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Title: Effects of Three Herbicides on Yields of Five Cultivars of Winter Wheat (*Triticum aestivum* L. em Thell).

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With the development of new selective herbicides and the frequent change in commercial wheat cultivars, information is needed as to the possible interaction between cultivars and herbicides. The responses of five genotypically diverse wheat cultivars (Bezostaya, Daws, Maris Hobbit, Stephens and Yamhill) to diuron [3-(3,4-dichlorophenyl)-1,1-dimethylurea], diclofop {methyl 2-[4-(2,4-dichlorophenoxy)phenoxy] propanoate} and 2,4-D (2,4-dichlorophenoxy acetic acid) herbicides were compared under field and greenhouse conditions during the 1979-80 growing season.

Grain yield was considered as a measure of herbicide injury when compared to the control plots for each cultivar. Effect on components of yield, plant height and grain protein content also were investigated.

Differences in yield performance and related agronomic characters could be attributed to specific herbicides, designated rates and growth stages at the time of application. The lower (1.4 kg/ha) rate of diuron, diclofop and 2,4-D reduced yields less than the higher rate (2.8 kg/ha). Diuron and diclofop applied at the earlier (three to

to five leaf) growth stage caused greater yield reductions than when applied at the later (five to six tiller) growth stage.

Differential yield responses were found among and within the five winter wheat cultivars. The higher rate of diuron (2.8 kg/ha) caused the most injury in all of the cultivars tested. Major injury from diclofop occurred on the cultivar Maris Hobbit with minor effects on the other four cultivars. The primary reduction in yield from application of 2,4-D was to the cultivar Bezostaya. Among the five wheat cultivars tested in this experiment, Daws was the most tolerant to the three herbicides tested.

Among the yield components (number of spikes per unit area, kernels per spike and 1000 kernel weight), number of kernels per spike accounted for most of the variation in yield. The data showed a direct relationship between kernel number and grain yield. Grain protein percentage of Daws, Maris Hobbit, Stephens and Yamhill significantly increased at the higher rate of diuron; whereas a similar increase was noted only in Bezostaya at the lower rate of 2,4-D. These increases in protein were associated with significant decreases in yield.

Yield reductions due to herbicide treatments were generally lower than those due to weed competition.

Reductions in yield and corresponding changes in the other agronomic characteristics observed in this experiment were the result of concentrations which are higher than those normally used in spraying wheat for weed control. This high chemical dosage was chosen for each herbicide to assure a greater differential response among and within the wheat cultivars. It also provided information for the plant breeder as to which cultivars had higher levels of tolerance. Such information is important when making hybrid combinations for the development of future varieties if higher levels of tolerance to specific herbicides are required.

Effects of Three Herbicides on Yields of Five Cultivars of Winter Wheat (*Triticum aestivum* L. em Thell)

by

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Typed by Kathie Klahn for Amor Yahyaoui

In Dedication To:

My parents, for their patience and love

and

The Cereal Team, for their friendship

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INTRODUCTION

The use of chemicals has rapidly increased since the mid-1940's when 2,4-dichlorophenoxy acetic acid (2,4-D) was first used as a herbicide. Since then, the chemical nature of the phenoxys has become better known and related compounds are synthesized and tested for effects on plant growth. Certain phenoxy acetic acids, including 2,4-D, were found to be plant growth regulators. Further research lead to the commercial use of several phenoxy herbicides. These pioneer accomplishments have now expanded into a world-wide effort by industry, public and private agencies, institutes and universities to discover, develop and distribute a wide array of useful herbicides, most of which are chemically and functionally unrelated to the phenoxys. The urea herbicides, for example, have grown both in effective number and in agricultural importance. The gradual evolution of their use has gone from primarily nonselective soil sterilants to include more use, especailly at low rates, for selective weed control in crops. Other selective herbicides that will not harm specific crops and provide control of wild oats in wheat are of particular importance. The phenoxy, urea and other herbicides such as diclofop have proven to be essential and successful tools for weed control in a wide selection of agricultural crops. The rapid development of selective weed killers (herbicides) has provided an new major field of agricultural technology.

Although herbicides offer an effective and economical means of weed control, certain risks such as physiological crop injury are inherent in their use. Selectivity of herbicides is relative depending on concentration or dosage, and time of application. All herbicides are potentially phytotoxic; if applied at high enough dosages they kill all plants; if the dosage is sufficiently low, no plants die. At dosages between these extremes, some plants are killed and some are uninjured. It is essential, then, to know the relative effects, if any, of herbicides on cultivars of a specific crop such as wheat.

In recent years, new wheat cultivars, particularly the light-insensitive high-yielding semi-dwarf cultivars, have been introduced to wheat production areas in many countries of the world. These cultivars display their high yielding potential when associated with a proper package of practices. Two major components of the management practices are fertilizers and herbicides. Response of wheat cultivars to fertilizers has been well-documented; however, their reaction to herbicides has not been an issue because it has been assumed that treatment effects from herbicides are insignificant. While the validity of this concept is subject to question, it is certainly true that yield reduction from improperly selected chemicals, rate and application timing can be demonstrated. The occurrence of certain cultivars susceptible to a particular herbicide may act as a stimulus to further understanding of the biochemical and genetic interactions between plants and herbicides; whereas, tolerant cultivars would provide a source of improvement of weed control effectiveness and thus increased crop production.

For an orientation on this subject the response of some especially chosen winter wheat cultivars to three selected herbicides, from different families, were compared under greenhouse and field conditions. The objectives of this study were:

1. To evaluate the response of five winter wheat cultivars to different rates and application dates of three herbicides.
2. To compare the related agronomic characters and grain yield by the response of the cultivars to herbicides.

LITERATURE REVIEW

Crop losses from weed competition have necessitated the extensive use of broadleaf and grass herbicides. Weeds have been estimated to cause an average annual loss of 12% from potential production of wheat (30). This estimate includes losses from both broadleaf and grass weeds. In recent years, widely adapted, semi-dwarf wheat cultivars have rapidly replaced the taller, locally adapted types. Also, newly developed selective herbicides have increased weed control in commercially produced small grains.

Although the new herbicides, as well as the older ones, offer an effective and economical means of weed control and thus result in increased yield, certain risks are inherent in their use. There are no crops completely free of herbicide injury, but there are degrees of tolerance in some crops for certain dosages. Physiologic injury is one of these risks. It can range from complete kill of the crop to slight stunting or discoloration often having no adverse effect on total yield. Despite the extensive use of chemicals and the experience acquired, reports of herbicide injury are not uncommon.

Herbicide injury can result from improperly selected chemicals, as well as from improper dosage and application timing of the herbicide. Therefore, it is very important to the agronomist as well as the grower to know the tolerance level of a crop species to herbicides. It is also well to keep in mind that any given plant may, at different stages of growth, exhibit different degrees of resistance.

Phenoxy herbicide: 2,4-dichlorophenoxy acetic acid (2,4-D)

Several investigators have demonstrated the importance of early weed removal if optimum yield benefit is to be obtained (4,5). Broadleaf weed control has received more attention than grass weed control because of general availability of phenoxy herbicides.

The phenoxy and related materials are selective herbicides widely used in crop production. These chemicals are related to naturally occurring plant growth regulators. They kill plants by causing malfunction in growth processes. Many broadleaf plants are susceptible to the phenoxy herbicides, whereas most grasses are relatively resistant.

The herbicide 2,4-D (2,4-dichlorophenoxy acetic acid) has been the principal phenoxy herbicide used for broadleaf weed control. Klingman (16) measured the effect of 2,4-D on weed free plots by applying three rates on three different dates. The equivalent of 1, 2 and 3 pounds[1] of parent acid per acre[2] was used. The plants were treated at the growth stages of 4 to 8 inches[3], 12 inches (early) boot) and at the beginning of heading. Grain yields for the treated plots were lower than the check plot. Application of 2,4-D at early boot stage produced the lowest yield of all rates tested. Height of the wheat plants was significantly reduced only for the plots treated at the boot stage. Test weight of the grain decreased as the rate of application increased and was lowest in plots that had been treated at the boot stage. Some growth abnormalities were also noted when plants were sprayed at the 4- to 8-inch (20.32 cm) growth stage.

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[1]one pound: 454 gm [2]one acre: 0.405 ha [3]one inch: 2.54 cm

In a later article, Klingman (17) presented an extensive review of the literature on the use of 2,4-D on wheat. He established 2,4-D rates and dates of application relative to wheat growth stages to obtain effective weed control with minimized wheat injury. The author concluded from his study that a desired rate of 2,4-D should not exceed 0.5 pound (227 gm) ester or 1 pound (454 gm) amine per acre (0.405 ha) on winter wheat and higher rates would cause severe injury. He also found that with high rates application at the early boot and flowering stages resulted in more injury that at the jointing or late boot stage.

Olson _et_ _al_. (24) concluded from research on the application of 2,4-D on various growth stages of winter wheat, that wheat was most tolerant to 2,4-D during the tillering stage and again after heading. There as been a general preference for the herbicide 2,4-D to control broadleaf weeds in a variety of crops such as grasses because of their ability to resist its toxicity.

Unrau (28) studied cytoplasmic effects of 2,4-D on cereal crops. He indicated that regardless of the application date and treatment rate, 2,4-D caused significant chromosomal abnormalities.

Differential yield response of varieites of 2,4-D tolerant crops have been reported (8, 27). Derscheid (8) reported that differences in sensitivity to 2,4-D exist between varieties of barley. Scragg (26) found that treatment with 2,4-D increased the 1000 kernel weight of barley. Erickson _et_ _al_. (9) and Warden (31) reported slight increase in protein content in spring wheat cultivars when treated with 2,4-D. Crop cultivar (11, 13) and chemical formulation have also been reported to influence selectivity patterns.

Urea herbicide: diuron [3-(3,4-dichlorophenyl)-1,1-dimethylurea]

The urea herbicides are relatively non-selective at high rates of usage and are usually applied to the soil (18). At low rates of application, they may be selective.

Diuron, a phenylurea herbicide, is primarily used to control annual grass and broadleaf weeds before emergence in several crops. In studying selectivity, Upchurch and Pierce (29) reported higher injury in cotton than in Italian ryegrass under high rates of incorporated diuron. Culp and McWhorter (7) found that increased depth of planting of castor beans reduced injury from diuron . Soil types have also been reported (10) to have an influence on the adsorption of diuron. Kearney and Kaufman (14) reported that adsorption appears to be lowest in sandy soils, intermediate in clay loams and highest in organic soil with high organic matter content.

Many investigators (2, 6, 22) demonstrated the importance of light for the expression of toxicity symptoms of phenylurea herbicides. The inhibition of the Hill reaction (basic to photosynthesis) is generally acknowledged to indicate the primary site of action of the urea herbicides. Moreland and Hill (23) found that the sensitivity of the Hill reaction of isolated chloroplasts was inversely related to the water solubility of five phenylureas. Leonard (15) stated that photosynthesis-inhibiting herbicides exert rapid injury under conditions of rapid transpiration. An increase in transpiration rate would likely increase the herbicidal effects. Temperature is recognized as an important factor in transpiration, and influences the upward movement of diuron through the transpiration stream (12). It is, therefore, not surprising that factors which lower the rate of transpiration, including high external vapor pressure, low temperature or closure of foliar stomata, decrease the amount of herbicide adsorbed and translocated. Thus, in areas where high temperature prevails, crop injury is more likely to occur.

Homesley (12) found definite differences among cultivars in stand reduction from diuron.

Diclofop herbicide (Hoe 23408): {methyl 2-[4-(2,4-dichlorophenoxy) phenoxy]propanoate}

Diclofop has been developed by the American Hoechst Company for annual grass control in broadleaf and cereal crops. Miller et al. (20) tested six spring wheat cultivars for response to the wild oat herbicide, difenzoquat. Significant cultivar differences in percentage crop injury and percent yield reduction were found. When testing diclofop Miller and Nalewaja (19) noticed that wheat has an excellent tolerance and little or no injury was observed at rates as high as 32 oz. per acre (2.23 kg/ha). These same workers also reported that higher yield were obtained when wheat was sprayed with diclofop at the two-leaf stage and at a rate of 16 oz. per acre (1.12 kg/ha). Miller and Nalewaja (21) also reported that wheat showed excellent tolerance to diclofop up to 2.34 kg/ha. Behrens et al. (3) reported that diclofop is a very selective chemical for wild oats and causes no apparent injury to wheat. Appleby (1) stated that "the excellent grass control and flexibility of timing with which Hoe 23408 may be used makes this compound an exciting and promising material for grass weed control in western Oregon." So far, from the literature available, diclofop has shown considerable promise for control of annual grasses. Particular interest has been shown in the postemergence control of wild oats (*Avena fatua*).

Weed control has proven to be an essential part of wheat production but it is also essential to determine what effect, if any, herbicides have on different wheat cultivars. In view of results obtained to date, concerning reaction of herbicides on crop plants, there is a definite need for more information as to the effect of herbicides on cereal grains and the possible cultivar x herbicide interaction.

MATERIALS AND METHODS

A field experiment was conducted at the Oregon State University East Farm during the 1979-80 crop season. Detailed meterological data for the location are given in Appendix Table 1. The same experiment was conducted in the greenhouse and partially duplicated in the growth chamber during the same season.

The experiment consisted of five winter wheat cultivars treated at two dates with two rates of chemicals from three herbicidal families.

Materials

1. Winter Wheat Cultivars

Five high yielding winter wheat cultivars were used in this study. The criterion for selection of the cultivars was based on the diversity of pedigree and phenotype attempting to avoid parental relationships.

Pedigree and description of the cultivars:

Bezostaya: Lutescens 17//Skorospelka 2.

Bezostaya is a hard red winter wheat cultivar developed at the Krasnodar Scientific Research Institute for Agriculture in Russia. The variety is medium early in maturity. It is a medium tall cultivar (115-125 cm) having strong straw and good resistance to lodging. The spike type is awnless and the red seed is semi-hard although classified as hard. Bezostaya is characterized by its wide adaptability. It is grown in both winter and spring environments, has average to below average winterhardiness but above average drought resistance.

Daws: CI 14484//CI 13645/PI 178383, WA 6009.

Daws wheat, a semi-dwarf (90-100 cm), soft white winter wheat, was developed cooperatively by ARS, USDA and Washington State Agricultural Research Center. It was released jointly in 1976 for production in the Pacific Northwest by the Agricultural Experiment Stations of Washington, Oregon, and Idaho, and the ARS, USDA. Daws is adapted to wheat growing areas of northern Idaho, eastern Oregon and eastern Washington. It is awned, medium in maturity, has soft white seed and adequate winterhardiness for the region.

Maris Hobbit: Professeur Marchal//Marne Desprez/Vogel 9144/4/CI 12633/4*Capelle Desprez//Heine 110/Capelle Desprez/3/Nord Desprez.

Maris Hobbit is a soft red winter wheat cultivar developed and released by the Plant Breeding Institute, Cambridge, Great Britain. The variety is short (80-90 cm), medium late, awnless and has a soft red seed. It has a high yield potential in cool, moist, high fertility environments. Its late maturity causes marked reduction of yield in stress conditions.

Stephens: Nord Desprez/Pullman 101, OR 65-116-70-MBW-2.

Stephens is a soft white winter wheat developed and released by the Oregon Agricultural Experiment Station in cooperation with SEA, USDA. It is adapted to the winter wheat growing areas of the Pacific Northwest and has a superior yield potential under high rainfall or irrigated conditions. Stephens is semi-dwarf (90-100 cm) and has a strong stem. It is early, awned, has large soft white seed and good quality.

Yamhill: Heines VII/Redmond (Alba), Sel 61-1227-66-7

Yamhill is a soft winter wheat cultivar developed and released by the Oregon Agricultural Experiment Station. It is a midtall variety (115-125 cm) with white, stiff straw and good resistance to lodging. Yamhill is adapted to the winter wheat growing areas of western Oregon and Washington. It is medium late, awnless and has soft white seed. This variety is recommended for cultivation on hillside land and low areas having saturated soils during the winter rainfally period.

2. Herbicides

The herbicides selected for the study were diuron, diclofop and 2,4-D. The criterion for selection of the herbicides was based on the differences between their herbicidal families, the physical and chemical properties, and mode of action of these particular herbicides. Some pertinent information relative to the herbicides is shown in the Appendix Table 2.

Diuron (urea family): Diuron is a substituted urea herbicide used primarly to control annual grass and broadleaf weeds before emergence.

At high rates, diuron, as well as most urea herbicides, is relatively non-selective and usually applied to the soil. At low rates of application diuron may be selective. Diuron has low water solubility and is extensively adsorbed on soil constituents, particularly organic matter. It is characterized by its low leachability so that appreciable precipitation is required to move the chemical into the root zone of the plants. Diuron is a systemic herbicide that is adsorbed primarily by roots. It is a strong inhibitor of the Hill reaction of photosynthesis.

Diclofop (Hoe 23408): Diclofop is a herbicide that has a high selectivity. It is used to control wild oats and other annual grasses in wheat and broadleaf crops. This herbicide has proven effective when incorporated before planting, applied preemergence or applied postemergence. Its delay in use in recent years was due to hesitancy of the Environmental Protection Agency for registration within the USA. Diclofop (Hoe 23408) has been released in Canada[1] and in Mexico[2] and is becoming popular within these countries because of its effective control of wild oats.

2,4-D (phenoxy family): Phenoxys are selective herbicides widely used in crop production. They are related to naturally occurring plant growth regulators. They kill by causing malfunction in growth processes. The phenoxy used in this experiment is 2,4-D amine (nitrogen-based salt). It is very soluble in water and has low volatility.

3. Herbicide rates (HR) and application dates (AD).

In this study herbicide rate 2 (HR 2) represents two times the recommended rate (HR 1). The growth stages, at which the herbicides

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[1]In Canada, diclofop is known as Hoegrass.

[2]In Mexico, diclofop is known as Illoxan.

were applied are referred to as application date 1 (AD 1), which is the recommended date and application date 2 (AD 2), a later date of application suspected to cause damage to the crop. The following table shows the herbicide rates and application dates used in this study. The number in parentheses represents the range of the recommended rate, which is based on the kind of weed problem present.

Herbicide	Percent Active Ingredient	Herbicide Rate (kg/ha)		Growth Stage[1]	
		HR 1	HR 2	AD 1	AD 2
Diuron	80	1.4 (0.89-1.79)	2.8	3-5 leaves	5-6 tillers
Diclofop	36	1.4 (1.12-2.34)	2.8	3-5 leaves	5-6 tillers
2,4-D	3-4[2]	1.4 (1.12-1.67)	2.8	5-6 tillers	3-5 nodes

Each cultivar was treated with the three herbicides which were applied in the following four combinations: a) (HR 1 - AD 1), b) (HR 1 - AD 2), c) (HR 2 - AD 1), d) (HR 2 - AD 2). An equal volume of 235 l/ha of water was applied with each of the herbicidal treatments.

The excessively high chemical dose (HR 2) and the later application date (AD 2) were chosen for each herbicide to assure as great a differential response as possible among and within the winter wheat cultivars studied.

[1] Diuron and diclofop were applied on the 22nd of January (AD 1) and on the 22nd of March, 1980 (AD 2). 2,4-D was applied on the 22nd of March (AD 1) then on the 6th of May (AD 2), 1980.

[2] kg/ha acid equivalent

Methods

1. Field Experiment

The five winter wheat cultivars were planted in three replications at the Oregon State Universtity East Farm. The soil type at this location is a Chehalis sandy loam with good drainage.

The field study was sown on the 7th of November, 1979 using an "Oyjord" experimental seed drill designed in Norway. The planting depth was adjusted to approximately 7 cm to avoid damage from surface applied herbicide, particularly diuron. The seeding rate used was 100 kg/ha which is standard for the region. Urea fertilizer (46-0-0) was applied at a rate of 90 kg/ha in a split application, one-half at planting and the other half at a later tillering stage.

The herbicides were applied with an AZ Field Test Service hand-carried sprayer, with carbon dioxide (CO_2) from a cartridge carried on a belt. Constant pressure was maintained for all applications, and four flat pattern nozzles were used on a 90-cm boom, so that one pass covered the entire plot.

Each plot of the experiment consisted of twelve rows, at 15 cm spacing between rows, and six meters long.

A randomized strip-block was chosen to facilitate the application of herbicides. A detailed field diagram is given in Appendix Figure 1.

The experiment consisted of twelve herbicide treatments, a hand-weeded control (Ct) and an untreated control referred to as competition treatment (Cp).

All plots (except the untreated control) were kept weed-free by hand weeding when and where necessary to avoid confounding possible herbicide injury effects with the effects of weed competition.

At harvest, each plot (six meters in length) was trimmed to 3.5 m in length and only the eight center rows were harvested. A 'Hege' experimental plot combine from West Germany was used to harvest the experiment.

The parameters evaluated were:

1. Visual observation: Four visual observations were made following each herbicide application. A scale of 0 to 100 was used with 0 = no injury and 100 = complete kill.
2. Yield: The yield was determined in grams per plot. The harvested plot area was 4.2 m^2.
3. Spikes per Area: A 1-m linear rod was randomly placed three times within each plot and the number of spikes was counted. The average was then computed and recorded.
4. Kernels per Spike: Ten spikes were randomly selected from each plot, the number of kernels per head was then counted and averaged for reporting.
5. 1000 Kernel Weight: 1000 kernels were counted from the bulk seed of each plot. They were then weighed and recorded in grams.
6. Test Weight: Test weight was measured in kilograms per hectoliter (kg/hl) from the bulk seed used for yield analyses.
7. Plant Height: The plant height of each plot was measured in centimeters (cm) just prior to harvest as the distance from the soil surface to the tip of the upper spikelet of the spike, disregarding awns when present.

8. Protein content: The percent protein for each sample from the bulk seed used for yield analyses was determined using a Technicon Industrial Systems InfraAlyzer 400.

The results were then subjected to an analysis of variance. All analyses were done by computer except for hand calculation of the percent reduction for each treatment as compared to the control.

2. Greenhouse Experiment

The same cultivars were studied in the greenhouse to verify the relative response of the different genotypes to the herbicides used in the field. The same rates and dates of application were used in the greenhouse.

The greenhouse experiment consisted of twelve herbicide treatments and a control. The cultivars were planted in plastic pots. The soil used was from the same site as the field experiment (East Farm). Each pot contained only one plant, and each herbicide treatment was applied to three pots per cultivar.

The herbicides were applied with an overhead sprayer. A flat pattern nozzle was used. The temperature was maintained at 20°C days and 15°C nights, however, at times it was not possible to keep the temperature within this range. The temperature (maximum-minimum) range is reported in Appendix Table 3. The daily photoperiod was 16 hours until the first spraying date and then changed to 12 hours thereafter.

The experimental lay-out and statistical analyses were best suited to a completely randomized design with three replications.

Plants were harvested at maturity and the following parameters were evaluated: number of fertile tillers, kernels per spike and kernel weight per spike.

The results were subjected to an analysis of variance and means were compared by using LSD at the 5% level of probability.

3. Growth Chamber Experiment

Three cultivars* were studied in the growth chamber, however, only the chemical, diuron, was tested. The rates were the same as those used in the field (HR 1 and HR 2) and in the greenhouse, but applied only at one growth stage (AD 1). The cultivars were planted in plastic pots (one plant per pot) and the soil used was a clay loam mixed with peat moss.

The temperature was maintained at 20°C days and 15°C nights. The daily photoperiod was 16 hours until the application of diuron, then was changed to 12 hours thereafter. The experiment was initiated in the growth chamber because diuron completely killed all cultivars in the greenhouse environment.

The statistical design and the parameters evaluated were the same as those of the greenhouse experiment. The data gathered were then subjected to an analysis of variance and the means were compared by using LSD at the 5% level of probability.

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*Bezostaya, Stephens and Yamhill

RESULTS

Field Experiment

Winter Wheat Response to Herbicides

None of the wheat cultivars are completely resistant to herbicide injury, however, some cultivars have better tolerance to certain dosages. Five winter wheat cultivars (Bezostaya, Daws, Maris Hobbit, Stephens and Yamhill) were investigated for their reaction to various treatments of three herbicides (diuron, diclofop and 2,4-D). The cultivars were compared based on seven agronomic characters: yield, yield components (spikes per unit area, kernels per spike and 1000 kernel weight), test weight, height and protein. Differences were observed among the cultivars, the herbicides and most importantly, the cultivar x herbicide interaction (Appendix Table 4). There were important differences for several of the characters among the herbicides, rates, application dates, first order interaction herbicide x rate and herbicide x date (Appendix Table 5). All possible first, second and third order interactions were evaluated.

The agronomic characters considered in this study expressed important differences due to the (cultivar x herbicide x rate) and the (cultivar x herbicide x date) interactions. The five winter wheat cultivars differed in their performance with regard to yield, kernels per spike, 1000 kernel weight, test weight, height and protein due to the herbicide treatments (Appendix Table 7). The herbicide treatments and competition resulted in lower mean yields and reduced height compared to the control (Appendix Table 7). Differences between herbicide treatments and control were not consistent with regard to the yield components. The performance of the cultivars for the agronomic characters studied is shown in Appendix Table 8.

Deviation, expressed as percent of control for each character, shows the differences among as well as within cultivars due to herbicides (Appendix Table 9). The percent reduction in yield (Appendix Table 9) varied from 15.4 (Daws) to 42.8 (Maris Hobbit) when treated with diuron. With the application of diclofop, variation among the cultivars due to the effect of this herbicide ranged from 18.3% reduction in yield of Maris Hobbit to an increase of 5.9% in yield for the variety Daws. Differences in yield among the cultivars due to the application of 2,4-D were greater than those due to diclofop. The phenoxy herbicide, 2,4-D, decreased the yield of the cultivar Bezostaya by 49% whereas an increase in yield of 14.4% resulted in the cultivar Daws (Appendix Table 9).

Variations within and between cultivars, due to herbicide application, also occurred in test weight, number of spikes per unit area, number of kernels per spike, 1000 kernel weight, height and protein (Appendix Table 9B - 9G). Variations was observed in protein percentage within cultivars as influenced by herbicides. Yamhill, for example, showed a decrease in protein of 1.8% when treated with diclofop and an increase of 4% and 3.9% when treated with diuron and 2,4-D, respectively.

The yield, yield components, test weight, height and protein for the five winter wheat cultivars were shown to be affected by herbicides. It is important then to study the relative effects of each herbicide with regard to its interaction with the winter wheat cultivars.

Effects of Herbicide Rate and Application Date on the Wheat Cultivars

Diuron

The higher rate (2.8 kg/ha) of diuron reduced the yields of all the winter wheat cultivars studied (Table 1A), and caused a decrease in all of the other traits with the exception of 1000 kernel weight (Table 1E) and grain protein percentage (Table 1F). A yield decrease of 71.5% was observed for Maris Hobbit from the higher rate and a decrease of 14.1% from the lower rate (1.4 kg/ha) of diuron. The latter rate also caused a 23.7% yield reduction for the cultivar Bezostaya.

With regard to application date, the yields were reduced due to the earlier (three to five leaf stage) application of diuron, for all the cultivars except Daws. The second date of application (five to six tillers) of this herbicide markedly affected the yields of Maris Hobbit, Stephens, Bezostaya and Yamhill (Table 1A).

The number of spikes per unit area of the five cultivars was reduced by the higher rate and later application date of diuron (Table 1C). Effects due to the lower rate (1.4 kg/ha) and the earlier application date were observed on Maris Hobbit and Yamhill cultivars. The five winter wheat cultivars showed a decrease in the number of kernels per spike when sprayed at the three to five leaf growth stage (Table 1D). Reductions in kernels per spike for Bezostaya of 39.3%, 46.1% and 43.8% were due to the higher rate (2.8 kg/ha), the earlier application date of diuron and to weed competition, respectively (Table 1D). At the rate of 2.8 kg/ha and at both of the application dates of diuron, the 1000 kernel weight of Maris Hobbit and Yamhill decreased. At the lower rate only Yamhill showed a decrease in this trait (Table 1E).

An increase of more than 10% in grain protein was observed on four of the cultivars (Maris Hobbit, Daws, Stephens and Yamhill) due to the herbicide application (Table 1F).

Diclofop (Hoe 23408)

Reductions in yield resulted from diclofop treatments on the cultivar Maris Hobbit (Table 2A). The number of spikes per unit area of Daws, Maris Hobbit, Stephens and Yamhill was affected by the rates and application dates of diclofop herbicide (Table 2C). Bezostaya, however, showed a decrease than an increase, with regard to this trait, as a result of the earlier then the later application dates, respectively. Diclofop, when sprayed at the five to six tiller growth stage, increased the number of kernels per spike of Daws and Yamhill and decreased that of Bezostaya, Maris Hobbit and Stephens (Table 2D). The earlier application date (three to five leaves) resulted in a decrease in the number of kernels per spike of Bezostaya and Yamhill but an increase in the number of kernels per spike of Daws.

The rates (1.4 and 2.8 kg/ha) of diclofop decreased the number of kernels per spike of Maris Hobbit and increased that of Daws.

2,4-D

The rates (1.4 and 2.8 kg/ha) and the later (three to five node) application date of 2,4-D markedly reduced the yield of Bezostaya. The lower rate also caused a reduction in the yield of Yamhill (Table 3A).

The first application (five to six tiller growth stage) of 2,4-D reduced the number of spikes per unit area of Bezostaya, Daws, Maris Hobbit and Yamhill but increased the number of spikes of Stephens; whereas the application of 2,4-D at the three to five node growth stage decreased the number of spikes per unit area for Bezostaya and Yamhill but increased it for Daws, Maris Hobbit and Stephens (Table 3C).

At both rates and application dates of 2,4-D, the number of kernels per spike decreased for Bezostaya, Maris Hobbit and Stephens but increased for Daws (Table 3D). The lower rate (1.4 kg/ha) and second application date of 2,4-D resulted in a reduction in number of kernels per spike of Yamhill.

An increase in the 1000 kernel weight was observed for Daws, Maris Hobbit and Stephens when treated with 2,4-D at the five to six tiller growth stage, however, the same treatment decreased the 1000 kernel weight of Yamhill by 8.1 percent (Table 3E). The higher rate (2.8 kg/ha) of 2,4-D increased the 1000 kernel weight of Maris Hobbit and Stephens by 4.0 and 3.3 percent, respectively.

The rate of 2.8 kg/ha and the later application date (three to five nodes) of 2,4-D on Bezostaya resulted in an increase in protein of 11.5 and 8.9 percent, respectively (Table 3F).

Other Interactions

The rates (1.4 and 2.8 kg/ha) and application dates of diuron, diclofop and 2,4-D (Appendix Table 10) reduced the number of spikes per unit area of Daws, Maris Hobbit, Stephens and Yamhill. Bezostaya, however, showed a reduction in this trait, only at the higher rate and at both application dates of the herbicides.

The test weight of Maris Hobbit and Yamhill decreased due to the higher rate of diuron at both application dates; but increased following the application of 2,4-D at the three to five node growth stage and both application rates (Appendix Table 11).

At the higher rate and the two growth stages, diuron decreased the 1000 kernel weight of Maris Hobbit, Stephens and Yamhill. At the rates of 1.4 and 2.8 kg/ha, 2,4-D when applied at the five to six tiller growth stage, increased the 1000 kernel weight of Yamhill (Appendix Table 12).

Greenhouse Experiment

An attempt was made to screen five winter wheat varieties for their response to three herbicides based on the response of their respective kernel numbers, kernel weight and tiller number. The herbicide rates and application dates were the same as those used in the field experiment. Appendix Table 13 shows the mean square values for the traits analyzed as influenced by the herbicides. Diuron, when applied in the greenhouse, killed all the plants, regardless of its rates and application dates. There were no effects of 2,4-D on any of the traits studied at either rate of application date (Appendix Table 13B). Diclofop had an effect only on the kernel number of Bezostaya (Appendix Table 13A).

The means of kernel number, kernel weight and tiller number for Bezostaya, Daws, Maris Hobbit, Stephens and Yamhill as influenced by four treatments of diclofop and 2,4-D are reported in Appendix Tables 14 and 15, respectively. The percent deviation from the control and a dash, in cases where the treatment killed the plant, are also shown in Appendix Tables 14 and 15.

The lack of significance encountered in the greenhouse as compared to the field experiment, can be attributed to the high variation among the treatments and thus the high values of the error mean squares (Appendix Table 13) made it difficult to detect any statistical differences. In the greenhouse, the photoperiod and temperature were out of control at times and thus could have created the variability encountered in this experiment. The temperature data (maximum and minimum) are reported in Appendix Table 3.

Growth Chamber

The growth chamber experiment consisted of two rates of diuron applied to Bezostaya, Stephens and Yamhill cultivars at the three to five leaf growth stage. The exact number of cultivars and diuron treatments was not duplicated due to the limited space area in the growth chamber.

The higher rate of diuron killed all the plants; whereas, the lower rate had insignificant effect on the kernel number, kernel weight and tiller number of Bezostaya, Stephens and Yamhill cultivars (Appendix Table 13C). The means and percent deviation from the control of the relative traits for the three cultivars are reported in Appendix Table 16.

Table 1.
Means of yield, yield components, protein and deviation from the control in percent for five winter wheat cultivars treated with two rates of diuron applied on two different dates. East Farm, 1979-80

Treatments	Bezostaya		Daws		Maris Hobbit		Stephens		Yamhill	
	Mean	% Deviation	Mean	% Deviation	Mean	% Deviation	Mean	% Deviation	Mean	% Deviation
A. YIELD (kg/plot)										
Herbicide Rate 1	2.112	-23.7	2.758	10.0	3.834	-14.1	3.801	-4.2	2.492	-11.3
Herbicide Rate 2	1.407	-49.1	1.484	-40.8	1.272	-71.5	1.513	-61.9	1.213	-56.8
Application Date 1	1.355	-51.0	1.969	-21.4	2.073	-53.5	2.306	-41.9	1.635	-41.8
Application Date 2	2.164	-21.8	2.272	-9.3	3.032	-32.1	3.008	-24.2	2.069	-26.4
Competition	1.558	-43.7	2.305	-8.0	3.418	-23.4	4.035	1.6	3.114	10.8
Control	2.767	0.0	2.506	0.0	4.462	0.0	3.970	0.0	2.810	0.0
LSD .05 = .718										
B. TEST WEIGHT (kg/hl)										
Herbicide Rate 1	81.617	-0.5	78.167	-0.2	73.367	-1.1	78.450	-1.3	76.467	-0.7
Herbicide Rate 2	81.617	-0.5	76.917	-1.8	72.417	-2.3	78.267	-1.5	75.117	-2.5
Application Date 1	81.744	-0.4	78.42	0.1	73.956	-0.3	78.900	-0.7	76.844	-0.2
Application Date 2	81.500	-0.7	78.500	0.2	74.478	0.4	79.800	0.4	77.389	0.5
Competition	82.167	0.1	79.133	1.0	74.300	0.2	79.933	0.6	77.733	0.9
Control	82.067	0.0	78.333	0.0	74.167	0.0	79.467	0.0	77.033	0.0
LSD .05 = .809										

Table 1, (continued)

Treatments	Bezostaya Mean	Bezostaya % Deviation	Daws Mean	Daws % Deviation	Maris Hobbit Mean	Maris Hobbit % Deviation	Stephens Mean	Stephens % Deviation	Yamhill Mean	Yamhill % Deviation
C. SPIKES PER UNIT AREA										
Herbicide Rate 1	63.830	-8.6	78.218	-8.2	61.275	-27.3	78.633	-4.6	71.718	-12.6
Herbicide Rate 2	59.898	-14.3	69.280	-18.7	56.930	-27.8	49.942	-39.4	52.795	-35.7
Application Date 1	64.232	-8.1	77.002	-9.6	59.820	-24.2	74.053	-10.2	68.128	-17.0
Application Date 2	59.497	-14.8	70.497	-17.3	58.385	-25.9	54.552	-33.8	56.385	-31.3
Competition	71.330	2.1	73.107	-14.2	60.330	-23.5	82.440	0.0	76.323	-7.0
Control	69.877	0.0	85.220	0.0	78.883	0.0	82.440	0.0	82.107	0.0
LSD .05 = 1.011										
D. KERNELS PER SPIKE										
Herbicide Rate 1	23.442	-16.0	29.766	17.3	45.823	10.3	32.856	1.9	29.926	6.8
Herbicide Rate 2	16.930	-39.3	17.677	-30.3	17.144	-58.7	25.727	-20.2	22.269	-20.5
Application Date 1	15.028	-46.1	21.859	-13.8	25.265	-39.1	19.709	-38.9	19.879	-29.1
Application Date 2	25.344	-9.2	25.584	0.8	37.701	-9.2	38.874	20.5	32.316	15.3
Competition	15.688	-43.8	24.944	-1.7	39.470	-4.9	32.802	1.7	33.496	19.5
Control	27.909	0.0	25.367	0.0	41.523	0.0	32.255	0.0	28.026	0.0
LSD .05 = .921										

Table 1. (continued)

Treatments	Bezostaya Mean	Bezostaya % Deviation	Daws Mean	Daws % Deviation	Maris Hobbit Mean	Maris Hobbit % Deviation	Stephens Mean	Stephens % Deviation	Yamhill Mean	Yamhill % Deviation
E. 1000 KERNEL WEIGHT (gm)										
Herbicide Rate 1	51.958	0.0	45.177	3.6	50.685	-0.3	55.312	0.5	43.223	-3.9
Herbicide Rate 2	53.205	2.4	42.197	-3.2	47.517	-6.5	52.683	-4.3	39.197	-12.9
Application Date 1	52.447	0.9	44.013	0.9	49.030	-3.5	54.913	-0.2	42.482	-5.6
Application Date 2	52.717	1.4	43.360	-0.6	49.172	-3.3	53.082	-3.6	39.935	-11.3
Competition	50.980	-1.9	45.163	3.6	52.683	3.6	55.817	1.4	45.543	1.2
Control	51.960	0.0	43.607	0.0	50.837	0.0	55.053	0.0	45.017	0.0
LSD .05 = 1.597										
F. PROTEIN (%)										
Herbicide Rate 1	12.74	5.5	8.03	-4.5	8.65	-1.2	8.26	1.6	8.98	-2.5
Herbicide Rate 2	12.81	6.1	9.52	13.2	9.83	12.2	9.40	15.6	10.18	10.5
Application Date 1	13.23	9.6	8.63	2.6	9.36	6.8	8.99	10.6	9.23	0.2
Application Date 2	12.32	2.1	8.91	5.9	9.13	4.2	8.68	6.8	9.92	7.7
Competition	12.31	2.0	8.52	1.3	8.52	-2.7	8.03	-1.2	9.71	5.4
Control	12.07	0.0	8.41	0.0	8.76	0.0	8.13	0.0	9.21	0.0
LSD .05 = .845										

(CULTIVARS: Bezostaya, Daws, Maris Hobbit, Stephens, Yamhill)

Table 2.

Means of yield, yield components, protein and deviation from control in percent for five winter wheat cultivars treated with two rates of diclofop (Hoe 23408) applied on two different dates. East Farm, 1979-80.

	CULTIVARS									
	Bezostaya		Daws		Maris Hobbit		Stephens		Yamhill	
Treatments	Mean	% Deviation	Mean	% Deviation	Mean	% Deviation	Mean	% Deviation	Mean	% Deviation
A. YIELD (kg/plot)										
Herbicide Rate 1	2.355	-14.9	2.874	14.7	3.842	-13.9	3.823	-3.7	2.698	-3.9
Herbicide Rate 2	2.332	-15.7	2.432	-2.9	3.454	-22.6	3.322	-16.3	2.177	-22.5
Application Date 1	2.278	-17.7	2.361	-5.8	3.591	-19.5	3.508	-11.6	2.160	-23.1
Application Date 2	2.408	-12.9	2.946	17.5	3.705	-16.9	3.637	-8.4	2.715	-3.4
Competition	1.558	-43.7	2.305	-8.0	3.418	-23.4	4.035	1.6	3.114	10.8
Control	2.767	0.0	2.506	0.0	4.462	0.0	3.970	0.0	2.810	0.0
LSD .05 = .718										
B. TEST WEIGHT (kg/hl)										
Herbicide Rate 1	81.883	-0.2	78.400	0.1	74.117	0.0	79.750	0.3	77.433	0.5
Herbicide Rate 2	81.783	-0.3	78.533	0.2	74.067	-0.1	79.950	0.6	77.033	0.0
Application Date 1	81.850	-0.3	78.567	0.3	73.917	-0.3	79.800	0.4	77.200	0.2
Application Date 2	81.817	-0.3	78.367	0.0	74.267	0.1	79.900	0.5	77.267	0.3
Competition	82.167	0.1	79.133	1.0	74.300	0.2	79.933	0.6	77.733	0.9
Control	82.067	0.0	78.333	0.0	74.167	0.0	79.467	0.0	77.033	0.0
LSD .05 = .809										
C. SPIKES PER UNIT AREA										
Herbicide Rate 1	76.163	9.0	79.277	-7.0	69.997	-11.3	78.718	-4.5	80.275	-2.2
Herbicide Rate 2	60.052	-14.1	64.220	-24.6	64.552	-18.2	69.830	-15.3	64.997	-20.8
Application Date 1	62.108	-11.1	64.942	-23.8	61.942	-21.5	71.777	-12.9	68.275	-16.8
Application Date 2	74.107	6.0	78.555	-7.8	72.607	-7.9	76.772	-6.9	76.997	-6.2
Competition	71.330	2.1	73.107	-14.2	60.330	-23.5	82.440	0.0	76.323	-7.0
Control	69.877	0.0	85.220	0.0	78.883	0.0	82.440	0.0	82.107	0.0
LSD .05 = 1.011										

Table 2. (continued)

Treatments	Bezostaya Mean	Bezostaya % Deviation	Daws Mean	Daws % Deviation	Maris Hobbit Mean	Maris Hobbit % Deviation	Stephens Mean	Stephens % Deviation	Yamhill Mean	Yamhill % Deviation
D. KERNELS PER SPIKE										
Herbicide Rate 1	22.111	-20.8	30.549	20.4	39.647	-4.5	32.011	-0.7	28.210	0.6
Herbicide Rate 2	27.932	-0.1	31.391	23.7	38.378	-7.6	30.589	-5.2	28.781	2.7
Application Date 1	26.295	-5.8	29.794	17.4	42.010	1.2	31.904	-1.1	26.913	-4.0
Application Date 2	23.749	-14.9	32.146	26.7	36.016	-13.3	30.697	-4.8	30.078	7.3
Competition	15.688	-43.8	24.944	-1.7	39.470	-4.9	32.802	1.7	33.496	19.5
Control	27.909	0.0	25.367	0.0	41.523	0.0	32.255	0.0	28.026	0.0
LSD .05 = .921										
E. 1000 KERNEL WEIGHT (gm)										
Herbicide Rate 1	51.288	-1.3	44.148	1.2	51.402	1.1	56.470	2.6	44.005	-2.2
Herbicide Rate 2	51.063	-1.7	43.997	0.9	51.637	1.6	56.670	2.9	42.477	-5.6
Application Date 1	51.285	-1.3	44.613	2.3	51.242	0.8	56.325	2.3	43.153	-4.1
Application Date 2	51.067	-1.7	43.532	-0.2	51.797	1.9	56.815	3.2	43.378	-3.7
Competition	50.980	-1.9	45.163	3.0	52.683	3.6	55.817	1.4	45.543	1.2
Control	51.960	0.0	43.607	0.0	50.837	0.0	55.053	0.0	45.017	0.0
LSD .05 = 1.597										
F. PROTEIN (%)										
Herbicide Rate 1	11.33	-6.1	8.50	1.1	8.62	-1.6	8.30	1.5	8.90	-3.4
Herbicide Rate 2	11.68	-3.2	8.50	1.1	8.14	-7.1	8.42	2.9	9.18	-0.3
Application Date 1	11.81	-2.1	8.56	1.7	8.61	-1.7	8.49	3.8	9.06	-1.6
Application Date 2	11.21	-7.1	8.44	0.3	8.15	-6.9	8.23	0.6	9.01	-2.2
Competition	12.31	1.9	8.52	1.3	8.52	-2.7	8.03	-1.8	9.71	5.4
Control	12.07	0.0	8.41	0.0	8.76	0.0	8.18	0.0	9.21	0.0
LSD .05 = 1.108										

Table 3.

Means of yield, yield components, protein and deviation from control in percent for five winter wheat cultivars treated with two rates of 2,4-D applied on two different dates. East Farm, 1979-80.

	CULTIVARS									
	Bezostaya		Daws		Maris Hobbit		Stephens		Yamhill	
Treatments	Mean	% Deviation	Mean	% Deviation	Mean	% Deviation	Mean	% Deviation	Mean	% Deviation
A. YIELD (kg/plot)										
Herbicide Rate 1	1.641	-40.7	2.829	12.9	3.985	-10.7	3.876	-2.4	1.795	-36.1
Herbicide Rate 2	1.184	-57.2	2.908	16.0	4.177	-6.4	3.860	-2.8	2.631	-4.6
Application Date 1	2.078	-25.9	2.866	14.4	3.836	-14.0	3.938	-0.8	2.306	-17.9
Application Date 2	0.747	-73.0	2.870	14.5	4.326	-3.0	3.798	-4.3	2.170	-22.8
Competition	1.558	-43.7	2.305	-8.0	3.418	-23.4	4.035	1.6	3.114	10.8
Control	2.767	0.0	2.506	0.0	4.462	0.0	3.970	0.0	2.810	0.0
LSD .05 = .718										
B. TEST WEIGHT (kg/hl)										
Herbicide Rate 1	81.367	-0.8	78.817	0.6	75.617	1.3	79.850	0.5	77.450	0.5
Herbicide Rate 2	80.967	-1.3	78.967	0.8	75.317	1.5	79.967	0.6	77.217	0.2
Application Date 1	81.400	-0.8	78.700	0.5	74.633	0.6	79.683	0.3	76.300	-0.9
Application Date 2	80.933	-1.4	79.083	0.9	75.850	2.3	80.133	0.8	78.367	1.7
Competition	82.167	0.1	79.133	1.0	74.300	0.2	79.933	0.6	77.733	0.5
Control	82.067	0.0	78.333	0.0	74.167	0.0	79.467	0.0	77.033	0.0
LSD .05 = .809										
C. SPIKES PER UNIT AREA										
Herbicide Rate 1	71.773	2.7	74.328	-12.8	78.053	-1.0	87.552	6.2	76.218	-7.2
Herbicide Rate 2	63.442	-9.2	81.275	-4.6	75.277	-4.6	85.832	4.1	78.552	-4.3
Application Date 1	68.552	-1.9	68.997	-19.0	70.608	-10.5	84.775	2.8	76.108	-7.3
Application Date 2	66.663	-4.6	86.607	1.6	82.722	4.8	88.608	7.5	78.602	-4.2
Competition	71.330	2.1	73.107	-14.2	60.330	-23.5	82.440	0.0	76.323	-7.0
Control	69.877	0.0	85.220	0.0	78.883	0.0	82.440	0.0	82.107	0.0
LSD .05 = 1.011										

Table 3. (continued)

	CULTIVARS									
	Bezostaya		Daws		Maris Hobbit		Stephens		Yamhill	
Treatments	Mean	% Deviation	Mean	% Deviation	Mean	% Deviation	Mean	% Deviation	Mean	% Deviation
D. KERNELS PER SPIKE										
Herbicide Rate 1	15.229	-45.4	31.220	23.1	35.874	-13.6	28.902	-10.4	20.465	-26.9
Herbicide Rate 2	13.864	-50.3	30.057	18.5	39.237	-5.5	29.376	-8.9	29.278	4.5
Application Date 1	20.819	-25.4	33.231	31.0	37.749	-9.1	30.002	-6.9	27.469	-2.0
Application Date 2	8.274	-70.3	28.047	10.6	37.361	-10.0	28.276	-12.3	22.275	-20.5
Competition	15.688	-43.8	24.944	-1.6	39.470	-4.9	32.802	1.7	33.496	19.5
Control	27.909	0.0	25.367	0.0	41.523	0.0	32.255	0.0	28.026	0.0
LSD .05 = .921										
E. 1000 KERNEL WEIGHT (gm)										
Herbicide Rate 1	52.448	0.9	45.065	3.3	52.635	3.5	56.358	2.4	43.458	-3.5
Herbicide Rate 2	52.107	0.3	44.607	2.3	52.895	4.0	56.885	3.3	43.808	-2.7
Application Date 1	53.193	2.4	45.858	5.2	53.917	6.0	57.543	4.5	41.375	-8.1
Application Date 2	51.362	-1.1	43.813	0.5	51.613	1.5	55.700	1.2	45.892	1.9
Competition	50.980	-1.9	45.163	3.0	52.683	3.6	55.817	1.4	45.543	1.2
Control	51.960	0.0	43.607	0.0	50.837	0.0	55.053	0.0	45.017	0.0
LSD .05 = 1.597										
F. PROTEIN (%)										
Herbicide Rate 1	12.13	0.5	8.37	-0.5	8.34	-4.8	8.23	0.6	9.69	5.2
Herbicide Rate 2	13.46	11.5	8.42	0.1	8.62	-1.6	8.35	2.1	9.44	2.5
Application Date 1	12.45	3.1	8.32	-1.1	8.54	-2.5	8.44	3.2	9.75	5.8
Application Date 2	13.14	8.9	8.47	0.7	8.42	-3.9	8.15	-0.4	9.38	1.8
Competition	12.31	2.0	8.52	1.3	8.52	-2.7	8.03	-1.8	9.71	5.4
Control	12.07	0.0	8.41	0.0	8.76	0.0	8.18	0.0	9.21	0.0
LSD .05 = .845										

DISCUSSION

Wheat crop losses due to weed competition have necessitated the extensive use of herbicides; however, the screening of wheat cultivars for herbicide tolerance has been of limited scope. It is essential then to know the effects of herbicides on various important agronomic traits of the wheat cultivar.

The three selective herbicides, diuron, diclofop and 2,4-D chosen for this study have been reported to be effective for weed control but their effects on new wheat cultivars of diverse origin is now well known. Therefore, five genetically diverse winter wheat cultivars, Bezostaya, Daws, Maris Hobbit, Stephens and Yamhill were compared under field and greenhouse conditions for their reactions to different rates and application dates of these three commercial herbicides.

As one might have expected, a range of genetic variation in the level of tolerance to herbicides was found among the cultivars. It should be noted, however, that the reductions in yield and corresponding changes in other characters observed in this experiment were the results of chemical treatments which should not normally be used in spraying wheat for weed control.

Field Experiment

Yield, in general, is a very complex trait. It is determined by many factors. The major factors affecting yield of the cultivars are its resistance to specific diseases and insects, possession of desired agronomic characteristics for yield potential, adaptability to environmental conditions, soil and crop management practices, particularly response to fertilizer and weed control. The latter is considered in this study to compare five winter wheat cultivars based primarily on their yield response to three selected herbicides. Other agronomic characters were also analyzed in order to evaluate and compare their responses to the herbicides. Deviations in the response of some of these characters will account for the relative deviations in yield among the cultivars.

Interaction of herbicides and wheat cultivars

Among the five winter wheat cultivars studied, Daws appears to be the most tolerant to diuron, diclofop and 2,4-D; whereas Maris Hobbit seems to be sensitive to the same herbicides (Appendix Figure 2). The herbicide diuron reduced the yields of Bezostaya, Maris Hobbit, Stephens and Yamhill by over 30 percent (Appendix Table 9A), the highest reduction (42.8%) being observed for the cultivar Maris Hobbit. In contrast, diclofop reduced the yield of Maris Hobbit by 18.3% and the phenoxy herbicide 2,4-D reduced the yield of Bezostaya by 49 percent.

If we consider two of the components of yield, the number of spikes per unit area and the number of kernels per spike, we should be able to determine, in part at least, their contribution to the loss of yield. The effect of herbicides on the number of spikes per unit area accounted for only a small part of the differences in yield loss among the cultivars (Appendix Table 9A, 9C), the greatest loss being due to a reduction in the number of kernels per spike. It appears that in general, the deviation (increase of decrease) in kernel number per spike was proportional to deviations in yield (Appendix Table 9A,9D). Daws, for example, when treated with diclofop and 2,4-D showed an increase in the number of kernels per spike and grain yield. Increases in protein percentage due to herbicides agree with findings by Erickson (9) and Warden (31) who reported an increase in protein when treated with 2,4-D. In our experiment, there were generally inverse relationships between yield and protein of the five winter wheat cultivars (Appendix Figure 2, 3); when yields were low, protein percentage was high. This was true for three of the cultivars (Bezostaya, Stephens and Yamhill) when treated with diuron and 2,4-D herbicides (Appendix Table 9A, 9F). The application of diclofop caused reduced yield and protein percentage for the cultivars Bezostaya, Maris Hobbit and Yamhill.

Treatments with diuron and 2,4-D reduced the height of Bezostaya and Daws. The latter also expressed a reduction in height when treated with diclofop herbicide (Appendix Table 9G). Stephens, in contrast, did not show reduction in height. From these data, we can conclude that the genes for height in the cultivar Daws are sensitive to herbicides. Klingman (16) also found significant reductions in the height of wheat cultivars when sprayed with 2,4-D herbicide.

Interaction of wheat cultivars to herbicide families and rates of application

One of the first rules of toxicology is that the 'dose makes the poison'; unless the latter is well explained, the trade-off of plus and minus factors or risks versus benefits of chemical herbicides will not be recognized. Thus, there should be a wide margin of safety between the concentrations used for acceptable weed control and those that produce the first signs of injury to the crop.

Cultivars with exceptional tolerance to a certain herbicide will enable more effective weed control as higher rates can be used, if and when necessary. In this experiment, differences have been found in the five cultivars used, with regard to their response to diuron, diclofop and 2,4-D herbicides applied at rates* of 1.4 and 2.8 kg/ha (Table 1, 2 and 3). The major differences were noted in yield response, percentage protein, number of spikes per unit area, number of kernels per spike and kernel weight.

The substituted phenylurea herbicides such as diuron are known as nonselective at high rates of usage (Klingman and Ashton). The higher rate (2.8 kg/ha) of diuron reduced the test weight, number of spikes per unit area, number of kernels per spike and total plot yield in all of the five cultivars. The reduction in yield were associated with marked increased in the protein percentage (Appendix Figure 4A, 5A). At the lower rate (1.4 kg/ha) of diuron, the cultivar Daws seems to have better tolerance than the other cultivars, expressing (as did Stephens) an increase in number of kernels per spike, kernel weight and an increase of 10% in yield.

The herbicide diclofop applied at the rates of up to 2.23 kg/ha, did not cause injury on wheat (Miller, 19). In this experiment, diclofop, when applied at a rate of 2.8 kg/ha, decreased

*Recommended rates for relative herbicides are shown in the Materials and Methods Section.

the yield of Maris Hobbit. Even though statistically non-significant reductions were observed in the yield of the other cultivars, this does not necessarily mean that these reductions should not be considered. At the higher rate of diclofop (2.8 kg/ha), Yamhill, Bezostaya and Stephens showed decreases in yield of 22.5, 15.7 and 16.3 percent, respectively. Such reductions should not be ignored. Thus, in this experiment, Maris Hobbit was sensitive to the high rate of diclofop and Daws was more tolerant than Bezostaya, Stephens and Yamhill (Appendix Figure 4B). With regard to diclofop rates, the respective losses in yield of the cultivars could be better accounted for by a decrease in the number of kernels per spike rather than number of spikes per unit area.

Treatment of the wheat cultivars with the phenoxy herbicide, 2,4-D resulted in fairly consistent responses. As the rate of 2,4-D increased from 1.4 to 2.8 kg/ha, the yield of Bezostaya decreased by 40.7 and 57.2 percent; whereas the yield of Daws increased by 12.9 and 16 percent, respectively. The cultivars, Maris Hobbit and Yamhill also showed yield reductions at both rates of 2,4-D but not of the same magnitude as for Bezostaya. The yield of Stephens was not affected by the 2,4-D herbicide (Appendix Figure 4C). Thus, with regard to yield, the data show that Daws and Stephens have higher levels of tolerance to 2,4-D than Maris Hobbit and Yamhill. Bezostaya, on the other hand, was sensitive to both rates of 2,4-D. These data agree with the findings of Derscheid (8) who reported differences in sensitivity to 2,4-D between varieties of barley.

Results from Klingman (16) have shown that high rates of 2,4-D will reduce test weight. In this experiment the higher rate (2.8 kg/ha) of 2,4-D decreased the test weight of Bezostaya but increased that of Maris Hobbit and had no effect on the test weights of Daws, Stephens and Yamhill. It was also found, in this study, that 2,4-D dosages have significant effects on the number of spikes per unit area and the kernel weight of the wheat cultivars (Table 3C,3D).

The rates (1.4 and 2.8 kg/ha) of diuron, diclofop and 2,4-D herbicides generally caused changes in protein percentage and grain yield of most of the cultivars (Appendix Figures 4,5). Also various effects of the herbicide per se and its rates of application were found on some of the important agronomic characters of the winter wheat cultivars. Based on the higher rate of diuron, for instance, it appears that for all cultivars except Bezostaya, the reduction in yield is associated with a decrease in the number of kernels per spike, the number of spikes per unit area and, in some instances, the kernel weight. Treatment of Daws with diclofop and 2,4-D herbicides resulted in an increase in the number of kernels per spike and kernel weight with a corresponding increase in yield, whereas the decrease in number of spikes per unit area did not seem to affect its yield.

Response of cutlivars to herbicide families and application dates

Wheat cultivars can be tolerant to a given herbicide at a certain growth stage but may be susceptible at another. Thus, the time of herbicide application should be accurately determined so that crop injury and yield losses could be avoided or minimized. Higher degrees of selectivity of wheat cultivars can often be achieved by critical timing of herbicide application. In fact, cultivars with more flexibility to the timing of herbicide application should experience little damage and result in higher yields. Such cultivars would provide better use of herbicides thereby controlling weeds that might be only partially controlled at the recommended application time.

In this study, differential yield response was found among the cultivars (Appendix Figure 6A). Bezostaya, Maris Hobbit, Stephens and Yamhill when treated with diuron at the three to five leaf growth stage, produced approximately 20% lower yields than from the later application (tillering). Reduction in the yield of Daws was not significant and was lower than the other cultivars at the second application date.

Diuron, a urea soil-applied herbicide, is generally taken up by the plant roots. In this experiment, less reduction in yield occurred at the second application date perhaps due to the well-developed root system of the cultivars at this stage of growth (tillering) compared to the earlier date (three to five leaves). The cultivar Daws expressed less yield reduction which would suggest that it is either tolerant to diuron or has a deeper root system than the other cultivars. The effects of diuron on the other agronomic traits, with regard to application dates, were similar to those due to the rates of application, with the exception of the number of kernels per spike of Stephens and Yamhill which increased by 20.5 and 15.3 percent, respectively (Table 1D).

The data for application dates of diclofop (Table 2A, Appendix Figure 6B) show no major yield reduction on four of the wheat cultivars (Bezostaya, Daws, Stephens and Yamhill). In contrast, the cultivar Maris Hobbit appears to be sensitive to time of application of diclofop. There were no major changes in the other agronomic characters for dates of application as compared to those due to the rates of diclofop (Table 2B-F) discussed earlier.

Among the five winter wheat cultivars, only Bezostaya expressed a reduction in yield due to 2,4-D applied at jointing stage (three to five nodes, Appendix Figure 7C). In this experiment, the greatest yield loss (73%) observed on Bezostaya, was partially due to the reduction in the number of spikes per unit area but mostly to the reduction in the number of kernels per spike. The increase in the yield of Daws (14.5%, Table 3A) was attributed to an increase in the number of spikes per unit area and number of kernels per spike.

Marked increases in the protein percentage were noted only for the Bezostaya cultivar (Appendix Figure 7C) when treated with 2,4-D at the three to five node growth stage. The highest reduction in yield also occurred from treatment at the same stage of growth.

In this study, Daws expressed the highest level of tolerance and Bezostaya the highest sensitivity to the application date of the phenoxy herbicide 2,4-D.

Visual Observations

Evaluation of herbicide injury on the wheat crop is difficult for both researchers and farmers. A method is needed that could estimate the effect that a given type and degree of injury would inflict on yield. Often growers must weigh the economics of destroying or keeping an injured wheat field. In this experiment, an attempt was made to evaluate yield losses based on visual observations. Dates and estimated rating of the expected yield reductions are listed in Appendix Table 17. After harvest, the actual yield loss for each treatment was determined and is also listed in this table as percent deviation from the control. The observations were taken approximately one month after each treatment application and the last observation (July 25) was taken just prior to harvest. The estimated losses were generally higher than the actual reductions in yield. No single observation date gave an accurate estimation, although the last one seems to be more realistic but not consistent for all treatments.

Thus, visual estimation of injury alone can not be relied on to give an indication of potential for yield reduction. It is, therefore, necessary to use the actual yield for quantitative measurement of herbicidal injury.

CONCLUSIONS

There are no crops reported to be completely free of herbicide injury, although there are degrees of tolerance in some crops for certain dosages. Injury results from improperly selected chemicals as well as dosage and application timing of herbicides. The identification of certain cultivars tolerant to specific herbicides would provide an effective means of improving weed control. These cultivars could be of value to wheat breeding programs for varietal development as well as screening new herbicides.

Although the herbicides utilized in this study vary in mode of action and thus in the type of injury produced, several observations concerning the response of cultivars to herbicides can be made:

1. Cultivars differed in their response to specific herbicides. Although no single herbicide affected all cultivars to the same degree, wheat breeders should consider screening advanced breeding materials for tolerance to the herbicides commonly used for weed control in their area of production. Yield losses were closely associated with loss in the number of kernels per spike. Protein percentage generally increased when there was a decrease in yield.
2. The substituted urea herbicide, diuron, caused the most damage to the winter wheat cultivars used in this study. Extra caution should be taken with regard to its proper usage. Diclofop (Hoe 23408) on the other hand, can be safely used at different growth stages and even at high rates (2.8 kg/ha), if necessary,

for the wheat cultivars tested, except for Maris Hobbit, and particularly in areas where wild oats are a problem. The phenoxy herbicide, 2,4-D, did not cause major damage to the wheat crop, although the cultivar Bezostaya showed a significant yield reduction.

3. Herbicide injury can be reduced by adjusting the herbicide rate and the application date to the specific cultivars.

In view of the results obtained in this study, there were differences among the cultivars associated with the different herbicide treatments. These differences were more apparent with regard to the yield response of the cultivars to the higher rate of herbicide application.

-Diuron reduced the yield of the five cultivars.

-Bezostaya was sensitive to 2,4-D but not to diclofop

-Maris Hobbit was the only cultivar sensitive to diclofop but it was tolerant to 2,4-D.

-Daws had good tolerance to diclofop and to 2,4-D. Daws was the only cultivar tolerant to diuron treatments although it showed injury at the high application rate (2.8 kg/ha).

-Stephens showed a good tolerance to diclofop and to 2,4-D.

-Yamhill could be classified as less tolerant to the herbicides than Stephens but better than Bezostaya and Maris Hobbit.

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APPENDICES

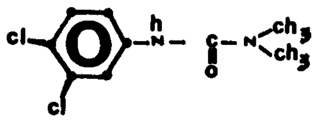
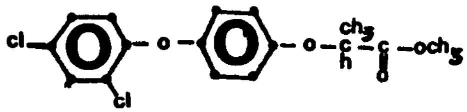
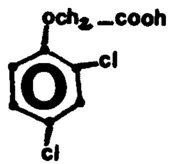
Appendix Table 1. Meterological data, monthly averages. Hyslop Farm, 1979-80[1]

	TEMPERATURE (°F)							
	Air		Ground Level		Soil (4 inch)			
Months	Max.	Min.	Max.	Min.	Max.	Min.	Precipitation (inches)	Evaporation (Total)
September	76.5	50.0	81.3	49.6	--	--	2.15	3.917
October	67.4	45.9	70.6	45.3	62.2	56.5	7.21	2.580
November	51.2	36.1	54.6	36.4	46.5	43.4	4.11	.034
December	49.9	37.1	50.7	36.8	44.8	42.4	6.26	--
January	44.8	29.9	45.9	29.8	40.5	38.1	6.69	2.1
22*	48.0	27.0	50.0	27.0	38.0	36.0	0	--
February	50.8	35.4	52.5	35.0	42.8	39.1	3.88	--
March	53.8	37.5	57.4	37.4	50.3	46.3	4.02	1.554
22*	55.0	37.0	59.0	36.0	50.0	44.0	0	.035
April	62.0	40.1	65.6	39.5	58.2	48.0	3.63	2.820
May	64.9	43.1	69.2	41.4	64.3	54.9	0	3.767
6*	69.0	41.0	73.0	41.0	68.0	59.0	0	.125
June	67.8	48.2	70.4	46.3	66.2	57.3	1.75	4.519

[1]No data is available for East Farm. Hyslop's data is used since it does not differ much from East Farm.

*Dates when herbicide was applied.

Appendix Table 2. Herbicide Characteristics.

			Physical and Chemical Properties		
Common and Trade Name	Structural Formula	Chemical Designation	Molecular Weight, Water Solubility (ppm)	Melting Point (MP) Vapor Pressure (VP)	Acute Oral LD_{50}
Diuron (Karmex)		3-(3,4-dichlorophenyl) -1,1-dimethyl urea	233.1 42(25°C)	MP: 190 VP:$5X10^{7}$ (25°C)	3400
Diclofop (Hoe 23408)		{methyl 2-[4-(2,4-dichloro-phenoxy)phenoxy]propanoate}			
2,4-D (Many)		2,4-dichlorophenoxy acetic acid	210 725	MP: 138 VP: $1X10^{-2}$ - $4X10^{-3}$ (25°C)	375 - 666

Appendix Table 3.

Temperatures (°F) registered at greenhouse, 1979-80.

	MONTH					
	March		April		May	
Date	Max.	Min.	Max.	Min.	Max.	Min.
1	84	36	80	28	56	36
2	95	36	105	24	60	40
3	76	38	68	28	56	36
4	72	36	68	26	84	40
5	68	36	64	36	76	40
6	68	32	72	32	72	40
7	--	--	60	40		
8	68	28	60	30		
9	80	28	82	36		
10	64	33	72	36		
11	72	32	72	28		
12	64	30	92	36		
13	64	32	92	36		
14	72	30	66	36		
15	--	--	76	32		
16	--	--	80	28		
17	64	24	80	36		
18	76	28	72	40		
19	76	36	64	44		
20	76	36	60	44		
21	80	32	--	--		
22	72	32	80	44		
23	100	28	72	32		
24	92	32	100	32		
25	88	28	80	36		
26	88	34	76	32		
27	88	28	80	40		
28	100	28	88	44		
29	88	36	--	--		
30	80	28	72	32		
31	92	28				

Appendix Table 4.
Mean square values for yield, yield components, height and protein for five winter wheat cultivars and three herbicides. East Farm, 1979-80.

Source of Variation	df	MEAN SQUARE VALUE						
		Yield (gm/plot)x10^3	Test Weight (kg/hl)	Spikes per Unit Area (x 10^2)	Kernels per Spike (x10^2)	1000 Kernel Weight (gm)	Height (cm)	Protein %
Total	209							
Replication	2	5.029	11.065	18.919	1.100	24.449	532.633	.545
Cultivars	4	21.762**	33.321**	7.554 ns	14.811**	1218.39**	6684.100**	112.700**
Error (a)	8	.666	1.459	3.212	.365	10.310	76.666	.684
Herbicides	13	6.191**	6.284**	11.628**	4.658**	18.598**	106.802**	2.630**
Error (b)	26	.928	.273	1.781	1.402	2.545	24.089	.782
Cultivars X Herbicides	52	.760**	1.268**	1.359**	.747**	6.366**	27.284*	.603*
Error (c)	104	.259	.329	.514	.426	1.282	17.414	.359

*Significant at the 5% probability level.
**Significant at the 1% probability level.
ns: Not significant.

Appendix Table 5.
Partition of mean square values of herbicides for yield, yield components, height and protein for five winter wheat cultivars. East Farm, 1979-80.

Source of Variation	df	Yield (gm/plot)x10^3	Test Weight (kg/hl)	Spikes per Unit Area (x 10^2)	Kernels per Spike (x10^2	1000 Kernel Weight (gm)	Height (cm)	Protein %
		MEAN SQUARE VALUE						
Herbicides	13	6.191**	6.284**	11.628.**	4.658**	18.598**	106.802**	2.630**
HF	2	10.504**	27.672**	25.254**	3.753 ns	55.995**	75.950 ns	7.022**
HR	1	17.301**	3.472**	33.379**	4.493 ns	32.207**	454.422**	9.434**
AO	1	2.604 ns	8.022**	3.247 ns	1.660 ns	13.480*	235.756**	.731 ns
HF x HR	2	12.268**	2.473**	7.051*	9.678**	24.645**	26.772 ns	3.723*
HF x AD	2	2.843 ns	1.737**	15.174**	11.224**	3.363 ns	14.305 ns	.359 ns
HR x AD	1	3.312 ns	.174 ns	.975 ns	2.170 ns	1.267 ns	.555 ns	.103 ns
HF x HR x AO	2	.059 ns	.147 ns	3.661 ns	.834 ns	7.947 ns	10.372 ns	.611 ns
Ct. vs Cp.	1	1.305 ns	1.452*	3.674 ns	.226 ns	4.136 ns	17.633 ns	.062 ns
Herbicides vs No Herbicides	1	4.612*	4.512**	7.613*	1.021 ns	6.778 ns	425.257**	.435 ns
Error (b)	26	.928	.273	1.781	1.402	2.545	24.089	.782

HF: Herbicide Family
HR: Herbicide Rate
AO: Application Date
Ct: Control
Cp: Competition

*Significant at the 5% probability level.
**Significant at the 1% probability level.
ns: Not Significant.

Appendix Table 6.
Partition of mean square values of cultivar x herbicide interaction for yield, yield components, height and protein for five winter wheat cultivars. East Farm, 1979-80.

Source of Variation	df	MEAN SQUARE VALUE						
		Yield (gm/plot)x10^3	Test Weight (kg/hl)	Spikes per Unit Area (x 10^2)	Kernels per Spike (x10^2)	1000 Kernel Weight (gm)	Height (cm)	Protein %
Cultivars X Herbicides	52	.760**	1.268**	1.359**	.747**	6.366**	27.284*	.603**
Cultivars X HF	8	1.806**	3.549**	2.220**	1.013*	10.910**	74.887**	1.206**
Cultivars X HR	4	.774*	.596 ns	1.195 ns	1.209*	4.749**	21.519 ns	.083 ns
Cultivars X AD	4	.498 ns	1.407**	2.212**	.665 ns	5.322**	23.714 ns	.379 ns
Cultivars X HF X HR	8	.931**	.458 ns	1.939**	1.107*	5.023**	23.306 ns	1.116**
Cultivars X HF X AD	8	.625*	2.095**	.734 ns	.669 ns	13.118**	31.993 ns	.725*
Cultivars X HR X AD	4	.109 ns	.611 ns	2.509**	.424 ns	2.033 ns	24.319 ns	.252 ns
Cultivars X HF X HR X AD	8	.215 ns	.673*	.288 ns	.346 ns	1.388 ns	1.657 ns	.376 ns
Cultivars X (Ct vs Cp)	4	.682*	.153 ns	1.055	.633 ns	1.836 ns	8.050	.134 ns
Cultivars X (Herbicides vs No Herbicides)	4	.661*	.171 ns	3.353	.510 ns	7.945**	13.406 ns	.145 ns
Error (c)	104	.259	.329	.514	.426	1.282	17.414	.359

HF: Herbicide Family
HR: Herbicide Rate
AD: Application Date
Ct: Control
Cp: Competition

*Significant at the 5% probability level.
**Significant at the 1% probability level.
ns: Not Significant.

Appendix Table 7.

Effects of rate and application date of three herbicides on yield, yield components, height and protein for five winter wheat cultivars. East Farm, 1979-80.

	HERBICIDE TREATMENTS													
	Diuron				Hoe 23408				2,4-D					
	HR1		HR2		HR1		HR2		HR1		HR2			
Agronomic Traits	AD1	AD2	AD1	AD2	AD1	AD2	AD1	AD2	AD1	AD2	AD1	AD2	Cp	Ct
Yield (kg/plot)	2.811	.924	3.187	1.831	3.136	2.424	3.102	3.064	3.041	2.968	2.608	2.956	2.885	3.303
Test Weight (kg/hl) (kg/hl)	77.460	76.540	77.770	78.190	78.280	78.250	78.350	78.290	78.180	78.110	78.880	78.880	78.650	78.210
Spikes per Unit Area	73.110	64.270	68.460	51.260	73.950	57.660	79.820	71.800	76.420	71.200	78.750	82.550	72.710	79.700
Kernels per Spike	28.900	11.790	35.820	28.100	31.880	30.880	29.130	31.940	28.840	30.870	23.840	25.850	29.280	31.020
1000 Kernel Weight (gm)	50.230	46.930	48.310	46.990	49.270	49.370	49.650	48.960	50.290	50.460	49.690	49.660	50.040	49.290
Height (cm)	106.900	103.100	109.700	104.100	108.800	105.700	109.900	107.700	106.100	103.100	108.700	107.300	110.100	111.600
Protein (%)	9.330	10.450	9.340	10.250	9.260	9.350	8.990	9.020	9.490	9.520	9.230	9.800	9.420	9.330

HR: Herbicide Rate
AD: Application Date
Cp: Competition
Ct: Control

Appendix Table 8.

Mean values for five winter wheat cultivars for yield, yield components, heiaht and protein. East Farm, 1979-80.

	CULTIVARS				
Agronomic Traits	Bezostaya	Daws	Maris Hobbit	Stephens	Yamhill
Yield (kg/plot)	2.767	2.506	4.462	3.970	2.810
Test Weight (kg/hl)	82.067	78.333	74.167	79.467	77.033
Spikes per Unit Area	69.877	85.220	78.883	82.440	82.107
Kernels per Spike	27.909	25.367	41.523	32.255	28.026
1000 Kernel Weight (gm)	51.960	43.607	50.837	55.053	45.017
Height (cm)	121.0	117.7	92.7	104.0	122.7
Protein (%)	12.07	8.41	8.76	8.13	9.21

Appendix Table 9.

Means of yield, yield components, height, protein, and deviation from the control in percent for five winter wheat cultivars as influenced by three herbicides and competition. East Farm, 1979-80.

	CULTIVARS									
	Bezostaya		Daws		Maris Hobbit		Stephens		Yamhill	
Treatments	Mean	% Deviation	Mean	% Deviation	Mean	% Deviation	Mean	% Deviation	Mean	% Deviation
A. YIELD (kg/plot)										
Control	2.767	0.0	2.506	0.0	4.462	0.0	3.970	0.0	2.810	0.0
Competition	1.558	-43.7	2.305	-8.0	3.418	-23.4	4.035	1.6	3.114	10.8
Diuron	1.759	-36.4	2.121	-15.4	2.553	-42.8	2.657	-33.1	1.852	-34.1
Hoe 23408	2.343	-15.3	2.653	5.9	3.648	-18.3	3.573	-10.0	2.437	-13.3
2,4-D	1.412	-49.0	2.868	14.4	4.081	- 8.5	3.868	-2.6	2.238	-20.4
LSD .05 = .655										
B. TEST WEIGHT (kg/hl)										
Control	82.067	0.0	78.333	0.0	74.167	0.0	79.467	0.0	77.033	0.0
Competition	82.167	0.1	79.917	2.0	74.300	0.2	79.933	0.6	77.733	0.9
Diuron	81.617	-0.5	77.542	-1.0	72.892	-1.7	78.358	-1.4	75.792	-1.6
Hoe 23408	81.833	-0.3	78.467	0.2	74.092	-0.1	79.850	0.5	77.233	0.2
2,4-D	81.164	-1.1	78.892	0.7	75.242	1.4	79.908	0.5	77.333	0.9
LSD .05 = .738										
C. SPIKES PER UNIT AREA										
Control	69.877	0.0	85.220	0.0	78.883	0.0	82.440	0.0	82.107	0.0
Competition	71.330	2.1	73.107	-14.2	60.330	-23.5	82.440	0.0	76.323	-7.0
Diuron	61.864	-11.5	73.749	-13.5	59.103	-25.1	64.330	-21.9	62.257	-24.2
Hoe 23408	68.108	-2.5	71.748	-15.8	67.274	-14.7	74.274	-9.9	72.636	-11.5
2,4-D	67.608	-3.2	77.802	-8.7	76.665	-2.8	86.692	5.1	77.385	-5.7
LSD .05 = .923										

Appendix Table 9. (continued)

	CULTIVARS									
	Bezostaya		Daws		Maris Hobbit		Stephens		Yamhill	
Treatments	Mean	% Deviation	Mean	% Deviation	Mean	% Deviation	Mean	% Deviation	Mean	% Deviation
D. KERNELS PER SPIKE										
Control	27.909	0.0	25.367	0.0	41.523	0.0	32.255	0.0	28.026	0.0
Competition	15.688	-43.8	24.944	-1.7	39.470	-4.9	32.802	1.7	33.496	19.5
Diuron	20.186	-27.7	23.722	-6.5	31.483	-24.2	29.292	-9.2	26.097	-6.9
Hoe 23408	25.022	-10.3	30.970	22.1	39.013	-6.0	31.300	-2.9	28.495	1.7
2,4-D	14.547	-47.9	30.639	20.8	37.555	-9.5	29.139	-9.7	24.872	-11.2
LSD .05 = .840										
E. 1000 KERNEL WEIGHT (gm)										
Control	51.960	0.0	43.607	0.0	50.837	0.0	55.053	0.0	45.017	0.0
Competition	50.980	-1.9	45.163	3.6	52.683	3.6	55.817	1.4	45.543	1.2
Diuron	52.582	1.2	43.687	0.2	49.101	-3.4	53.997	-1.9	41.210	-8.4
Hoe 23408	51.176	-1.5	44.072	1.1	51.519	1.3	56.570	2.7	43.241	-3.9
2,4-D	52.277	0.6	44.836	2.8	52.765	3.8	56.622	2.8	43.633	-3.1
LSD .05 = 1.458										
F. PROTEIN %										
Control	12.07	0.0	8.41	0.0	8.76	0.0	8.13	0.0	9.21	0.0
Competition	12.31	1.9	8.52	1.3	8.52	-2.7	8.03	-1.2	9.71	5.4
Diuron	12.78	5.9	8.77	4.3	9.24	5.5	8.83	8.6	9.58	4.0
Hoe 23408	11.51	-4.6	8.50	1.1	8.38	-4.3	8.36	2.8	9.04	-1.8
2,4-D	12.79	5.9	8.40	-0.1	8.48	-3.2	8.29	1.9	9.57	3.9
LSD .05 = .771										
G. HEIGHT (cm)										
Control	121.0	0.0	117.7	0.0	92.7	0.0	104.0	0.0	122.7	0.0
Competition										
Diuron	114.3	-5.5	108.3	-7.9	86.7	-6.	100.9	-2.9	118.4	-3.5
Hoe 23408	119.9	-0.9	109.2	-7.2	89.0	-3.9	100.1	-3.7	122.1	-0.5
2,4-D	110.5	-9.1	111.5	-5.3	89.2	-3.8	100.7	-3.2	119.7	-2.4
LSD .05 = 5.374										

Appendix Table 10.

Means of spikes per unit area and deviation as a percent of control for five winter wheat cultivars as influenced by the rate and the application date of three herbicides. East Farm, 1979-80.

	CULTIVARS									
	Bezostaya		Daws		Maris Hobbit		Stephens		Yamhill	
Treatment	Mean	% Deviation	Mean	% Deviation	Mean	% Deviation	Mean	% Deviation	Mean	% Deviation
HR 1 AD 1	71.256	1.9	71.256	-16.4	68.071	-13.7	81.441	-1.2	80.293	-2.2
HR 1 AD 2	69.922	0.1	83.293	-2.3	71.479	-9.4	81.848	-0.7	71.848	-12.5
HR 2 AD 1	58.672	-16.0	69.371	-18.6	60.176	-23.7	72.296	-12.3	61.381	-25.2
HR 2 AD 2	63.589	-8.9	73.812	-13.4	70.997	-10.0	64.773	-21.4	69.514	-15.3
Competition	71.330	2.1	73.107	-14.2	60.330	-23.5	82.440	0.0	76.323	-7.0
Control	69.877	0.0	85.220	0.0	78.883	0.0	82.440	0.0	82.107	0.0
LSD .05 = .953										

HR: Herbicide Rate
AD: Application Date

Appendix Table 11.

Means of test weight and deviation as a percent of control for five winter wheat cultivars as influenced by the rate, the application date and the herbicide family. East Farm, 1979-80.

	CULTIVARS									
	Bezostaya		Daws		Maris Hobbit		Stephens		Yamhill	
Treatment	Mean	% Deviation	Mean	% Deviation	Mean	% Deviation	Mean	% Deviation	Mean	% Deviation
Diuron										
HR 1 AD 1	81.833	0.3	78.167	-0.2	73.267	-1.2	77.367	-2.6	76.667	-0.5
HR 1 AD 2	81.400	0.8	78.167	-0.2	73.467	-0.9	79.533	0.1	76.267	-1.0
HR 2 AD 1	81.633	-0.5	75.667	-3.4	71.767	-3.2	77.933	-1.9	75.700	-1.7
HR 2 AD 2	81.600	-0.6	78.167	-0.2	73.067	-1.5	78.600	-1.1	74.533	-3.2
Hoe 23408										
HR 1 AD 1	81.867	-0.2	78.467	0.2	74.033	-0.2	79.600	0.2	77.433	0.5
HR 1 AD 2	81.900	-0.2	78.333	0.0	74.200	0.0	79.900	0.5	77.433	0.5
HR 2 AD 1	81.833	-0.3	78.667	0.4	73.800	-0.5	80.000	0.7	76.967	-0.1
HR 2 AD 2	81.733	-0.4	78.400	0.1	74.333	0.2	79.900	0.5	77.100	0.1
2,4-D										
HR 1 AD 1	81.533	-0.6	78.633	0.4	74.567	0.5	79.733	0.3	76.433	-0.8
HR 1 AD 2	81.200	-1.0	79.000	0.8	75.767	2.1	79.967	0.6	78.467	1.9
HR 2 AD 1	81.267	-1.0	78.767	0.5	74.700	0.7	79.633	0.2	76.167	-1.1
HR 2 AD 2	80.667	-1.7	79.167	1.1	75.933	2.4	80.300	1.0	78.267	1.6
Competition	82.167	0.1	79.133	1.0	74.300	0.2	79.933	0.6	77.733	0.9
Control	82.067	0.0	78.333	0.0	74.167	0.0	79.467	0.0	77.033	0.0
LSD .05 = .934										

HR: Herbicide Rate
AD: Application Date

Appendix Table 12.

Means of 1000 kernel weight and deviation from control in percent for five winter wheat cultivars as influenced by the rate, the application date and the herbicide family. East Farm, 1979-80.

	CULTIVARS									
	Bezostaya		Daws		Maris Hobbit		Stephens		Yamhill	
Treatments	Mean	% Deviation	Mean	% Deviation	Mean	% Deviation	Mean	% Deviation	Mean	% Deviation
Diuron										
HR 1 AD 1	51.723	-0.4	46.063	5.6	51.760	1.8	56.963	3.5	44.633	-0.8
HR 1 AD 2	52.193	0.4	44.290	1.6	49.610	-2.3	53.660	-2.5	41.813	-7.1
HR 2 AD 1	53.170	2.3	41.963	-3.8	46.300	-8.9	52.863	-3.9	40.337	-10.4
HR 2 AD 2	53.240	2.5	42.430	-2.7	48.733	-4.1	52.503	-4.6	38.057	-15.5
Hoe 23408										
HR 1 AO 1	50.997	-1.8	44.603	2.3	51.150	D.6	55.963	1.6	43.660	3.0
HR 1 AD 2	51.580	-0.7	43.693	0.2	51.653	1.6	56.977	3.5	44.350	-1.5
HR 2 AD 1	51.573	-0.7	44.623	2.3	51.333	1.0	56.687	3.0	42.647	-5.3
HR 2 AD 2	50.553	-2.7	43.370	-0.5	51.940	2.2	56.653	2.9	42.307	-6.0
2,4-D										
HR 1 AD 1	53.607	3.2	46.47D	6.6	53.653	5.5	57.063	3.6	40.987	-9.6
HR 1 AD 2	51.290	-1.2	43.660	0.1	51.617	1.5	55.653	1.1	46.230	2.7
HR 2 AD 1	52.780	1.6	45.247	3.7	54.180	6.6	58.023	5.4	42.063	-6.6
HR 2 AD 2	51.433	-1.0	43.967	0.8	51.610	1.5	55.747	1.3	45.553	1.2
Control	51.960	0.0	43.607	0.0	50.837	0.0	55.053	0.0	45.017	0.0
LSD .05 = 1.844										

HR: Herbicide Rate
AD: Application Date

Appendix Table 13.

Mean square values for kernel number, kernel weight and tiller number for five winter wheat cultivars as influenced by: (a) Diclofop (Hoe 23408), (b) 2,4-D and (c) diuron herbicides. Greenhouse, 1979-80

	HERBICIDES											
	A. Hoe 23408				B. 2,4-D				C. Diuron[1]			
Cultivars and Source of Variation	df	Kernel Number	Kernel Weight	Tiller Number	df	Kernel Number	Kernel Weight	Tiller Number	df	Kernel Number	Kernel Weight	Tiller Number
Bezostaya												
Between Treatments	3	386.43**	2.1108 ns	3.969 ns	4	239.30 ns	3.09 ns	.90 ns	1	1380.16 ns	3.65 ns	1.50 ns
Error	7	36.62	.574	1.713	10	305.75	1.89	1.00	4	451.16	.525	1.33
Daws												
Between Treatments	2	99.59 ns	5.902 ns	.833 ns	3	60.91 ns	3.52 ns	.522 ns				
Error	3	350.63	1.416	1.055	6	290.34	1.71	1.55				
Maris Hobbit												
Between Treatments	4	308.44 ns	25.377 ns	.256 ns	3	354.44 ns	4.44 ns	.681 ns				
Error	8	236.74	29.674	1.333	7	545.14	1.98	.643				
Stephens												
Between Treatments	2	184.01 ns	7.386	12.750 ns	4	144.91 ns	1.98 ns	1.39 ns	1	640.67 ns	.025 ns	1.50 ns
Error	3	33.51	4.612	2.167	6	58.04	.708	1.89	4	366.67	.690	1.33
Yamhill												
Between Treatments	4	277.03 ns	2.556 ns	4.731 ns	4	175.48	4.22 ns	.768	1	313.50 ns	.264 ns	.167 ns
Error	8	131.36	1.457	1.750	10	203.14	1.11	1.73	4	345.00	.472	.667

[1] Diuron herbicide was tested in the growth chamber and only three cultivars were used.
**Significant at the 1% level of probability.
ns: Not significant.

Appendix Table 14.

Means of kernel number, kernel weight, tiller number and percent deviation from the control for five winter wheat cultivars treated with two rates of diclofop applied on two different dates. Greenhouse, 1979-80.

	CULTIVARS									
	Bezostaya		Daws		Maris Hobbit		Stephens		Yamhill	
Treatments	Mean	% Deviation	Mean	% Deviation	Mean	% Deviation	Mean	% Deviation	Mean	% Deviation
A. Kernel Number										
AD 1 HR 1			11.00	-54.5	34.66	-32.2	24.00	27.1	19.25	-46.0
AD 1 HR 2	16.83	-53.5	--		43.00	-15.8	--		7.83	-78.0
AD 2 HR 1	9.18	-74.6	--		23.99	-53.0	4.00	-78.8	25.77	-27.7
AD 2 HR 2	19.00	-47.5	13.75	-43.2	31.44	-38.5	--		16.55	-53.6
Control	36.22	0	24.21	0	51.11	0	18.88	0	35.66	0
LSD .05	6.10		34.40		13.92		10.63		10.75	
B. Kernel Weight (gm)										
AD 1 HR 1			3.57	-17.3	4.96	90.4	1.36	-75.9	5.29	75.1
AD 1 HR 2	2.78	-33.3			2.30	-25.5			5.23	73.2
AD 2 HR 1	2.72	-34.7			1.76	-43.7	3.68	-34.7	3.81	26.1
AD 2 HR 2	2.21	-47.0	1.21	-72.0	2.42	-22.7			4.84	60.2
Control	4.17	0	4.32	0	3.13	0	5.64	0	3.02	0
LSD .05	.76		2.186		4.93		3.94		1.09	
C. Tiller Number										
AD 1 HR 1			3.00	-18.0	3.00	-18.0	3.00	-50.0	3.00	-30.7
AD 1 HR 2	2.00	-53.8			3.00	-18.0			2.00	-53.8
AD 2 HR 1	2.33	-46.2			3.00	-18.0	1.50	-75.0	4.33	0
AD 2 HR 2	2.66	-38.5	2.50	-31.7	3.00	-18.0			5.66	30.7
Control	4.33	0	3.66	0	3.66	0	6.00	0	4.33	0
LSD .05	1.32		1.89		1.04		2.70		1.20	

AD 1: First Application Date - three to five leaf growth stage
AD 2: Second Application Date - five to six tiller growth stage
HR 1: Herbicide Rate 1 - 1.4 kg/ha
HR 2: Herbicide Rate 2 - 2.8 kg/ha

Appendix Table 15.

Means of kernel number, kernel weight, tiller number and percent deviation from the control for five winter wheat cultivars treated with two rates of 2,4-D applied on two different dates. Greenhouse, 1979-80.

	CULTIVARS									
	Bezostaya		Daws		Maris Hobbit		Stephens		Yamhill	
Treatments	Mean	% Deviation	Mean	% Deviation	Mean	% Deviation	Mean	% Deviation	Mean	% Deviation
A. Kernel Number										
AD 1 HR 1	40.05	10.5	14.73	-39.1	68.66	34.3	30.55	61.8	22.77	-36.1
AD 1 HR 2	17.05	-52.9	14.77	-38.9	52.11	1.9	29.99	58.8	35.44	- 0.6
AD 2 HR 1	26.88	-25.8	20.00	-17.4			28.33	50.0	20.99	-41.1
AD 2 HR 2	28.46	-21.4	--		40.16	-21.4	45.33	40.1	21.16	-40.6
Control	36.22	0	24.21	0	51.11	0	18.88	0	35.66	0
LSD .05	14.22		11.53		18.0		12.21		11.59	
B. Kernel Weight (gm)										
AD 1 HR 1	2.96	-19.8	2.50	-42.1	2.61	-16.6	4.11	-27.1	4.54	50.3
AD 1 HR 2	2.94	-20.3	1.80	-58.3	5.00	59.7	3.55	-37.0	4.17	34.7
AD 2 HR 1	5.06	37.1	3.57	-17.3			4.34	-23.0	6.15	103.6
AD 2 HR 2	2.46	-33.3			2.04	-34.8	3.41	-39.5	5.26	74.2
Control	3.69	0	4.32	0	3.13	0	5.64	0	3.02	0
LSD .05	.52		.35		.56		.46		.52	
C. Tiller Number										
AD 1 HR 1	2.66	-33.5	3.00	-18.0	3.66	0	6.33	5.5	4.33	0
AD 1 HR 2	4.00	0	2.66	-27.3	3.33	- 9.0	6.33	5.5	5.33	23.1
AD 2 HR 1	3.66	- 8.5	3.00	-18.0			4.00	-33.3	4.66	7.6
AD 2 HR 2	3.66	- 8.5			2.50	-31.7	7.00	16.7	5.33	23.1
Control	4.00	0	3.66	0	3.66	0	6.00	0	4.33	0
LSD .05	.81		1.09		.76		1.90		1.07	

AD 1: First Application Date - five to six tiller growth stage
AD 2: Second Application Date - three to five node growth stage
HR 1: Herbicide Rate 1 - 1.4 kg/ha
HR 2: Herbicide Rate 2 - 2.8 kg/ha

Appendix Table 16.

Means of kernel number, kernel weight, tiller number and percent deviation from the control for three winter wheat cultivars treated with one rate of diuron applied on one date. Growth Chamber, 1979-80.

	CULTIVARS					
	Bezostaya		Stephens		Yamhill	
Treatments	Mean	% Deviation	Mean	% Deviation	Mean	% Deviation
A. Kernel Number						
AD 1 HR 1	65.66	-31.6	13.00	61.4	28.00	12.0
Control	96.00	0	33.66	0	25.00	0
LSD .05	34.04		30.68		27.77	
B. Kernel Weight						
AD 1 HR 1	2.20	-41.5	3.22	-1.8	3.18	-11.7
Control	3.76	0	3.34	0	3.60	0
LSD .05	1.16		1.33		1.10	
C. Tiller Number						
AD 1 HR 1	2.66	-27.3	2.33	-39.0	3.00	- 9.9
Control	3.60	0	3.33	0	3.33	0
LSD .05	1.85		1.85		1.31	

AD 1: Application Date - three to five leaf growth stage
HR 1: Herbicide Rate - 1.4 kg/ha

Appendix Table 17.

Estimated and observed percent deviation of yield from the control for five winter wheat cultivars as affected by herbicides. East Farm, 1979-80.

Cultivars, Observation Date and % Deviation	HERBICIDE TREATMENTS											
	Diuron				Hoe 23408				2,4-D			
	AD 1		AD 2		AD 1		AD 2		AD 1		AD 2	
	HR 1	HR 2	HR 1	HR 2	HR 1	HR 2	HR 1	HR 2	HR 1	HR 2	HR 1	HR 2
Bezostaya												
Feb. 19, 1980	40	90	--	--	5	30	--	--	0	5	--	--
April 21, 1980	35	95	5	20	5	15	5	5	5	15	--	--
May 15, 1980	40	70	10	25	10	25	0	5	5	15	60	70
July 25, 1980	30	80	25	40	5	10	15	10	10	35	70	80
Deviation	-23.7	-78.4	-23.7	-20	-15.7	-19.6	-14.0	-11.8	-10.7	-39.0	-70.6	-75
Daws												
Feb. 19, 1980	30	80	--	--	15	40	--	--	10	15	--	--
April 21, 1980	20	60	0	40	10	25	15	30	10	10	--	--
June 3, 1980	25	60	0	30	5	25	10	25	5	20	5	10
July 25, 1980	15	40	5	30	5	20	5	5	0	10	0	0
Deviation	6.9	-49.7	13.3	-58.1	9.2	-20.8	20.1	14.9	12.7	15.8	12.2	10.2
Maris Hobbit												
Feb. 19, 1980	40	85	--	--	10	40	--	--	10	0	--	--
April 21, 1980	30	80	15	30	15	20	20	35	5	5	--	--
June 3, 1980	35	70	5	45	10	25	10	25	10	0	5	15
July 25, 1980	25	90	10	70	5	20	10	15	20	15	5	10
Deviation	-22.9	-84.1	-5.2	-58.9	-8.0	-31.0	-19.7	-14.2	-13.0	-15.0	-8.4	2.3
Stephens												
Feb. 19, 1980	40	80	--	--	10	25	--	--	10	15	--	--
April 21, 1980	20	60	15	30	10	35	15	20	10	10	--	--
June 3, 1980	35	80	10	25	15	25	10	10	5	5	5	10
July 25, 1980	20	75	35	40	10	10	5	10	0	5	5	5
Deviation	-11.1	-74.2	1.1	-49.6	0	-23.3	-7.4	-9.4	0	-1.7	-4.8	-3.9
Yamhill												
Feb. 19, 1980	30	60	--	--	10	30	--	--		10	--	--
April 21, 1980	15	70	15	30	5	20	10	15		5	--	--
June 3, 1980	20	50	5	20	10	30	5	5		10	30	10
July 15, 1980	20	70	15	45	20	30	20	25		20	45	15
Deviation	-20.2	-63.4	-2.4	-50.2	-9.8	-36.5	-1.8	-8.6	-26.8	-9.1	-45.4	-0.1

AD: Application Date *Evaluation scale: 0 = no effect
HR: Herbicide Rate 100 = complete kill

Appendix Figure 1.

Field Experiment Design*

Herbicides

H1: Diuron
H2: Diclofop
H3: 2,4-D

Cp: Competition
Ct: Control

Rates

R1: 1.4 kg/ha
R2: 2.8 kg/ha

Dates

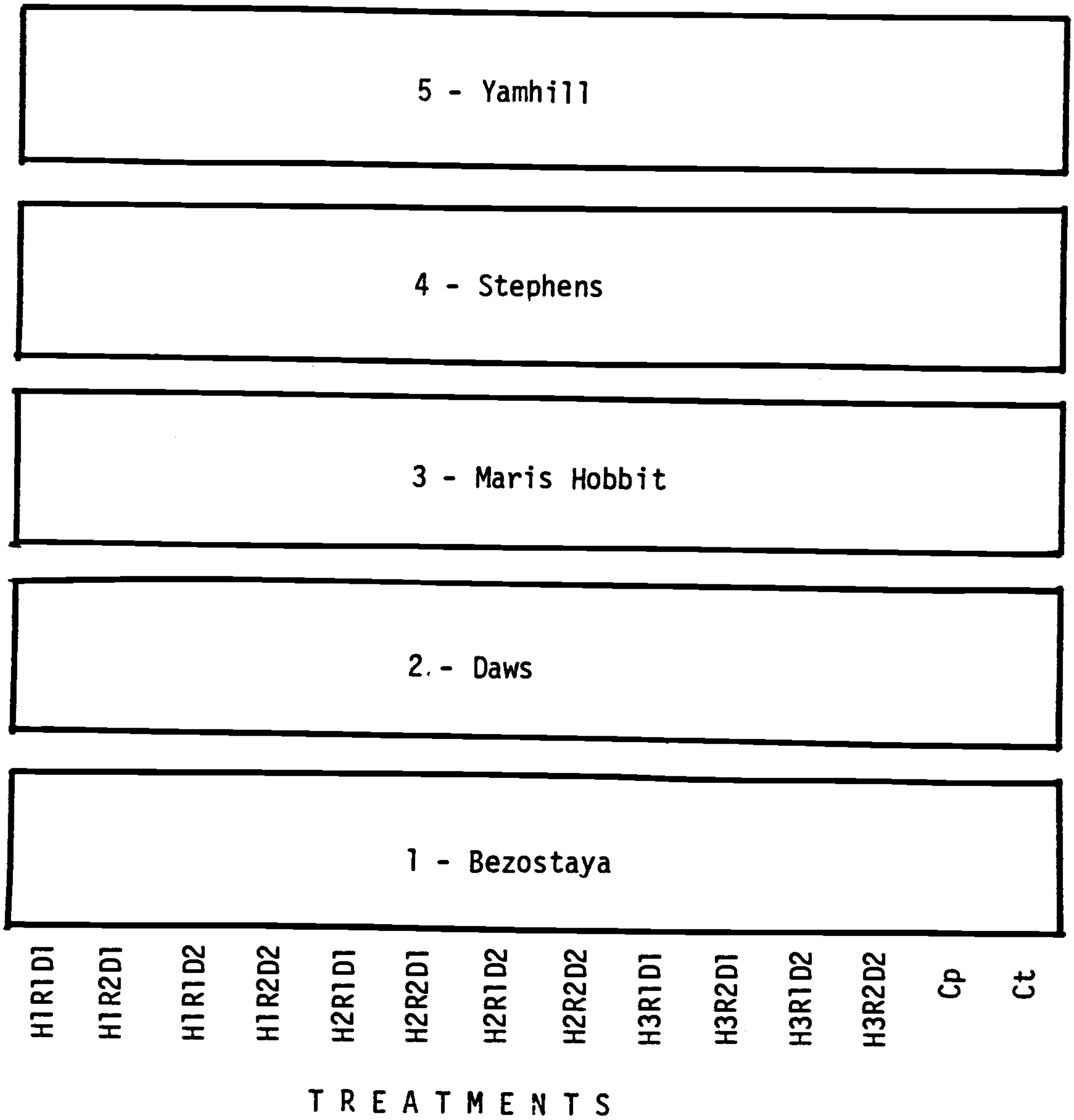
Diuron and Diclofop

D1: 3 to 5 leaves
D2: 5 to 6 tillers

2,4-D

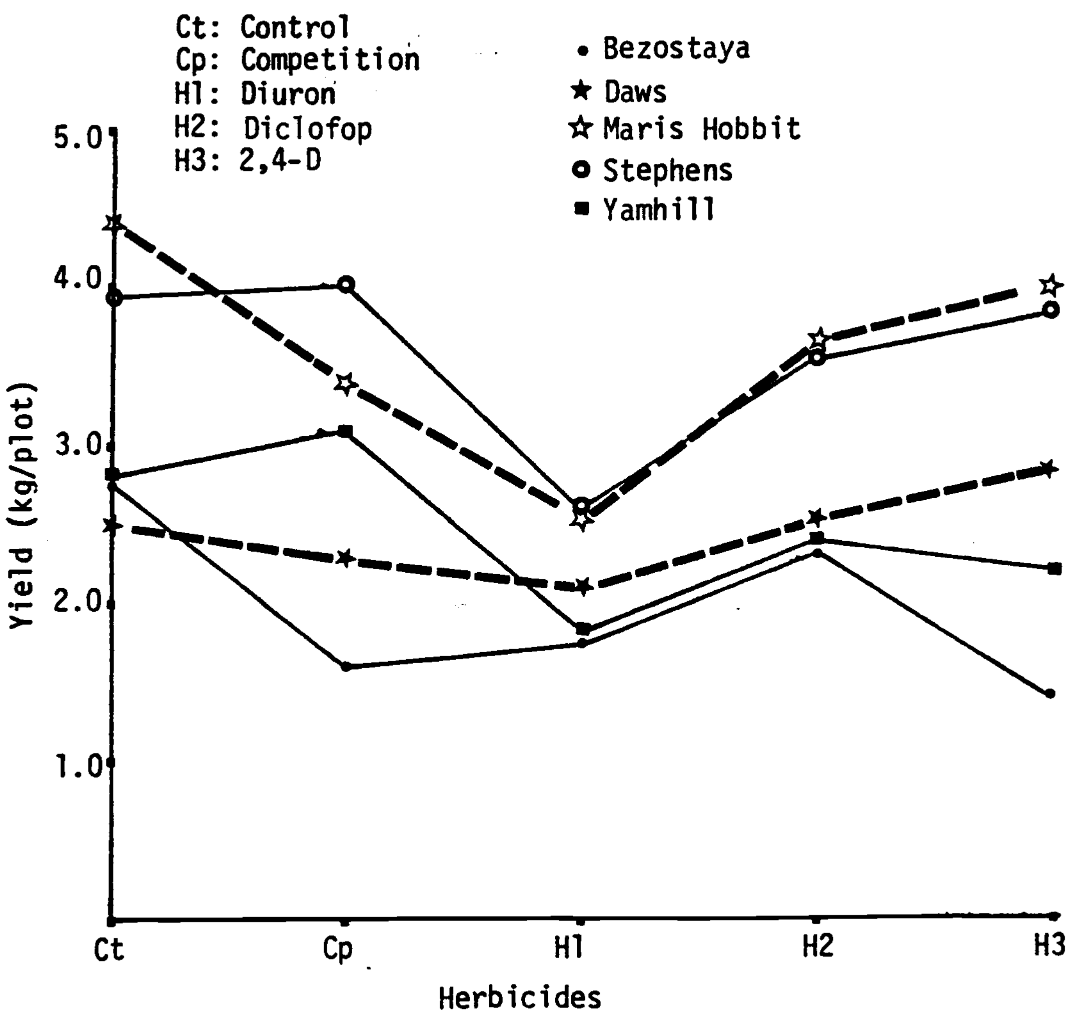
D1: 5 to 6 tillers
D2: 3 to 5 nodes

*Design shown for Replication I, treatments and varieties were randomized for Replications II and III.



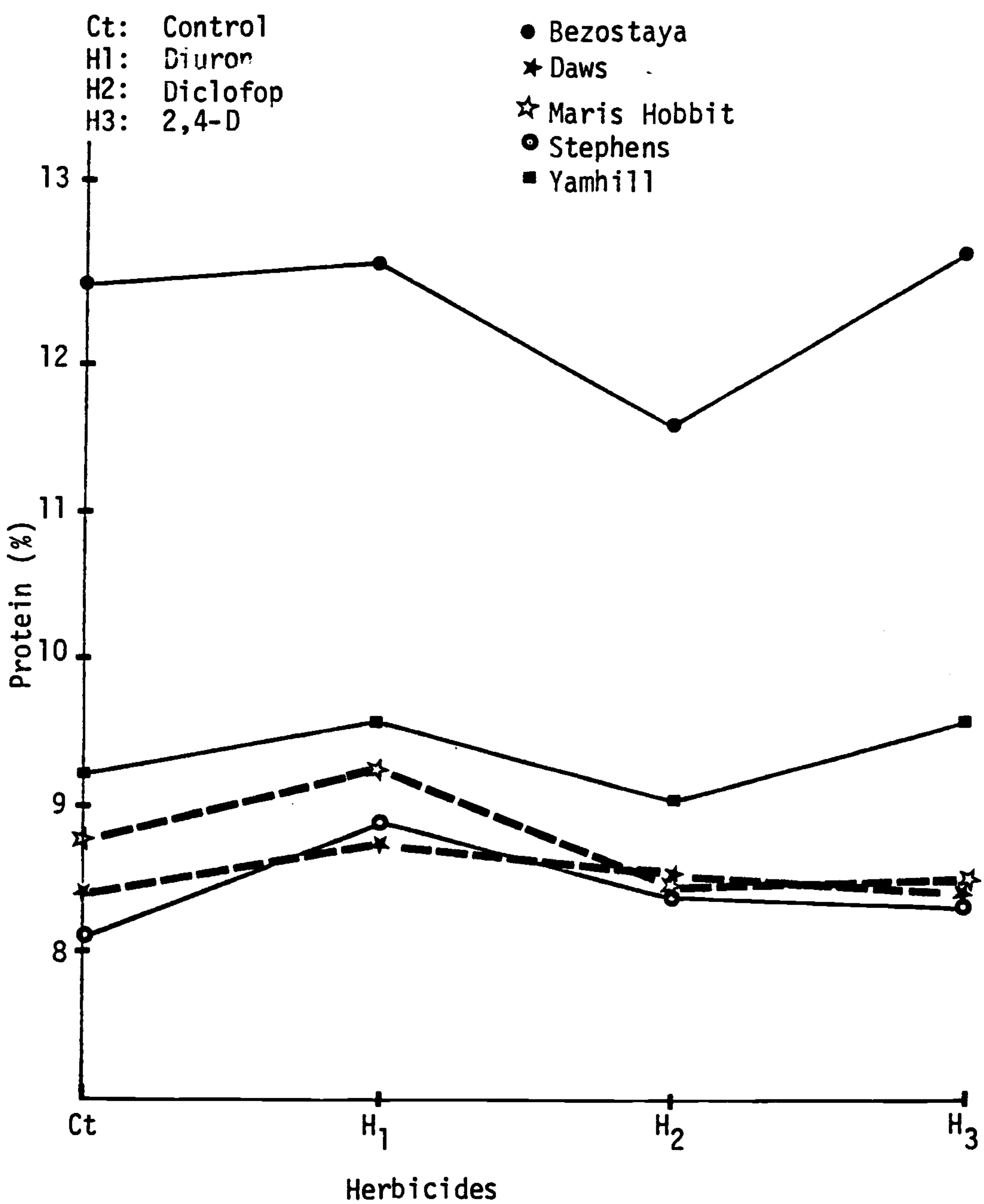
Appendix Figure 2

Yield vs Herbicide Family



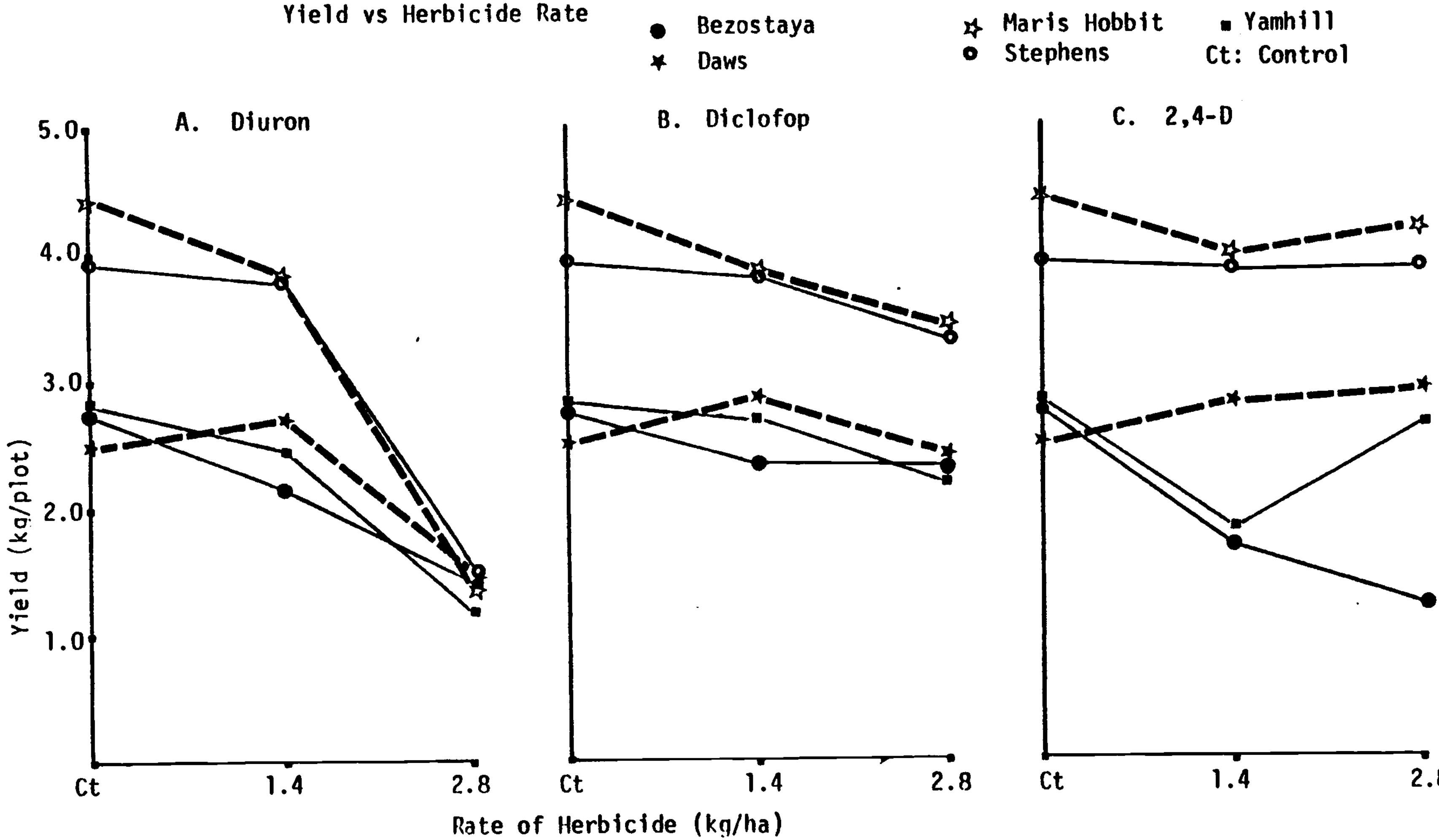
Appendix Figure 3

Protein (%) vs Herbicide Family



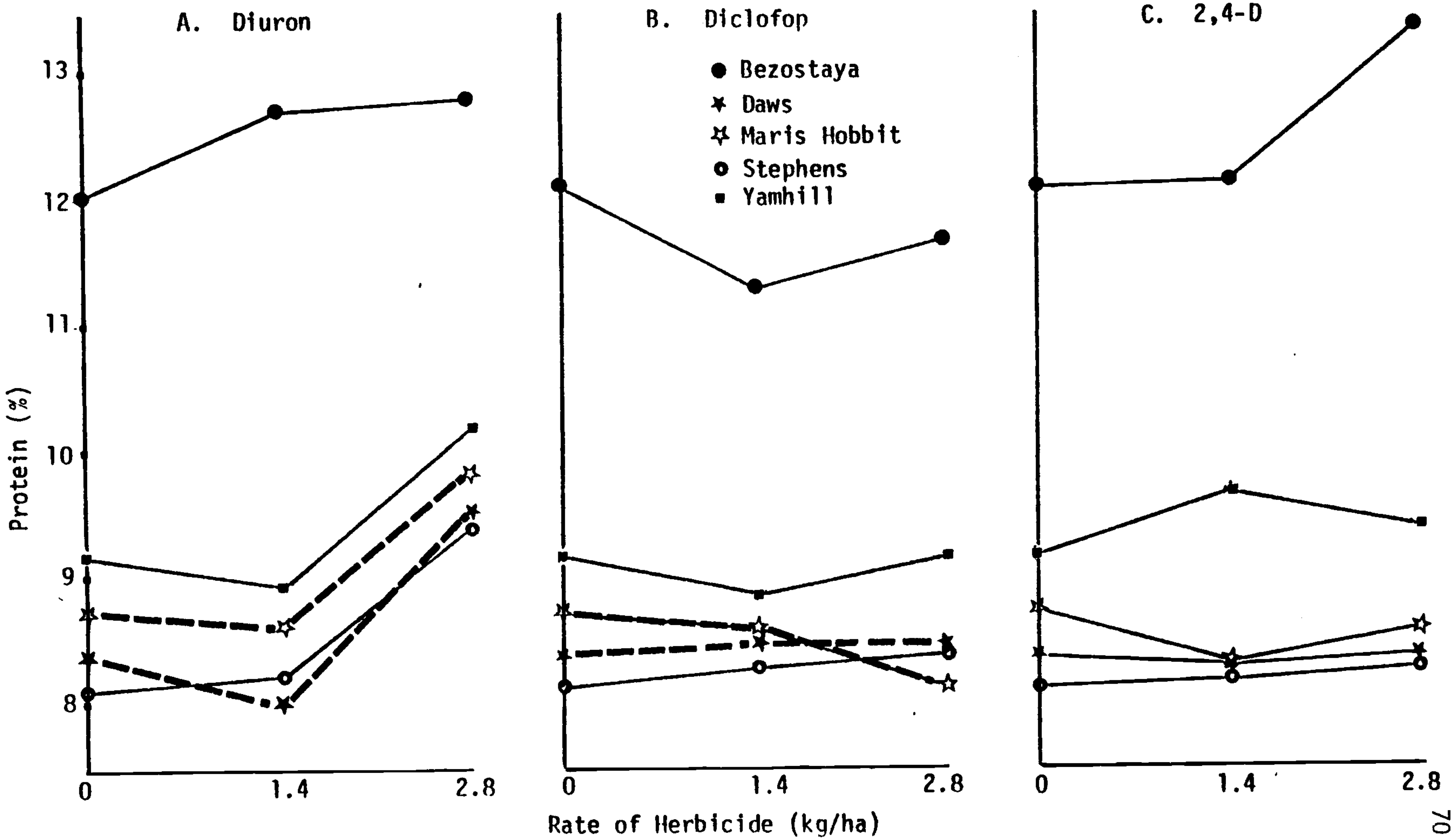
Appendix Figure 4

Yield vs Herbicide Rate



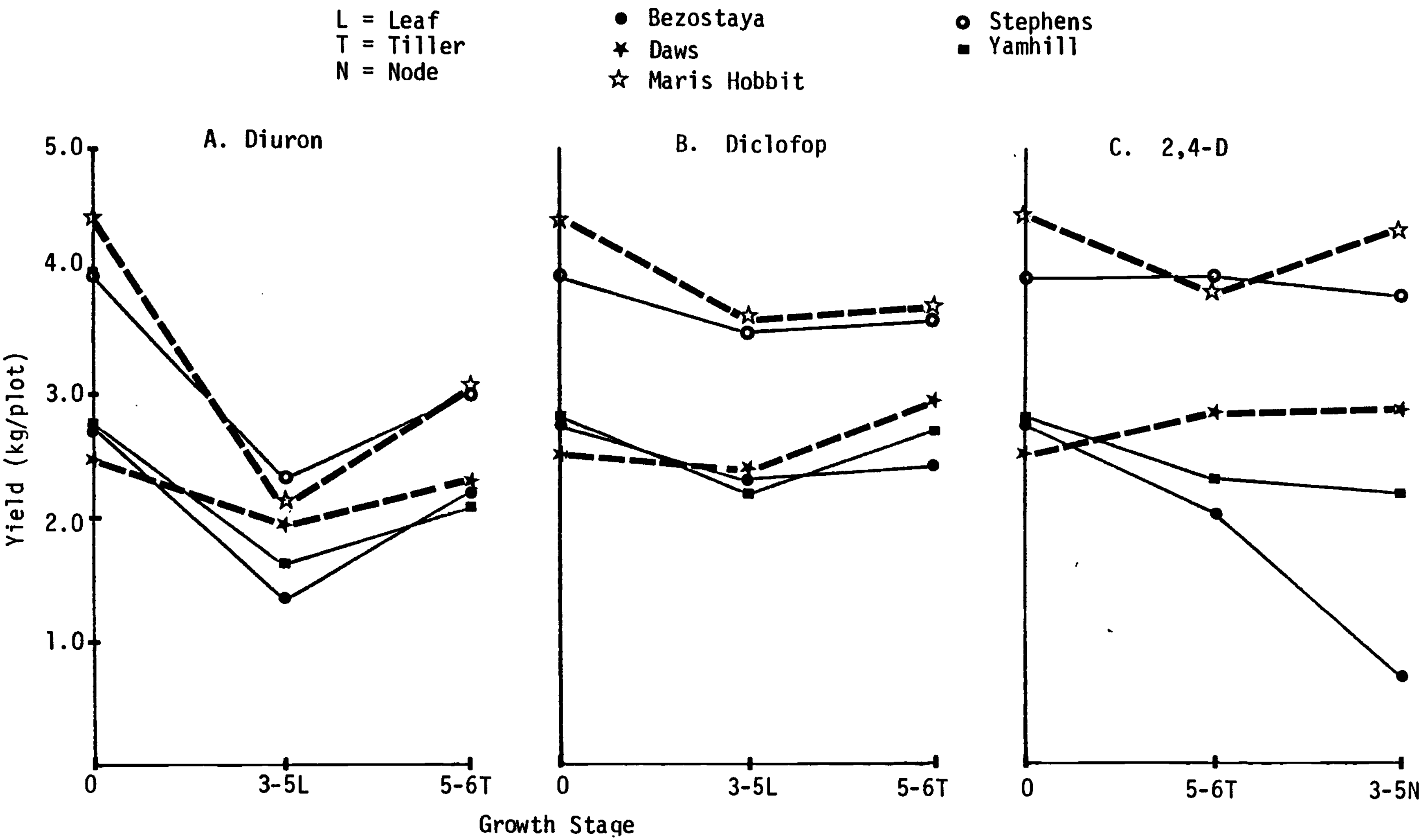
Appendix Figure 5

Protein (%) vs Herbicide Rate



Appendix Figure 6.

Yield vs Herbicide Application Date.



Appendix Figure 7.
Protein (%) vs Herbicide Application Date