	3	153.42	51.141	0.43 N.S
Herb * Cul	3	18.92	6.307	0.05 N.S
Rate * Cul	3	559.80	186.599	1.57 N.S
Herb*Rate*Cul	3	330.17	110.057	0.92 N.S
Error	45	5362.20	119.16	

Coefficient of Variation = 9.88 %

Herb: Herbicides.
Cul : Cultivars.
N.S : Non Significant.
* : Significant at 5 % probability level.
** : Significant at 1 % probability level.

Appendix Table 42. Effect of two rates of metribuzin and ethyl metribuzin on the grains per spike of four winter wheat cultivars at Hyslop (expresed as percent of the check)

Treatments		Replications				
Herbicide	Variety	I	II	III	IV	Avg
Metribuzin 0.22 kg/ha	Stephens	98	167	53	71	97
	Hill 81	150	117	77	87	108
	Yamhill	135	126	140	73	119
	Malcolm	98	82	114	92	97
Metribuzin 0.45 kg/ha	Stephens	83	122	116	84	101
	Hill 81	135	165	111	134	136
	Yamhill	92	140	123	64	105
	Malcolm	90	79	95	117	95
Ethyl Metribuzin 1.12 kg/ha	Stephens	100	172	118	90	120
	Hill 81	140	138	121	95	124
	Yamhill	98	118	74	76	92
	Malcolm	88	90	89	119	97
Ethyl Metribuzin 2.24 kg/ha	Stephens	119	156	82	85	111
	Hill 81	175	162	105	113	139
	Yamhill	129	94	143	133	125
	Malcolm	115	56	92	83	87
Check	Stephens	100	100	100	100	100
	Hill 81	100	100	100	100	100
	Yamhill	100	100	100	100	100
	Malcolm	100	100	100	100	100

Appendix Table 43. Analysis of variance of Appendix Table 42 for effect of two rates of metribuzin and ethyl metribuzin on the number of grains per spike of four winter wheat cultivars at Hyslop.

SOV	DF	SS	MS	F ratio
Replications	3	7996.56	2665.521	3.90 *
Herbicides	1	297.56	297.563	0.44 N.S
Rates	1	540.56	540.563	0.79 N.S
Herb * Rate	1	33.06	33.063	0.05 N.S
Cultivars	3	8740.31	2913.438	4.26 **
Herb * Cul	3	1185.06	895.021	0.58 N.S
Rate * Cul	3	1910.56	636.854	0.93 N.S
Herb*Rate*Cul	3	2610.31	870.104	1.27 N.S
Error	45	30764.44	683.654	

Coefficient of Variation = 23.91 %

Herb: Herbicides.
Cul : Cultivars.
N.S : Non Significant.
* : Significant at 5 % probability level.
** : Significant at 1 % probability level.

Appendix Table 44. Effect of two rates of metribuzin and ethyl metribuzin on the grains per spike of four winter wheat cultivars at Moro (expresed as percent of the check)

Treatments		Replications				
Herbicide	Variety	I	II	III	IV	Avg
Metribuzin	Stephens	143	191	129	68	133
0.22 kg/ha	Hill 81	179	124	108	150	140
	Yamhill	122	113	100	112	112
	Malcolm	145	130	103	106	121
Metribuzin	Stephens	104	164	121	98	122
0.45 kg/ha	Hill 81	131	145	121	133	133
	Yamhill	163	109	111	124	152
	Malcolm	127	107	107	128	117
Ethyl	Stephens	122	141	143	88	124
Metribuzin	Hill 81	100	105	113	107	106
1.12 kg/ha	Yamhill	76	76	133	98	96
	Malcolm	139	119	110	103	118
Ethyl	Stephens	117	173	129	83	126
Metribuzin	Hill 81	112	179	156	169	154
2.24 kg/ha	Yamhill	171	113	107	129	130
	Malcolm	121	104	157	133	129
Check	Stephens	100	100	100	100	100
	Hill 81	100	100	100	100	100
	Yamhill	100	100	100	100	100
	Malcolm	100	100	100	100	100

Appendix Table 45. Analysis of variance of Appendix Table 44 for effect of two rates of metribuzin and ethyl metribuzin on the number of grains per spike of four winter wheat cultivars at Moro.

SOV	DF	SS	MS	F ratio
Replications	3	4358.56	1452.854	1.51 N.S
Herbicides	1	564.06	564.063	0.58 N.S
Rates	1	3164.06	3164.063	3.28 N.S
Herb * Rate	1	1501.56	1501.563	1.56 N.S
Cultivars	3	1421.81	473.938	0.49 N.S
Herb * Cul	3	1115.56	371.854	0.39 N.S
Rate * Cul	3	4082.56	1360.854	1.41 N.S
Herb*Rate*Cul	3	1998.31	666.104	0.69 N.S
Error	45	43401.94	964.488	

Coefficient of Variation = 24.72 %

Herb: Herbicides.
Cul : Cultivars.
N.S : Non Significant.
* : Significant at 5 % probability level.
** : Significant at 1 % probability level.

Appendix Table 46. Effect of two rates of metribuzin and ethyl metribuzin on the 1000 grain weight of four winter wheat cultivars at Hyslop (expresed as percent of the check)

Treatments		Replications				
Herbicide	Variety	I	II	III	IV	Avg
Metribuzin 0.22 kg/ha	Stephens	102	94	104	96	99
	Hill 81	95	100	100	102	99
	Yamhill	114	96	112	102	106
	Malcolm	96	120	107	100	106
Metribuzin 0.45 kg/ha	Stephens	91	102	102	87	96
	Hill 81	98	100	105	93	99
	Yamhill	121	102	121	93	109
	Malcolm	92	102	107	102	101
Ethyl Metribuzin 1.12 kg/ha	Stephens	94	96	88	87	91
	Hill 81	98	105	103	107	103
	Yamhill	112	94	107	104	104
	Malcolm	84	112	105	91	98
Ethyl Metribuzin 2.24 kg/ha	Stephens	92	84	94	89	90
	Hill 81	100	100	103	102	101
	Yamhill	114	96	117	98	106
	Malcolm	90	98	109	100	99
Check	Stephens	100	100	100	100	100
	Hill 81	100	100	100	100	100
	Yamhill	100	100	100	100	100
	Malcolm	100	100	100	100	100

Appendix Table 47. Analysis of variance of Appendix Table 46 for effect of two rates of metribuzin and ethyl metribuzin on the 1000-grain weight of four winter wheat cultivars at Hyslop.

SOV	DF	SS	MS	F ratio
Replications	3	567.17	189.057	3.54 *
Herbicides	1	112.89	112.891	2.12 N.S
Rates	1	8.27	8.266	0.15 N.S
Herb * Rate	1	6.89	6.891	0.13 N.S
Cultivars	3	1269.92	423.307	7.94 **
Herb * Cul	3	216.55	72.182	1.35 N.S
Rate * Cul	3	63.42	21.141	0.40 N.S
Herb*Rate*Cul	3	40.80	13.599	0.25 N.S
Error	45	2400.08	53.335	

Coefficient of Variation = 7.27 %

Herb: Herbicides.
Cul : Cultivars.
N.S : Non Significant.
* : Significant at 5 % probability level.
** : Significant at 1 % probability level.

Appendix Table 48. Effect of two rates of metribuzin and ethyl metribuzin on the 1000 grain weight of four winter wheat cultivars at Moro (expresed as percent of the check)

Treatments		Replications				
Herbicide	Variety	I	II	III	IV	Avg
Metribuzin 0.22 kg/ha	Stephens	97	90	88	105	95
	Hill 81	95	105	115	103	105
	Yamhill	105	106	106	108	106
	Malcolm	90	92	95	120	99
Metribuzin 0.45 kg/ha	Stephens	117	81	90	100	97
	Hill 81	108	89	94	97	97
	Yamhill	103	94	109	87	98
	Malcolm	100	85	97	120	101
Ethyl Metribuzin 1.12 kg/ha	Stephens	111	102	90	81	96
	Hill 81	97	100	97	13	102
	Yamhill	100	103	97	105	101
	Malcolm	100	97	108	110	104
Ethyl Metribuzin 2.24 kg/ha	Stephens	100	95	90	84	92
	Hill 81	95	103	109	113	105
	Yamhill	105	94	106	95	100
	Malcolm	105	95	87	110	99
Check	Stephens	100	100	100	100	100
	Hill 81	100	100	100	100	100
	Yamhill	100	100	100	100	100
	Malcolm	100	100	100	100	100

Appendix Table 49. Analysis of variance of Appendix Table 48 for effect of two rates of metribuzin and ethyl metribuzin on the 1000-grain weight of four winter wheat cultivars at Moro.

SOV	DF	SS	MS	F ratio
Replications	3	537.13	179.042	2.08 N.S
Herbicides	1	0.56	0.563	0.01 N.S
Rates	1	85.56	85.563	0.99 N.S
Herb * Rate	1	9.00	9.000	0.10 N.S
Cultivars	3	496.50	165.500	1.92 N.S
Herb * Cul	3	62.19	20.729	0.24 N.S
Rate * Cul	3	31.69	10.563	0.12 N.S
Herb*Rate*Cul	3	218.25	72.750	0.85 N.S
Error	45	3872.88	86.064	

Coefficient of Variation = 9.29 %

Herb: Herbicides.
Cul : Cultivars.
N.S : Non Significant.
* : Significant at 5 % probability level.
** : Significant at 1 % probability level.

Appendix Table 50. Effect of two rates of metribuzin and ethyl metribuzin on the biological yield of four winter wheat cultivars at Hyslop (expresed as percent of the check)

Treatments		Replications				
Herbicide	Variety	I	II	III	IV	Avg
Metribuzin 0.22 kg/ha	Stephens	145	126	93	99	116
	Hill 81	79	126	67	118	98
	Yamhill	111	109	108	140	117
	Malcolm	81	116	113	99	102
Metribuzin 0.45 kg/ha	Stephens	86	103	107	95	98
	Hill 81	83	147	98	71	100
	Yamhill	88	92	122	134	109
	Malcolm	93	95	107	116	103
Ethyl Metribuzin 1.12 kg/ha	Stephens	140	105	95	85	106
	Hill 81	88	154	97	100	110
	Yamhill	111	106	112	134	116
	Malcolm	85	109	99	123	104
Ethyl Metribuzin 2.24 kg/ha	Stephens	135	105	99	95	109
	Hill 81	75	146	72	90	96
	Yamhill	137	90	77	94	100
	Malcolm	85	110	111	116	106
Check	Stephens	100	100	100	100	100
	Hill 81	100	100	100	100	100
	Yamhill	100	100	100	100	100
	Malcolm	100	100	100	100	100

Appendix Table 51. Analysis of variance of Appendix Table 50 for effect of two rates of metribuzin and ethyl metribuzin on the biological yield of four winter wheat cultivars at Hyslop.

SOV	DF	SS	MS	F ratio
Replication	3	2494.55	831.516	1.74 N.S
Herbicides	1	2.64	2.641	0.01 N.S
Rates	1	618.77	618.766	1.29 N.S
Herb * Rate	1	2.64	2.641	0.01 N.S
Cultivars	3	836.05	278.682	0.58 N.S
Herb * Cul	3	202.80	67.599	0.14 N.S
Rate * Cul	3	359.42	119.807	0.25 N.S
Herb*Rate*Cul	3	740.55	246.849	0.52 N.S
Error	45	21518.20	478.182	

Coefficient of Variation = 20.74 %

Herb: Herbicides.
Cul : Cultivars.
N.S : Non Significant.
* : Significant at 5 % probability level.
** : Significant at 1 % probability level.

Appendix Table 52. Effect of two rates of metribuzin and ethyl Metribuzin on the biological yield of four winter wheat cultivars at Moro (expresed as percent of the check)

Treatments		Replications				
Herbicide	Variety	I	II	III	IV	Avg
Metribuzin 0.22 kg/ha	Stephens	108	136	117	148	127
	Hill 81	48	87	142	68	86
	Yamhill	59	68	49	145	78
	Malcolm	117	95	102	114	107
Metribuzin 0.45 kg/ha	Stephens	147	123	102	135	127
	Hill 81	67	117	113	95	98
	Yamhill	33	68	59	124	71
	Malcolm	133	84	108	86	103
Ethyl Metribuzin 1.12 kg/ha	Stephens	144	109	102	145	125
	Hill 81	93	76	110	129	102
	Yamhill	49	61	56	128	74
	Malcolm	152	134	108	130	131
Ethyl Metribuzin 2.24 kg/ha	Stephens	136	148	143	123	138
	Hill 81	72	96	130	113	103
	Yamhill	54	23	28	103	52
	Malcolm	117	100	106	98	105
Check	Stephens	100	100	100	100	100
	Hill 81	100	100	100	100	100
	Yamhill	100	100	100	100	100
	Malcolm	100	100	100	100	100

Appendix Table 53. Analysis of variance of Appendix Table 52 for effect of two rates of metribuzin and ethyl metribuzin on the biological yield of four winter wheat cultivars at Moro.

SOV	DF	SS	MS	F ratio
Replications	3	5613.42	1871.141	2.78 N.S
Herbicides	1	268.14	268.141	0.40 N.S
Rates	1	293.27	293.266	0.44 N.S
Herb * Rate	1	268.14	268.141	0.40 N.S
Cultivars	3	31324.55	10441.516	15.49 **
Herb * Cul	3	1532.67	510.891	0.76 N.S
Rate * Cul	3	1733.55	577.849	0.86 N.S
Herb*Rate*Cul	3	666.17	222.057	0.33 N.S
Error	45	30332.83	674.063	

Coefficient of Variation = 25.54

Herb: Herbicides.
Cul : Cultivars.
N.S : Non Significant.
* : Significant at 5 % probability level.
** : Significant at 1 % probability level.

Appendix Table 54. Effect of two rates of metribuzin and ethyl metribuzin on the economic yield of four winter wheat cultivars at Hyslop (expresed as percent of the check)

Treatments		Replications				
Herbicide	Variety	I	II	III	IV	Avg
Metribuzin 0.22 kg/ha	Stephens	131	114	84	91	105
	Hill 81	92	96	52	104	86
	Yamhill	129	112	115	129	121
	Malcolm	74	145	100	110	107
Metribuzin 0.45 kg/ha	Stephens	101	100	97	85	96
	Hill 81	98	136	103	97	109
	Yamhill	142	109	141	145	134
	Malcolm	79	100	92	79	88
Ethyl Metribuzin 1.12 kg/ha	Stephens	134	110	84	70	100
	Hill 81	100	126	88	103	104
	Yamhill	131	99	119	140	122
	Malcolm	73	102	82	130	97
Ethyl Metribuzin 2.24 kg/ha	Stephens	121	91	83	84	94
	Hill 81	82	119	71	85	89
	Yamhill	188	100	98	93	120
	Malcolm	70	119	107	122	105
Check	Stephens	100	100	100	100	100
	Hill 81	100	100	100	100	100
	Yamhill	100	100	100	100	100
	Malcolm	100	100	100	100	100

Appendix Table 55. Analysis of variance of Appendix Table 54 for effect of two rates of metribuzin and ethyl metribuzin on the economic yield of four winter wheat cultivars at Hyslop.

SOV	DF	SS	MS	F ratio
Replications	3	2552.81	850.938	1.75 N.S
Herbicides	1	52.56	52.563	0.11 N.S
Rates	1	16.00	16.000	0.03 N.S
Herb * Rate	1	110.25	110.250	0.23 N.S
Cultivars	3	8228.19	2742.729	5.64 **
Herb * Cul	3	215.19	71.729	0.15 N.S
Rate * Cul	3	490.50	163.500	0.34 N.S
Herb*Rate*Cul	3	2312.75	770.917	1.59 N.S
Error	45	21884.69	486.326	

Coefficient of Variation = 21.05 %

Herb: Herbicides.
Cul : Cultivars.
N.S : Non Significant.
* : Significant at 5 % probability level.
** : Significant at 1 % probability level.

Appendix Table 56. Effect of two rates of metribuzin and ethyl metribuzin on the economic yield of four winter wheat cultivars at Moro (expresed as percent of the check)

Treatments		Replications				
Herbicide	Variety	I	II	III	IV	Avg
Metribuzin 0.22 kg/ha	Stephens	102	151	124	115	123
	Hill 81	45	78	92	78	73
	Yamhill	84	78	22	84	67
	Malcolm	138	92	101	100	108
Metribuzin 0.45 kg/ha	Stephens	119	134	115	115	121
	Hill 81	72	83	94	100	87
	Yamhill	41	78	53	84	64
	Malcolm	165	80	112	90	112
Ethyl Metribuzin 1.12 kg/ha	Stephens	110	116	101	101	107
	Hill 81	92	78	87	123	95
	Yamhill	60	64	54	85	66
	Malcolm	159	138	117	121	134
Ethyl Metribuzin 2.24 kg/ha	Stephens	104	163	157	115	135
	Hill 81	72	81	109	92	89
	Yamhill	79	19	19	77	48
	Malcolm	130	92	101	100	106
Check	Stephens	100	100	100	100	100
	Hill 81	100	100	100	100	100
	Yamhill	100	100	100	100	100
	Malcolm	100	100	100	100	100

Appendix Table 57. Analysis of variance of Appendix Table 56 for effect of two rates of metribuzin and ethyl metribuzin on the economic yield of four winter wheat cultivars at Moro.

SOV	DF	SS	MS	F ratio
Replications	3	617.38	205.792	0.40 N.S
Herbicides	1	138.06	138.063	0.27 N.S
Rates	1	36.00	36.000	0.07 N.S
Herb * Rate	1	351.56	351.563	0.69 N.S
Cultivars	3	36985.25	12328.417	24.16 **
Herb * Cul	3	1101.19	367.063	0.72 N.S
Rate * Cul	3	1687.50	562.500	1.10 N.S
Herb*Rate*Cul	3	2217.69	739.229	1.45 N.S
Error	45	22967.13	510.381	

Coefficient of Variation = 23.58 %

Herb: Herbicides.
Cul : Cultivars.
N.S : Non Significant.
* : Significant at 5 % probability level.
** : Significant at 1 % probability level.

Appendix Table 58. Effect of two rates of metribuzin and ethyl metribuzin on the harvest index of four winter wheat cultivars at Hyslop (expresed as percent of the check).

Treatments		Replications				
Herbicide	Variety	I	II	III	IV	Avg
Metribuzin 0.22 kg/ha	Stephens	91	90	90	92	91
	Hill 81	117	76	78	88	90
	Yamhill	116	103	107	92	105
	Malcolm	91	125	88	111	104
Metribuzin 0.45 kg/ha	Stephens	118	97	91	90	99
	Hill 81	119	92	105	137	113
	Yamhill	162	118	115	108	126
	Malcolm	85	106	86	69	87
Ethyl Metribuzin 1.12 kg/ha	Stephens	95	105	88	82	93
	Hill 81	103	82	90	103	97
	Yamhill	118	93	106	105	106
	Malcolm	86	93	82	106	92
Ethyl Metribuzin 2.24 kg/ha	Stephens	89	87	83	89	87
	Hill 81	109	81	98	95	96
	Yamhill	137	111	128	100	119
	Malcolm	82	108	96	105	98
Check	Stephens	100	100	100	100	100
	Hill 81	100	100	100	100	100
	Yamhill	100	100	100	100	100
	Malcolm	100	100	100	100	100

Appendix Table 59. Analysis of variance of Appendix Table 58 for effect of two rates of metribuzin and ethyl metribuzin on the harvest index of four winter wheat cultivars at Hyslop.

SOV	DF	SS	MS	F ratio
Replications	3	1438.56	479.521	2.65 N.S
Herbicides	1	182.25	182.250	1.01 N.S
Rates	1	588.06	588.063	3.25 N.S
Herb * Rate	1	132.25	132.250	0.73 N.S
Cultivars	3	4371.19	1457.063	8.06 **
Herb * Cul	3	61.50	20.500	0.11 N.S
Rate * Cul	3	1248.69	416.229	2.30 N.S
Herb*Rate*Cul	3	1270.00	423.333	2.34 N.S
Error	45	8135.44	180.788	

Coefficient of Variation = 13.45 %

Herb: Herbicides.
Cul : Cultivars.
N.S : Non Significant.
* : Significant at 5 % probability level.
** : Significant at 1 % probability level.

Appendix Table 60. Effect of two rates of metribuzin and ethyl metribuzin on the harvest index of four winter wheat cultivars at Moro (expresed as percent of the check).

Treatments		Replications				
Herbicide	Variety	I	II	III	IV	Avg
Metribuzin 0.22 kg/ha	Stephens	94	111	106	78	97
	Hill 81	94	90	65	114	91
	Yamhill	142	114	54	58	92
	Malcolm	118	97	99	88	101
Metribuzin 0.45 kg/ha	Stephens	81	109	113	85	97
	Hill 81	111	71	83	105	93
	Yamhill	123	114	89	68	99
	Malcolm	124	95	104	104	107
Ethyl Metribuzin 1.12 kg/ha	Stephens	76	106	99	70	88
	Hill 81	99	102	80	95	94
	Yamhill	124	105	96	67	98
	Malcolm	104	103	108	93	102
Ethyl Metribuzin 2.24 kg/ha	Stephens	76	110	110	94	98
	Hill 81	100	84	82	81	87
	Yamhill	147	82	57	75	90
	Malcolm	111	92	95	102	100
Check	Stephens	100	100	100	100	100
	Hill 81	100	100	100	100	100
	Yamhill	100	100	100	100	100
	Malcolm	100	100	100	100	100

Appendix Table 61. Analysis of variance of Appendix Table 60 for effect of two rates of metribuzin and ethyl metribuzin on the harvest index of four winter wheat cultivars at Moro.

SOV	DF	SS	MS	F ratio
Replications	3	4510.06	1503.354	4.11 *
Herbicides	1	90.25	90.250	0.25 N.S
Rates	1	12.25	12.250	0.03 N.S
Herb * Rate	1	115.56	115.563	0.32 N.S
Cultivars	3	1080.31	360.104	0.98 N.S
Herb * Cul	3	29.63	9.875	0.03 N.S
Rate * Cul	3	127.88	42.625	0.12 N.S
Herb*Rate*Cul	3	336.56	112.188	0.31 N.S
Error	45	16452.44	365.610	

Coefficient of Variation = 19.98 %

Herb: Herbicides.
Cul : Cultivars.
N.S : Non Significant.
* : Significant at 5 % probability level.
** : Significant at 1 % probability level.

Appendix Table 62. Effect of two rates of metribuzin and ethyl metribuzin on the protein content of the grains of four winter wheat cultivars at Hyslop (expresed as percent of the check).

Treatments		Replications				
Herbicide	Variety	I	II	III	IV	Avg
Metribuzin 0.22 kg/ha	Stephens	109	116	91	101	104
	Hill 81	93	108	106	117	106
	Yamhill	87	111	97	112	102
	Malcolm	95	100	101	84	95
Metribuzin 0.45 kg/ha	Stephens	102	114	99	108	106
	Hill 81	104	111	96	119	108
	Yamhill	86	112	114	114	107
	Malcolm	97	100	99	85	95
Ethyl Metribuzin 1.12 kg/ha	Stephens	105	108	119	104	109
	Hill 81	107	103	115	107	108
	Yamhill	96	112	102	114	106
	Malcolm	101	91	88	92	93
Ethyl Metribuzin 2.24 kg/ha	Stephens	113	132	104	104	113
	Hill 81	112	120	116	128	119
	Yamhill	107	125	102	126	115
	Malcolm	97	114	99	90	100
Check	Stephens	100	100	100	100	100
	Hill 81	100	100	100	100	100
	Yamhill	100	100	100	100	100
	Malcolm	100	100	100	100	100

Appendix Table 63. Analysis of variance of Appendix Table 62 for effect of two rates of metribuzin and ethyl metribuzin on the protein content of grains of four winter wheat cultivars at Hyslop.

SOV	DF	SS	MS	F ratio
Replications	3	981.80	327.266	4.39 **
Herbicides	1	425.39	425.391	5.71 *
Rates	1	385.14	385.141	5.17 *
Herb * Rate	1	135.14	135.141	1.81 N.S
Cultivars	3	1999.55	666.516	8.95 **
Herb * Cul	3	77.05	25.682	0.34 N.S
Rate * Cul	3	45.80	15.266	0.20 N.S
Herb*Rate*Cul	3	26.30	8.766	0.12 N.S
Error	45	3351.95	74.488	

Coefficient of Variation = 8.19 %

Herb: Herbicides.
Cul : Cultivars.
N.S : Non Significant.
* : Significant at 5 % probability level.
** : Significant at 1 % probability level.

Appendix Table 64. Effect of two rates of metribuzin and ethyl metribuzin on the protein content of the grains of four winter wheat cultivars at Moro (expresed as percent of the check).

Treatments		Replications				
Herbicide	Variety	I	II	III	IV	Avg
Metribuzin	Stephens	162	103	134	54	113
0.22 kg/ha	Hill 81	151	124	93	128	124
	Yamhill	109	73	95	117	99
	Malcolm	106	110	112	86	104
Metribuzin	Stephens	141	195	117	59	128
0.45 kg/ha	Hill 81	112	118	104	102	109
	Yamhill	122	82	112	142	115
	Malcolm	96	134	107	84	105
Ethyl	Stephens	104	90	118	90	101
Metribuzin	Hill 81	95	109	104	120	116
1.12 kg/ha	Yamhill	88	115	128	129	115
	Malcolm	78	98	106	101	96
Ethyl	Stephens	100	121	126	106	113
Metribuzin	Hill 81	93	123	92	130	110
2.24 Kg/ha	Yamhill	108	88	105	149	113
	Malcolm	77	92	115	169	113
Check	Stephens	100	100	100	100	100
	Hill 81	100	100	100	100	100
	Yamhill	100	100	100	100	100
	Malcolm	100	100	100	100	100

<u>Appendix Table 65.</u> Analysis of variance of Appendix Table 64 for effect of two rates of metribuzin and ethyl metribuzin on the protein content of grains of four winter wheat cultivars at Moro.

SOV	DF	SS	MS	F ratio
Replications	3	123.05	41.016	0.05 N.S
Herbicides	1	102.52	102.516	0.13 N.S
Rates	1	375.39	375.391	0.49 N.S
Herb * Rate	1	3.52	3.516	0.00 N.S
Cultivars	3	1028.05	342.682	0.45 N.S
Herb * Cul	3	920.30	306.766	0.40 N.S
Rate * Cul	3	1395.92	465.307	0.61 N.S
Herb*Rate*Cul	3	663.05	221.016	0.29 N.S
Error	45	34178.70	759.527	

Coefficient of Variation = 24.89 %

Herb: Herbicides.
Cul : Cultivars.
N.S : Non Significant.
* : Significant at 5 % probability level.
** : Significant at 1 % probability level.

Appendix Table 66. Herbicide interaction studies of metribuzin and ethylmetribuzin for the control of downy brome in field at Sherman Experiment Station, Moro. (Recorded as a visable injury to the plants on a scale of 0 to 100)

Treatments		Replications				
Metri.	Ethyl Metri.	I	II	III	IV	Avg
--------kg/ha---------		----------------% plant injury------------------------				
0.20	0.00	80	75	75	95	81
0.15	0.00	70	95	60	70	70
0.10	0.00	65	60	50	60	58
0.05	0.00	5	15	10	10	10
0.00	1.00	75	90	75	85	81
0.00	0.75	70	90	70	85	78
0.00	0.50	15	15	25	30	21
0.00	0.25	5	15	10	15	11
0.15	0.75	100	100	100	100	100
0.15	0.50	100	100	100	90	98
0.15	0.25	85	80	60	70	76
0.10	0.75	85	95	100	80	91
0.10	0.50	85	85	85	90	86
0.10	0.25	70	85	60	75	73
0.05	0.75	75	75	100	85	84
0.05	0.50	45	30	50	50	44
0.05	0.25	30	30	40	20	30
0.00	0.00	0	0	0	0	00

a) Metri is used as an abreviation of metribuzin.

Appendix Table 67. Herbicide interaction studies of metribuzin and ethyl metribuzin for the control of downy brome in greenhouse. (Recorded as a visable injury to the plants on a scale of 0 to 100)

Treatments		Replications								
		- Experiment 1 -				- Experiment 2 -				
Metri.	E.Metri.	I	II	III	IV	I	II	111	IV	Avg
----- kg/ha -----		---------------- Visable injury to plants (%) ----------------								
0.01	-.-	0	0	0	0	0	0	0	0	0
0.02	-.-	15	10-	20	15	20	20	15	20	17
0.03	-.-	35	40	40	40	40	40	35	35	38
0.04	-.-	40	50	50	50	50	55	50	50	49
0.05	-.-	60	60	70	50	60	60	70	60	61
0.06	-.-	75	70	65	70	85	65	70	70	71
0.07	-.-	90	95	95	85	90	90	95	90	91
0.08	-.-	100	90	90	95	100	100	90	90	94
-.--	0.05	10	10	0	10	10	10	0	0	6
-.--	0.15	15	25	20	25	25	15	15	20	20
-.--	0.25	55	50	55	55	40	50	50	55	51
-.--	0.35	55	50	65	65	65	70	55	55	60
-.--	0.45	70	85	80	80	80	80	70	80	78
-.--	0.55	75	85	80	80	85	90	90	70	82
-.--	0.65	100	95	95	100	100	100	85	90	96
-.--	0.75	100	100	100	95	90	100	100	90	97
0.01	0.05	15	20	15	0	10	10	10	15	12
0.01	0.15	20	20	25	35	20	30	30	25	26
0.01	0.25	55	55	60	55	50	50	55	55	54
0.01	0.35	70	65	55	65	65	65	75	60	65
0.01	0.45	80	80	80	90	80	70	85	85	81
0.01	0.55	85	90	80	90	90	90	80	90	87
0.01	0.65	100	90	90	100	100	100	100	100	98
0.01	0.75	100	100	100	100	1200	100	100	100	100

Appendix Table 67 cont'd

Appendix Table 67 Cont'd

Treatments		Replications								
		- Experiment 1 -				- Experiment 2 -				
Metri.	E.Metri.	I	II	III	IV	I	II	111	IV	Avg
----- kg/ha -----		---------------- Visable injury to plants (%) ------------------								
0.02	0.05	30	25	35	25	20	25	25	15	25
0.02	0.15	35	35	25	35	35	25	40	35	33
0.02	0.25	60	65	50	50	55	65	55	65	58
0.02	0.35	70	80	70	70	85	65	70	70	73
0.02	0.45	75	85	85	85	90	90	70	85	83
0.02	0.55	100	90	90	100	100	90	100	80	94
0.02	0.65	100	100	100	100	100	100	100	100	100
0.02	0.75	100	100	100	100	100	100	100	100	100
0.03	0.05	35	50	40	35	40	50	40	50	43
0.03	0.15	50	50	50	45	45	35	45	50	46
0.03	0.25	75	70	60	60	65	70	70	65	67
0.03	0.35	85	95	80	80	95	95	80	85	87
0.03	0.45	100	100	80	100	100	90	100	100	96
0.03	0.55	100	100	100	100	100	100	100	100	100
0.03	0.65	100	100	100	100	100	100	100	100	100
0.03	0.75	100	100	100	100	100	100	100	100	100
0.04	0.05	65	50	50	45	55	55	55	45	53
0.04	0.15	55	65	55	50	65	65	70	50	59
0.04	0.25	70	85	85	85	95	90	80	80	84
0.04	0.35	100	80	100	100	80	90	100	100	94
0.04	0.45	100	100	80	100	100	90	100	100	100
0.04	0.55	100	100	100	100	100	100	100	100	100
0.04	0.65	100	100	100	100	100	100	100	100	100
0.04	0.75	100	100	100	100	100	100	100	100	100
0.05	0.05	70	65	80	65	50	65	65	80	68
0.05	0.15	75	90	85	85	70	70	85	80	80
0.05	0.25	100	90	90	100	80	100	100	100	95
0.05	0.35	100	100	100	100	100	100	90	100	99

Appendix Table 67 Cont'd

Appendix Table 67 Cont'd

Treatments		Replications								
		- Experiment 1 -				- Experiment 2 -				
Metri.	E.Metri.	I	II	III	IV	I	II	111	IV	Avg
----- kg/ha -----		---------------- Visable injury to plants (%) ------------------								
0.05	0.45	100	100	100	100	100	100	100	100	100
0.05	0.55	100	100	100	100	100	100	100	100	100
0.05	0.65	100	100	100	100	100	100	100	100	100
0.05	0.75	100	100	100	100	100	100	100	100	100
0.06	0.05	75	75	65	70	75	80	80	70	74
0.06	0.15	80	85	75	80	95	75	85	85	83
0.06	0.25	100	100	80	100	100	100	90	100	96
0.06	0.35	100	100	100	100	100	100	100	100	100
0.06	0.45	100	100	100	100	100	100	100	100	100
0.06	0.55	100	100	100	100	100	100	100	100	100
0.06	0.65	100	100	100	100	100	100	100	100	100
0.06	0.75	100	100	100	100	100	100	100	100	100
0.07	0.05	100	100	100	80	100	95	90	100	96
0.07	0.15	100	85	100	100	100	95	100	100	98
0.07	0.25	100	100	100	100	100	100	100	100	100
0.07	0.35	100	100	100	100	100	100	100	100	100
0.07	0.45	100	100	100	100	100	100	100	100	100
0.07	0.55	100	100	100	100	100	100	100	100	100
0.07	0.65	100	100	100	100	100	100	100	100	100
0.07	0.75	100	100	100	100	100	100	100	100	100
0.08	0.05	100	90	95	100	100	100	100	100	98
0.08	0.15	100	100	100	100	100	100	100	100	100
0.08	0.25	100	100	100	100	100	100	100	100	100
0.08	0.35	100	100	100	100	100	100	100	100	100
0.08	0.45	100	100	100	100	100	100	100	100	100
0.08	0.55	100	100	100	100	100	100	100	100	100
0.08	0.65	100	100	100	100	100	100	100	100	100
0.08	0.75	100	100	100	100	100	100	100	100	100

Appendix Table 68. Herbicide interaction studies of metribuzin and ethyl metribuzin in greenhouse. (Fresh weight of the downy brome plants)

Treatments		Replications								
		- Experiment 1 -				- Experiment 2 -				
Metri.	E.Metri.	I	II	III	IV	I	II	111	IV	Avg
----- kg/ha -----		--------------- % Fresh weight of seedlings -------------------								
0.01	-.-	107	126	97	111	92	118	102	129	110
0.02	-.-	95	109	91	103	87	96	119	85	98
0.03	-.-	82	75	89	72	79	84	72	80	79
0.04	-.-	79	68	62	73	65	59	65	76	68
0.05	-.-	55	70	51	40	45	63	52	55	54
0.06	-.-	45	25	42	50	35	51	39	42	41
0.07	-.-	22	15	18	21	13	20	22	18	20
0.08	-.-	15	19	24	13	17	15	21	19	18
-.--	0.05	135	110	97	124	103	117	92	101	110
-.--	0.15	98	89	93	83	109	102	92	96	95
-.--	0.25	62	70	48	65	72	62	68	57	63
-.--	0.35	55	68	48	53	41	39	53	58	52
-.--	0.45	48	30	38	29	43	35	38	41	38
-.--	0.55	38	29	35	35	32	17	22	47	32
-.--	0.65	15	22	19	27	15	12	31	23	21
-.--	0.75	17	14	24	15	17	21	19	24	19
0.01	0.05	98	85	105	125	114	109	105	92	92
0.01	0.15	97	87	93	78	94	83	80	86	100
0.01	0.25	62	57	53	60	68	72	45	59	60
0.01	0.35	43	49	58	46	56	42	39	54	48
0.01	0.45	38	33	29	36	35	49	25	38	35
0.01	0.55	34	27	24	39	19	39	24	31	30
0.01	0.65	12	23	32	17	15	26	24	15	21
0.01	0.75	18	22	11	13	18	15	29	16	18

Appendix Table 68 Cont'd

Appendix Table 68 Cont'd

Treatments		Replications								
		- Experiment 1 -				- Experiment 2 -				
Metri.	E.Metri.	I	II	III	IV	I	II	111	IV	Avg
----- kg/ha -----		--------------- % Fresh weight of seedlings -------------------								
0.02	0.05	87	93	78	89	95	79	78	102	88
0.02	0.15	78	75	90	85	78	89	73	76	81
0.02	0.25	55	48	62	68	58	56	52	49	56
0.02	0.35	54	33	40	48	28	45	42	47	41
0.02	0.45	39	30	25	27	27	30	42	28	31
0.02	0.55	15	27	32	11	18	26	13	37	22
0.02	0.65	12	21	13	17	14	12	12	26	16
0.02	0.75	13	20	15	21	17	12	11	15	16
0.03	0.05	78	62	75	79	70	69	72	64	71
0.03	0.15	60	68	65	72	68	80	60	63	67
0.03	0.25	35	48	53	56	45	44	42	48	46
0.03	0.35	29	23	35	32	17	21	33	27	27
0.03	0.45	14	18	25	11	19	23	17	15	18
0.03	0.55	20	21	15	14	17	12	19	15	17
0.03	0.65	18	12	18	15	20	12	12	19	16
0.03	0.75	15	19	22	14	17	17	12	13	16
0.04	0.05	45	65	62	70	55	59	53	72	60
0.04	0.15	58	46	55	67	42	53	48	60	54
0.04	0.25	43	33	25	29	19	27	38	36	31
0.04	0.35	19	35	24	17	33	22	28	11	24
0.04	0.45	10	13	24	19	15	19	14	29	18
0.04	0.55	17	26	17	18	13	16	22	13	18
0.04	0.65	14	18	13	22	10	19	22	15	17
0.04	0.75	13	11	15	19	18	19	21	18	17
0.05	0.05	46	50	35	52	60	48	48	32	46
0.05	0.15	40	27	26	33	42	45	29	36	35
0.05	0.25	19	29	31	18	35	21	14	18	23
0.05	0.35	22	18	20	12	24	15	11	21	18

Appendix Table 68 Cont'd

Appendix Table 68 Cont'd

Treatments		Replications								
		- Experiment 1 -				- Experiment 2 -				
Metri.	E.Metri.	I	II	III	IV	I	II	111	IV	Avg
----- kg/ha -----		--------------- % Fresh weight of seedlings -------------------								
0.05	0.45	15	19	24	14	17	12	17	21	17
0.05	0.55	19	13	13	26	13	22	18	12	17
0.05	0.65	10	23	17	11	18	21	12	13	16
0.05	0.75	13	25	10	15	17	17	11	10	15
0.06	0.05	42	48	55	454	48	33	30	46	43
0.06	0.15	32	28	41	35	44	35	32	47	37
0.06	0.25	19	33	13	26	18	25	18	14	21
0.06	0.35	18	12	18	20	15	12	18	12	16
0.06	0.45	10	23	17	11	21	22	12	19	17
0.06	0.55	15	19	24	14	17	12	17	20	17
0.06	0.65	16	11	24	19	14	14	21	16	17
0.06	0.75	11	20	18	18	15	19	13	13	16
0.07	0.05	15	18	23	42	19	19	13	16	21
0.07	0.15	18	36	15	26	11	19	15	16	20
0.07	0.25	20	11	22	19	19	15	20	13	17
0.07	0.35	18	12	18	20	27	14	16	18	18
0.07	0.45	12	17	14	24	18	12	19	11	16
0.07	0.55	26	13	13	19	10	19	12	16	16
0.07	0.65	13	10	17	11	18	21	12	13	14
0.07	0.75	15	19	24	14	17	12	18	12	16
0.08	0.05	13	32	27	18	21	12	17	15	19
0.08	0.15	12	18	17	21	11	18	23	19	17
0.08	0.25	21	22	12	19	15	12	14	12	16
0.08	0.35	18	13	17	18	24	15	20	17	18
0.08	0.45	11	26	14	19	12	20	13	14	16
0.08	0.55	17	13	24	15	20	18	13	15	17
0.08	0.65	23	13	19	11	18	12	18	21	17
0.08	0.75	10	19	15	13	22	18	15	13	16

Appendix Table 69. Analysis of variance of Appendix Table 66 of metribuzin and ethyl metribuzin interaction studies at Moro.

SOV	DF	SS	MS	F.Ratio	
Replication	3	84.38	28.125	0.54	NS
treatments	17	72428.13	4260.478	82.48	**
Error	51	2634.38	51.654		

Appendix Table 70. Analysis of variance of Appendix Table 68 of metribuzin and ethyl metribuzin interaction studies in greenhouse.

SOV	DF	SS	MS	F.Ratio	
Replication	7	948.64	135.519	1.96	NS
treatments	79	438167.55	5546.425	80.14	**
Error	553	38271.99	69.208		

Coefficient of Variation of Appendix Table 69 = 11.86%

Coefficient of Variation of Appendix Table 70 = 23.52%

N.S : Non Significant.

* : Significant at 5 % probability level.

** : Significant at 1 % probability level.