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Equipment for strip-till planting is under development in wheat-fallow rotations in the Columbia Basin of Oregon. This involves the absence of tillage during the fallow season. At planting time, the strip-till planter creates a narrow band into which the wheat seed is placed. The area between the rows is undisturbed except for the deposition of a 2-cm thick layer of soil displaced from the tilled area. Chemical weed control is required between the rows. Preliminary work has shown that metribuzin [4-amino-6-*tert*-butyl-3-(methylthio)-*as*-triazin-5(4H)-one] is a promising herbicide for this purpose. Factors influencing the application, effectiveness, and selectivity of metribuzin used in conjunction with strip-till planting were investigated in the laboratory and greenhouse.

Application of metribuzin in combination with liquid fertilizer would be convenient and economical. Laboratory experiments were conducted to determine the physical compatibility of four liquid

fertilizers: Solution 32 at 56 kg N/ha, 10-34-0 at 45 kg P_2O_5/ha, 0-0-15 at 22 kg K/ha, and 11-0-0-26 at 22 kg S/ha, with three metribuzin formulations each of Sencor and Lexone at 112 g a.i./ha.

Wettable powder, flowable, and dispersible granule formulations of both Sencor and Lexone were tested. Only the wettable powder formulations were sufficiently compatible with the liquid fertilizers tested to be recommended for practical commercial use. Large differences were seen between the other formulations. Their use with liquid fertilizers might require the addition of compatibility agents or mixing them with water first, before adding them to the fertilizers. When compatibility is obtained after mixing them with water first, continuous agitation might be required to maintain the suspension. No major differences were observed between comparable formulations of Sencor and Lexone.

Greenhouse experiments were conducted to determine the biological compatibility of Solution 32 and metribuzin on downy brome *(Bromus tectorum* L.*)*, the effect of Solution 32 on downy brome and wheat emergence, the effect of soil layer on metribuzin effectiveness for downy brome control, and the effect of banding width over the wheat row and wheat seeding depth on metribuzin phytotoxicity to wheat.

More effective downy brome control was obtained when metribuzin was mixed with Solution 32 than when it was used alone. Solution 32 was used at 0, 36, 54, and 79 kg N/ha, and metribuzin at 0, 14, 28, 56, and 112 g a.i./ha. Solution 32 itself had some phytotoxic effects on downy brome at the high rates. Wheat was not affected as severely as downy brome.

Application of metribuzin to the surface of the newly deposited soil layer was more effective in controlling downy brome than when the herbicide was applied and then covered with the soil layer. Results suggested that better downy brome control could be obtained with metribuzin applied after the strip-tiller had deposited the soil layer between the rows, especially if adequate rainfall is expected. Under such rainfall conditions, metribuzin covered with a soil layer may leach deeper out of the root zone and less effectiveness could result.

Both seeding depth of wheat and width of the unsprayed area were factors influencing metribuzin phytotoxicity to wheat. Greater wheat injury was observed when the herbicide was applied on top of, or too close to, the seed row, particularly when wheat was planted shallow. The results suggested that wheat should be planted 3 cm deep or deeper when the unsprayed band is 15 cm wide, and at least 5 cm deep when the unsprayed band is 10 cm wide.

FACTORS INFLUENCING METRIBUZIN USE IN STRIP-PLANTED WHEAT

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DEDICATION

This thesis is dedicated to my wife for her love, patience, and support throughout my graduate studies, and to my son Ryad.

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FACTORS INFLUENCING METRIBUZIN USE IN STRIP-PLANTED WHEAT

INTRODUCTION

Winter precipitation dryland areas commonly are devoted to cereal production. Several cropping systems are used, ranging from the conventional bare fallow to a complete chemical fallow or "no-till" system (6). The common base of these systems is a simple rotation consisting of about 14 months in fallow and 10 months in cropping.

Despite the relatively successful results obtained with the use of these systems, research is still being carried out to improve certain aspects. These are related to moisture storage, effective weed control, planting management, erosion control, and other factors related to the equipment used in each system. The most recent approach is the no-till system. This method uses herbicides to replace part or all of the tillage to control weeds during the fallow and before planting the crop.

Many aspects related to the equipment used in chemical fallow keep changing and improving. A new implement, recently assembled at Oregon State University, is the rotary strip-tiller. This machine is currently under investigation in the Columbia Plateau dryland region of Oregon (6). It consists of a heavy-duty rotary tiller with the following modifications:

- Width of cut of the blades has been reduced to 10 cm. The working depth can be controlled and can reach a maximum of 18 cm. Blades can be removed to a desired row spacing.

- A tillbar has been attached to the tiller to which planters are attached.

- A spray boom, attached to the front, permits the application of fertilizers and herbicides.

The rotary strip-tiller permits the following operations in a single path:

a. Seedbed preparation in narrow strips, 10 cm wide, leaving an untilled area between the rows (Figure 1).

b. Application of liquid fertilizers in the untilled strip between the rows.

c. Application of preemergence herbicides with the fertilizer between the rows.

d. Planting.

e. Application of starter fertilizers banded in the seedrow.

Before the system can be extensively used and widely accepted, many aspects remain to be investigated. Especially important are those related to the effective use of herbicides because the success of no-till is based on satisfactory weed control (27). In a no-till system, herbicides are often applied at planting time, preemergence to the crop and weeds. Therefore, they must have satisfactory soil persistence for weed control and they must be safe to the crop.

In eastern Oregon, one of the main weeds associated with winter precipitation dryland areas is downy brome *(Bromus tectorum* L.). This troublesome weed can be partially controlled by moldboard

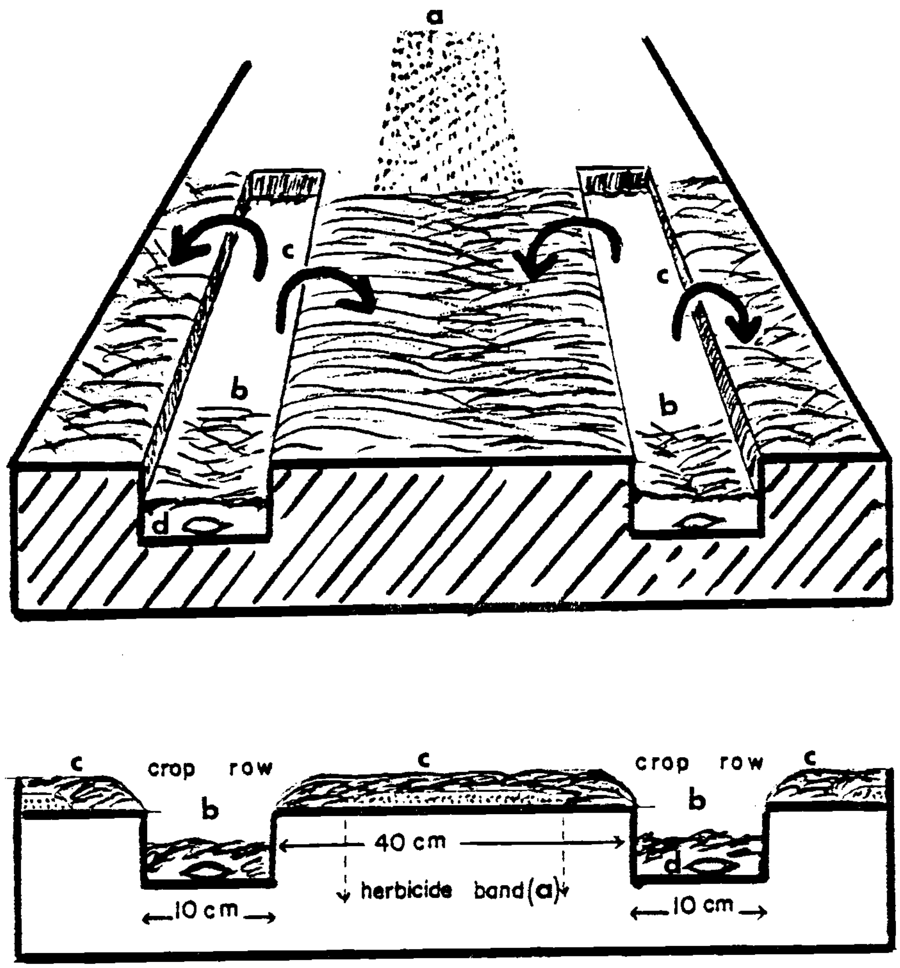


Figure 1. Rotary strip-tiller operations (a) herbicide-fertilizer band, (b) tilled strip, (c) soil from tilled strip deposited onto untilled area, (d) seed.

plowing (27), but it thrives in a minimum tillage situation and is not adequately controlled chemically. One of the few herbicides which gives partial control of this weed is metribuzin [4-amino-6-*tert*-butyl-3-(methylthio)-*as*-triazin-5(4H)-one] (23, 28, 44, 50, 62, 65).

Metribuzin used with a rotary strip-tiller could be influenced by several factors:

a. The herbicides and liquid fertilizers are mixed together and applied. When using a carrier for the herbicide other than water, it is important to know if the compounds can be safely tank-mixed and if they are mixed, whether their efficiency as herbicides and fertilizers is maintained.

b. When planting the crop, the herbicide-fertilizer mixture is applied between the crop rows. Then the soil is opened and the seed is deposited. The rotating blades deposit soil from the tilled area onto the sprayed area. The soil layer deposited between the rows may be up to 2 cm thick. This soil layer could have downy brome seeds included in it which could be deposited over the top of the metribuzin-sprayed soil. The movement of soil from the tilled area onto the untilled area could influence metribuzin, either adversely or beneficially.

c. In the strip-tiller operation, a 10-cm wide band is tilled and the seed is deposited within that band. Only the remaining area between the rows is sprayed with the herbicide. Herbicide band width and depth of seeding can be controlled.

Since metribuzin has limited selectivity when applied preemergence directly over planted wheat, some separation of the sprayed and unsprayed areas is necessary. Therefore, it is important to determine what effect changing the width of the unsprayed area and the depth of the wheat seeding might have on the degree of selectivity to the wheat.

The objectives of this study were to investigate: (a) the physical compatibility of metribuzin and liquid fertilizers, (b) the biological compatibility of metribuzin and liquid fertilizers, (c) the effect of a soil layer on metribuzin activity, and (d) the effect of band width and depth of seeding on metribuzin selectivity to wheat.

LITERATURE REVIEW

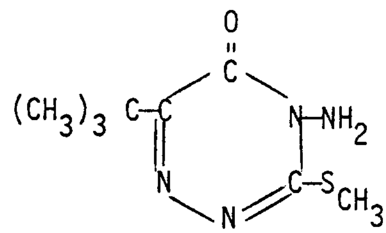
Reports in the scientific literature on the use of minimum tillage for wheat and corn production appeared in the 1940's (67). Strip planting is annually used for corn and other row crops in all North Central states, and more than 140,000 acres were strip-till planted in 1970 (67).

The key factor to the success of minimum tillage or no-till is weed control. In the Pacific Northwest and the Central Great Plains, downy brome *(Bromus tectorum* L.*)* is a major weed in dryland wheat production. Many herbicides are now used for weed control in dryland areas. The first ones to be used in no-till were the triazines, especially atrazine (2-chloro-4-ethylamino-6-isopropylamino-*s*-triazine) and propazine [2-chloro-4,6-bis(isopropylamino)-*s*-triazine] (66,67). Today many more herbicides are used for weed control in the dryland areas. Metribuzin [4-amino-6-*tert*-butyl-3-(methylthio)-*as*-triazin-5-(4H)-one] was recently registered in Oregon for brome control in wheat. It also has been used extensively in combination with other herbicides for use during the fallow season in no-till situations (7, 11, 17, 27, 38, 40, 42, 43, 51, 61, 65).

General Properties of Metribuzin

Metribuzin is manufactured by two companies in the United States and is sold as Lexone by du Pont and as Sencor by Mobay Chemicals (26). Each company sells wettable powder, flowable, and dispersible granular formulations of metribuzin.

Its structural formula is



Its empirical formula is $C_8H_{14}N_4OS$. Its water solubility is 1200 ppm, and the LD_{50} for male and female rats is 1090 and 1206 mg/kg, respectively.

Metribuzin can be applied preplant and incorporated, preemergence or postemergence (26).

The major route for metribuzin uptake is via the root system, but foliar absorption can also occur. It is translocated upward in the xylem. Downward movement in the phloem does not occur. Its concentration is highest in the roots, shoots, stems, and leaves, and lowest in the fruits and seeds (26).

Its mechanism of action is the inhibition of photosynthesis (1, 26). Pillai et al. (46) found that it also reduces RNA, DNA, and protein synthesis in the hypocotyl sections of soybeans (*Glycine max* L. Merr.). De Villiers and Van der Merwe (14) concluded that metribuzin indirectly affects RNA synthesis, protein synthesis, and lipid synthesis through its effect on photosynthesis, which provides most of the ATP for the synthesis processes.

Metribuzin does not interfere with germination, but exerts its effect after the seedling emerges (19).

The major routes of detoxification are hydroxylation, oxidation, and conversion to water-soluble conjugated products (1, 26). Mangeot et al. (33) found that tolerance of soybean varieties to metribuzin is due to their ability to rapidly detoxify the herbicide to unidentified metabolites. Tolerance of tomatoes *(Lypersicum esculentum* L.*)* to the herbicide also was found to be due to internal plant mechanisms of metabolism or detoxification (19).

Metribuzin is adsorbed on soil with high clay and organic matter content. It leaches easily through sandy soils (26). Sharom and Stephenson (57) found that adsorption of metribuzin is correlated with soil organic matter and not clay content. They further reported that its mobility is high on sandy soils.

Metribuzin is degraded by soil microorganisms. The degradation is more rapid on non-autoclaved soils and enriched with glucose than in soils that had been autoclaved or dry for 1 year (54).

Temperature also was found to affect the rate of degradation of metribuzin (54). It is more rapidly degraded at 30 C in soils with high organic matter than in soils at 20 C.

The loss of metribuzin from the soil surface was found to be due to photodecomposition and/or volatilization. Savage (55) 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.

General Use of Metribuzin

Metribuzin is effective on annual grasses and many broadleaf weeds, including hard-to-control weeds like cocklebur *(Xanthium* sp.*)*.

velvetleaf *(Abutilon theophrasti* Medic.*)*, jimsonweed *(Datura stramonium* L.*)*, coffeeweed *(Daubentonia texana* Pierce*)*, and sicklepod *(Cassia* sp.*)* (26). It can be applied preemergence, postemergence, and preplant incorporated when mixed with other herbicides.

Rates recommended for use vary, depending on the crop, the weeds, and the method of use. It is commonly used at rates 0.25 to 0.50 lb/A on annuals, and 0.50 to 1.0 lb/A on perennials (26).

Metribuzin is used on many major crops, such as soybeans, potatoes, tomatoes, established cereals, corn, established alfalfa, warm-season grasses, and range and pasture grasses (26).

Metribuzin is also often used in no-till wheat, soybeans, corn, and wheat fallow systems (7, 11, 17, 28, 31, 38, 40, 42, 43, 50, 51, 58, 59, 61, 62. 65). On soybeans, metribuzin is generally used preemergence but it also is applied preplant and incorporated with trifluralin (*a*,*a*,*a*-trifluoro-*N*,*N*-dipropyl-*p*-toluidine). Barrentine (2) found that the rates for acceptable weed control when using metribuzin plus trifluralin were 0.25 + 0.50 lb/A for light soils, 0.38 + 0.75 lb/A for medium soils, and 0.38 + 0.75 to 0.50 + 1 lb/A for heavy soils.

In a separate study, Barrentine et al. (4) found that metribuzin used alone and incorporated was very selective.

Metribuzin also was used in no-till planted soybeans. Triplett (61) reported that the combination of metribuzin with linuron [3-(3,4-dichlorophenyl)-1-methoxy-1-methylurea] and paraquat

(1,1'-dimethyl-4,4'-bipyridinium ion) or glyphosate [*N*-(phosphonomethyl)glycine], resulted in good weed control and increased soybean yield when applied preemergence to the crop.

Good weed control and crop selectivity were obtained when metribuzin and trifluralin were applied 6 weeks before planting soybeans (4). Trifluralin is used with metribuzin on soybeans to reduce crop injury from metribuzin (30, 37).

Moomaw and Martin (38) used metribuzin broadcast and row-banded on till-planted and slot-planted corn, and suggested that slot-planting requires more herbicide usage. In their study, till-planting gave better weed control.

Metribuzin was also used postemergence on transplanted tomatoes (15). Satisfactory weed control was obtained with 0.28 and 0.56 kg/ha. Weed control in potatoes is widely done with metribuzin. Callihan et al. (8) reported that early application of metribuzin on silt loam soils resulted in taller plants, higher yields, and larger tubers of potatoes. In irrigated areas, the herbicide is sometimes applied through sprinklers to potatoes (10).

Sugarcane is another crop where metribuzin is extensively used for weed control (41). Rates from 1 to 8 lbs/A were used on sugarcane without extensive injury to the crop.

Metribuzin also is used for weed control in a no-tillage soybean-wheat double cropping system (7, 61). Combined with metribuzin in this system were alachlor [2-chloro-2',6'-diethyl-*N*-(methoxymethyl) acetanilide] plus glyphosate, alachlor plus paraquat, or alachlor plus linuron.

Recently metribuzin was labeled for use on wheat for brome control (44). It is recommended for postemergence use only on cereal crops, but was often included among the herbicides used under wheat-fallow systems. It was first used on fallow-wheat rotation for annual weeds. On fallow, it is sometimes combined with long-residual herbicides such as atrazine (2-chloro-4-ethylamino-6-isopropylamino-*s*-triazine) plus terbutryn [2-(*tert*-butylamino)-4-(ethylamino)-6-(methylthio)-*s*-triazine], or atrazine plus cyanazine [2-4-chloro-6-(ethylamino)-*s*-triazine-2-yl amino-2-methylpropionitrile] for control of weeds such as kochia *Kochia scoparia* (L.) Schard.*)*, tumbling mustard *(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.*)*.

Metribuzin mixed with other herbicides, is applied in spring for weed control during fallow preceding winter wheat (47). Stahlman (58), in his work on spring application of herbicides for weed control during fallow, suggested that in order to use this practice practically and successfully, the herbicides should control weeds and volunteer crop plants through mid to late July but not persist into September to kill germinating wheat, or the wheat must tolerate the chemicals.

Metribuzin was applied in combination with other herbicides in growing wheat for weed control during fallow (59). The application of metribuzin at the prejointing wheat stage to control weeds in the growing wheat and during summer months after wheat harvest, resulted in good weed control. Fall application of metribuzin in combination with other herbicides for chemical fallow resulted in broad-spectrum weed control (42, 43). The herbicide combinations were buthidazole [3-5-(1,1-dimethylethyl)-1,3,4-thiadiazol-2-yl-4-hydroxy-1-methyl-2-imidazolidinone] at 2 lb/A, and buthidazole at 1 lb/A plus 0.75 lb/A of metribuzin or atrazine. On no-till continuous wheat, metribuzin used at a rate of 0.50 lb/A applied postemergence resulted in satisfactory weed control with no residual effects on the subsequent wheat crop (11).

Today, metribuzin is widely used for cheatgrass and downy brome control in winter wheat. Gigan (20) used metribuzin at different rates ranging from 0.28 kg/ha to 0.70 kg/ha. All rates applied postemergence gave good brome control except the lowest rate (0.28 kg/ha) and the highest rate (0.70 kg/ha) resulted in severe injury to wheat. It also is combined with other herbicides and applied postemergence for a broader spectrum weed control. Such herbicides were bromoxynil (3,5-dibromo-(4-hydroxybenzonitril] and chlorsulfuron [2-chloro-*N*[[(4,methoxy-6-methyl-1,3,5-triazin-2-yl)amino]carboxyl]benzenesulfonamide] (17, 40).

Pocock (47) used metribuzin in dryland and sprinkler-irrigated barley. He reported that weed control was more consistent with sprinkler irrigation than with surface irrigation. Under dryland conditions, control ranged from 25 to 97% and in irrigated land it was from 75 to 97%. On other crops, such as alfalfa, metribuzin is used only on the dormant crops to avoid extensive injury (55).

Factors Influencing Metribuzin Selectivity

Many factors have been reported to influence the effectivness, 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, temperature, and many other factors.

Soil type and organic matter. Differences in soil texture influence the mobility of soil-applied herbicides. Mobility of metribuzin was higher in sandy and clay soils than in muck soils (57). 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.

Savage (53) 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 level of clay. But metribuzin adsorption decreases significantly when high levels of clay were combined with high levels of organic matter. The addition of clay colloids appears to decrease the adsorbing 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.

Webber et al. (64) found that organic matter affected the performance of metribuzin. Its performance on weeds decreased with increasing organic matter of the soil. However, highly-water-soluble chemicals are less affected by organic matter than low-water-soluble chemicals (64).

Findings of Sharon and Stephenson (57) 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 adsorption of metribuzin was correlated with organic matter and not clay content.

Soil pH. Moomaw et al. (36) found that injury to soybeans from metribuzin was greater in soils with pH 7.8 than in soils with pH 6.6. Ladlie et al. (29) reported that metribuzin degradation by soil microorganisms decreased as the soil pH decreased, but its mobility increased with increasing concentration and soil pH. They also found that metribuzin adsorption increased with decreasing soil pH.

In a separate study, the above authors (30) 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.) with increasing soil pH.

The increase in phytotoxicity to soybeans and grass weeds with increasing soil pH was confirmed by Moomaw and Martin (36). 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 of the herbicide increases with increasing soil pH.

Rainfall and soil moisture. Moisture in the form of rainfall has been reported to have an effect on 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 (24). Apparently, rainfall moved metribuzin into the root zone of the plant. Heavy rains can also reduce activity. Metribuzin is highly water soluble (1200 ppm). This characteristic makes it mobile in the soil and it leaches easily in light soils.

Hardcastle (25) found that injury to soybeans from metribuzin was moderate even at higher rates, and the injury obtained was mostly associated with rainfall. Wax (63) found that under high rainfall, injury to soybeans was less than under low rainfall, and weed control was better.

Metribuzin applied preemergence in light soils could be less effective on weeds under heavy rainfall conditions. Presumably, the herbicide would leach too deeply (57).

Injury to wheat also was observed. Wheat was almost completely killed when metribuzin was applied postemergence and sprinkler-irrigated, whereas under dryland conditions, using the same rates as in sprinkler-irrigation (4 to 8 oz/A), the herbicide did not cause injury to wheat (39). Excessive rainfall following application of metribuzin can cause crop injury as a result of herbicide leaching into the root zone. Excessive rainfall also can result in a failure of the herbicide to control weeds by leaching the herbicide too deeply into the soil.

Metribuzin at rates of 0.25, 0.50, and 1.0 lb/A resulted in severe injury to corn when rainfall was abundant (12).

Temperature effect on metribuzin. Temperature was found to affect the fate of metribuzin and its phytotoxic activity on plants. Phatack and Stephenson (45) found that every increase in temperature from 21 C days and 13 C nights, to 25 C days and 18 C nights, to 27 C days and 18 C nights resulted in increased injury to tomatoes from 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 reserves by limiting its production.

Fortino (19) reported that higher susceptibility of tomatoes less than 10 cm tall occurred under high temperature when treated with metribuzin. Moomaw and Martin (37) found that metribuzin injury to soybeans was greater when high rainfall and cooler temperatures occurred following application, and Mangeot et al. (32) found that temperature was not a major factor affecting metribuzin injury to soybeans.

Temperature also has an effect on the degradation of metribuzin in the soil. More rapid degradation was obtained under 30 C than under 20 C (54). Surface application of metribuzin followed by high temperature and intense light, resulted in the dissipation of the herbicide by volatilization and photodecomposition (55), thus low effectiveness could result.

Light effect on metribuzin. Pritchard and Warren (48) reported that tomato tolerance to metribuzin was reduced when shading was applied for one day before treatment. The same response was obtained with jimsonweed and velvetleaf. Three days of shading gave further reduction in tolerance of the three species. Two or three days of sunshine were required after three 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 three days of shading and still control jimsonweed and velvetleaf.

Pritchard (49) found that periods of artificial shading reduced the tolerance of tomatoes to postemergence application of metribuzin and 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.

Stephenson et al. (60) 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 treatment.

Time of application of metribuzin. Time of application of metribuzin must be related to stage of weeds and crop stage (50). Da Silva and Warren (13) reported that tomatoes became more tolerant to metribuzin as they aged, probably because they had accumulated enough food and were able to detoxify the herbicide.

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. The herbicide rates used were 1 to 4 lb/A (8).

Good weed control results and excellent crop tolerance of soybeans were observed when metribuzin was applied preplant and incorporated with trifluralin 6 weeks before planting (2).

Becke (5), using metribuzin at 0.43 and 0.56 kg/ha, applied 0, 1, 2, 3, 4, 5, 6, 7, and 8 days after planting soybeans, found that the higher rate caused injury and reduced yield. No significant changes in soybean growth were detected when metribuzin was applied within 4 days after planting. Height was significantly reduced when application was delayed 5 days after planting, while yields were not affected until the interval reached 6 days.

Eldredge and Lee (17) 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 reductions from early treatment ranged from 60 to 90%, whereas the reduction was only 5 to 25% when the herbicide application 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 leaf to three tillers, and maximum wheat tolerance was found to be when the plant was in full tillering stage with prominent secondary root development (50). The optimum time of application on barley was found to be when the plant was in the fully tillered stage and the secondary roots were starting to form (61).

On alfalfa, application during active growth is not recommended. Treatment should only be made when alfalfa is dormant (56). On tomato, application to plants less than 10 cm tall could result in severe injury (19).

Uniform application, timing, proper rate, stage of growth of crops and weeds, and methods of application are all factors influencing metribuzin selectivity and effectiveness.

Interactions of metribuzin with other chemicals. The usual carrier for herbicides is water but with the development of liquid fertilizers, many herbicides and fertilizers are now applied simultaneously. This method is often called the "weed and feed" practice (34).

When herbicides are mixed with liquid fertilizers or other herbicides, compatibility tests are necessary to determine the physical stability of the mixtures and their selectivity (35).

Meyer et al. (35) studied the compatibility of five herbicides with a suspension fertilizer (15-15-15). They found that all herbicides studied (butylate, alachlor, alachlor + atrazine, norea + atrazine, and trifluralin) were equally effective whether applied separately or in combination with the fertilizer solution. They also reported that contact between the herbicides and the fertilizer solution for up to 100 days before application, did not alter herbicides or fertilizer effectiveness.

Martens et al. (34) reported that atrazine and linuron were more effective herbicides when applied preemergence or postemergence to corn in a 30% nitrogen solution. They further indicated that atrazine mixed with a 15-15-15 suspension fertilizer gave better control when applied preemergence than when applied preplant and incorporated. Agitation was essential for most mixtures, and mixtures not compatible for 15 minutes without agitation would require the addition of clay to increase the compatibility.

The practice of using liquid fertilizer as a carrier for herbicides is common for weed control in small grains, corn, and sorghum (52). If such combination is used, one should expect temporary crop injury which usually does not cause a reduction in yield (52).

Herbicide mixtures are used to broaden the weed control spectrum, but compatibility tests are required to determine if separation or precipitation occurs. When physically compatible, these mixtures should also give good weed control and be selective to the crops on which they are used. Tests of physical compatibility and experiments on weed control and crop selectivity are useful in order to avoid side effects such as loss of phytotoxicity and effectiveness, or loss of selectivity.

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 (21).

Ladlie et al. (30) found that the addition of trifluralin to metribuzin increased soybean tolerance to metribuzin. Moomaw and Martin (37) confirmed the findings of Ladlie. Ladlie et al. (30) 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 crops. Its preemergence application with these herbicides had often resulted in better weed control. Post-emergence applications were also used in combination with bromoxynil (17, 40).

<u>Differential crop tolerance to metribuzin</u>. 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 which have shown differential tolerance to metribuzin.

Barrentine et al. (3) reported that differential herbicide detoxification by conjugation may account for the difference in metribuzin injury between sensitive soybean cultivars and tolerant ones. Fedtke (18) also found that tolerant soybean cultivars have a better capacity to detoxify metribuzin in their leaves.

Eastin et al. (16) 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.

Graf and Ogg (22) 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. (60) 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. (9), using soil and foliar applications on wheat, barley, and oat, 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 wider range than oat but less than wheat.

Warren and Parish (62), using metribuzin for weed control in wheat and barley, found that barley was more tolerant to metribuzin than wheat. He also found that barley can stand two postemergence applications 14 to 21 days apart and recommended that this practice could be used for better control of wild oats and ryegrass.

In summary, metribuzin effectiveness and selectivity are affected by factors such as soil type, organic matter content of the soil, soil pH, soil moisture, interaction with other chemicals, cultural practices, light, temperature, crop cultivar, and interactions among these factors.

PHYSICAL COMPATIBILITY OF METRIBUZIN AND LIQUID FERTILIZERS

In the Columbia Plateau of Oregon, fertilizers are often applied in the summer or fall of the year in which the crop is planted. An operation could be eliminated if metribuzin could be mixed with the liquid fertilizer and applied with the strip-till planter at planting time. However, this requires that the metribuzin and the liquid fertilizer formulation be physically compatible. Experiments were conducted in the laboratory with several metribuzin formulations and different liquid fertilizers to determine the degree to which these formulations might be compatible.

Materials and Methods

Six metribuzin formulations each were mixed with four different liquid fertilizers. These are shown in Table 1.

Table 1. Metribuzin formulations and liquid fertilizers used in physical compatibility studies.

Herbicide trade name and	Formulation	Liquid fertilizers
Sencor	Wettable powder 50%	32-0-0 (Solution 32)
	Flowable 4L 41%	
	Dispersible granule 75%	10-34-0
Lexone	Wettable powder 50%	0-0-15
	Flowable	
	Dry flowable 75%	11-0-0-26

Liquid fertilizers and herbicide formulations were mixed in all possible combinations, using two different techniques. In the first experiment, herbicide formulations were added directly to the fertilizers, whereas in the second experiment, one part of herbicide was mixed with 2 parts of water and added to the fertilizer. Mixing the herbicide with water before adding it to the liquid fertilizer was done to determine whether making a slurry first could help improve the compatibility between the two chemicals.

The herbicide rate used was 112 g a.i./ha . This rate is not the one recommended under field conditions. It probably is too low to give satisfactory brome control. It was selected because it gave good control of downy brome under greenhouse conditions.

The nitrogen rates used in eastern Oregon dryland areas range from 30 to 100 lb/A (36 to 112 kg/ha), depending on rainfall, crop requirements, and soil analysis. For the purpose of this study, an average rate of 56 kg/ha of N was selected.

The rate chosen for the physical compatibility test was 45 kg/ha of phosphate. There was no precise figure on the rate of phosphate required for wheat in this area, probably because the soils usually are rich enough in phosphate to provide the requirements for the wheat crop.

Since potassium and sulfur were not limiting nutrients for wheat in previous years, in the eastern Oregon dryland wheat production area, a rate of 22 kg/ha of each was selected to conduct tests in this study. Herbicides were also suspended in water which served as a standard to compare the other treatments.

The herbicide-fertilizer mixtures were agitated vigorously, allowed to stand, and evaluated for separation 15 seconds after agitation and 5 minutes after a second agitation. Physical compatibility was evaluated according to the following rating system:

1. No visible separation; the herbicide and the fertilizer mixed very well and stayed mixed for 15 seconds after agitation. No clear deposit or separation was observed 5 minutes after agitation.

2. Particles in suspension were visible but stayed in suspension 15 seconds after agitation. The particles settled to the bottom or on the surface very slowly during the 5 minutes after agitation, with no clear separation. They resuspended very well after agitation.

3. Visible particles separated quickly after agitation and settled to the bottom or floated on the surface. Particles were too large for nozzle and screen.

4. Complete separation; herbicide floated on the surface or immediately settled to the bottom or formed large flakes.

Mixtures with average ratings of 1 or 2 were deemed compatible, although a mixture rated 2 required continuous agitation. Mixtures with ratings of 3 or 4 were considered to be incompatible.

Physical compatibility results are presented in Table 2.

Results and Discussion

Wettable powders. Both Sencor and Lexone were sufficiently compatible with all liquid fertilizers that they could be used for commercial use. When left unagitated for 5 minutes, the herbicide settled slightly faster in the fertilizer solution than in water.

Table 2. Physical compatibility of six metribuzin formulations with four liquid fertilizers.

Liquid fertilizer	Herbicide formulations											
	Wettable powder				Dispersible granules				Flowable			
	Sencor		Lexone		Sencor		Lexone		Sencor		Lexone	
	15 sec[a]	5 min[b]	15 sec	5 min	15 sec	5 min	15 sec	5 min	15 sec	5 min	15 sec	5 min
Solution 32	1	2	1	2	4	4	2	3	1	1	2	2
10-34-0	1	2	1	2	4	4	4	4	4	4	3	4
0-0-15	1	2	1	2	4	4	2	3	2	2	1	2
11-0-0-26	1	2	1	2	4	4	4	4	4	4	2	3
Water	1	1	1	1	1	2	1	2	1	1	1	1
	Herbicide + water (1:2) + fertilizer											
Solution 32	1	2	1	2	2	3	2	3	1	1	1	2
10-34-0	1	2	1	2	2	3	4	4	3	4	1	2
0-0-15	1	2	1	2	1	2	2	3	1	1	1	1
11-0-0-26	1	2	1	2	3	3	4	4	2	3	1	1

[a]Rating taken 15 seconds after agitation.

[b]Rating taken 5 minutes after a second agitation.

1 and 2 = compatible, 3 and 4 = not compatible.

Dispersing the wettable powders in water before adding to the fertilizers was of no benefit.

Flowable formulations. Both Sencor and Lexone flowable formulations mixed satisfactorily with Solution 32 and with 0-0-15. Sencor seemed to mix slightly better with Solution 32 and Lexone was slightly better with 0-0-15 but differences were minor.

Neither herbicide formulation was compatible when mixed directly with 10-34-0 and 11-0-0-26, but Lexone separated slightly less rapidly than Sencor. When mixed with water first, Lexone was compatible with those two fertilizer solutions but Sencor still probably was not compatible enough for commercial use.

Dispersible granules. Neither Sencor nor Lexone dispersible granule formulations was compatible enough to suggest mixing them with liquid fertilizers. By first dispersing in water, the Sencor dispersible granules could be mixed with 0-0-15 and, with the use of continuous and vigorous agitation, could probably be used commercially. However, the general pattern of compatibility of both dispersible granules with all of the liquid fertilizers was so poor that the use of this type of formulation probably should not be recommended on a general basis.

In general, the physical compatibility of wettable powder formulations of metribuzin appears adequate for mixing with liquid fertilizers. In common usage, simply recommending that the wettable powder formulations be used when mixtures with liquid fertilizers are planned is advisable. There were individual differences between Sencor and Lexone when dispersible granules of flowables were used with the various fertilizer solutions and, in some cases, adequate compatibility could be obtained. However, many more fertilizer solutions are sold on the market than were tested in these trials and the general pattern of compatibility with both the dispersible granules and flowables was uncertain at best. A general recommendation for the use of these two formulations with liquid fertilizers does not appear advisable.

BIOLOGICAL COMPATIBILITY OF METRIBUZIN AND SOLUTION 32

Studies were conducted to determine if mixing metribuzin with Solution 32 would affect its herbicidal activity. Previous studies had shown that the wettable powder formulation of metribuzin could be physically mixed with Solution 32 and the two materials applied simultaneously. However, more information was needed on any biological interactions that might occur when the two materials were mixed.

Materials and Methods

A Walla Walla silt loam soil was collected at the Sherman Branch Experimental Station at Moro, Oregon. The soil was screened through a 3 by 3-mm mesh sieve and used to fill 10 by 10 by 10-cm pots. The pots were first filled with loose soil, then the soil was firmed, leaving about 2 cm for more soil to be added on top. Two hundred fifty grams of brome seeds were mixed with 15 kg of soil and the mixture was used to complete the filling of the pots. Pots were sub-irrigated, then drained for 24 h before the chemicals were applied.

Three rates of Solution 32 (36, 54, and 79 kg N/ha) and five herbicide rates (0, 14, 28, 56, and 112 g/ha) were used in all possible combinations. Water was compared to Solution 32 as a carrier for the herbicide. The wettable powder formulation of Sencor was the only formulation used.

The chemicals were applied with a small hand sprayer. The pots were irrigated twice a week. Brome shoots were harvested 24 days after seeding. The experimental design was a randomized complete block with a factorial arrangement of treatments. The treatments were replicated four times.

Results and Discussion

In the first experiment, the combination of metribuzin and Solution 32 was clearly more toxic to germinating downy brome plants than metribuzin mixed with water (Table 3). In general, plants in pots treated with the herbicide-fertilizer mixture emerged 2 days later but began showing toxic symptoms about 5 days earlier than the plants in pots treated with the herbicide in water. In preliminary screening tests on the effect of metribuzin on downy brome, the herbicide effect usually occurred when the plant was at the 2- to 3-leaf stage, which corresponded to approximately 15 days after seeding. Emergence of brome plants in pots treated with only Solution 32 was erratic, especially at the two higher rates. No mathematical analysis was conducted on the interaction to attempt to determine whether additive action or synergistic action of the mixture was involved.

In the second experiment, brome emergence was completely eliminated in many pots from the application of the higher rates of Solution 32 alone. These effects were sufficiently severe that the two higher rates of Solution 32 were deleted from any statistical analysis. At 36 kg N/ha alone, dry weight of brome shoots was reduced appreciably. At most rates of metribuzin, the metribuzin-fertilizer mixture caused slightly more toxicity than did the metribuzin-water combination. This was not true at the 28 g/ha metribuzin rate and, in general, the differences were smaller than in the first experiment (Table 3,

Figure 2).

In general, data seem to indicate that Solution 32 and metribuzin each were having some toxic effect on downy brome and the effect of the mixture was due to an additive action of the two components rather than an increase in herbicidal activity of metribuzin caused by the Solution 32. Metribuzin effect on brome starts after the plant begins to actively photosynthesize, whereas the Solution 32 effect seems to start earlier, probably when the brome seed germination process begins.

Table 3. Effect of preemergence application of metribuzin with Solution 32 or water on *Bromus tectorum* (dry weight expressed as a percent of untreated control).

metribuzin (g/ha)	First Experiment: Solution 32 (36 kg/ha)	First Experiment: Water	Second Experiment: Solution 32 (36 kg/ha)	Second Experiment: Water
	(%)			
0	100	100	100	100
14	30.25*	70.00	51.75	65.25
28	15.00*	30.75	52.25	44.25
56	10.75	21.25	23.00	30.00
112	1.25	3.50	2.75	5.75

*Means from application in Solution 32 significantly different from application in water at the same rate of metribuzin at 5% (*) level as determined by the paired t-test.

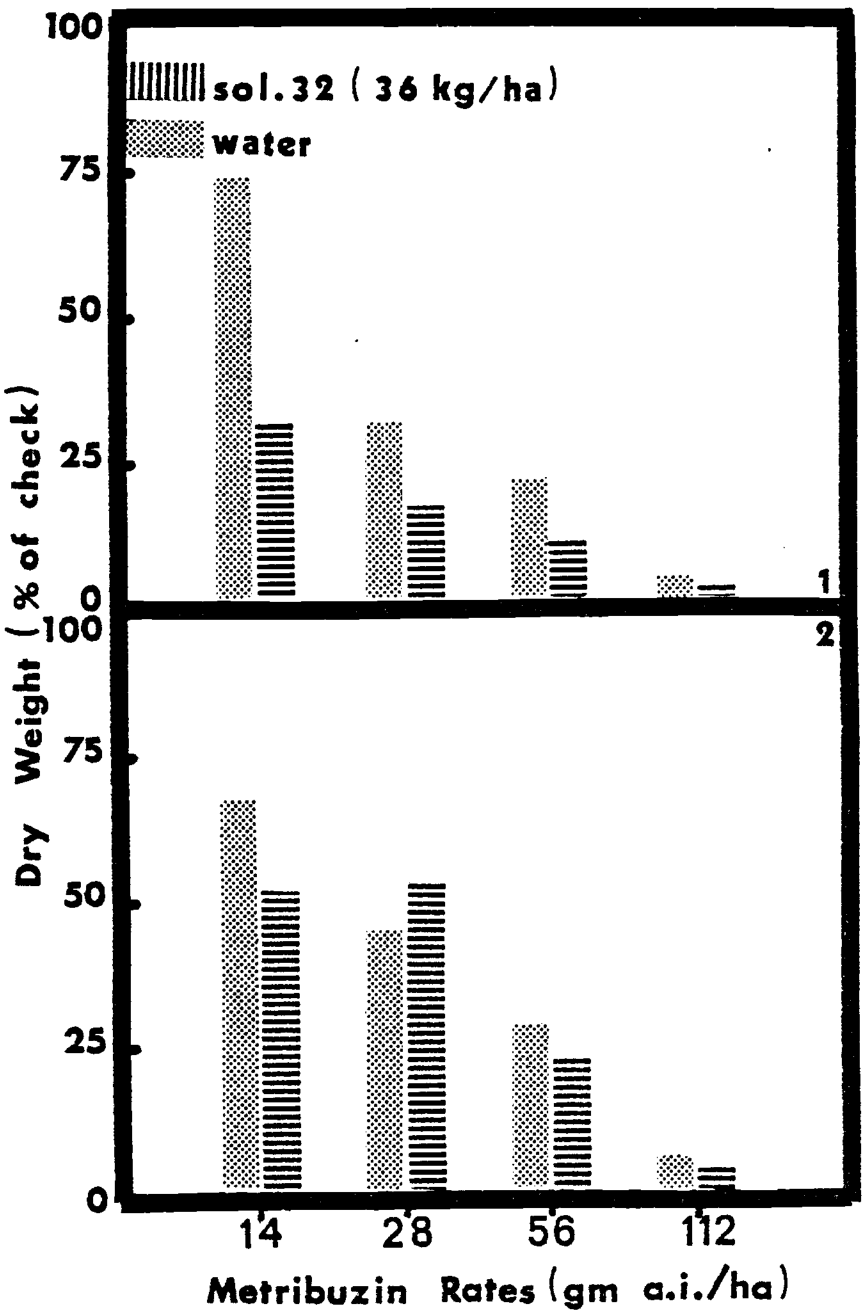


Figure 2. Response of *Bromus tectorum* L. to preemergence application of metribuzin with Solution 32 or water.

EFFECT OF SOLUTION 32 ON *BROMUS TECTORUM* EMERGENCE

In studies involving the biological compatibility of Solution 32 and metribuzin, treatments of Solution 32 alone caused severe reductions in brome emergence. This was an unexpected result and could have important ramifications on strip-till planting. Two sets of experiments were established in the greenhouse to further investigate the effect of Solution 32 on both brome and wheat emergence when the fertilizer was applied to a wet or to a dry soil surface.

Materials and Methods

Uniform seeding depth. In the first set of experiments, 100 brome seeds and 10 wheat seeds were planted at a depth of 2 cm in 10 by 10 by 10-cm pots. In some pots, the seeds were planted, covered, subirrigated, allowed to drain for 24 h, and Solution 32 was applied directly to the wet soil. In the other pots, brome and wheat seeds were planted on the surface and the pots were subirrigated and allowed to drain for 24 h. The seeds were then covered with a 2-cm layer of dry soil and the liquid fertilizer was applied to the surface. The Solution 32 was applied at rates of 36 and 54 kg N/ha, using a small hand-sprayer in the first experiment and a single nozzle track sprayer in the second experiment. At 2 weeks following treatment, percentage emergence was determined. Each treatment was replicated six times in a randomized complete block design.

Seeds mixed in soil. In the second set of experiments, brome seeds were mixed with the soil in a 1:60 ratio and used to fill up the top 2 cm of the pots. The pots were subirrigated and allowed to drain for 24 h and Solution 32 was applied at two rates, 36 and 54 kg N/ha. In the first experiment a small hand-sprayer was used to apply the liquid nitrogen; the greenhouse single nozzle track sprayer was used in the second experiment. Water was applied as a control treatment. Each treatment was replicated 12 times in a randomized complete block design. Brome shoot dry weight was determined 25 days following treatment.

Results and Discussion

Uniform seeding depth. In the first experiment, Solution 32 severely reduced emergence of downy brome, under both wet and dry conditions (Table 4). The severity of this effect seemed to be slightly greater in the dry soil than in the wet soil. Solution 32 significantly reduced wheat emergence at the high fertilizer rate in the wet soil (Table 5). No effects were recorded under the dry conditions or at the low rate of fertilizer. In the second trial, Solution 32 had no effect on brome or wheat germination at either fertilizer rate or in the wet or dry soil (Figure 3).

The reasons for these wide differences in results between the trials are not known. In the first trial, Solution 32 was applied with a small hand-sprayer which probably was less accurate than the track sprayer used in the second repetition of this experiment. However, due care was used and while more variation might be expected using the hand-sprayer, the overall total amount applied is believed to be reasonably accurate.

Seeds mixed in soil. In the second set of experiments, the first trial was marked by a wide variation in results from the fertilizer rates applied (Table 6). Brome shoot dry weights were greatly reduced at both fertilizer rates. In the second trial of this experiment, where the track sprayer was used to apply the liquid nitrogen, only high rates of nitrogen significantly reduced shoot dry weight. Although the differences were smaller when the track sprayer was used, the results obtained suggest that Solution 32 had an effect on brome dry weight.

The detrimental effect of Solution 32 on downy brome emergence was observed not only in the experiments reported here, but also in the biological compatibility studies reported earlier. One possible reason for this effect might be an adjustment of the pH surrounding the seed that would prove detrimental to brome germination. pH measurements were made in the seed zone following applications of the various rates of Solution 32 and are reported in Table 7. The Solution 32 did cause a reduction in pH. Whether this reduction in pH is great enough and persistent enough to cause practical effects in the field is open to speculation. These results suggest that further work should be conducted, including experiments in the field.

Table 4. Effect of Solution 32 on *Bromus tectorum* emergence, applied to wet soil and dry soil. Seeds all planted at 2-cm depth.

Solution 32 (kg N/ha)	Brome emergence			
	First experiment		Second experiment	
	Wet soil	Dry soil	Wet soil	Dry soil
	(%)			
0	100	100	100	100
36	75*	65**	99	100
54	60**	23**	94	96
$LSD_{.05}$	22%		n.s.	
$LSD_{.01}$	30%			

Means significantly different from appropriate check at 5% (*) and 1% (**)

Table 5. Effect of Solution 32 on wheat emergence, applied to wet soil and dry soil.

Solution 32 (kg N/ha)	Wheat emergence			
	First experiment		Second experiment	
	Wet soil	Dry soil	Wet soil	Dry soil
	(%)			
0	100	100	100	100
36	99	112	97	97
54	60*	93	93	100
$LSD_{.05}$	31%		n.s.	

Means significantly different from appropriate check at 5% (*) level as determined by the LSD.

Table 6. Effect of Solution 32 on *Bromus tectorum* germination. Seeds uniformly mixed in top 2 cm of soil. (Foliage dry weight expressed as a percentage of appropriate check)

Solution 32 (kg N/ha)	Dry foliage weight	
	First experiment	Second experiment
	(%)	
0	100	100
36	44.92**	91.33
54	25.75**	88
$LSD_{.05}$	10.54%	n.s.
$LSD_{.01}$	14.87%	

Means significantly different from appropriate check at 1% (**) level as determined by the LSD.

Table 7. pH measurement of greenhouse soil and Walla Walla silt loam soil treated with Solution 32 at three rates.

Solution 32 (kg N/ha)	Walla Walla silt loam	Greenhouse soil
	pH (average of 3 readings)	
0	7.01	5.40
36	5.73	4.53
54	5.68	4.47
79	5.54	4.46

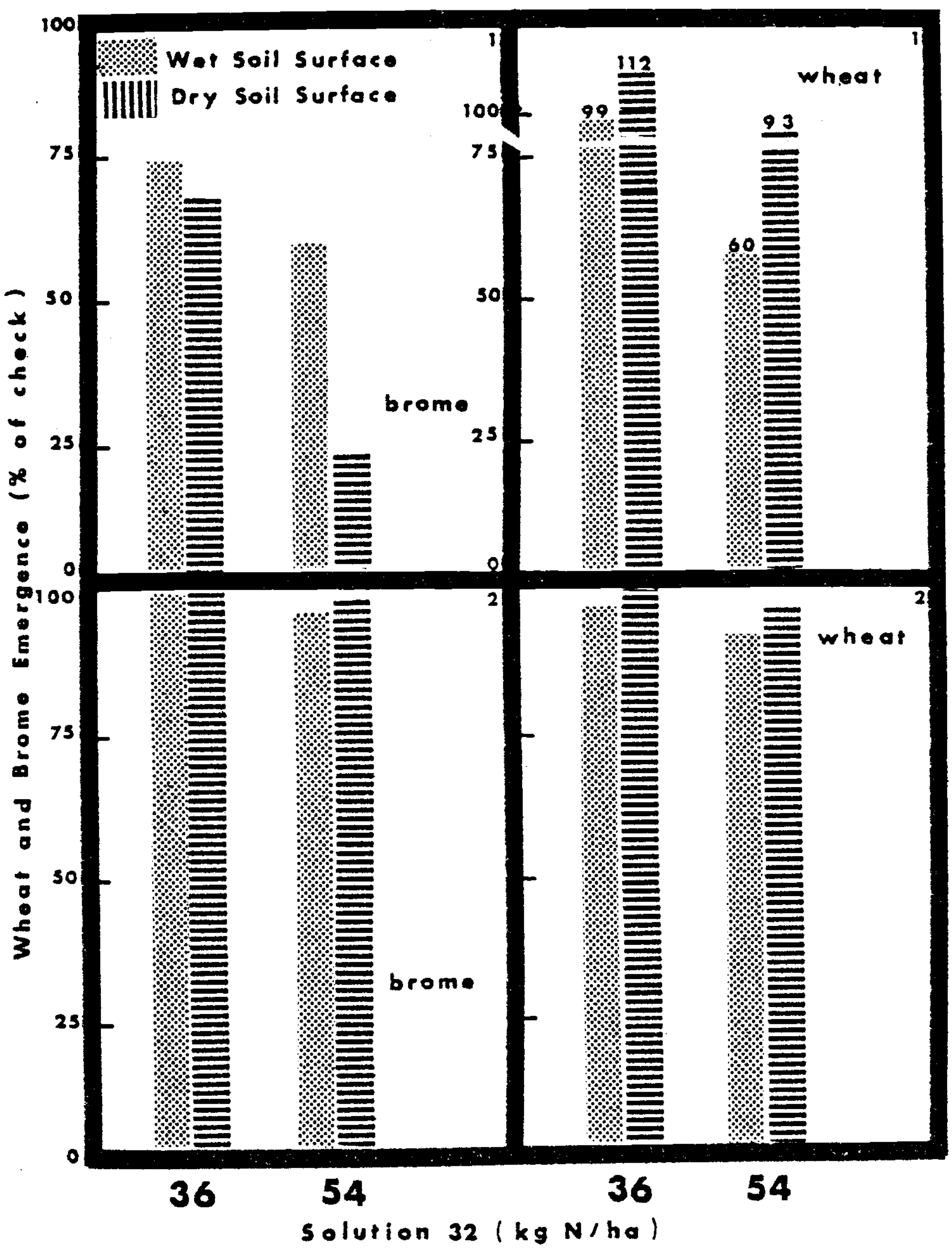


Figure 3. Effect of Solution 32 on *Bromus tectorum* and wheat emergence, applied to wet soil and dry soil.

EFFECT OF SOIL LAYER ON METRIBUZIN SELECTIVITY

In the strip-till operation, a considerable amount of soil is displaced from the tilled area onto the untilled area between the rows. This forms a layer approximately 2 cm thick lying on otherwise undisturbed soil (Figure 1). In the present model, the spray nozzle used to apply metribuzin between the rows is placed in front of the tiller, in which case the metribuzin is covered by the soil. However, it could be mounted behind the tiller and the metribuzin applied to the newly-formed soil surface.

Studies were conducted in the greenhouse to compare the effectiveness of metribuzin on downy brome when applied under the two conditions.

Materials and Methods

Downy brome seeds were mixed with Walla Walla silt loam soil in a ratio of 1:60 (w/w). Plastic pots, 10 by 10 by 10 cm, were filled within 2 cm of the top with soil. Some of the pots were sprayed with metribuzin and all pots were then filled with a 2-cm layer of the seed-soil mixture. The untreated pots were then sprayed with metribuzin applied to the surface. In each case, the pots were subirrigated and allowed to drain for 24 h before the herbicide was applied. Five metribuzin rates were used, 0, 14, 28, 56, and 112 g/ha. After germination, the pots were irrigated whenever needed, usually twice a week, and the amount of water added was not determined.

Visible symptoms of phytotoxicity were evaluated at 15 days and dry weight of shoots was determined at 23 days following herbicide application. The experiment was conducted twice. The experimental design used was a randomized complete block design with four replications. Data were subjected to analysis of variance.

Results and Discussion

Differences in effectiveness of metribuzin when applied to the surface or incorporated beneath a 2-cm layer of soil were not always large (Tables 7, 8, Figure 4). Significant differences between the two methods of application of the herbicide were detected only at 14 g/ha in the first experiment, and at 28 g/ha in the second experiment. But in general, the metribuzin was more effective when applied to the surface than when incorporated.

The somewhat superior results obtained when metribuzin was applied to the surface might be explained by the effect of metribuzin leaching. When the herbicide was deposited 2 cm below the soil surface, it possibly leached downward faster than the roots from downy brome in the top 2 cm were growing. Therefore, the concentration of metribuzin in the immediate rooting zone of the young seedlings would tend to be lower than when the metribuzin was applied after the soil layer was deposited. Prior to the seeding operation, most of the viable downy brome seeds would be on the soil surface, since a high percentage of seeds deposited in previous years would have germinated and seeds from the current year would not have been tilled into the soil. In the strip-till operation, soil from the tilled area containing downy brome seeds would then be deposited onto the untilled area. As a result, a high percentage of seeds between the rows would be at 2 cm or less in depth.

Based upon the results of these experiments, if adequate overhead rainfall is received, the more effective way of applying metribuzin would be to mount the spray nozzle at the rear of the machine rather than at the front so that the metribuzin is applied to the surface of the deposited soil layer. Under very dry conditions, or when no overhead water is received, the incorporated method might be more effective, although this was not studied in these experiments.

Table 8. Visual evaluations of brome phytotoxicity from metribuzin applied to the soil surface or incorporated. Evaluated 15 days following treatment.

Experiment 1

metribuzin (g/ha)	Surface	Incorporation	Surface	Incorporation
	% control		$\sqrt{\text{arcsine}}$	
14	25.00	7.50	29.36	11.25
28	45.00	37.50	41.83	37.66
56	82.50	91.25	65.37	72.94
112	97.50	92.50	85.39	74.32
Check	0	0	0	0
$LSD_{.05}$				12.026
$LSD_{.01}$				16.243

Experiment 2

metribuzin (g/ha)	Surface	Incorporation	Surface	Incorporation
14	41.25	2.50	39.89	4.61
28	62.50	38.75	52.35	38.38
56	82.50	82.50	65.47	65.83
112	96.25	96.25	82.16	82.16
Check	0	0	0	0
$LSD_{.05}$				10.938
$LSD_{.01}$				14.770

Evaluation scale: 0 = no injury, 100 = complete kill.

Table 9. Effect of metribuzin on *Bromus tectorum* when applied to the soil surface or incorporated. (Dry weight expressed as percent of untreated control)

metribuzin	First experiment		Second experiment	
(g/ha)	Soil surface	Incorporated	Soil surface	Incorporated
	(%)			
0	100	100	100	100
14	78.00*	95.25	46.75	66.00
28	55.75	65.50	34.50*	58.50
56	29.75	17.25	20.25	24.50
112	6.25	8.50	3.00	4.75

Means from metribuzin application to the soil surface significantly different from metribuzin incorporated at 5% (*) level as determined by the paired t-test.

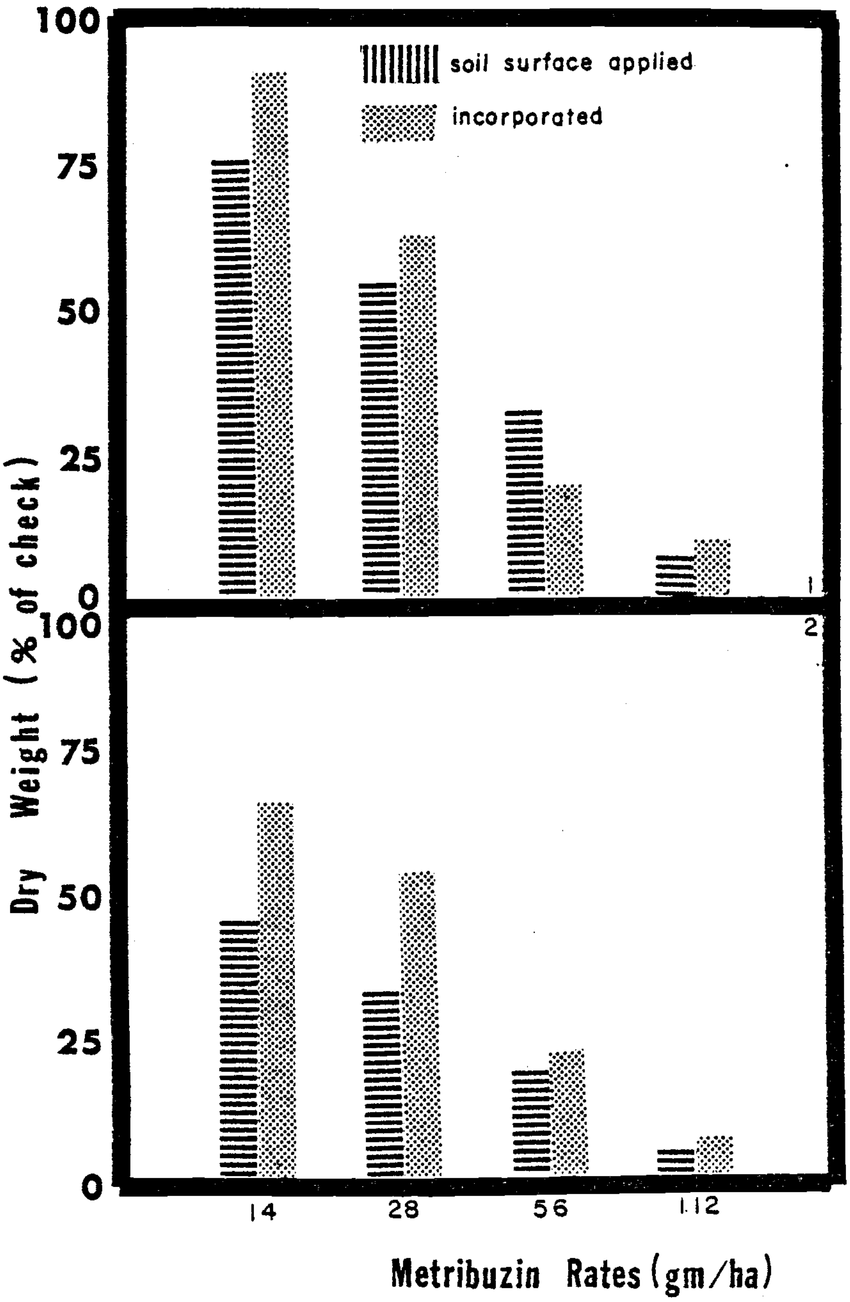


Figure 4. Effect of metribuzin on downy brome *(Bromus tectorum* L.) when applied to the soil surface or incorporated.

EFFECT OF BAND WIDTH AND SEEDING DEPTH ON METRIBUZIN SELECTIVITY

As discussed previously, the strip-till operation involves applying a herbicide, such as metribuzin, between the rows but not over the tilled area where wheat is planted. Studies were conducted in the greenhouse to determine the effect of the width of the unsprayed area over the row and the depth of wheat seeding on metribuzin selectivity.

Materials and Methods

Wheat was planted in plastic pans 33.8 by 27.5 by 13.8 cm. One row of wheat was planted across the middle of each pan. Three seeding depths were used, 1, 3, and 5 cm. Strips of thick, absorbent paper, 5, 10, and 15 cm wide, were used to cover the seeded row to obtain the various unsprayed band widths. An unprotected treatment also was included. Metribuzin was applied with a single nozzle track sprayer at 225 g/ha in 230 L/ha of water. Some pans were left untreated to provide controls for each planting depth. The pans were subirrigated and then drained for 24 h.

At intervals, overhead irrigation was applied using a 2-nozzle boom attached to the greenhouse sprayer to simulate rainfall (Table 9). The amount of water applied represented that which may be expected during the first two months if the herbicide had been applied under field conditions in Sherman County. In a normal year, that would total about 68 mm of rainfall.

The experiments were observed daily and changes in appearance of the plants were noted. After 55 days following treatment, wheat seedlings were cut off at the ground level, oven-dried at 70 C, and dry weights were recorded. Experiments were arranged in a randomized complete block design with a factorial arrangement of treatments with four replications. Foliage dry weights were subjected to analysis of variance. The experiment was conducted twice.

Results and Discussion

Metribuzin caused severe injury to wheat in the pans with 0 banding width (Table 10). Herbicide symptoms first appeared 14 days after emergence in the first experiment and after 10 days in the second experiment. Symptoms first appeared at banding widths of 0 and 5 cm, and the 1-cm seeding depth. Symptoms observed ranged from slight marginal chlorosis and necrosis to severe chlorosis, leading to the complete death of the plant.

The extent of injury decreased as the protected band width and the seeding depth increased. The shallower depths with a wide band caused somewhat less injury than deeper seeding depths with no banding. This might indicate that the metribuzin moves faster downward than it does laterally. However, the movement of the herbicide would depend on the amount and distribution of overhead water.

Although injury symptoms to wheat that was planted deeper under a wide, unsprayed band appeared much less quickly than in wheat seeded in a narrow, protected band, symptoms increased each time an additional irrigation was received. This injury was probably worse than might be expected in the field because of the confinement of the wheat roots. In the field, the roots would have been able to grow deeper and possibly escape exposure to metribuzin but in the relatively shallow pans, there was no way in which the roots could escape exposure to metribuzin, particularly as the amount of irrigation water increased.

No specific recommendations can be made relative to the width of the unsprayed band and the depth of wheat seeding in the field until actual experiments are conducted, since the conditions in the greenhouse are somewhat different from those in the field. However, the results (Table 11, Figure 5) of these experiments clearly show that increasing the width of the unsprayed band with an increasing depth of wheat seeding will provide a larger margin of safety to the wheat.

Table 10. Schedule of sprinkler irrigation for 7 weeks after metribuzin was applied

First experiment		Second experiment	
Days after seeding	mm of water added	Days after seeding	mm of water added
11	7.0	8	4.0
15	6.0	11	4.0
20	5.5	15	5.5
25	5.5	18	6.5
28	6.0	21	6.0
31	6.0	25	7.0
35	7.0	29	7.0
39	6.5	32	6.0
43	6.0	35	6.0
46	7.0	39	4.0
49	5.5	43	5.0
Total	68 mm	47	5.0
		50	5.0
		Total	71 mm

Table 11. Visual evaluation of phytotoxicity to wheat from metribuzin at 225 g/ha at 28 days following treatment.

First experiment

Width of banding (cm)	Depth of seeding (cm) 1	3	5	Depth of seeding (cm) 1	3	5
	—— (% damage)[a] ——			—— √arcsine ——		
0	98.75	98.75	97.50	86.77	86.77	85.44
5	90.00	76.25	85.00	74.71	62.02	67.60
10	91.25	65.00	30.00	73.09	53.84	32.83
15	66.25	20.00	11.25	54.80	22.72	16.94
Check	0	0	0	0	0	0
$LSD_{.05}$					13.628	
$LSD_{.01}$					18.353	

Second experiment

0	100	90.00	97.50	90.00	83.39	78.75
5	96.25	82.16	88.75	82.16	70.76	53.39
10	87.50	70.26	67.50	70.26	55.44	14.94
15	53.75	47.18	26.25	47.18	30.65	15.86
Check	0	0	0	0	0	0
$LSD_{.05}$					13.76	
$LSD_{.01}$					18.53	

[a]Evaluation scale: 0 = no injury, 100 = complete kill.

Table 12. Wheat foliage dry weight as affected by wheat seeding depth and herbicide banding width, expressed as percent of untreated control (herbicide applied at 225 g/ha).

Banding width (cm)	First experiment			Second experiment		
	Seeding depth (cm)			Seeding depth (cm)		
	1	3	5	1	3	5
	(%)[a]			(%)[a]		
0	0**	0**	0**	0**	0**	4**
5	6.75**	37.25**	42.00**	0**	10.75**	20.00**
10	18.00**	44.75**	86.00	12.00**	29.75**	88.75
15	65.75**	88.50	99.00	52.75**	84.75	105.75
Check	100	100	100	100	100	100
$LSD_{.05}$		21.98%			15.69%	
$LSD_{.01}$		29.60%			21.14%	

[a]Means significantly different from appropriate check at 5% (*) or 1% (**) levels as determined by the LSD.

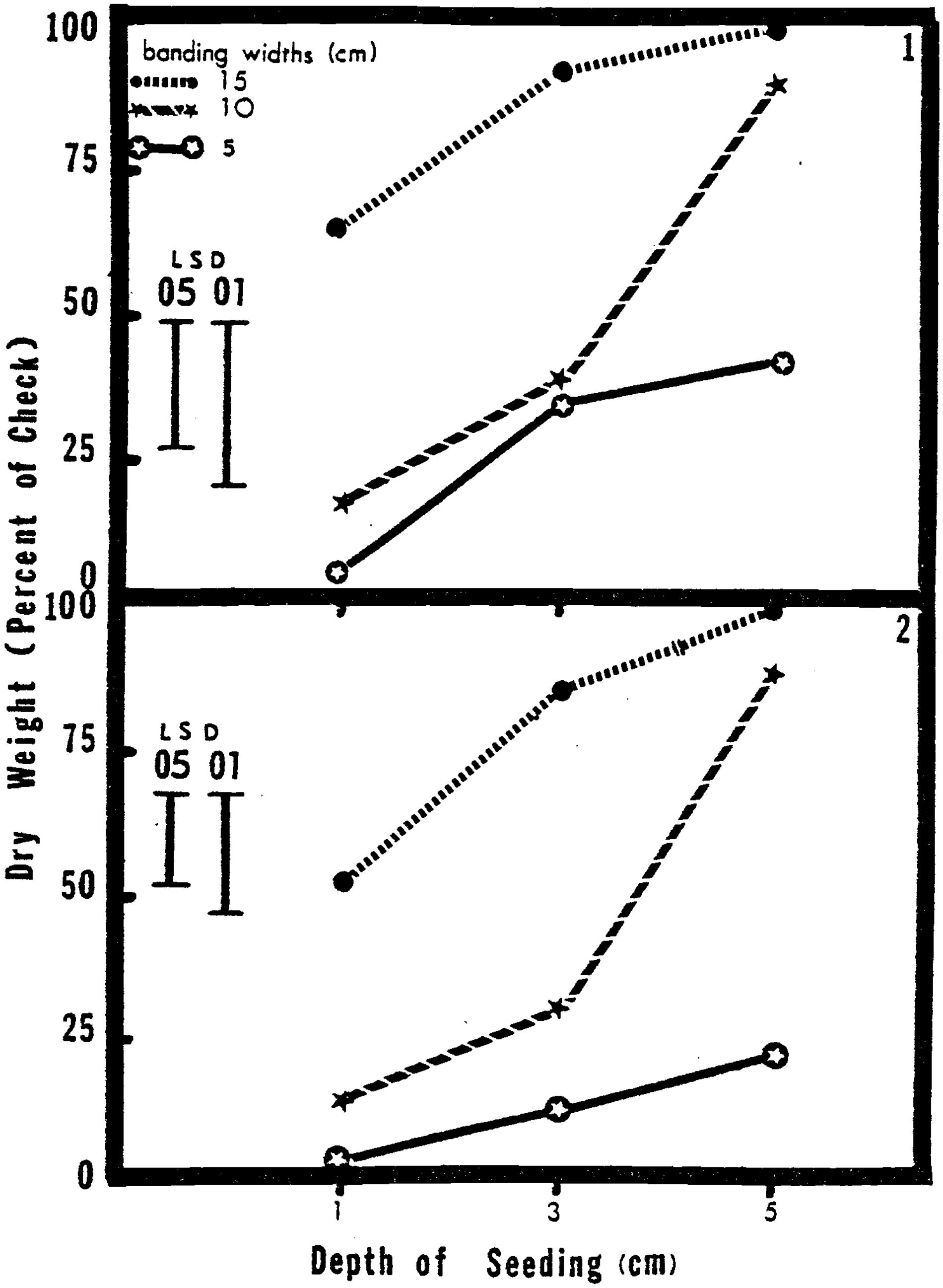


Figure 5. Wheat response to metribuzin at 225 g a.i./ha, as affected by seeding depth and banding width of untreated areas on top of seedrow.

GENERAL CONCLUSIONS

The objectives of this research were to investigate several factors which might influence the activity and selectivity of metribuzin when used in conjunction with a strip-planting operation in the Columbia Basin.

Considerable differences were seen between different formulations of metribuzin when mixed with several liquid fertilizers. For practical recommendations, only the wettable powder seemed to be adequately compatible with the range of liquid fertilizers studied. Other formulations might be used if proper technique and procedures are followed, such as mixing with water and using a compatibility agent, and then mixing only with certain of the liquid fertilizers. Certainly, agitation of the mixture was a key element in maintaining the suspension. Only very minor differences were noted between Sencor and Lexone formulations.

Mixing metribuzin with Solution 32, a liquid mixture of urea and ammonium nitrate, and applied preemergence, was more effective in controlling downy brome than metribuzin used alone. The Solution 32 itself had some phytotoxic effect on the downy brome seedlings under some conditions.

Metribuzin applied on the surface following tillage of the seed row was somewhat more effective in controlling downy brome than when the herbicide was covered with a soil layer. Based upon these results, the spray nozzle perhaps should be mounted behind the strip-tiller rather than in front of it, especially if adequate rainfall is expected.

When using metribuzin preemergence in strip-planted wheat, careful attention should be made to both seeding depth and the width of the unsprayed area over the row. Excessive injury to wheat can occur if metribuzin is applied over the top of the wheat or too close to the wheat row, particularly when the wheat is seeded shallow. In general, if the unsprayed band is 10 cm or less, the depth of seeding should be at least 5 cm. If the untreated band is more than 10 cm wide, wheat should be seeded between 3 and 5 cm.

The results of these studies should help establish some concepts that will be useful in the development of strip-till planting of wheat. Details of certain of the parameters will need to be researched further in the field because of the differences in conditions between the greenhouse and the field situations.

LITERATURE CITED

1. Ashton, F.M. and A.S. Crafts. 1981. Mode of action of herbicides. 2nd Ed. Wiley-Interscience Publ. New York. 525 pp.

2. Barrentine, W.L. 1974. Soybean control with metribuzin and preplanting herbicides. Proc. 27th South. Weed Sci. Soc. 27:88.

3. Barrentine, W.L., C.H. Edwards, Jr., and E.E. Hartwig. 1976. Screening soybeans for tolerance to metribuzin. Agron. J. 68:351-353.

4. Barrentine, W.L., O.B. Wooten, and J.R. Williford. 1979. Effect of incorporation methods and time of application on the performance of trifluralin and metribuzin. Weed Sci. 27:64-68.

5. Becke, B.J. 1980. Response of soybeans to metribuzin time of application. Abstr. of Weed Sci. Soc. Am. pp. 23.

6. Bolton, F.E. and D.E. Booster. 1981. Strip-till planting in dryland cereal production. Amer. Soc. Agric. Eng. 24(1):59-62.

7. Bullock, F.D. and L.S. Jeffery. 1980. Weed control in no-tillage soybean-wheat double cropping system. Proc. 33rd South. Weed Sci. Soc. 33:43.

8. Callihan, R.H., G.F. Stallneck, B.R. Dwelle, M. Blicharczyk, and A.C. Scoggan. 1976. Influence of time and date of metribuzin application on potato yield and quality. Proc. 29th West. Soc. Weed Sci. 29:174.

9. Callihan, R.H., S.W. Gawronski, and B.L. Potter. 1977. Differential tolerance of small grains to metribuzin. Proc. 30th West. Soc. Weed Sci. 30:20.

10. Callihan, R.H., G.M. Master, P.W. Leino, H. Slawinska, and D. Corsini. 1978. Potato herbicide application through sprinklers. Proc. 31st West. Soc. Weed Sci. 31:97.

11. Cleary, C.L. and T.F. Peeper. 1979. Weed control for no-till continuous wheat. Proc. 32nd South. Weed Sci. Soc. 32:41.

12. Coultas, J.S. and R.G. Harvey. 1978. Using a rainfall simulator to study the influence of environment on corn injury from preemergence herbicides. Proc. 33rd North Cent. Weed Cont. Conf. 33:33-34.

13. Da Silva, J.F. and G.F. Warren. 1976. Effect of stage of growth on metribuzin tolerance. Weed Sci. 24:612-615.

14. De Villiers, O.J. and . . Van Der Merwe. 1978. A study of the mode of action of methabenthiazuron and metribuzin in isolated cells of *Phaseolus vulgaris*. South African J. of Sci. 74:440-442.

15. Dircks, V.A. and G.H. Friesen. 1980. Metribuzin used postemergence on established transplanted tomatoes for broadleaf weed control. Can. J. Plant Sci. 60:759-761.

16. Eastin, E.F., J.W. Sij, and J.P. Craigmils. 1980. Tolerance of soybean genotypes to metribuzin. Agron. J. 72:167-168.

17. Eldredge, E. and G.A. Lee. 1980. Weed control in no-till winter wheat. Proc. 33rd West. Soc. Weed Sci. 33:70.

18. Fedtke, C. 1972. Influence of photosynthesis-inhibiting herbicides on the regulation of crop plant metabolism. Pest. Biochem. Physiol. 2:312-323.

19. Fortino, J. 1973. Some physiological effects of metribuzin and its usefulness for weed control in tomatoes. Dissert. Abstr. Internat. B. 34.6:4138.

20. Gigan, D.R. 1979. Winter wheat weed control with metribuzin. Proc. 32nd South. Weed Sci. Soc. 34:36.

21. Glamery, M.D. and L.M. Wax. 1974. Metribuzin-atrazine interaction in soybeans. Proc. 27th South. Weed Sci. Soc. 27:83-85.

22. Graf, G.T. and A.G. Ogg, Jr. 1976. Differential response of potato cultivars to metribuzin. Weed Sci. 24:137-139.

23. Greer, H. and D. Fain. 1980. Cheat control in wheat. Proc. 33rd South. Weed Sci. Soc. 33:314.

24. Haggood, E.S., J.L. Williams, and T.T. Bauman. 1980. Influence of herbicide injury on the yield potential of soybeans. Weed Sci. 28:40-45.

25. Hardcastle, W.S. 1979. Soybean cultivar response to metribuzin solution culture. Weed Sci. 27:278-279.

26. Herbicide handbook of the Weed Science Society of America. 1979. 4th Edition.

27. Kronstad, W.E., W.L. McCuistion, M.L. Swearingin, and C.O. Qualset. 1979. Crop selection for specific residue management system. Am. Soc. Agron. Spec. Publ. #31. pp. 207-217.

28. Kukas, R.D., G.A. Lee, and H.P. Alley. 1972. Herbicide weed control of annual weeds in wheat-fallow in Wyoming. Res. Prog. Rep. West. Soc. Weed Sci. pp. 94.

29. Ladlie, J.S., W.F. Meggit, and D. Penner. 1976. Effect of soil pH on metribuzin activity in the soil. Weed Sci. 24:505-507.

30. Ladlie, J.S., W.F. Meggit, and D. Penner. 1977. Effect of trifluralin and metribuzin combination on soybean tolerance to metribuzin. Weed Sci. 25:55-59.

31. Lee, A.G., H.P. Alley, and A.F. Gale. 1974. Downy brome control in wheat-fallow system in Wyoming. Res. Prog. Rep. West. Soc. Weed Sci. 23:123.

32. Mangeot, B.L., C.E. Rieck, and R.M. Hayes. 1974. The effect of temperature and moisture on metribuzin injury to soybeans. Proc. 29th North Cent. Weed Cont. Conf. 29:34.

33. Mangeot, B.L., F.E. Slife, and C.E. Rieck. 1979. Differential metabolism in two soybean cultivars. Weed Sci. 27:267-269.

34. Martens, A.R., O.C. Burnside, and G.L. Cramer. 1978. Compatibility and phytotoxicity of herbicide-fertilizer combinations. Agron. J. 70:1089-1098.

35. Meyer, L.J., L.S. Murphy, and O.G. Russ. 1973. Compatibility of five herbicides with a suspension fertilizer. Agron. J. 65:911-914.

36. Moomaw, R.S., A.R. Martin, and O.C. Burnside. 1974. Soybean injury from metribuzin on two pH level soils. Proc. 29th North Cent. Weed Cont. Conf. 29:85-87.

37. Moomaw, R.W. and A.R. Martin. 1978. Interaction of metribuzin and trifluralin with soil type on soybean growth. Weed Sci. 26:327-331.

38. Moomaw, R.W. and A.R. Martin. 1978. Weed control in reduced tillage corn production system. Agron. J. 70:91-94.

39. Moore, J.L. 1978. The effect of metribuzin in dryland and sprinkler irrigated wheat. Proc. 31st West. Soc. Weed Sci. 31:97.

40. Morishita, D.W., A.G. Lee, and W.S. Belles. 1980. Field evaluation of DPX 4189 in winter wheat under two tillage systems. Proc. 33rd West. Soc. Weed Sci. 33:72-76.

41. Millhollon, R.W. 1974. Metribuzin for preemergence weed control in sugar cane. Proc. 27th South. Weed Sci. Soc. 27:165.

42. Miller, S.D. 1978. Herbicide fall-applied for chemical fallow. Res. Prog. Rep. North Cent. Weed Cont. Conf. 33:72-73.

43. Miller, S.D. 1980. Hexazinone for weed control in fallow. Res. Prog. Rep. North Cent. Weed Cont. Conf. 5:33-56.

44. Oregon Weed Control Handbook. 1981. Crop Sc. Dept., Ore. State Univ., Corvallis.

45. Phatak, S.C. and G.R. Stephenson. 1973. Influence of light and temperature on metribuzin phytotoxicity to tomatoes. Can. J. Plant Sci. 53:843-847.

46. Pillai, P., D.E. Davis, and B. Truelove. Herbicide effects on RNA, DNA, and protein synthesis. Proc. 31st South. Weed Sci. Soc. 31:205.

47. Pocock, R.L. 1980. Metribuzin as a barley herbicide. Proc. 33rd West. Soc. Weed Sci. 33:84.

48. Pritchard, M.K. and G.T. Warren. 1976. Effect of light on the response of tomato and two weed species to metribuzin. Weed Sci. 24:612-615.

49. Pritchard, M.K. 1980. Plant response to light influenced by herbicides. Dissert. Abstr. Intern. B. 41.4:10.

50. Ramsey, H.C. 1980. Performance of metribuzin for downy brome control in winter wheat grown in the Northwest. Proc. 33rd West. Soc. Weed Sci. 33:71-72.

51. Rushing, D.W. and T.F. Peeper. 1980. Reduced tillage with herbicides for wheat production. Proc. 33rd West. Soc. Weed Sci. 33:22.

52. Russ, O.G., R.F. Sloan, and L.S. Murphy. 1973. Evaluation of nitrogen solution as a carrier of herbicides. Proc. 28th North Cent. Weed Cont. Conf. pp. 28-79.

53. Savage, K.E. 1976. Adsorption and immobility of metribuzin in soil. Weed Sci. 24:525-528.

54. Savage, K.E. 1977. Metribuzin persistence in soil. Weed Sci. 25:55-59.

55. Savage, K.E. 1980. Metribuzin persistence in soil surface. Proc. 33rd South. Weed Sci. Soc. 33:288.

56. Scoggan, A.C. 1979. Alfalfa improvement with metribuzin herbicide. Proc. 32nd West. Soc. Weed Sci. 32:61.

57. Sharom, M.S. and G.R. Stephenson. 1976. Behavior and fate of metribuzin in eight Ontario soils. Weed Sci. 24:153-160.

58. Stahlman, P.W. 1978. Evaluation of spring-applied herbicides for weed control during fallow preceding winter wheat. Res. Prog. Rep. North Cent. Weed Cont. Conf. 33:65-67.

59. Stahlman, P.W. 1978. Herbicides applied in growing wheat for weed control during fallow. Res. Prog. Rep. North Cent. Weed Cont. Conf. 33:68.

60. Stephenson, G.R., J.E. McLeod, and S.C. Phatak. 1976. Differential tolerance of tomato cultivars to metribuzin. Weed Sci. 24:161-165.

61. Tripplet, G.B.,Jr. 1978. Weed control for double crop soybeans planted with no-till following small grain harvest. Agron J. 70:571-581.

62. Warren, J.W. and D.S. Parish. 1977. The use of metribuzin for weed control in wheat and barley in the Pacific Northwest. Proc. 30th West. Soc. Weed Sci. 30:51.

63. Wax, L.M. 1977. Incorporation depth and rainfall effect on weed control in soybeans with metribuzin. Agron. J. 69:107-110.

64. Weber, J.B., T.J. Monaco, R.D. Garringer, and D.W. Eaddy. 1974. Effect of organic matter and volume weight of North Carolina soils on herbicide performance. Proc. 27th South. Weed Sci. Soc. 27:371.

65. Wicks, G.A. and C.R. Fenster. 1980. Brome control with metribuzin in growing no-till continuous winter wheat in the Great Plains. Proc. 33rd South. Weed Sci. Soc. 33:41-42.

66. Wiese, A.F. and D.W. Staniforth. 1973. Weed control in conservation tillage: the proceedings of a national coference. Soil Cons. Soc. of Am. pp. 109-114.

67. Wittmus, H.D., D.E. Lane, and B.R. Somerhalder. 1971. Strip-till planting of row crops through surface residue. Transactions of the Am. Soc. Agric. Eng. 14(1):60-63, 68.

A P P E N D I C E S

Appendix Table 1. Dry weight of downy brome shoots treated with 4 rates of Solution 32 in combination with 5 rates of metribuzin to determine the biological compatibility of metribuzin and Solution 32. (First trial)

Treatment			Replications I	II	III	IV	Total	Mean
			(mg)					
Solution 32 0 kg N/ha	metribuzin	0 g/ha	833	634	731	833	3031	757.75
		14 g/ha	739	366	562	453	2120	530.00
		28 g/ha	200	263	227	225	915	228.75
		56 g/ha	45	218	198	161	622	155.50
		112 g/ha	0	41	0	66	107	26.75
Solution 32 36 kg N/ha	metribuzin	0 g/ha	406	708	647	501	2262	565.50
		14 g/ha	111	168	175	215	669	167.25
		28 g/ha	63	115	96	63	337	84.25
		56 g/ha	44	93	126	0	263	65.75
		112 g/ha	0	0	32	0	32	8.00
Solution 32 54 kg N/ha	metribuzin	0 g/ha	230	510	175	152	1067	266.75
		14 g/ha	202	101	79	170	552	138.00
		28 g/ha	92	83	106	100	381	95.25
		56 g/ha	23	81	54	71	229	57.25
		112 g/ha	0	52	0	43	95	23.75
Solution 32 79 kg N/ha	metribuzin	0 g/ha	217	131	120	167	635	158.75
		14 g/ha	213	96	176	121	606	151.50
		28 g/ha	127	103	195	181	606	151.50
		56 g/ha	0	48	15	34	97	24.25
		112 g/ha	30	0	68	24	122	30.50

Appendix Table 2. Analysis of Variance of Table 1.

Source of variation	S.S.	d.f.	M.S.	F
Reps	2419.702	3	806.567	0.108 ns
Treatments	3047890.400	19	160415.280	21.655**
Carrier (Sol. 32 vs water)	708022.500	3	236007.500	31.859**
Dates of herbicide	1725906.900	4	431476.730	58.247**
Carrier x rate	613961.0	12	51163.416	6.906**
Error	422238.090	57	7407.686	
Total	3472548.200			

LSD (0.05) = 121.718 C.V. = 46.68%

LSD (0.01) = 161.885

Appendix Table 3. Data from Table 1 expressed as percent of untreated control. (First trial)

Treatment			Replications I	II	III	IV	Total	Mean
			(%)					
Solution 32	metribuzin	0 g/ha	100	100	100	100	400	100.00
0 kg N/ha		14 g/ha	89	58	79	54	280	70.00
		28 g/ha	24	41	31	27	123	30.75
		56 g/ha	5	34	27	19	85	21.25
		112 g/ha	0	6	0	8	14	3.50
Solution 32	metribuzin	0 g/ha	100	100	100	100	400	100.00
36 kg N/ha		14 g/ha	27	24	27	43	121	30.25
		28 g/ha	16	16	15	13	60	15.00
		56 g/ha	11	13	19	0	43	10.75
		112 g/ha	0	0	5	0	5	1.25
Solution 32	metribuzin	0 g/ha	100	100	100	100	400	100.00
54 kg N/ha		14 g/ha	88	26	15	112	235	58.75
		28 g/ha	46	16	21	66	143	35.75
		56 g/ha	10	16	34	47	107	26.75
		112 g/ha	0	0	0	28	38	9.50
Solution 32	metribuzin	0 g/ha	100	100	100	100	400	100.00
79 kg N/ha		14 g/ha	98	73	147	72	390	97.50
		28 g/ha	59	79	163	108	409	102.25
		56 g/ha	0	37	13	20	70	17.50
		112 g/ha	14	0	57	14	85	21.25

Appendix Table 4. Analysis of Variance of Table 3.

Source of Variation	S.S.	d.f.	M.S.	F
Reps	2085.25	3	695.083	1.403 ns
Treatments	59108.50	15	3940.566	7.956**
Carriers (Sol. 32 vs water)	16829.625	3	5609.875	11.327**
Rates (herbicide)	30454.625	3	10151.541	20.497**
Carrier x rate	11824.250	9	1313.805	2.652**
Error	22286.249	45	495.250	
Total	83480	63		

LSD (0.05) = 31.78 C.V. = 64.50%

LSD (0.01) = 42.55

Appendix Table 5. Analysis of variance of Table 3, excluding Solution 32 at 54 kg N/ha and 79 kg N/ha treatments.

Source of variation	S.S.	d.f.	M.S.	F
Reps	120.34	3	40.11	0.589 ns
Treatments	13567.47	7	1938.21	28.465**
Carrier (Sol. 32 vs water)	2329.03	1	2329.03	34.205**
Rate of herbicide	9680.59	3	3226.84	47.319**
Carrier vs carrier	1557.84	3	519.28	7.626**
Error	1838.40	21	68.09	
Total	15526.22			

C.V. = 36.12%

Table 6. Dry weight of downy brome shoots, treated with 4 rates of Solution 32 in combination with 5 rates of metribuzin to determine the biological compatibility of metribuzin and Solution 32. (Second trial)

Treatment			Replications I	II	III	IV	Total	Mean
			(mg)					
Solution 32 0 kg N/ha	metribuzin	0 g/ha	1243	1410	920	1473	5046	1261.50
		14 g/ha	822	890	740	765	3217	804.25
		28 g/ha	435	620	564	540	2159	539.75
		56 g/ha	327	268	372	512	1479	369.75
		112 g/ha	0	90	105	91	286	71.50
Solution 32 36 kg N/ha	metribuzin	0 g/ha	1290	827	1078	1204	4399	1099.75
		14 g/ha	465	416	678	702	2261	565.25
		28 g/ha	441	464	662	691	2258	564.50
		56 g/ha	183	365	0	406	954	238.50
		112 g/ha	0	0	0	132	132	33.00
Solution 32 54 kg N/ha	metribuzin	0 g/ha	146	127	245	230	748	187.00
		14 g/ha	201	0	165	325	691	172.75
		28 g/ha	142	0	0	0	142	35.50
		56 g/ha	0	108	0	0	108	27.00
		112 g/ha	86	0	0	0	86	21.50
Solution 32 79 kg N/ha	metribuzin	0 g/ha	89	78	138	210	515	128.75
		14 g/ha	215	0	112	67	394	98.50
		28 g/ha	0	138	0	0	138	34.50
		56 g/ha	0	0	115	115	230	57.50
		112 g/ha	0	0	0	0	0	0

Appendix Table 7. Data from Table 6, expressed as percent of untreated check, excluding Solution 32 at 54 kg N/ha and 79 kg N/ha treatments.

Treatment			Replications I	II	III	IV	Total	Mean
			(%)					
Solution 32	metribuzin	0 g/ha	100	100	100	100	400	100.00
0 kg N/ha		14 g/ha	66	63	80	52	261	65.25
		28 g/ha	35	44	61	37	177	44.25
		56 g/ha	26	19	40	35	120	30.00
		112 g/ha	0	6	11	6	23	5.75
Solution 32	metribuzin	0 g/ha	100	100	100	100	400	100.00
36 kg N/ha		14 g/ha	36	50	63	58	207	51.75
		28 g/ha	34	56	62	57	208	52.25
		56 g/ha	14	44	0	34	92	23.00
		112 g/ha	0	0	0	11	11	2.75

Appendix Table 8. Analysis of variance of table 6, excluding Solution 32 at 54 kg N/ha and 79 kg N/ha treatments.

Source of variation	S.S.	d.f.	M.S.	F
Reps	127723.3	3	42574.43	2.393 ns
Treatment	5996775.2	9	666308.36	37.452**
Carrier	119137.26	1	119137.26	6.696**
Rate	5791564.3	11	1447891.0	81.383**
Carrier x rate	86073.64	4	21518.41	1.209 ns
Error	480358.5	27	17791.05	
Total	6604857.0	39		

C.V. = 24.04%

Appendix Table 9. Analysis of variance of Table 7.

Source of variation	S.S.	d.f.	M.S.	F
Reps	760.25	3	253.41	2.115 ns
Treatment	14561.00	7	2080.14	17.367**
Carrier	120.12	1	120.12	1.00 ns
Rate	13952.50	3	4650.83	38.830**
Carrier x rate	488.37	3	162.79	1.359 ns
Error	2515.25	21	119.77	
Total	17837.5	31		

C.V. = 31.78%

Appendix Table 10. Solution 32 effect on downy brome emergence when applied to a wet soil surface and a dry soil surface. (First trial)

	Solution 32 (kg N/ha)	Replications I	II	III	IV	V	VI	Total	Mean
		Emergence (plant/pot)							
Wet soil	0	42	54	49	36	56	61	298	49.50
	36	37	22	41	33	41	42	216	36.00
	54	40	38	27	16	35	19	175	29.16
Dry soil	0	71	54	53	63	49	57	347	57.83
	36	47	36	44	31	37	26	219	36.50
	54	8	16	13	6	11	21	77	12.83

Appendix Table 11. Solution 32 effect on downy brome emergence, expressed as a percent of check, applied to wet and dry soil surfaces.

	Solution 32 (kg N/ha)	Replications I	II	III	IV	V	VI	Total	Mean
		(%)							
Wet soil	0	100	100	100	100	100	100	600	100.00
	36	88	41	84	92	73	69	447	74.50
	54	95	70	55	44	63	31	358	59.66
Dry soil	0	100	100	100	100	100	100	600	100.00
	36	66	67	83	49	76	47	388	64.66
	54	11	30	25	10	22	37	135	22.50

Appendix Table 12. Analysis of variance of Table 10.

Source of variation	S.S.	d.f.	M.S.	F
Reps	332	5	66.4	0.936 ns
Treatment	7446.667	5	1489.3	20.996**
Appl. method	58.777	1	58.777	0.828 ns
Rates	6445.388	2	3222.75	45.433**
Appl. m. x rates	942.388	2	471.194	6.642**
Error	1773.333	25	70.933	
Total	9552	35		

LSD (0.05) = 10.016 C.V. = 22.76%

LSD (0.01) = 13.550

Appendix Table 13. Analysis of variance of Table 11.

Source of variation	S.S	d.f.	M.S.	F
Reps	1144.884	5	228.966	0.741 ns
Treatment	9307.667	3	3102.555	10.041**
Appl. method	3313.500	1	3313.500	10.724**
Rates	4873.500	1	4873.500	15.773**
Rates x Appl. m.	1120.666	1	1120.666	3.627 ns
Error	4634.498	15	308.966	
Total	15087.334	23		

LSD (0.05) = 21.626 C.V. = 31.77%

LSD (0.01) = 29.907

Appendix Table 14. Effect of Solution 32 on downy brome emergence (plants/pot) applied to wet and dry soil surfaces. (Second trial)

	Solution 32 (kg N/ha)	Replications I	II	III	IV	V	VI	Total	Mean
		Emergence (plants/pot)							
Wet soil	0	73	25	78	79	81	76	472	78.66
	36	74	76	81	75	78	83	467	77.83
	54	72	83	69	75	78	67	444	74.00
Dry soil	0	82	89	92	81	84	88	516	86.00
	36	80	75	89	91	88	90	513	85.50
	54	84	88	77	83	82	82	496	82.66

Appendix Table 15. Effect of Solution 32 on downy brome emergence (expressed as percent of check) applied to wet and dry soil surfaces.

	Solution 32 (kg N/ha)	Replications I	II	III	IV	V	VI	Total	Mean
		(%)							
Wet soil	0	100	100	100	100	100	100	600	100.00
	36	101	89	104	95	96	106	594	99.00
	54	99	98	88	95	96	88	564	94.00
Dry soil	0	100	100	100	100	100	100	600	100.00
	36	98	84	97	112	105	102	598	99.67
	54	102	99	84	102	98	93	578	96.33

Appendix Table 16. Analysis of variance of Table 14.

Source of variation	S.S.	d.f.	M.S.	F
Reps	93.23	5	18.64	0.779 ns
Treatment	673.23	5	134.64	5.631**
Appl. method	560.119	1	560.119	23.425**
Rates	110.23	2	55.115	2.305 ns
Appl. m x rates	2.88	2	1.44	0.60 ns
Error	597.76	25	23.9	
Total	1364.23	35		

C.V. = 6.05%

Appendix Table 17. Analysis of variance of Table 15.

Source of variation	S.S.	d.f.	M.S.	F
Reps	252.00	5	50.40	0.946 ns
Treatment	121.83	3	40.61	0.762 ns
Appl. method	13.50	1	13.50	0.25 ns
Rates	104.16	1	104.16	1.95 ns
Appl. m x rates	4.16	1	4.16	0.078 ns
Error	798.67	15	53.24	
Total	1172.50	23		

C.V. = 7.50%

Appendix Table 18. Solution 32 applied to wet and dry soil surfaces and its effect on wheat germination. (First trial)

	Solution 32 (kg N/ha)	Replications I	II	III	IV	V	VI	Total	Mean
		Emergence							
Wet soil	0	7	8	8	9	7	9	48	8.00
	36	10	8	8	8	6	7	47	7.83
	54	1	4	5	8	7	4	29	4.83
Dry soil	0	10	8	7	8	9	8	50	8.38
	36	10	9	9	9	8	10	55	9.16
	54	0	6	8	8	6	9	46	7.66

Appendix Table 19. Solution 32 effect on wheat germination. (Second trial)

	Solution 32 (kg N/ha)	Replications I	II	III	IV	V	VI	Total	Mean
		Emergence							
Wet soil	0	10	8	9	7	10	10	54	9.0
	36	9	7	10	8	8	10	52	8.66
	54	10	8	9	7	8	8	50	8.33
Dry soil	0	9	9	10	10	10	10	58	9.66
	36	10	10	10	10	8	10	58	9.66
	54	10	9	9	8	10	10	56	9.33

Appendix Table 20. Solution 32 applied to wet and dry soil surfaces and its effect on wheat germination (expressed as percent of check). (First trial)

	Solution 32 (kg N/ha)	Replications I	II	III	IV	V	VI	Total	Mean
		(%)							
Wet soil	0	100	100	100	100	100	100	600	100.00
	36	142	100	100	89	86	78	595	99.16
	54	14	50	22	89	100	44	359	59.83
Dry soil	0	100	100	100	100	100	100	600	100.00
	36	100	113	129	113	89	125	669	111.50
	54	90	75	114	100	67	113	559	93.16

Appendix Table 21. Solution 32 applied to wet and dry soil surfaces and its effect on wheat germination (expressed as percent of check). (Second trial)

	Solution 32 (kg N/ha)	Replications						Total	Mean
		I	II	III	IV	V	VI		
		(%)							
Wet soil	0	100	100	100	100	100	100	600	100.0
	36	90	88	111	114	80	100	583	97.16
	54	100	100	100	100	80	80	560	93.33
Dry soil	0	100	100	100	100	100	100	600	100.00
	36	111	111	100	100	80	100	602	100.33
	54	111	100	90	80	100	100	581	96.83

Appendix Table 22. Analysis of variance of Table 18.

Source of variation	S.S.	d.f.	M.S.	F
Reps	6.139	5	1.23	ns
Treatment	65.139	5	13.03	**
Appl. method	20.25	1	20.25	**
Rates	35.389	2	17.70	**
Appl. m. x rates	9.50	2	4.75	ns
Error	55.63	25	2.20	
Total	126.305	35		

LSD (0.05) = 1.76 C.V. + 19.31%
LSD (0.01) = 2.38

Appendix Table 23. Analysis of variance of Table 19.

Source of variation	S.S.	d.f.	M.S.	F
Reps	10.55	5	2.11	2.914*
Treatment	8.88	5	1.77	2.454 ns
Appl. method	7.11	1	7.11	9.816**
Rates	1.55	2	0.77	1.073 ns
Appl. m. x rates	0.22	2	0.11	0.153 ns
Error	18.11	25	0.724	
Total	126.305	35		

LSD (0.05) = 0.58 C.V. = 9.34%
LSD (0.01) = 0.79

Appendix Table 24. Analysis of variance of Table 20.

Source of variation	S.S.	d.f.	M.S.	F
Reps	976.66	5	195.33	0.307 ns
Treatment	8777.84	3	2925.94	4.604*
Appl. method	3127.17	1	3127.17	4.922*
Rate	4988.17	1	4988.17	7.85 *
Appl. m. x rate	662.49	1	662.49	1.042 ns
Error	9531.34	15	635.42	
Total	19285.84	23		

LSD (0.05) = 31.013 C.V. = 27.728%

Appendix Table 25. Analysis of variance of Table 21.

Source of variation	S.S.	d.f.	M.S.	F
Reps	817.84	5	163.46	1.339 ns
Treatment	147.50	3	49.16	0.402 ns
Appli. method	66.67	1	66.67	0.546 ns
Rate	80.67	1	80.67	0.660 ns
Appl. m. x rate	0.66	1	0.66	0.005 ns
Error	1830.99	15		
Total	2795.84	23		

C.V. = 11.40%

Appendix Table 26. Effect of Solution 32 at 3 rates (0, 36, and 54 kg N/ha) on downy brome shoot dry weight. (Trial 1)

Solution 32 (kg N/ha)	Replications												Total	Mean
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII		
	(mg)													
0	1432	1431	1294	1298	1466	1414	1350	1140	1402	1273	1043	1206	15749	1312.42
36	893	406	968	590	553	875	358	361	514	498	518	534	7068	589.00
54	190	103	591	412	556	175	195	282	292	447	477	245	3963	330.25

Appendix Table 27. Effect of Solution 32 on downy brome shoot dry weight (expressed as percent of check). (Trial 1)

Solution 32 (kg N/ha)	Replications												Total	Mean
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII		
	(%)													
0	100	100	100	100	100	100	100	100	100	100	100	100	1200	100.00
36	62	28	75	45	38	62	27	32	37	39	50	44	539	44.92
54	13	7	46	32	38	12	14	25	21	35	46	20	309	25.75

Appendix Table 28. Analysis of variance of Table 26.

Source of variation	S.S.	d.f.	M.S.	F
Reps	378816.67	11	34437.88	1.319 ns
Treatment	6219738.80	2	3109869.40	119.13**
Error	574310.53	22	26105.02	
Total	7172866	35		

LSD (0.05) = 136.80 C.V. = 21.72%

LSD (0.01) = 185.94

Appendix Table 29. Analysis of variance of Table 27.

Source of variation	S.S.	d.f.	M.S.	F
Reps	2914.334	11	264.94	1.93 ns
Treatment	2204.167	1	2204.167	16.027**
Error	1512.8326	11	137.530	
Total	6631.334	23		

LSD (0.05) = 10.54 C.V. = 33.19%

LSD (0.01) = 14.87

Appendix Table 30. Effect of Solution 32 at 3 rates (0, 36, and 54 kg N/ha) on the dry weight of downy brome shoots (mg). (Trial 2)

Solution 32 (kg N/ha)	Replications I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Total	Mean
	(mg)													
0	862	784	899	801	1142	930	1048	914	1050	822	874	882	11008	917.33
36	783	706	724	976	907	892	805	866	755	802	854	857	9927	827.25
54	802	820	710	894	926	834	503	892	825	782	835	719	9542	795.16

Appendix Table 31. Effect of Solution 32 on downy brome shoot dry weight (expressed as percent of check). (Trial 2)

Solution 32 (kg N/ha)	Replications I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Total	Mean
	(%)													
0	100	100	100	100	100	100	100	100	100	100	100	100	1200	100.00
36	91	90	81	122	79	96	77	95	72	98	98	97	1096	91.33
54	93	105	79	112	81	90	48	96	79	95	96	82	1056	88.00

Appendix Table 32. Analysis of variance of Table 30.

Source of variation	S.S.	d.f.	M.S.	F
Reps	136276.34	11	12388.758	1.33 ns
Treatment	96276.43	2	48138.215	5.168*
Error	204922.23	22		
Total	437475	35		

LSD (0.05) = 81.717 C.V. = 11.4%

LSD (0.01) = 111.07

Appendix Table 33. Analysis of variance of Table 31.

Source of variation	S.S	d.f.	M.S.	F
Reps	4170.34	11	379.12	6.094**
Treatment	66.67	1	66.67	1.071 ns
Error	684.33	11	62.21	
Total	4921.34	23		

LSD (0.05) = 17.36 C.V. = 8.8%

LSD (0.01) = 24.49

Appendix Table 34. Dry weight of downy brome treated with metribuzin when applied to the soil surface or incorporated. (Experiment 1)

	Treatment		Replications				Total	Mean
			I	II	III	IV		
			(mg)					
Soil surface applied	metribuzin	0 g/ha	473	456	518	564	2011	502.75
		14 g/ha	325	404	435	393	1557	389.25
		28 g/ha	257	242	332	293	1124	281.00
		56 g/ha	89	183	158	171	601	150.25
		112 g/ha	14	90	12	0	116	29.00
Incorporated	metribuzin	0 g/ha	494	614	541	637	2286	571.50
		14 g/ha	380	661	533	615	2189	547.25
		28 g/ha	401	404	286	397	1488	372.00
		56 g/ha	91	115	98	87	391	97.75
		112 g/ha	51	20	66	55	192	48.00

Appendix Table 35. Dry weight of downy brome shoots treated with metribuzin when applied to the soil surface or incorporated. (Experiment 2)

	Treatment		Replications				Total	Mean
			I	II	III	IV		
			(%)					
Soil surface applied	metribuzin	0 g/ha	704	780	866	839	3189	797.25
		14 g/ha	311	308	482	401	1502	375.50
		28 g/ha	220	300	301	288	1109	277.25
		56 g/ha	111	154	109	265	639	159.75
		112 g/ha	0	28	73	0	101	25.25
Incorporated	metribuzin	0 g/ha	888	806	776	768	3238	809.50
		14 g/ha	528	671	391	552	2142	535.00
		28 g/ha	480	519	356	529	1184	471.00
		56 g/ha	123	277	207	174	781	195.25
		112 g/ha	0	123	0	33	156	39.00

Appendix Table 36. Dry weight of downy brome from Table 34, expressed as percent of untreated control (Experiment 1).

	Treatment		Replications					
			I	II	III	IV	Total	Mean
			(%)					
Soil surface applied	metribuzin	0 g/ha	100	100	100	100	400	100.00
		14 g/ha	69	89	84	70	312	78.00
		28 g/ha	54	53	64	52	223	55.75
		56 g/ha	19	40	31	30	120	30.00
		112 g/ha	3	20	2	0	25	6.25
Incorporated	metribuzin	0 g/ha	100	100	100	100	400	100.00
		14 g/ha	77	108	99	97	381	95.25
		28 g/ha	81	66	53	62	262	65.50
		56 g/ha	18	19	18	14	69	17.25
		112 g/ha	10	3	12	9	34	8.50

Appendix Table 37. Downy brome shoot dry weight from Table 35, expressed as percent of untreated control (Experiment 2)

	Treatment		Replications					
			I	II	III	IV	Total	Mean
			(%)					
Soil surface applied	metribuzin	0 g/ha	100	100	100	100	400	100.00
		14 g/ha	44	39	56	48	187	46.75
		28 g/ha	31	38	35	34	138	34.50
		56 g/ha	16	20	13	32	81	20.25
		112 g/ha	0	4	8	0	12	3.00
Incorporated	metribuzin	0 g/ha	100	100	100	100	400	100.00
		14 g/ha	59	83	50	72	264	66.00
		28 g/ha	54	64	46	69		58.50
		56 g/ha	14	34	27	23		24.50
		112 g/ha	0	15	0	4	19	4.75

Appendix Table 38. Downy brome injury from metribuzin and soil surface applied or incorporated at 5 rates. (Experiment 1)

Treatment		Replications I	II	III	IV	Total	Mean	Replications I	II	III	IV	Total	Mean
		— % injury —						— Arcsine transformation —					
Soil surface applied metribuzin	0 g/ha	0	0	0	0	0	0	0	0	0	0	0	0
	14 g/ha	30	20	10	40	100	25	33.21	26.56	18.44	39.23	117.44	29.36
	28 g/ha	60	40	60	20	180	45	50.77	39.23	50.77	26.56	167.33	41.83
	56 g/ha	90	80	80	80	330	82.5	71.56	63.44	63.44	63.44	261.88	65.47
	112 g/ha	100	90	100	100	390	97.5	90.00	71.56	90.00	90.00	341.56	85.39
Incorporated metribuzin	0 g/ha	0	0	0	0	0	0	0	0	0	0	0	0
	14 g/ha	20	0	10	0	30	7.5	26.56	0	18.44	0	45.00	11.25
	28 g/ha	30	50	30	40	150	37.5	33.21	45.00	33.21	39.23	150.65	37.66
	56 g/ha	90	90	90	95	365	91.25	71.56	71.56	71.56	77.08	291.76	72.94
	112 g/ha	90	95	90	95	370	92.50	71.56	77.08	71.56	77.08	297.28	74.32

Appendix Table 39. Downy brome injury from metribuzin, soil surface applied or incorporated at 5 rates. (Experiment 2)

Treatment		Replications I	II	III	IV	Total	Mean	Replications I	II	III	IV	Total	Mean
		— % injury —						— Arcsine transformation —					
Soil surface applied metribuzin	0 g/ha	0	0	0	0	0	0	0	0	0	0	0	0
	14 g/ha	45	50	40	30	165	41.25	42.13	45.00	39.23	33.21	159.57	39.89
	28 g/ha	75	60	60	55	250	62.50	60.00	50.77	50.77	47.87	209.41	52.35
	56 g/ha	80	80	90	80	330	82.50	63.44	63.44	71.56	63.44	261.88	65.47
	112 g/ha	95	90	100	100	400	100.00	77.08	71.56	90.00	90.00	328.64	82.16
Incorporated metribuzin	0 g/ha	0	0	0	0	0	0	0	0	0	0	0	0
	14 g/ha	10	0	0	0	10	2.50	18.44	0	0	0	18.44	4.61
	28 g/ha	30	50	30	45	155	38.75	33.21	45.00	33.21	42.13	153.55	38.88
	56 g/ha	80	90	70	90	330	82.50	63.44	71.56	56.79	71.56	263.35	65.83
	122 g/ha	100	90	100	95	385	96.25	90.00	71.56	90.00	77.08	328.64	82.16

Appendix Table 40. Analysis of variance of Table 34.

Source of variation	S.S.	d.f.	M.S.	F
Reps	26122.50	3	8707.50	3.22*
Treatment	1558901.60	9	173211.29	64.18**
Application method	32319.25	1	32319.25	11.97**
Rates	14767.24	4	369181.00	136.79**
Appl. m. x rates	49858.34	4	12464.58	4.61**
Error	72866.298	27	2698.75	
Total	1657890.4	39		

C.V. = 17.38%

Appendix Table 41. Analysis of variance of Table 35.

Source of variation	S.S.	d.f.	M.S.	F
Reps	22363.30	3	7454.43	1.57 ns
Treatment	2900245.2	9	322249.46	67.92**
Application method	68973	1	68973	14.53**
Rates	2770768.3	4	692692.09	146.00**
Appl. m. x rates	60503.9	4	15125.97	3.88**
Error	128097.43	27	4744.34	
Total	3050706	39		

C.V. = 18.69%

Appendix Table 42. Analysis of variance of Table 36.

Source of variation	S.S.	d.f.	M.S.	F
Reps	447.21	3	149.07	2.22 ns
Treatment	31938.21	7	4562.60	68.12**
Application method	140.28	1	140.28	2.09 ns
Rates	303830.34	3	10276.28	153.43**
Appl. m. x rates	967.59	3	322.53	4.81*
Error	1406.53	21	66.97	
Total	33791.96	31		

C.V. = 18.37%

Appendix Table 43. Analysis of variance for Table 37.

Source of variation	S.S.	d.f.	M.S.	F
Reps	518.34	3	172.78	2.99 ns
Treatment	15437.21	7	2205.31	38.18**
Application method	1212.78	1	1212.78	20.99**
Rates	13501.84	3	4500.61	77.92**
Appl. m. x rates	722.59	3	240.86	4.17*
Error	1212.90	21	57.75	
Total	17168.47	31		

C.V. = 23.54%

Appendix Table 44. Analysis of variance for Table 38.

Source of variation	S.S.	d.f.	M.S.	F
Reps	188.83	3	62.92	0.915 ns
Treatment	18857.82	7	2693.97	39.198**
Application method	334.88	1	334.88	4.872*
Rates	17854.16	3	5951.38	86.596**
Appl. m. x rates	668.76	3	222.92	3.243*
Error	1443.24	21	68.73	
Total	20489.88	31		

LSD (0.05) = 12.028
LSD (0.01) = 16.243

C.V. = 19.82%

Appendix Table 45. Analysis of variance for Table 39.

Source of variation	S.S.	d.f.	M.S.	F
Reps	57.46	3	19.15	0.337 ns
Treatment	18969.43	7	2709.92	47.684**
Application method	1194.62	1	1194.62	21.021**
Rates	16089.40	3	5363.13	94.372**
Appl. m. x rates	1685.39	3	561.79	9.885**
Error	1193.42	21	56.83	
Total	20220.32	31		

LSD (0.05) = 10.938
LSD(0.01) = 14.770

C.V. = 14%

Appendix Table 46. Dry weight of wheat shoots seeded at 3 depths and treated with metribuzin at 225 g/ha, using 4 band widths over the wheat rows. (Experiment 1)

Treatments			Replications I	II	III	IV	Total	Means
			(%)					
Seeding depth (1 cm)	Band width (cm)	-0	0	0	0	0	0	0
		-5	0	106	0	0	106	26.5
		-10	0	0	117	102	219	54.75
		-15	287	138	195	227	847	211.75
		-Check	312	391	266	362	1331	332.15
Seeding depth (3 cm)	Band width (cm)	-0	0	0	0	0	0	0
		-5	105	125	138	109	477	119.25
		-10	160	140	127	133	560	140.00
		-15	299	240	219	330	1088	272.00
		-Check	290	344	396	262	1292	323.00
Seeding depth (5 cm)	Band width (cm)	-0	0	0	0	0	0	0
		-5	106	118	120	107	451	112.75
		-10	226	176	232	296	930	232.50
		-15	264	267	254	292	1107	276.75
		-Check	251	303	229	304	1087	271.75

Appendix Table 47. Dry weight of wheat shoots from Table 46 expressed as percent of the check.

Treatments			Replications I	II	III	IV	Total	Means
			(%)					
Seeding depth (1 cm)	Band width (cm)	0	0	0	0	0	0	0
		5	0	27	0	0	27	6.75
		10	0	0	44	28	72	18.00
		15	92	35	73	63	263	53.00
		Check	100	100	100	100	400	100.00
Seeding depth (3 cm)	Band width (cm)	0	0	0	0	0	0	0
		5	36	36	35	42	149	37.25
		10	55	41	32	51	179	44.75
		15	103	70	55	126	354	88.50
		Check	100	100	100	100	100	100.00
Seeding depth (5 cm)	Band width (cm)	0	0	0	0	0	0	0
		5	42	39	52	35	168	42.00
		10	90	58	101	97	346	86.5
		15	105	88	111	96	400	100.00
		Check	100	100	100	100	100	100.00

Appendix Table 48. Dry weight of wheat shoots seeded at 3 depths, treated with metribuzin at 225 g/ha, using 4 banding widths. (Experiment 2)

Treatments			Replications I	II	III	IV	Total	Means
			(mg)					
Seeding depth (1 cm)	Band width (cm)	0	0	0	0	0	0	0
		5	0	0	0	0	0	0
		10	86	278	94	140	592	148.00
		15	685	587	747	710	2729	682.25
		Check	1248	1224	1380	1313	5165	1291.25
Seeding depth (3 cm)	Band width (cm)	0	0	0	0	0	0	0
		5	0	228	94	185	507	126.75
		10	288	350	341	430	1409	352.25
		15	869	1047	900	1232	4048	1012.00
		Check	1263	1184	1104	1232	4783	1195.75
Seeding depth (5 cm)	Band width (cm)	0	152	0	0	0	152	38.00
		5	232	0	448	170	850	212.50
		10	1134	213	994	860	3801	950.25
		15	1225	1176	1083	1067	4771	1142.75
		Check	961	1237	1113	1054	4365	1091.25

Appendix Table 49. Dry weight of wheat from Table 48, expressed as percent of the check.

Treatments			Replications I	II	III	IV	Total	Means
			(%)					
Seeding depth (1 cm)	Band width (cm)	0	0	0	0	0	0	0
		5	0	0	0	0	0	0
		10	6	23	7	11	47	11.75
		15	55	48	54	54	211	52.75
		Check	100	100	100	100	400	100.00
Seeding depth (3 cm)	Band width (cm)	0	0	0	0	0	0	0
		5	0	19	9	15	43	10.75
		10	23	30	31	35	119	29.75
		15	69	88	82	100	339	84.75
		Check	100	100	100	100	400	100.00
Seeding depth (5 cm)	Band width (cm)	0	16	0	0	0	16	4.00
		5	24	0	40	16	80	20.00
		10	118	66	89	82	355	88.75
		15	128	95	47	101	421	105.25
		Check	100	100	100	100		100.00

Appendix Table 50. Analysis of variance for Table 46.

Source of variation	S.S.	d.f.	M.S.	F
Reps	494.367	3	164.789	0.09 ns
Treatment	844922.05	14	60351.575	34.67**
Seeding depth	32292.45	2	16146.225	9.28**
Width	742403.05	4	185600.76	106.66**
Seed depth x width	70226.55	8	8778.3187	5.04**
Error	73084.881	42	1740.1162	
Total	918501.3	59		

LSD (0.05) = 59.61 C.V. = 26.46%
LSD (0.01) = 79.76

Appendix Table 51. Analysis of variance for Table 47.

Source of variation	S.S.	d.f.	M.S.	F
Reps	1048.166	3	349.388	1.507 ns
Treatment	60593.	11	5508.454	23.768**
Seeding depth	8361.31	2	4180.656	18.039**
Width	45847.166	3	15282.388	65.942**
Seed depth x width	6384.521	6	1064.0869	4.591**
Error	7647.833	33	231.752	
Total	69289.	47		

LSD (0.05) = 21.98 C.V. = 37.35%
LSD (0.01) = 29.60

Appendix Table 52. Analysis of variance for Table 48.

Source of variation	S.S.	d.f.	M.S.	F
Reps	217.417	3	72.47	0.613 ns
Treatment	66717.417	11	6065.219	51.306**
Seeding depth	11998.292	2	5999.146	50.747**
Width	47259.083	3	15753.027	133.257**
Seed depth x width	7460.042	6	1243.3403	10.517**
Error	3901.082	33	118.214	
Total	70835.917	47		

LSD (0.05) = 15.69 C.V. = 31.93%
LSD (0.01) = 21.14

Appendix Table 53. Analysis of variance for Table 49.

Source of variation	S.S.	d.f.	M.S.	F
Reps	3821.54	3	1273.846	0.125 ns
Treatment	1466111.8	14	1047222.7	103.496**
Seeding depth	694303.31	2	347151.15	34.308**
Width	12644689.	4	3161172.3	312.416**
Seed depth x width	1322125.6	8	165265.71	16.33**
Error	424975.43	42	10118.462	
Total	15089915.	59		

LSD (0.05) = 143.75 C.V. = 18.30%
LSD (0.01) = 192.33

Appendix Table 54. Visual evaluations of wheat injury from metribuzin as affected by band width and seeding depth. (Experiment 1)

Treatment			Replications I	II	III	IV	Total	Mean	Replications I	II	III	IV	Total	Mean
			(% injury)						Arcsine transformation					
Seeding depth (1 cm)	Band width (cm)	0	100	100	100	95	395	98.75	90	90	90	77.08	347.08	86.77
		5	90	75	95	100	360	90	71.76	60	77.08	90	298.84	74.71
		10	90	95	90	90	365	91.25	71.76	77.08	71.76	71.76	292.36	73.09
		15	50	75	60	80	265	66.25	45.0	60	63.44	50.77	219.21	54.80
		Check	0	0	0	0	0	0	0	0	0	0	0	0
(3 cm)		0	100	95	100	100	395	98.75	90	77.08	90	90	347.08	86.77
		5	70	60	75	80	305	76.25	56.79	50.77	77.08	63.44	248.08	62.00
		10	70	50	75	70	260	65	56.79	45	56.79	56.79	215.37	53.84
		15	10	0	40	30	80	20	18.44	0	39.23	33.21	90.88	22.72
		Check	0	0	0	0	0	0	0	0	0	0	0	0
(5 cm)		0	100	100	90	100	390	97.50	90	90	71.76	90	341.76	85.44
		5	90	80	90	80	340	85	71.76	63.44	71.76	63.44	270.40	67.60
		10	20	50	20	30	120	30	26.56	45	26.56	33.21	131.33	32.83
		15	0	15	10	20	45	11.25	0	22.79	18.44	26.56	67.79	16.94
		Check	0	0	0	0	0	0	0	0	0	0	0	0

Appendix Table 55. Visual evaluations of wheat injury from metribuzin as affected by band width and seeding depth. (Experiment 2)

Treatment			Replications (% injury) I	II	III	IV	Total	Mean	Replications (Arcsine transformation) I	II	III	IV	Total	Mean
Seeding depth (1 cm)	Band width (cm)	0	100	100	100	100	100	100	90	90	90	90	360	90
		5	95	100	100	90	385	96.25	77.08	90	90	71.56	328.64	82.16
		10	95	95	80	80	350	87.50	77.08	77.08	63.44	63.44	281.04	70.26
		15	60	50	40	65	215	53.75	50.77	45	39.23	53.73	188.73	47.18
		Check	0	0	0	0	0	0	0	0	0	0	0	0
(3 cm)		0	100	100	90	100	390	97.50	40	90	71.56	90	341.56	85.39
		5	95	85	90	85	355	88.75	77.08	67.21	71.56	67.21	283.06	70.76
		10	60	70	80	60	270	67.50	50.77	56.79	63.44	50.77	221.77	55.44
		15	30	20	20	35	105	26.25	33.21	26.56	26.56	36.27	122.60	30.65
		Check	0	0	0	0	0	0	0	0	0	0	0	0
(5 cm)		0	90	100	80	100	370	92.50	71.56	90	63.44	90	315	78.75
		5	75	90	60	40	265	66.25	60	71.56	50.77	39.23	221.56	55.39
		10	0	20	0	30	50	12.50	0	26.56	0	31.21	59.77	14.95
		15	0	10	10	20	40	10	0	18.44	18.44	26.56	63.44	15.86
		Check	0	0	0	0	0	0	0	0	0	0	0	0

Appendix Table 56. Analysis of variance for Table 54.

Source of variation	S.S.	d.f.	M.S.	F
Reps	357.7536	3	119.25	1.33 ns
Treatment	26303.4	11	2391.2	26.68**
Seeding depth	4032.54	2	2061.27	22.49**
Width	19404.167	3	6468.05	72.16**
Seed depth x width	2866.68	6	477.78	5.33**
Error	2957.75	33	89.63	
Total	29618.9	47		

LSD (0.05) = 13.628 C.V. = 19.73%
LSD (0.01) = 18.353

Appendix Table 57. Analysis of variance for Table 55.

Source of variation	S.S.	d.f.	M.S.	F
Reps	473.79	3	157.93	1.74 ns
Treatment	30439.22	11	2767.20	30.46**
Seeding depth	7919.56	2	3959.78	43.58**
Width	20215.52	3	6738.50	74.17**
Seed depth x width	2304.13	6	384.02	4.23*
Error	2997.94	3	90.84	
Total	33910.955	47		

LSD (0.05) = 13.76 C.V. = 20.53%
LSD (0.01) = 18.53