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Factors Influencing the Performance of Bromoxynil 4(2,4-DB), or a Companion Crop for Weed Control in Seedling Alfalfa

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FACTORS INFLUENCING THE PERFORMANCE OF BROMOXYNIL 4(2,4-DB), OR A COMPANION CROP FOR WEED CONTROL IN SEEDLING ALFALFA

by

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ABSTRACT

Factors Influencing the Performance of Bromoxynil

4(2,4-DB), or a Companion Crop for Weed

Control in Seedling Alfalfa

by

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Some of the factors influencing the performance of bromoxynil, 4(2,4-DB), or a companion crop for weed control in seedling alfalfa were studied in the greenhouse and at field locations in Farmington and Logan, Utah. The effect of application rate, stage of growth, temperature, and soil moisture on the phytotoxicity of bromoxynil and 4(2,4-DB) to alfalfa and weeds were studied.

Alfalfa yields were increased by 4(2,4-DB) at all rates and stages of application. All rates and stages of bromoxynil treatment except the one-fourth pound per acre three to four trifoliate application resulted in alfalfa yields below that of the control.

The use of a companion crop was not conducive to the growth and development of alfalfa although it did control the weeds. Bromoxynil at all rates and at both stages of application resulted in effective mustard control. Mustard control in the 4(2,4-DB) plots was excellent at the early stage of application but required three-fourths pound per acre for control at the later stage of weed growth. Pigweed control was rather ineffective in bromoxynil plots at Logan where moisture was

optimum, but effective in plots at Farmington where moisture was limited for 18-20 days following application. The density of the pigweed stand in bromoxynil treatments at Logan was attributed to an influx of weed growth following initial control of weeds. Control of pigweed by 4(2,4-DB) was in excess of 90 percent at the four to five leaf stage of weed growth.

(52 pages)

INTRODUCTION

The United States loses eleven billion dollars in agriculture each year, of which weed losses account for more than one-third. These losses are considerably reduced in a number of crops by the use of herbicides. The development and testing of new herbicides to take care of a wider range of weed problems is of prime importance to the continuation of productive agriculture.

The allocation of research funds to a given project in weed control is determined by the state crop population and the demand for weed control. Of the major crops in Utah, alfalfa has the highest acreage at 450,000 acres compared to spring and winter wheat at 279,000 acres, barley at 125,000 acres, and oats at 30,000 acres. In establishing alfalfa for seed or hay production, weeds are the most serious limitation. Herbicides for control of these weeds have been limited, and as a result, many have used a companion crop for alfalfa establishment. Severe reduction or loss of alfalfa stands has resulted. A systemic herbicide, 4(2,4-DB), has been recommended for alfalfa broadleaf weed control for a number of years. Since the spectrum of broadleaf weed control is narrow with 4(2,4-DB), applications of the chemical have only been partially effective in solving the weed problem associated with alfalfa establishment. A number of other herbicides recommended for use in seedling alfalfa establishment also have limitations. Much more work needs to be done to find suitable herbicides for both broadleaf and grassy weed control in seedling alfalfa establishment.

Preliminary studies with a new herbicide, bromoxynil, (3,5-dibromo-4-hydroxybenzonitrile) indicated excellent broadleaf weed control in seedling alfalfa with alfalfa phytotoxicity at higher temperatures being a limiting factor. This limited the use of bromoxynil in agricultural areas where temperatures were higher, such as areas of the West Coast or in Southern Utah. Because of the number of alfalfa acres and the mildness of climate, Logan, Utah, was selected as an experimental area. A detailed study to determine the significance of alfalfa injury and weed response to bromoxynil was considered important.

REVIEW OF LITERATURE

The degree to which an alfalfa plant benefits from the reduction of companion crop seeding rate is dependant upon seasonal climatic conditions. During seasons of limited rainfall, the vigor of alfalfa stands has been improved by decreasing the seeding rate of the companion grain crop or by widening the drill row width (18,44). These results were attributed to the decrease in competition for moisture and an increase in light intensity at the alfalfa level. By contrast, decreasing the seeding rate of the small grain in years of ample rainfall did not favor legume establishment (5, 18, 44). The decrease in competition from the small grain due to seeding rate reduction was counter-balanced by an increase in weed growth. Where fields were relatively weed free, Pendleton and Dungan (35) found that it was very difficult to establish successive seeding rates of small grains since at the lower planting rates they tend to compensate and fill in by producing larger plants with greater tillering capacity and more spikelets per plant. The height of the small grain, tillering capacity, kernal size, culm diameter, and spikelets per plant increased directly as row spacing was increased.

In trials conducted by Pendleton and Dungan (35), there were no significant differences in clover stands as a result of row spacing or seeding rate except during one year when a three-week dry period occurred in May resulting in clover sown in eight-inch rows producing only 62 percent as much as when it was planted in sixteen-inch rows. They also recorded an almost complete loss of stand as the eight-inch rows with a companion crop gave only 12 percent stand the following year when compared to eight-inch row plantings of alfalfa alone.

Bula, Miller, and Smith (5) recorded light intensities at the legume level from planting until harvesting when various rates of companion crops were sown with the legumes. There were no differences in legume stands under six rates of grain sowing since there was ample rainfall during the season. It was noted that weeds will equalize the total amount of growth possible on a given area of land if moisture is not a limiting factor.

Legume seedlings below a companion crop must compete for light, moisture, and nutrients. The magnitude of such competition is reflected in seedling vigor and survival (5, 42). Of the competitive restrictions imposed by the companion crop on the underseeded legumes, Bula, Rhykerd, and Langston (6) believe that light has the greatest effect. The large roots characteristic of alfalfa do not develop at low light intensities. Drought tolerance, normally present in alfalfa with an extensive root system, is not present under limited light conditions and plants suffer greatly during drought periods.

One explanation for a lack of drought tolerance in the alfalfa is the effect that light has on the root to top ratio (11, 18, 19, 40). Dry weight of plant tops under 14,400 foot-candle-hours (ft-c) of light was three and one-half times greater than the top weights of plants under 2,400 ft-c. Root weights at the high light levels were approximately seven times greater than those under low light levels. Since less of the dry matter accumulated was partitioned into roots and more into stems at decreasing light quantities, the top to root ratios increased with a decrease in light intensity. The decrease in partition of growth into roots at low light intensity appears to be a major factor in the survival of seedlings grown with exposure to heavy competition. Dense stands of companion crops or weeds readily extract valuable water from the soil surface in the region of restricted alfalfa root growth. Unless the surface soil moisture is replenished, severe alfalfa stand reductions due to drought can be expected.

Further effects of light are discussed by Rhykerd, Langston, and Mott (41) and Bula, Miller, and Smith (5). Leaf to stem ratios were high at low light intensities and low (less than one) at high light intensities.

An extensive study by Gist and Mott (18) to determine temperature and light interactions on alfalfa development, demonstrated the top growth of alfalfa at 600 ft-c of light and a temperature of 60 F and 600 ft-c conditions were less than 50 percent that at 90 F and 1200 ft-c. Since soil moisture was kept constant, it is apparent that root growth was affected much more by a decrease in light intensity than was top growth.

Some investigators (22) believe that barley is a more vigorous competitor against the new legumes than other types of small grain. The presence of germinating barley seedlings has been found to inhibit lucerne seed germination and radicle growth even before shading could be an important factor.

The development of high yielding oat varieties increases the severity of competition to underseeded legumes as demonstrated by Pritchett and Nelson (40). These investigators found that the greater demand for nutrients and moisture associated with high yielding varieties accounts for the greater competition. If oats are used in legume establishment, they propose the use of short, stiff-strawed, early maturing types.

Nitrogen fertilization maintains high yields and increases crop competition while decreasing light penetration of the companion canopy. In short, it has generally been found that nitrogen additions limit the probability of successful legume establishment (18, 40). In opposition, fertilization with P_2O_5 (43) generally decreases vegetative growth of the companion crop as compared to nitrogen fertilizer and will likely favor the stability of the legume.

Seeding rates for the companion crop have ranged from 2-3 bushels per acre (bu/A) on heavy, moist soils to one bu/A on lighter soils where moisture is likely to be limiting. Reduced seeding rates increase the possibility of weed infestations. Weeds are usually more competitive against alfalfa than is the companion crop (43).

The stage of growth of the companion crop at the time it is removed as a cover is also a critical factor in evaluating the wisdom of using a companion crop for legume seedling establishment. By harvesting an oat companion crop just as it began to head, Pardee (33) obtained yields of 3.5 to 4 tons of oat hay per acre. Early removal of the oats left sufficient moisture to obtain an additional one to 1.5 tons of weed-free alfalfa in the same year.

Peters (37) made studies to compare forage yields with and without a companion crop. The presence of the companion crop resulted in only a 14 percent yield when compared with no-oat check plots, but only 10 percent as much alfalfa was obtained. Growth of grassy weeds was reduced under the companion crop. Weights of barnyard grass plants were 4.8 gm with and 20.7 gm without a companion crop. Hand separation of the plant species in the trial showed the alfalfa to represent only 270 pounds of the total of 5990 pounds in the companion series whereas alfalfa weight of 2780 pounds was observed in the weedy check. In the second cutting, the alfalfa with companion crop was only about half what it was on the pure legume stands. While seasonal yields were higher for the oat plots, yields of total protein were comparable for the oat and no-oat. Alfalfa contains 17.2 percent total digestable protein (TDP), whereas oats contain only 8.2 percent TDP.

It seems reasonable to assume that if the companion crop is used to control early germinating weeds and then removed in the early summer while moisture is still abundant, the alfalfa should recover and be relatively weed free. The total yield of good quality hay under this system would likely exceed the yields of alfalfa planted alone. The first crop from the pure stands would be of little value due to high weed content. Peters (37) reported 86 percent more weeds in the first cut of pure stand alfalfa than in the first cut of alfalfa plus oats.

Baenziger (3) studied the influence of the companion crop by taking second year yields. In the year prior to the study, the oats underseeded with brome plus alfalfa had been removed for silage as one treatment and pastured at three different dates as another. The control was a planting of alfalfa plus brome. The control yielded 4.77 tons per acre (T/A) while the companion crop plus three grazing stages produced 3.66 T/A, and the companion crop ungrazed yielded 2.97 T/A. The grazing operation prevented the legume seedlings from being smothered in the early seedling stage. Repeated pasturing in the first year of establishment kept the oats from competing severely with the forage seedlings.

The majority of herbicides presently available for use on seedling legumes is not sufficiently effective to exceed the first year yield resulting from the use of a companion crop for legume establishment (25, 28, 37). The companion crop not only plays a role in controlling both grassy and broadleaf weeds, but also produces a crop of hay, silage, or cereal (37). Proper management by maintenance of moisture, limiting companion crop density, and adjusting soil fertility to favor the legume will result in high yields the seeding year (3). The under-seeded legumes must be considered throughout the season. Permanent injury to root systems can occur if the companion crop is not removed early for silage, hay, or pasture since alfalfa is sensitive to shading.

Dalapon and 4(2,4-DB) were found by Mazzoni and Scholl (28) to cause little visible damage to seedling alfalfa when applied for broad-leaf and grassy weed control. Both give the most suitable weed control when applied at the 2-4 leaf stage of alfalfa growth (4, 14, 27, 28, 39, 46). Although chemicals do an adequate job of weed control, many still maintain that the companion crop under proper management yields more and is economically the best method for establishment since under some conditions it can be demonstrated that the herbicides will injure the young crop (25, 28, 37). Either method of establishment results in a significant second year yield reduction compared to pure stands of alfalfa with no treatment (3, 46). Second year yields of alfalfa using Dalapon and 4(2,4-DB) combination resulted in a reduction of 426 lb/A compared to plots where no chemical was applied. Second year seasonal yields under the companion crop system resulted in a 1.80 T/A reduction in yield compared to pure stands of alfalfa. A considerable part of the yield reduction may be due to winter kill resulting from poor root development in the first year of growth (11, 18, 19, 40).

The establishment of alfalfa without a companion crop could be a possibility with the advent of new herbicides already registered for use (43). Bromoxynil (3,5-dibromo-4-hydroxybenzonitrile) is a promising new herbicide for broadleaf control in alfalfa (42). Another herbicide, 4(2,4-DB), has a good potential if proper techniques are used in application (48). Weed elimination with chemicals in the first crop of a seedling planting could make a difference of $10 to $15 per ton in the selling price.

Bromoxynil is limited by significant alfalfa injury under certain environmental conditions (4, 27). Temperature, humidity, and soil moisture appear to be factors contributing to phytotoxicity in the crops (16). However, conclusive evidence has not been demonstrated.

Bromoxynil is only effective when applied to the foliage. Soil applications have no herbicidal effect (8). Excellent broadleaf weed control is obtained at economic rates of application if applied when the weeds are still quite small (7, 10, 15, 23, 38, 40, 45, 48).

As temperature rises the phytotoxicity of bromoxynil increases (38). The octanoic ester of bromoxynil applied at 0.5 lb/A gave good control of Raphanus raphanistrum and Stellaria media at 83 F, whereas at 67 F control was poor. At 90 F, 0.5 lb/A gave a complete kill of both weeds, but caused only slight injury at 50 F.

Penetration into the plant tissue is enhanced if the stomates are open at the time the chemical is applied. Whether the stomates are open or closed is determined in part by the plants' aerial environment (12, 31, 47). In tobacco and cotton Wilson (47) demonstrated that the period of opening and the rate of movement of the guard cells decreased with decreasing temperatures. High relative humidity and light also stimulate opening of the stomates (13, 20, 29, 31, 47).

The fast rate of weed kill following bromoxynil application is a factor of importance especially on dry land (8, 24). The conservation of moisture is considerable compared to systemic herbicides. Within one day, the contact herbicide, bromoxynil, reduced transpiration of tartary buckwheat by 50 percent, while a systemic herbicide, dicamba, reduced it by 10 percent. After two days, bromoxynil reduced transpiration by 80 percent. By contrast, it took dicamba twelve days to reach the same level. After four days, 80 percent of the tartary buckwheat plants were erradicated in the bromoxynil treatments. The quantity of water saved due to fast weed kill was not determined on an acre basis, but we can conclude that quick removal of weeds will affect the total yield of alfalfa if moisture is a limiting factor (17).

Bromoxynil is a contact chemical and there is very little movement of the herbicide once it is absorbed. It has a profound effect on a number of biochemical reactions in the plant. Included are the following:

1. Inhibition of the hill reaction in photosynthesis (8, 24).
2. Destruction of chlorophyll (8).
3. Uncoupler of oxidative phosphorylation in mitochondria (34).
4. As high as 70 percent reduction in the activity of proteolytic enzymes (2, 36).

Due to the high level of phytotoxicity, low rates of bromoxynil must be used to obtain selectivity.

A systemic herbicide, 4(2,4-DB), has been used a number of years on alfalfa for broadleaf weed control with varying degrees of success. Effective control results if the chemical is applied early and if weeds are actively growing. Since the movement of 4(2,4-DB) is with the photosynthate (12, 13) weeds need not be actively growing to facilitate translocation throughout the plant. Environmental factors that affect the production of photosynthate, such as light, temperature, nutrient, and water supply, also affect successful translocation of 4(2,4-DB) to active sites (1, 32). The main distinction then is that both systemic and contact herbicides must penetrate the plant tissue, but the latter types need not rely on translocation processes to be effective.

In Smith et al. (44) experiments, alfalfa yields were increased the first year due to chemical treatment. However, in the second year, yields of alfalfa were significantly reduced by weed control treatments imposed during the seedling year. Colley (9) observed similar results when 2,4-DB was used. Gas chromatographic analysis of soil samples from fields sprayed with 2,4-DB established a direct correlation between alfalfa injury and 2,4-DB accumulation in the soil.

Greenhouse grown lucerne seedlings showed a marked increase in tolerance to 2,4-DB during the month after emergence (9). Conversion of 2,4-DB to homologs by alfalfa is suggested by Linscott (26) as a mechanism for tolerance. Production of herbicidally inactive chlorophenoxy compounds within the alfalfa plant, having longer side chains than the parent herbicide, prevents the production of 2,4-D in lethal quantities by β-oxidation and subsequent translocation to sites of action (21, 26).

MATERIALS AND METHODS

Resistador alfalfa (Medicago sativa) was selected for planting in all experiments. Pigweed seed (Amaranthus retroflexus) was taken from a large bulk sample collected by the weeds project from a natural infestation in Box Elder County. Mustard seed (Brassica nigra) was obtained from a commercial source in California. The pigweed seed had a 70 percent germination whereas the mustard seed had a 30 percent germination. This was taken into consideration when planting the two species to supplement the natural weed population and to insure an adequate weed stand. Butoxy ethyl ester formulations of both bromoxynil and 4(2,4-DB) were selected to allow more accurate comparisons of their herbicidal properties. Treatments were made using a bicycle sprayer with 8003 nozzle tips at 30 pounds per square inch applying 20 gallons of water per acre. Stand and vigor reduction ratings were taken on alfalfa, mustard, and pigweed prior to harvest. At harvest, botanical separations were made and total dry weights of alfalfa, mustard, and pigweed were determined for individual treatments. A computer program was written for an analysis of variance test of the experimental data. The results are given in the Appendix.

Greenhouse Experiments

Influence of stage of growth on the response of weeds to herbicides

Alfalfa and pigweed seeds were broadcast on the surface of a 3 : 1 mixture of mountain soil and sand in a six-inch pot and covered with one-fourth inch of the same soil. Both species were thinned to a uniform number of plants in each pot after they were of sufficient size to select large vigorous plants. Seven replications were prepared, each consisting of three treatments; a control, three-eights lb/A bromoxynil and one-half lb/A 4(2,4-DB), applied at the pigweed two-leaf stage. The same treatments were repeated again when the pigweed reached the four-leaf stage. The plants were maintained in a controlled environment chamber until the alfalfa reached the 10-12 trifoliate leaf stage. Air temperature was held constant at 21.0 C (70 F).

Effect of companion crop seeding rate on alfalfa growth during and following removal of the companion crop

The plant population in each pot was eight plants. The ratio of alfalfa to oats increased through a series of seven treatments from 7 : 1 to a 1 : 7 ratio. Controls were 8 oat plants per pot with no alfalfa and 8 alfalfa plants per pot with no oats planted. Ten replications per treatment were established.

When the oats were at the soft dough stage, they and the alfalfa were harvested. Botanical separations were made, and dry weights were recorded. Another harvest was made at a thirty day interval after the first harvest to determine the effect of oat density on alfalfa recovery and growth subsequent to removal of the companion crop.

Field Experiments

Factors influencing the phytotoxicity of bromoxynil, and 4(2,4-DB) for weed control in seedling alfalfa

Irrigated land on the Evans Farm near Logan, Utah, was prepared during the fall of 1968 for seeding the following spring. Final seedbed preparation was accomplished in the spring of 1969. Prior to planting the mustard and pigweed seeds were broadcast on the experimental area with a cyclone seeder. Alfalfa was planted at 12 lb/A in rows spaced one foot apart to permit irrigation. Three plantings at approximately 3 week intervals were made to allow plants to reach comparable stages of growth at successively later periods in the growing season to demonstrate the influence of temperature on plant response to the herbicide. A split plot design was used to separate the influence of temperature and stage of growth on the response of alfalfa seedlings to herbicides. Chemical applications to alfalfa were made at the 3-4 and 5-7 trifoliate leaf stages. Corresponding growth stages of the weeds were 2-3 and 4-5 true leaves for the pigweed and 2 and 4 true leaves for the mustard. Four replications of the treatments were established.

Prior to harvest, height measurements and stand counts were taken on alfalfa, mustard, and pigweed. These were determined within square foot quadrants randomly selected within each plot. Harvesting consisted of removing with a power mower the three center rows of the seven in each plot. Wet weights were recorded and a 5-6 pound sample was removed for botanical separation. Tables of dry weights and enumeration data are recorded in the Appendix.

Factors influencing the use of bromoxynil, clipping, or a companion crop for weed control in seedling alfalfa

To compare pure stands of alfalfa with plantings using a companion crop, a second trial was established on the research station at

Farmington, Utah. Prior to planting the crop, mustard and pigweed seeds were broadcast with a cyclone seeder at 4.0 and 8.5 lb/A, respectively, and incorporated with a harrow. Alfalfa plantings were made with hand row-seeders on April 19, 1969. The seeding rate of the crop was maintained at 12 lb/A throughout the experiment.

Treatments on the plots planted to alfalfa alone included bromoxynil at three-eights lb/A, clipping at the alfalfa 7-10 trifoliate leaf stage and a control. Treatments within the companion crop plots were bromoxynil at three-eights lb/A and a control.

Injury index ratings of weed and alfalfa response to the herbicides and to the companion crop were taken throughout the growing season to assist in data evaluation.

Prior to harvest, height measurements and stand counts were taken on alfalfa, barley, mustard, and pigweed. Harvesting consisted of removing with a power mower the four center rows of the eight row plot. Total plot wet weights were taken and a 5-6 pound sample was removed for the botanical separation of alfalfa, barley heads, barley straw, and weeds.

RESULTS AND DISCUSSION

Greenhouse Experiments

Influence of the stage of growth on the response of weeds to herbicides

The alfalfa was harvested in the 10-12 trifoliate leaf stage to demonstrate the initial effects of the chemical treatment on alfalfa. Phytotoxicity to alfalfa was greater at the early stage than at the later stage of application for both bromoxynil and 4(2,4-DB). The early treatments resulted in plants with only half the yield compared to the later treatments (Table 1). The early treatments in this trial

Table 1. Dry weights of alfalfa and pigweed (gm/pot) treated with bromoxynil and 4(2,4-DB) at the 2-3 trifoliate leaf stage of alfalfa growth. Temperature held at 21.0 C (70 F)

Treatment	lb/A	Application stage	Alfalfa yield gm/pot	% of control plus weeds	% of control minus weeds	Weed yield gm/pot
Bromoxynil	3/8	A	.65	53.21	20.31	.01
		B	1.02	83.29	31.79	.58
4(2,4-DB)	1/2	A	.42	34.47	13.16	.48
		B	1.04	85.09	32.48	1.24
Control plus weeds			1.23	100.00	38.14	1.46
Control minus weeds			3.21	261.93	100.00	--

Growth stage: Pigweed, A = 2-3 true leaves, B = 4-5 true leaves

adequately controlled the weeds but resulted in injury which significantly reduced first cutting yields. Presumably, these treatments could recover in a short time to nearly equal the growth of the pots where no treatment was applied since the injury is only temporary. Bromoxynil proved to be more effective in removing the pigweed than 4(2,4-DB) at the rates tested. Neither bromoxynil nor 4(2,4-DB) was effective in removing the broadleaf weeds at the later stages.

The pronounced reduction in yield caused by weeds was demonstrated in this trial. Nearly two-thirds of the crop was lost to weeds. This reduction was credited to competition for moisture, nutrients, and possibly even more important, to the release of inhibitors by germinating pigweed affecting alfalfa germination and seedling vigor. This reasoning has also been put forth by other investigators to account for the extreme competition of weeds on new seedling crops. Similar results were observed when alfalfa was grown in the presence of shepherd's-purse or combinations of shepherd's-purse and pigweed.

Effect of companion crop seeding rate on alfalfa growth before and after removal of the companion crop

When the number of oat plants per six-inch pot was decreased from 7 plants per pot to 1 plant per pot, the height of individual oat plants increased 48 percent, the yield increased 280 percent, and the number of tillers per plant rose from zero to nearly two per plant (Table 3). The growth of alfalfa was limited more by the number rather than the size of the individual oat plants indicating that light rather than nutrients was probably the greatest limiting factor. However, the presence of a single oat plant in a pot of eight plants resulted in nearly a 30 percent yield reduction of alfalfa. The direct effect of oat density on alfalfa recovery was also noted in harvest yields taken 30 days after oat removal. Alfalfa yield per plant was decreased from 73 percent to 28 percent of eight alfalfa plants alone,

Table 2. The effect of several concentrations of pigweed and shepherd's-purse seed on alfalfa seedling emergence

Treatment gm/pot	Alfalfa seeds/pot	Alfalfa plants emerging						Total emergence*
		Days after planting						
		3	4	5	6	7	8	
Pigweed								
.08	4	0.4	0.8	1.2	0.4	0.4	0.0	3.2
.16	4	0.5	0.3	1.1	0.5	0.5	0.1	3.0
.24	4	0.2	0.4	0.4	1.2	0.1	0.1	2.4
.32	4	0.3	0.4	1.1	0.6	0.5	0.0	2.9
Shepherd's-purse								
.06	4	0.2	0.0	1.0	1.4	0.3	0.2	3.1
.12	4	0.3	0.2	0.9	0.9	0.5	0.2	3.0
.18	4	0.4	0.4	0.2	1.6	0.1	0.1	2.8
.24	4	0.2	0.2	0.6	1.3	0.6	0.1	3.0
Combinations								
Pigweed Shepherd's-purse								
.08 + .06	4	0.3	0.6	0.6	0.5	0.2	0.0	2.2
.16 + .12	4	0.2	0.2	0.8	0.6	0.3	0.0	2.1
.24 + .18	4	0.2	0.5	0.8	0.4	0.0	0.1	2.0
.32 + .24	4	0.1	0.3	1.0	0.4	0.2	0.0	2.0
Control	4	1.7	0.4	1.0	0.5	0.0	0.0	3.6

* No emergence occurred beyond the eighth day after planting.

Table 3. The influence of companion crop (oat) seeding ratio on alfalfa yield and on oat height and vigor

Ratio of oats to alfalfa	Alfalfa yield gm/pot	Alfalfa % of control	Oats yield gm/pot	Oats ht.	Oats tillers /plant	Oats + alfalfa yield gm/pot
7 : 1	.024	28.6	.33	20.1	0.0	2.4
6 : 2	.025	29.8	.39	24.0	0.0	2.4
5 : 3	.031	36.9	.41	25.9	0.0	2.2
4 : 4	.041	48.8	.47	27.3	.29	2.0
3 : 5	.041	48.8	.57	27.7	.61	1.9
2 : 6	.051	60.7	.78	29.3	.79	1.9
1 : 7	.061	72.6	.93	29.8	1.86	1.4
Control 8	.084	100.0				.67

when oat density was increased from 1 to 7 plants per pot (Figure 1). Recovery of alfalfa was negligable until the oat rate was reduced from 7 to 4 oat plants per pot. The severe reduction in yield and vigor of alfalfa imposed by the companion crop has caused considerable concern. Although total yields of dry matter are higher the first year with the companion crop establishment method, reduction in alfalfa growth and root development under low light intensities may affect yields for a considerable period of time. Significant second year yield reductions have been noted.

Field Experiments

Factors influencing the phytotoxicity of bromoxynil and 4(2,4-DB) for weed control in seedling alfalfa

In plots at the Evans Farm, soil moisture was replenished at weekly intervals to keep it as nearly optimum as possible for the alfalfa. The surface soil moisture was adequate to stimulate germination of weed seeds throughout the growing season.

Applications of bromoxynil resulted in an 85 to 90 percent reduction in stand of the pigweed plants ten days after the chemical was applied. Similar applications to mustard resulted in essentially 100 percent reduction in stand (Table 9). The fast weed kill, instead of benefiting the alfalfa by conserving moisture, provided unshaded soil where a second flush of germinating weeds could start. As a result, pigweed stand ratings dropped from an average of 90 percent at the first evaluation to 37.7 percent just prior to the first harvest for early applications of bromoxynil. Preharvest pigweed counts of the early treatments ranged from approximately 50

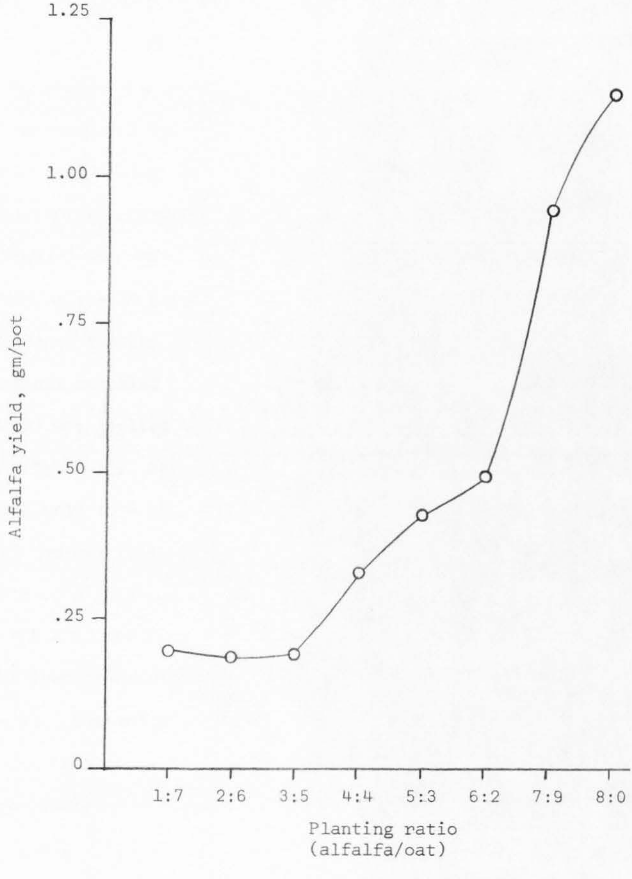

Figure 1. Growth of alfalfa for a 30-day interval following removal of the companion crop.

percent as many weeds in the one-fourth lb/A rate of bromoxynil and 18 percent in the three-fourths lb/A rate when compared to the untreated controls and 98 percent and 70 percent, respectively, in the second stage treatment (Table 4).

Since neither moisture nor weed seeds were limiting, penetration of light to the soil level encouraged weed seed germination. Factors contributing to good light penetration were (a) fast removal of weeds including mustard which had the potential of reducing pigweed germination and regrowth by shading; and, (b) alfalfa vigor reduction for 10 to 14 days following application, thus reducing shading and allowing seeds to compete with the growth of alfalfa.

Significant reductions in stand of pigweed by 4(2,4-DB) was not observed at the 10 day evaluation although vigor was reduced by 79 percent and 58.5 percent in the early and late treatments. Later evaluations revealed a considerable increase in stand reductions when 4(2,4-DB) was applied at the 2-3 and 4-5 true leaf stage of pigweed growth (Table 5). Neither pigweed nor mustard plants had been killed but were held to 4 to 8 inches in height. Alfalfa shading assisted in weed control following the initial retardation of weed growth. The presence of significant pigweed populations, although they were not harvestable in the first cutting because of their reduced height, is evident from preharvest weed density counts and height measurements (Table 4). Mustard plants, on the other hand, although low in density were harvestable.

Second germination of mustard or pigweed in 4(2,4-DB) plots was not evident. Vigorous alfalfa and the presence of original weeds likely reduced the light penetration sufficiently to prevent second

Table 4. Effect of bromoxynil and 4(2,4-DB) applied at two stages of growth on height and density of pigweed and mustard immediately prior to first crop harvest

			Preharvest evaluation					
			Pigweed			Mustard		
Treatment	lbs/A	Stage	ht.	Plants per 3 sq ft	% of control	ht.	Plants per 3 sq ft	% of control
Bromoxynil	1/4	A	16	61	49.6	24	2	15.4
	1/2	A	16	38	30.9	0	0	0.0
	3/4	A	15	22	17.9	0	0	0.0
Bromoxynil	1/4	B	14	121	98.4	0	0	0.0
	1/2	B	13	93	75.6	0	0	0.0
	3/4	B	17	86	69.9	0	0	0.0
4(2,4-DB)	1/2	A	8	44	35.8	29	3	16.7
	3/4	A	7	64	52.0	21	4	22.2
4(2,4-DB	1/2	B	6	91	74.0	19	2	15.4
	3/4	B	4	72	58.5	21	5	27.8
Control			18	123	100.0	33	13	100.0

	Pigweed	Mustard
Growth stage A	2-3 true leaves	2 true leaves
B	4-5 true leaves	4 true leaves

Table 5. Stand and vigor evaluations for alfalfa and pigweed treated with bromoxynil and 4(2,4-DB) at two growth stages

			Visual Evaluations							
			10 days after chemical application				Prior to first harvest			
Treatment	lbs/A	Stage	% stand red.		% vigor red.		% stand red.		% vigor red.	
			Alf	Pw	Alf	Pw	Alf	Pw	Alf	Pw
Bromoxynil	1/4	A		85	5	85	2	29	3	18
	1/2	A	5	95	13	95	6	51	5	18
	3/4	A	4	99	18	99	13	33	10	13
	1/4	B		25	4	10	4	14	5	19
	1/2	B	3	23	13	31	9	13	6	41
	3/4	B	4	47	16	54	15	15	10	29
4(2,4-DB)	1/2	A	0	0	0	78	1	81	0	40
	3/4	A	0	0	0	80	1	86	0	38
	1/2	B	0	3	0	42	4	87	0	30
	3/4	B	0	0	0	75	4	88	0	49

Growth stage:		Alfalfa	Pigweed	
	A	3-4 trifoliate	2-3 true leaves	Alf = alfalfa
	B	5-7 trifoliate	4-5 true leaves	Pw = pigweed

weed germination. Retardation rather than removal of weeds can be a benefit in stopping second germination of weeds where moisture is abundant. However, if moisture is limiting, simply retarding the growth of weeds may allow them to significantly compete with the crop for the available moisture. Apparently large quantities of water are used by 4(2,4-DB) treated weeds before they die when compared with bromoxynil treated weeds. With dry-land alfalfa, this could be an extremely important factor.

Control of mustard by bromoxynil was excellent. On a seasonal weight basis, considering two harvests and three planting dates, 81 to 98 percent of the mustard was controlled by application of one-fourth, one-half, or three-fourths lb/A at the 2 true leaf stage and 87 to 94 percent when applied at the 4 leaf stage of weed growth (Table 6). Since mustard was highly susceptible to bromoxynil, control was equally as efficient at the later stages as at the early stage. Mustard control with 4(2,4-DB) was completely satisfactory at either the early or late stage when three-fourths lb/A was used, but when lighter dosages were used, only the early treatment stage was satisfactory.

Fast weed erradication eliminating mustard and its shading effect, ample moisture, light and temperature, and temporary injury to the alfalfa all contributed to reinfestation of bromoxynil plots with new pigweed growth. The one-fourth, one-half, and three-fourth lb/A treatment levels applied at the 2-3 leaf stage resulted in 22.0, 6.1, and 17.6 percent more weeds than the control. Inhibition of pigweed growth in untreated plots by high growing mustard needs to be considered when evaluating these results.

Table 6. Control of pigweed and mustard with foliar treatments of bromoxynil and 4(2,4-DB) applied at two stages of weed growth

			Mustard (% control)*				Pigweed (% control)*			
Treatment	lb/A	Stage	Planting I	II	III	Ave.	I	II	III	Ave.
Bromoxynil	1/4	A	81.9	79.2	82.3	81.1	31.9	18.5	36.7	29.0
	1/2	A	95.4	90.2	93.3	93.0	38.5	0.0	55.8	31.4
	3/4	A	97.4	96.0	100.0	97.8	23.2	4.6	62.2	30.0
	1/4	B	63.3	99.0	99.2	87.1	16.3	0.0	17.4	11.2
	1/2	B	77.6	93.2	99.1	90.0	0.0	0.0	20.8	6.9
	3/4	B	86.7	95.7	100.0	94.1	0.0	0.0	0.0	0.0
4(2,4-DB)	1/2	A	78.5	83.3	68.8	76.9	55.1	35.1	85.7	58.6
	3/4	A	84.7	86.3	90.6	87.2	78.1	50.1	89.3	72.5
	1/2	B	57.3	0.0	84.8	46.3	96.2	91.2	91.3	92.9
	3/4	B	75.4	80.8	86.9	81.0	96.1	88.6	96.5	93.7

*Average of two harvests (Botanical separations)

		Mustard	Pigweed
Growth stage:	A	2 true leaves	2-3 true leaves
	B	4 true leaves	4-5 true leaves

The seasonal yields in the bromoxynil plots were well below that of the untreated control except with early applications at one-fourth and one-half lb/A (Table 7). A large part of the alfalfa yield reduction was due to pigweed competition. In 4(2,4-DB) plots, yields at all planting dates were consistently greater than the plots with no chemical treatment. Early application of 4(2,4-DB) at one-half and three fourths lb/A produced 39 and 29 percent more alfalfa than the weedy control.

Factors influencing the use of bromoxynil, clipping, or a companion crop for weed control in seedling alfalfa

The effectiveness of weed control in underseeded legumes by the companion crop is well demonstrated by the Farmington experiment. A control of 89 percent of the weeds throughout the season was achieved with a barley companion crop. Additions of three-eights lb/A of bromoxynil applied in the early stages of barley growth and at the 3-4 trifoliate stage of alfalfa growth assisted the companion crop in controlling 96 percent of the weeds on a seasonal basis (Table 8). However, the yield of alfalfa was reduced by more than one-fourth T/A compared to the companion crop alone. Bromoxynil applied alone to seedling alfalfa gave the highest seasonal yields of alfalfa exceeding the control by slightly more than one-half T/A. The lowest yields were obtained when clipping was used for weed control.

The additional 60 bushels of barley per acre from the companion crop more than compensated for the loss in alfalfa yield compared to chemical establishment during the season being studied. It is quite probable, however, that second year yields from the companion crop

Table 7. Alfalfa yields as influenced by treatments of bromoxynil and 4(2,4-DB) applied at the 3-4 and 5-7 trifoliate leaf stages and at three planting dates

Herbicide	Rate lb/A	Application stage	Seasonal yields: First planting (4/23/69)	Seasonal yields: Second planting (5/16/69)	Seasonal yields: Third planting (5/31/69)	Season ave. of 3 trials: T/A	Season ave. of 3 trials: % of check
	Control		1.96	1.43	1.57	1.65	100.0
Bromoxynil	1/4	A	1.88	1.84	1.69	1.80	109.1
	1/4	B	1.80	1.53	1.52	1.62	98.0
Bromoxynil	1/2	A	1.76	1.75	1.52	1.68	101.8
	1/2	B	1.36	1.66	1.45	1.49	90.3
Bromoxynil	3/4	A	1.58	1.56	1.66	1.60	97.0
	3/4	B	1.52	1.49	1.40	1.47	89.1
4(2,4-DB)	1/2	A	2.55	2.28	2.07	2.30	139.4
	1/2	B	2.12	1.58	1.88	1.86	112.7
4(2,4-DB)	3/4	A	2.30	2.26	1.82	2.13	129.1
	3/4	B	2.03	2.01	2.00	2.01	121.8

Growth stage: Alfalfa
A 3-4 trifoliate
B 5-7 trifoliate

Table 8. A comparative evaluation of yields received from the use of a companion crop, chemicals, or clipping as a method for weed control in seedling alfalfa

	Alfalfa T/A			Barley Bu/A	Weeds lb/A			
Treatment	Harvest-1	2	Total	1	1	2	Total	Control
1. Barley + alfalfa + pigweed + bromoxynil 3/8 lb/A	.21	.87	1.08	60.0	46.0	62.5	108.5	96.1
2. Barley + alfalfa + pigweed	.32	1.07	1.39	58.5	239.2	60.4	299.6	89.1
3. Alfalfa + pigweed + bromoxynil 3/8 lb/A	.81	1.19	2.00		490.8	221.3	712.1	74.2
4. Alfalfa + pigweed + clipping at the 7-10 trifoliate leaf stage of alfalfa growth	.38	.68	1.06		943.4	230.9	1174.3	57.5
5. Alfalfa + pigweed	.44	1.14	1.58		2530.3	230.8	2761.1	

establishment will be lower since alfalfa root development and top growth was inhibited for a greater part of the season due to reduced light.

Alfalfa establishment with chemicals for weed control yielded more alfalfa in the first year than any other method. The barley nurse crop, as well as the control with weeds, inhibited normal alfalfa development increasing the possibility of losses due to drought, winter kill and decreased second year yields. Even though the companion crop establishment system yields more dry matter or dollars the first year, the existence of a significant second year yield reduction should limit its use for alfalfa establishment.

SUMMARY

The response of seedling alfalfa, mustard and pigweed to treatments of bromoxynil and 4(2,4-DB) applied at the 3-4 and 5-7 trifoliate leaf stage of alfalfa growth was studied at Logan, Utah. Additional studies at Farmington, Utah, included a comparative evaluation of yields received from the use of a companion crop, chemicals, or clipping for weed control in seedling alfalfa.

In the experiments at Logan, alfalfa yields were greater than the control at all rates and stages of 4(2,4-DB) application. All rates and stages of bromoxynil treatment except the 1/4 lb/A 3-4 trifoliate application resulted in alfalfa yields below that of the control. Plots treated with bromoxynil at Farmington gave higher yields than the other methods of establishment used.

The companion crop was not conducive to the growth and development of alfalfa although it did control the weeds. Bromoxynil at all rates and at both stages of application resulted in effective mustard control. Mustard control in the 4(2,4-DB) plots was excellent at the early stage of application but required 3/4 lb/A for control at the later stage of weed growth. Pigweed control was rather ineffective in bromoxynil plots at Logan where moisture was optimum but effective in plots at Farmington where moisture was limited for 18-20 days following application. The density of the pigweed stand in bromoxynil treatments at Logan was attributed to an influx of weed growth following initial control of weeds. Control of pigweed by 4(2,4-DB) was in excess of 90 percent at the 4-5 leaf stage of weed growth.

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APPENDIXES

Table 10. Effects of bromoxynil and 4(2,4-DB) on height and density of alfalfa, mustard, and pigweed at two planting dates (Evaluations made at the 1/8 blossom stage of alfalfa growth prior to the first harvest)

			2nd planting (5-16-69)						3rd planting (5-31-69)					
			Plant height			Plants/3 sq ft			Plant height			Plants/3 sq ft		
Treatment	lb/A	Stage	Alf	Pw	M	Alf	Pw	M	Alf	Pw	M	Alf	Pw	M
Bromoxynil	1/4	A	26.0	16.5	36.0	110.3	9.5	2.3	21.2	16.4	24.0	118.0	60.8	1.8
		B	23.5	17.4		74.3	32.8	1.5	20.0	14.1	0.0	127.8	120.5	0.0
	1/2	A	25.6	19.3		97.5	15.0	0.0	20.7	15.7	0.0	107.0	37.8	0.0
		B	21.9	13.5		84.5	25.0	1.3	18.7	13.2	0.0	140.0	92.8	0.0
	3/4	A	23.9	18.1		76.8	10.0	0.8	20.3	14.6	20.0	143.0	22.0	0.25
		B	22.1	14.3		63.0	24.5	0.0	20.0	16.8	0.0	145.0	85.8	0.0
4(2,4-DB)	1/2	A	26.7	12.5		129.8	14.5	4.3	20.4	7.6	29.4	153.0	43.8	2.5
		B	28.8	9.5		72.5	22.5	10.8	22.2	6.4	19.2	120.7	91.0	1.5
	3/4	A	25.8	13.5		134.5	11.5	1.8	21.9	7.1	21.4	123.8	63.8	4.0
		B	23.8	6.4		109.3	22.8	5.0	21.8	3.9	20.9	135.0	72.0	5.0
Control		A	27.5	14.33		84.0	34.5	10.5	23.9	17.4	34.0	83.3	119.0	14.8
		B	27.2	19.43		76.0	35.5	10.5	23.5	18.4	32.2	86.3	127.5	12.0

		Alfalfa	Mustard	Pigweed
Growth stage	A	3-4 trifoliate	2 true leaves	2-3 true leaves
	B	5-7 trifoliate	4 true leaves	4-5 true leaves

Alf = Alfalfa
Pw = Pigweed
M = Mustard

Table 11. Effect of bromoxynil and 4(2,4-DB) applied at two stages of growth on the seasonal yield of seedling alfalfa at three planting dates, T/A

Herbicide	Rate lb/A	Application stage	First planting (4/23/69) Harvest			Second planting (5/16/69) Harvest			Third planting (5/31/69) Harvest			Season ave of 3 trials	% of control
			1	2	Total	1	2	Total	1	2	Total		
Weedy	Check		0.81	1.15	1.96	0.55	0.88	1.43	0.62	0.95	1.57	1.65	100.0
Bromoxynil	1/4	A	0.83	1.05	1.88	0.77	1.07	1.84	0.63	1.03	1.69	1.80	109.1
	1/4	B	0.78	1.02	1.80	0.50	1.03	1.53	0.47	1.05	1.52	1.62	98.0
Bromoxynil	1/2	A	0.73	1.03	1.76	0.64	1.11	1.75	0.57	0.95	1.52	1.68	101.8
	1/2	B	0.46	0.90	1.36	0.59	1.07	1.66	0.59	0.86	1.45	1.49	90.3
Bromoxynil	3/4	A	0.63	0.95	1.58	0.51	1.05	1.56	0.64	1.02	1.66	1.60	97.0
	3/4	B	0.52	1.00	1.52	0.54	0.95	1.49	0.49	0.91	1.40	1.47	89.1
4(2,4-DB)	1/2	A	1.33	1.23	2.55	0.98	1.30	2.28	0.90	1.17	2.07	2.30	139.4
	1/2	B	1.02	1.10	2.12	0.65	0.93	1.58	0.92	0.96	1.88	1.86	112.7
4(2,4-DB)	3/4	A	1.19	1.11	2.30	1.00	1.26	2.26	0.76	1.06	1.82	2.13	129.1
	3/4	B	0.92	1.11	2.03	0.86	1.15	2.01	0.80	1.20	2.00	2.01	121.8

		Alfalfa
Growth stage	A	3-4 trifoliate
	B	5-7 trifoliate

Table 12. Control of mustard and pigweed with bromoxynil and 4(2,4-DB) applied at two stages of weed growth (Yields determined by botanical separation)

			Seasonal Yields					
		Appli- cation	First planting 4/23/69		Second planting 5/16/69		Third planting 5/31/69	
Treatment	lb/A	stage	Mustard	Pigweed	Mustard	Pigweed	Mustard	Pigweed
Bromoxynil	1/4	A	85.5	196.4	156.2	213.3	274.8	224.8
	1/4	B	173.2	216.9	7.8	559.7	2.3	294.9
	1/2	A	21.7	212.0	73.3	296.0	18.8	156.2
	1/2	B	105.9	318.2	50.9	320.4	2.6	296.0
	3/4	A	12.4	307.3	29.8	245.8	0.0	135.6
	3/4	B	62.8	347.4	32.5	312.2	0.0	387.7
4(2,4-DB)	1/2	A	101.3	135.9	125.7	167.3	87.8	55.2
	1/2	B	201.3	27.7	775.3	34.9	40.6	32.3
	3/4	A	77.4	70.7	102.9	140.0	26.4	41.8
	3/4	B	117.0	38.2	144.3	36.4	38.2	14.2
Control			471.4	269.7	750.6	279.5	281.3	344.8

	Mustard	Pigweed
Growth stage A	2 true leaves	2-3 true leaves
	4 true leaves	4-5 true leaves

Appendix B

Table 13. Analysis of variance on alfalfa yields as influenced by treatments of bromoxynil and 4(2,4-DB) applied at the 3-4 and 5-7 trifoliate leaf stage at three planting dates

Source of variation	DF	SS	MS	F
Planting	2	779,678.00	389,839.00	4.54*
Treatment	5	5,767,433.00	1,152,887.00	13.63**
Stage	1	215,281.30	215,281.30	2.48
Treatment x stage	5	90,874.77	18,174.95	.18
Plant x treatment	10	816,310.60	81,631.06	.82
Plant x stage	2	154,816.60	77,408.32	.77
Plant x treatment x stage	10	380,135.40	38,013.54	.38
Error	108	9,051,622.00	83,811.31	
Total	143	17,253,150.00	120,651.40	

*Significant at .05
**H. Significant at .01

Table 14. Analysis of variance on mustard yields as influenced by treatments of bromoxynil and 4(2,4-DB) applied at the 2 and 4 true leaf stages of growth and at three planting dates

Source of variance	DF	SS	MS	F
Planting	2	591,074.00	295,537.00	17.52**
Treatment	5	3,654,173.00	730,834.50	42.13**
Stage	1	46,037.07	46,037.07	2.69
Treatment x stage	5	369,789.50	73,957.90	4.33**
Plant x treatment	10	902,823.30	90,282.33	5.28**
Plant x stage	2	140,629.50	70,314.74	4.11*
Plant x treatment x stage	10	553,119.40	55,311.94	3.23**
Error	108	1,844,180.00	17,075.74	
Total	143	8,101,825.00	56,656.12	

*Significant at .05
** H. Significant at .01

Table 15. Analysis of variance on pigweed yields as influenced by treatments of bromoxynil and 4(2,4-DB) applied at the 2-3 and 4-5 true leaf stage of growth and at three planting dates

Source of variation	DF	SS	MS	F
Planting	2	47,963.81	23,981.90	1.98
Treatment	5	1,510,776.00	302,155.20	21.48**
Stage	1	57,656.01	57,656.01	4.10*
Treatment x stage	5	266,753.50	53,350.70	3.11*
Plant x treatment	10	186,409.80	18,640.98	1.45
Plant x stage	2	34,546.97	17,273.49	1.30
Plant x treatment x stage	10	291,964.80	29,196.48	2.88**
Error	108	1,529,128.00	14,158.59	
Total	143	3,925,199.00	27,448.94	

*Significant at .05
**H. Significant at .01