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The effects of some soil- and foliar-borne biotic factors on grain yield and the components of yield were evaluated using five winter wheat varieties sown at two dates. Within each planting date, varieties were grown under four different combinations of two soil treatments (fumigation and nonfumigation) and two foliar treatments (fungicide protection and nonprotection).

The conditions created by fumigation induced a luxuriant growth and subsequent lodging of all varieties especially in the first date of planting. This prevented an accurate assessment to be made on the influence of biotic soil factors on grain yield. Despite the larger number of fertile spikes observed for all varieties when sown in fumigated plots, grain yield, grain weight of ten spikes, harvest index, and weight of 300 kernels were reduced as a result of lodging.

The comparison between protected and nonprotected plots revealed that foliar diseases were important in causing grain yield reductions. Development of foliar diseases was accelerated in

nonprotected, fumigated plots due to the lodging. This was also accompanied by a greater reduction in grain yield and the components of yield.

Date of planting did influence the time of expression of foliar diseases as a consequence of lodging and the more luxuriant growth which created a more favorable microclimate for the pathogen. Also, field proximity between dates of planting may have increased the inoculum pressure in the second planting date resulting in greater yield reduction.

Yield Loss Assessment in Nonprotected Winter Wheat Varieties
(*Triticum aestivum*, L. em Thell)

by

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IN DEDICATION TO:

Elisa, my wife

Francisco and Josefina, my parents

and

Vernon and Esther, my wife's parents

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INTRODUCTION

To be economically competitive a wheat variety must be resistant or tolerant to many abiotic and biotic factors. However, as the number of factors is increased the less likely it is that progeny in segregating populations can be found which have all the desired attributes. Therefore, as the breeders manipulate the genetics of the wheat plant through hybridization, they must identify the most limiting factors to maximum production and establish priorities.

With the exception of high cash crops where the producer can afford to use more pesticides, in most field crops like wheat, disease resistance is the most economic means of protection. In the Pacific Northwest there are many soil and foliar pathogens which attack wheat. These pathogens incite diseases due to the favorable environmental conditions prevailing in this region. Also there are many physiological races of various pathogens. Thus, when these disease complexes are added to all the other agronomic traits required of new varieties, the wheat breeders' task becomes complicated.

Wheat breeders are becoming more aware that an increasing amount of their resources are being expended just to maintain existing yield levels. In fact, concerns have been expressed that yield plateaus have been reached with very little opportunity to increase yield per se. If such is the case, then breeders need to become more efficient and focus on improving those traits which have the greatest impact on grain yield and the quality of the end product.

The objective of this study was to assess the importance of soil and foliar biotic factors on grain yield of five winter wheat varieties. This would help substantiate if the breeders are justified in placing as much effort in breeding for resistance or tolerance to such biotic stresses.

LITERATURE REVIEW

Crop losses may be caused by numerous biotic agents. In cultivated plants, pathogenic agents which include organisms that attack the foliage, spikes and roots are recognized as important factors influencing the final economic end product.

Commonly used definitions and classifications are worth mentioning as they relate to the present crop loss study.

Crop Loss: Crop loss may be defined as the difference between actual and attainable yield. The latter is defined as the yield obtained when crops are grown under optimal conditions using the available modern agronomic practices.

Theoretical Loss: Theoretical loss is defined as the difference between actual and theoretical yield. The latter is estimated under the best conditions according to calculations based on considerations from plant and crop physiologists.

Economic Loss: Economic loss is the difference between actual and economic yield. Economic yield is the highest yield that can be obtained using affordable management practices.

Potential and Actual Losses: Potential losses are those that may occur in the absence of control measures. Actual losses refer to those which have already and are still occurring.

Direct and Indirect Losses: Direct losses refer to those of quantity or quality of produce and of yield capacity. Indirect losses are those losses encompassing the economical and social effects of plant diseases beyond the immediate agricultural impact.

Included are the not-well-known and less tangible losses to the abiotic factors as a result of unavoidable environmental stresses.

Primary and Secondary Losses: Primary losses are preharvest and postharvest losses of plant products due to plant diseases. Secondary losses are losses in the yielding capacity of future crops as a result of the cumulative effect of soil-, seed-, or tuber-borne diseases.

Incidental Losses: Incidental losses refer to those occurring only once or at irregular intervals. Historically, important epidemics causing incidental losses can be mentioned. For example, the devastating 1932 epidemic of Stem Rust, *Puccinia graminis*, on wheat in Eastern Europe was favored by exceptional weather conditions over a prolonged period of time. Another example is the 1950 epidemic of Stem Rust on wheat in the United States caused by the appearance of the race 15B of the pathogen.

Regular Losses: Regular losses are those losses that occur each season in more or less equal amounts. These represent greater losses when considered in the long-term average. By far, they are the most important and subjected to crop loss studies because they imply the constant use of control measures in an attempt to rescue yield from damage caused by pathogens.

Transitional and Structural Losses: Transitional losses are those of a temporary nature mainly occurring when farming systems are modified. Structural losses are unavoidable losses in a given agricultural situation.

Recognized and Hidden Losses: Recognized losses include all types previously mentioned. Hidden losses refer to those caused by uncontrolled factors interfering with the full expression of the genetic potential of the crop variety. Determining the genetic potential or maximum theoretical yield involves growing the crop under conditions where losses are prevented.

Determination of Crop Losses

The subject of determining crop losses has been extensively reviewed by Zadoks and Schein (1979) and James (1974 and 1983). Crop loss assessment can be carried out using different techniques. Field experiments are more likely to provide reliable information based on attainable or economic yield. This technique is similar to the technique of yield determination; however, records must be kept on growth stages and disease severities at regular intervals throughout the growing season.

Le Clerg (1971) points out that loss assessment field experiments have much in common with agronomic and horticultural yield tests because of variability caused by such factors as crop varieties and rotations sequences, soil types and fertility, time of planting, temperature, rainfall, etc. He also explains that experiments are complicated by the pest(s) component and by its (their) interaction with the crop plant under a given set of growing conditions. His comments support the general opinion that absolute values for losses cannot therefore be obtained in practice; however, useful results can be obtained from properly designed and well-conducted field experiments.

In spite of being one of the most reliable methods for crop loss assessment, experimental designs have some restrictions, for example, plot size and shape, interplot distance, and number of replications which should be selected to produce results representative of losses in commercial fields. James and Shih (1973) recommend conducting preliminary experiments to determine sample sizes needed to produce results with a certain level of precision. Madden (1983) comments that "often there is a conflict between the desired level of precision and that obtainable in the experiment within realistic limits of time and resources."

The three most common experimental designs used for determining the effects of disease intensity on crop losses are randomized complete block, latin square and split-plot. The split-plot design is considered to have more practical advantages when randomization of factors and levels in the field are difficult to achieve with other experimental designs. It has the advantage that the adjacent plots or rows may be more homogeneous than separated plots or rows, and this increases the sensitivity of the analysis for this design, even though the degrees of freedom are lower.

When carrying out experiments to estimate crop losses, a disease-free control is essential as the point of reference to estimate the loss in yield. In experiments where the objective is to quantify the effect of varying levels of disease at different growth stages, additional treatments should be included which combine varying levels of disease at different growth stages. James (1983) suggested that experiments which include varying levels of disease should consider the effect of interplot interference due to the movement of air-borne spores from one plot to another. Large (1966) concluded that interplot interference is not important in disease loss experiments when the control plots are free from disease. James et al. (1968), Large (1945), and Large and Doling (1962), cited by James (1974) concluded that systemic fungicides suppress interplot interference more than erradicant or protectant fungicides; however, systemic fungicides may not give complete control throughout the life of some crops.

An estimate of crop losses due to diseases depends on the presence of the causal agent. In this regard, a general consensus exists among researchers to conduct disease loss experiments under natural infection. Development of an epidemic depends on the presence of a susceptible host, a virulent pathogen and the appropriate environmental conditions. Agronomic practices should not be forgotten as they may influence any of the factors previously mentioned. In practice, due to unpredictability of epidemic development, chances of disease stress can be increased by means of artificial inoculations. Forrer and Zadoks (1983) reported that yield and average kernel weight differed significantly between inoculated and noninoculated plots in wheat in relation to leaf necrosis caused by *Septoria tritici*. Bronniman (1968), in Switzerland, showed that under conditions of artificial infection (inoculation), *Septoria nodorum* could cause yield losses of up to 65 percent. In Australia, Shipton (1968) recorded yield reduction of 29 percent in field experiments where natural infection with both Septoria diseases where partially controlled by spraying with fungicides. Cooke and Jones (1970) found that artificial infection of the spikes of spring wheat resulted in yield losses of up to 19.5 percent with Septoria nodorum and 9.1 percent with Septoria tritici.

Loss Model for Crops

Abundant information is available in the current literature regarding crop loss models. Symposia have been organized to present and evaluate methodologies and techniques available for quantifying food-crop yield reductions that may be attributed primarily to stress factors associated with plant disease (Pennypacker, 1983). For the past several years, the Journal of Phytopathology has included a section on disease detection and losses.

Evaluation of crop loss models is not a topic covered in the present study. However, this topic is addressed by the following authors: Chiarappa (1971), James (1974), Calpouzos et al. (1976), Richardson et al. (1976), Zadoks and Schein (1979), Madden et al. (1981 a and b), Madden (1983), Teng (1983), and James (1983).

Regression analysis has been a widely used technique to describe the relationship between disease level and loss. The regression models use one or more variables to predict loss. Commonly used predictor variables are disease severity at one or more points in time, growth stage at which a certain disease level is reached, area under the disease progress curve, and slope of a linearized disease progress curve (James, 1983 and Madden et al., 1981a and 1981b). Contemporary models are usually selected with ordinary least squares regression and have been developed to satisfy specific cases without inherent flexibility. Madden et al. (1981a) developed a generalized non-linear model with inherent flexibility to characterize the disease level-loss relationship. This model, in addition to providing loss predictions at various levels of disease, also incorporates a threshold disease level below which no loss occurs. A maximum level of loss that may occur prior to the maximum amount of disease and a large family of curve slopes to depict disease level-loss relationships are also included.

Physiological and Morphological Effects of Diseases

Generally, factors affecting growth, development and productivity of plants are first classified as abiotic and biotic factors. Bateman (1979) referred by Teng (1983) defines a disease as "the injurious alteration of one or more ordered processes of energy utilization in a living system caused by the continued irritation of a primary factor or factors". This definition of disease implies both transient and permanent effects of pathogens on plant growth and development. Pathogens are considered one of the main biotic factors preventing crop plants from expressing their full yield potential, (Teng, 1983).

There are several levels at which the effects of pest populations on plants can be coupled to carbon flow processes in crop growth simulators. Pests may reduce inputs such as light, CO_2 and water; therefore they directly affect rates of metabolic and growth processes or may remove previously produced assimilates or crop structural materials, as suggested by Boot et al. (1983). These authors also classify pests as stand and photosynthetic rate reducers, leaf senescence accelerators, light stealers, assimilate sappers, tissue users, and turgor reducers.

Yield reduction caused by disease is fully explained by the negative effect the disease has on the physiology of the plant, and in turn the components of yield. Different researchers have reported on the effect different diseases have on different yield components. Forrer and Zadoks (1983) reported that in wheat inoculated with Septoria tritici, a decrease of average kernel weight occurred which completely explained yield loss. Ziv and Eyal (1978), studying the effect of different isolates of Septoria tritici on tolerant and nontolerant wheat varieties, reported that kernel weight per spike, 1000-kernel weight, and number of kernels/spike were reduced when plants were inoculated. This reduction was higher in non-tolerant varieties.

Jacobsen (1977) presented results on the effect several diseases had on wheat yield and test weight using fungicides. He observed that more precise information on kernel weight could have been gathered by hand harvesting the grain since the combine blows out much of the light-weight grain with the chaff. Backmann (1962) and Kelman and Cook (1977) showed that yield increases following application of fungicides are due primarily to increased kernel weight.

Hendrix and Fuchs (1970), studying the influence of fall Stripe Rust infection on tillering and yield of wheat, reported that Stripe Rust often occurs as conspicuous centers of infection - "hot spots" - in early-seeded fields of young wheat in late fall in the Pacific Northwest. In their study, they found that hotspot plants produced 18.6 to 24% fewer tillers, 19.6 to 25.4% less straw, and 18.3 to 30.8% less kernels than their "healthy" counterparts.

Soil Fumigation

As already mentioned in the classification of yield losses, determining the genetic potential of a variety involves growing a crop under conditions where losses are prevented. The criteria to determine how healthy a plant or a crop is relies mainly on its foliage appearance with little consideration regarding the roots. Besides giving anchorage and functioning as the collector of moisture and nutrients, roots are also exposed to environmental conditions directly affecting plant development, growth, size and activities, and subsequently the growth and yield of above ground plant parts.

Compared to foliar, soil-borne biotic factors are more difficult to detect by simple observation. In many instances they may be limiting factors in establishing or obtaining a closer estimate of the yield genetic potential of a crop. According to Cook and Haglund (1982), the winter wheat/fallow rotation of the Pacific Northwest States has favored the incidence of Strawbreaker or Eyespot Foot Rot (*Pseudocercosporella herpotricoides*), Cephalosporium Stripe (*Cephalosporium gramineum*), Root Crown Rot (*Fusarium roseum* culmorum) and Basal Stem Rot (F. roseum graminearum). This problem is more severe when wheat is sown in early fall.

Cook et al (1968) reported Take-All caused by Gaeumannomyces graminis var. tritici is considered the main disease caused by a soil-borne pathogen in the annual-cropped irrigated wheat in the Columbia Basin and Snake River Plains areas.

Soil temperature, oxygen content and the supply of water and nutrients are important features of the root environment. Favorable growing conditions promote rapid germination, seedling establishment, and rapid and vigorous root growth. These conditions may be key factors in successful crop production. Stoskopf (1981) noted that a major factor associated with winter plant survival of annuals is the build-up of adequate plant food reserves to withstand stress conditions. He pointed out that as temperatures decline in the fall, growth is slowed. Therefore, winter annuals such as fall-seeded cereals must be planted in time to allow for the development of a sufficient leaf area and root growth and for differentiation of tiller buds.

Cook and Haglund (1982) reported that gaps of 10-20 cm without plants are common in late planted winter wheat fields in spite of seeding rates of about 100 Kg/ha. Related to this problem is the presence of small, poorly tillered plants intermixed with large vigorous plants. According to these researchers, those fields show many symptoms to indicate root disease problems other than those currently recognized in the Pacific Northwest. In no-till wheat experiments, Cook et al. (1980) observed Pythium Root Rot associated with poor plant development in late planted wheat fields. These authors noted that preliminary studies involving soil fumigation had indicated these problems were associated with harmful soil organisms.

Fumigation studies carried out by Cook and Haglund (1982) in wheat included work to distinguish between a plant growth response caused by release of mineral nutrients and a growth response caused by elimination of pathogens. This work also attempted to determine which pathogens are most important in late-sown annual-cropped wheat and the role, if any, of Pythium. These researchers reported increases in yield of 15 to 20 percent, with increases of 25 percent and more at some minimum and no-till sites where the growth response to fumigation was most evident as a result of improved root health. They also reported that wheat plants when sown in a fumigated soil were taller and more uniform in height, had greater leaf area, were earlier in heading and anthesis, had 20 to 25 percent more tillers, and had a deeper root penetration. Regarding diseases present in their experiments, Cook and Haglund (1982) commented that disease problems such as Cephalosporium Stripe and Take-all, tended to mask Pythium damage; but in the absence of these acute diseases, losses of 750-1000 kg/ha still occurred in the majority of late-sown and annual cropped fields and particularly minimum and no-till fields apparently because of Pythium Root Rot.

Soil Fumigation and Foliage Protection

Protecting the foliage of a plant by means of fungicide applications alone may not give full protection against harmful organisms. Thus, a way to approach the genetic yield potential is offered by the combination of soil fumigation and foliar applications of fungicide. Several researchers have used soil fumigation as a means to control soil-borne pathogens and achieve the full production capability of wheat and barley (Bruehl, 1957; Ebbels, 1969 and 1970; Rovira, 1976; Williams and Salt, 1970; McLaughlin and Melhus, 1943; and Cook and Haglund, 1982). An increased growth response is the most common finding after soil fumigation treatment. MacLaughlin and Melhus (1943) explained this increased growth as being a result of Pythium control after soil fumigation. Rovira (1976) attributed this response to an increased availability of nutrients in the soil as a result of fumigation.

Only two reports were found regarding studies on the effect of the combination of soil fumigation and foliar fungicides on grain yield and other characteristics of wheat. Frank et al. (1980a) reported the effects of soil fumigation (Methyl bromide) and foliar fungicides (Bayleton 50W plus Dithane M-45) on grain yield of six varieties of hard red winter wheat. The spray treatment was found to provide excellent Powdery Mildew (*Erysiphe graminis* f. sp. tritici) control on all varieties. However, Septoria Leaf Blight was not suppressed by the Bayleton-Dithane foliar spray treatment used. Their results indicated that the foliar spray treatment showed a consistently greater grain yield, while soil fumigation did not.

Moreover, the varieties Illinois 33 and Century 35 showed a statistically significant grain yield reduction which, according to these researchers, may have been due to fumigant interference with competing soil organisms including mycorrizal relationships. The data indicated that both soil- and foliar-borne biotic factors may cause severe losses in Hard Red Winter Wheat yields. It is the opinion of Frank et al. (1980a) that a complete generalization may not be made with regard to yield response to soil fumigation because in one variety, Dakota 4, a yield increase of almost 50 percent was obtained by the combination of soil fumigation and foliar fungicide treatment.

Frank et al. (1980b) reported the effects of soil fumigation and foliar fungicides on Powdery Mildew, Septoria Leaf Blotch, and the resulting grain yield. Six varieties of Soft Red Winter Wheat were used. Data indicated that soil fumigation resulted in a consistent trend of yield increases in most of the foliarly protected plots. The foliar spray treatment, Bayleton 50W-Dithane M-45, resulted in a consistent trend of yield increase in both fumigated and nonfumigated plots. However, in the variety Redcoat, a yield increase due to foliar protection occurred only in the nonfumigated plots, while a yield reduction due to fumigation occurred in both foliarly protected and nonprotected plots. Again, they found that the spray treatment provided a consistent Powdery Mildew control for all varieties, and that Septoria Leaf Blotch control was partial with no variety being completely free of the disease. In this experiment, the Soft Red Winter Wheat variety MO-W9545 showed a yield increase of almost 50 percent when a combination of soil fumigation plus foliar fungicide treatment was employed.

Kittle and Gray (1982) studied the effect that interaction between soil- and foliar-borne biotic factors has on the yield and development of foliar diseases of soybeans. Results arising from their study are worth mentioning since it involved soil fumigation and foliar fungicide sprays. Soil fumigation reduced populations of *Macrophomina phaseolina* in crop residue and of M. *phaseolina*, *Mycoleptodiscus terrestria* and *Fusarium* spp. in roots. Fumigation also reduced vascular discoloration in stem and roots, but increased infection rate of *Septoria glycines* on leaves compared with check plots. Fungicide sprays reduced brown spot disease severity and S. *glycines* infection rate. When soil fumigation and fungicide spray treatments were combined, there was a 26 percent increase in yield compared to the untreated control.

From all reports found for this literature review, it can be summarized that wheat grain yield losses can be significantly avoided by protecting the crop from foliar- and/or soil-borne biotic factors. Regarding the effect of diseases on wheat grain yield components, most researchers have found that the effect of foliar diseases, when left uncontrolled, is on reducing kernel weight which directly translates into grain yield losses. Soil-borne biotic factors cause wheat grain yield reduction by interfering in the production of tillers. This causes a reduction in the amount of fertile spikes mainly when winter wheat is sown late in the fall.

MATERIALS AND METHODS

The effects of the combination of two foliar treatments (F), fungicide protection and nonprotection, with two soil treatments (S), soil fumigation and nonfumigation, were evaluated using five wheat varieties (V). Varieties included were Stephens, Hill, Yamhill, Daws and Lewjain. All five are commercially grown in the Pacific Northwest. The Analysis of Variance consisted of the following sources of variation: replications; main factors (S, F, and V); first-order interactions (SxF, SxV, and FxV); and a second-order interaction (SxVxF).

In the Fall of 1983, the experiment was sown on two planting dates (P): October 19 and November 8 on the Hyslop Agronomy Farm. On each planting date, the experiment was arranged as a split plot design with five replications. For practical reasons, the soil treatment factor was the main plot and the combination of varieties and foliar treatments were randomly assigned within each main plot. Six rows formed the subplots. Each six-row plot was 6.7 m long with 20.3 cm between rows. Seeding rate used was 90 kg/ha.

Ten days prior to the first planting date the soil was mechanically fumigated using a mixture of methyl bromide (67%) and chloropicrin (33%) at a rate of 390 kg/ha. The fumigated soil was covered with a plastic tarp for 72 hours and rototilled to promote aeration seven days before planting the first experiment.

The fungicide "Tilt" was used at a rate of 0.23 kg of a.i/ha as the foliar protectant. This fungicide was chosen because of its broad spectrum against the foliar diseases most likely to be present on wheat under the conditions observed in the Willamette Valley. Five fungicide sprays were applied at 5- to 12-day intervals beginning at the jointing stage and ending at the soft dough stage using the Large scale (Large, 1954).

Weeds were not a problem in any of the experiments. In the nonfumigated plots, an early application of Bromoxynil at a rate of 420 gr of a.i./ha was used for weed control.

Fertilizer application consisted of 33.6 kg of N/ha and 42 kg/ha of P incorporated prior to planting using the 16-20-00 formulation. A split application of 168 kg of N/ha was carried out in two equal amounts. The first application was on February 25 at the tillering stage, and the second application on May 5 when most of the varieties were at the jointing stage. For the nonfumigated plots, urea was used as the nitrogen (N) source. In the fumigated plots, the first spring application of N consisted of 67 kg of N/ha as ammonium chloride plus 17 kg of N/ha as ammonium sulphate while the second application consisted of 84 kg of N/ha applied as urea. Ammonium chloride and ammonium sulphate were used to enhance root protection in the fumigated plots.

The variety Stephens, which is susceptible to Septoria Leaf Blotch (Septoria tritici), was planted around each experiment to insure a uniform spread of natural infection.

Assessment of foliar diseases was initiated when senescence was first observed on the lower leaves. The first pathogen observed was Septoria tritici. No direct assessment of soil biotic factors was conducted. Foliar disease observations for all varieties not receiving foliar protection are presented in Appendix Tables 1 and 2 for the first and second planting dates respectively.

The following agronomic traits were measured on a plot basis:

Plant Height: Plant height was determined at maturity as an average of three random measurements taken within each plot. The measurement was taken from the soil surface to the tip of the spike of a main tiller.

Number of Fertile Spikes: The number of fertile spikes was recorded by counting the number of fertile spikes in a 60-cm sample taken from a central row.

Biological Yield: Biological yield was recorded by weighing the total biomass harvested in a 60-cm row.

Harvest Index: This measurement was computed for each plot as the ratio of grain weight to total biomass recorded in a 60-cm row.

Grain Weight of Ten Spikes: This measurement was recorded by determining the grain weight of ten randomly selected fertile spikes from each plot. These spikes were each threshed in an individual head thresher.

Weight of 300 Kernels: The weight of 300 kernels was determined from each of the samples for ten-spike grain weight.

Grain Yield: Grain yield was recorded on a kilograms per plot basis. All samples were uniformly cleaned and dried.

Heading Date: Heading date was determined when spikes appeared in approximately 50 percent of the main tillers.

Lodging: Lodging was recorded as a percent of the plot area where plants were no longer standing.

For each trait and planting date included in the study, the analysis of variance was carried out using the standard statistical procedures of the Split-Plot Design described by Steel and Torrie (1980). Data from the two planting dates were combined after an F test showed homogeneity of the error mean square terms in the two individual analyses of variance. This combination of experiments over planting dates resulted in the addition of the following sources of variation: P, PxS, PxF, PxV, PxSxV, PxFxV and PxSxFxV. Treatment comparisons were carried out by means of a protected Least Significant Difference (LSD) test.

RESULTS

Analysis of variance (ANOVA) for the traits measured at each planting date are presented in Appendix Tables 3 to 8. Tables 1, 2 and 3 provide results of the combined ANOVA over the two planting dates for all traits with the exception of heading date, where the error mean squares were not homogeneous. When comparing treatments, interactions including foliar (F) and soil (S) treatments will be emphasized.

Analysis of Variance

Observed mean square values from the combined ANOVA for seven agronomic traits are presented in Tables 1, 2 and 3. The planting date x variety x foliar treatment (PxVxF) and the planting date x soil treatment x variety x foliar treatment (PxSxVxF) interactions were not significant for any of the traits measured.

Differences in grain yield were noted for foliar treatments (F), variety (V); the first-order interactions soil treatments x foliar treatments (SxF), soil treatments x varieties (SxV), planting dates x varieties (PxV), varieties x foliar treatments (VxF); the second-order interactions soil treatments x varieties x foliar treatments (SxVxF), planting dates x soil treatments x varieties (PxSxV), and to a lesser extent for soil treatments (S), planting dates x soil treatments (PxS) and planting dates x foliar treatments (PxF). The coefficient of variation (C.V.) was low for subplots (8.81%) and high for the main plots (29.06%).

Table 1. Observed mean square values for grain yield per plot, fertile spikes per 60 cm row and ten-spike grain weight from a combined analysis of variance over two planting dates for two soil and two foliar treatments, and five soft-white winter wheat varieties sown at Hyslop Agronomy Farm in 1983-84.

Source of Variation	D.F.	Observed Mean Squares		
		Yield Per Plot	Spikes Per 60 cm	Ten-Spike Grain Weight
Replications/Planting dates (R/P)	8	0.4711	161.9219	21.9004
Planting dates (P)	1	4.3286	315.0000	1.2734
Soil treatments (S)	1	9.3291*	9,480.5625**	1,341.6172**
PxS	1	11.6106*	11.1250	141.1250**
Error (a)	8	1.0852	89.2500	3.7446
Varieties (V)	4	0.6938**	4,240.2250**	383.5567**
Foliar treatments (F)	1	50.4927**	99.3750	1,404.5000**
PxV	4	0.4996**	184.8438*	14.5195
PxF	1	0.3210*	91.0625	20.4844
SxV	4	1.4184**	175.0313*	10.4336
SxF	1	3.9138**	325.1875*	60.5000**
VxF	4	0.4577**	46.2031	8.0117
PxSxV	4	0.5759**	138.0156	25.6309*
PxSxF	1	0.0139	257.5625	5.1250
PxVxF	4	0.1875	30.0313	17.7422
SxVxF	4	0.6106**	64.7344	41.4883**
PxSxVxF	4	0.1151	85.1688	4.6553
Error (b)	144	0.0998	71.1290	8.8636

* Significant at the 5 percent probability level.
** Significant at the 1 percent probability level.

Table 2. Observed mean square values for biological yield per 60 cm row and harvest index from a combined analysis of variance over two planting dates for two soil and two foliar treatments, and five soft-white winter wheat varieties sown at Hyslop Agronomy Farm in 1983-84.

Source of Variation	D.F.	Observed Mean Squares: Biological Yield Per 60 cm row	Observed Mean Squares: Harvest Index
Replications/Planting dates (R/P)	8	3,752.25	31.6328
Planting dates (P)	1	4,608.00	627.6562**
Soil treatments (S)	1	8,192.00	2,257.6875**
PxS	1	23,762.00*	46.9688*
Error (a)	8	2,204.50	7.1953
Varieties (V)	4	2,977.00	36.9610**
Foliar treatments (F)	1	91,420.00**	1,662.0938**
PxV	4	1,991.00	7.6719
PxF	1	6,728.00*	0.1875
SxV	4	2,222.00	42.3906**
SxF	1	17,824.00**	275.4062**
VxF	4	1,280.50	72.2813**
PxSxV	4	1,861.00	9.6641
PxSxF	1	720.00	0.3438
PxVxF	4	309.00	11.4141
SxVxF	4	2,797.00	47.3906**
PxSxVxF	4	1,636.50	10.9024
Error (b)	144	1,673.40	8.8423

* Significant at the 5 percent probability level.
** Significant at the 1 percent probability level.

Table 3. Observed mean square values for 300-kernel weight and plant height from a combined analysis of variance over two planting dates for two soil and two foliar treatments, and five soft-white winter wheat varieties sown at Hyslop Agronomy Farm in 1983-84.

Source of Variation	D.F.	Observed Mean Squares	
		300-Kernel Weight	Plant Height
Replications/Planting dates (R/P)	8	1.2764	37.7188
Planting dates (P)	1	12.6836**	623.0000**
Soil treatments (S)	1	162.9453**	2,305.2500**
PxS	1	9.3711*	239.7500**
Error (a)	8	0.9875	7.4063
Varieties (V)	4	96.6904**	2,141.9375**
Foliar treatments (F)	1	403.0547**	70.5000**
PxV	4	0.8203	20.2500
PxF	1	0.1133	0.2500
SxV	4	11.4199**	28.4375*
SxF	1	28.4336**	0.2500
VxF	4	9.4638**	3.3125
PxSxV	4	0.1758	22.5000
PxSxF	1	0.0000	0.0000
PxVxF	4	0.7949	5.5625
SxVxF	4	7.2324**	2.3750
PxSxVxF	4	0.3472	12.5625
Error (b)	144	0.7107	9.7716

* Significant at the 5 percent probability level.
** Significant at the 1 percent probability level.

Differences in the number of fertile spikes in a 60-cm row were observed for S, V, and to a lesser extent for SxF, PxV and SxV. High coefficients of variation were obtained for both subplots (13.57%) and main plots (15.20%).

Grain weight of ten spikes differed for F, S, V, PxS, SxF, SxVxF, and to a lesser extent for PxSxV. The C.V. was high for subplots (13.88%) and low for main plots (9.02%).

Biological yield estimated from a 60-cm row sample resulted in differences at the 1% level for F, SxF, and at the 5% level for PxS and PxF interactions. The C.V. was high for both subplots (13.47%) and main plots (15.45%).

Observed mean square values involving harvest index for S, F, P, SxF, VxF, SxVxF, SxV, and V were large, with a smaller but significant value for the PxS interaction. The C.V. values were low for both subplots and main plots, 7.83% and 7.06%, respectively.

Differences in weight of 300 kernels were observed for F, S, V, SxF, P, SxV, VxF, SxVxF, and to a lesser degree for PxS. The subplot and main plot C.V. values recorded were low, 6.43% and 7.58% respectively.

The analysis of variance for plant height detected differences for F, S, V, P, PxS, and SxV. Computed C.V. values were low for both main plots and subplots, 2.21% and 2.54%, respectively.

In regard to heading date for which the combined ANOVA was not conducted, the source of variation due to varieties was the only one where differences resulted in both planting dates. Recorded C.V. values for subplots and main plots were low, 0.04% and 0.16%, respectively at the first planting date, and 1.15% and 0.55%, respectively at the second planting date.

Treatment Comparisons

As suggested by the observed mean square values in the combined ANOVA, foliar treatments (F) and soil treatments (S) had the greatest influence on grain yield. However, all first order interactions and two second order interactions (SxVxF and PxSxF) also had observed mean square values that were significant (Table 1).

The SxF interaction was chosen to start comparing the effect of treatments on grain yield due to its large absolute value. Differences between foliar protection and nonprotection treatments within soil treatments are presented in Table 4. This difference favored the foliarly protected treatment in both the fumigated and nonfumigated situations.

Comparing the two soil treatments resulted in grain yield differences that favored the nonfumigated treatment; however, a considerably larger difference was detected only when the comparison was made within nonprotected plots.

Although the difference in grain yield between foliarly protected and nonprotected plots, and between fumigated and nonfumigated plots was large, the presence of SxVxF interaction indicated that the previous comparisons were not homogeneous from variety to variety. The comparison of grain yield between foliar treatments within varieties and soil treatments is presented in Tables 5 and 6. Differences in grain yield favorable to foliar

Table 4. Grain yield differences within foliar and soil treatments. Mean values from five wheat varieties sown in two planting dates at Hyslop Agronomy Farm in 1983-84.

Soil Treatment	Foliar Treatment Protected	Foliar Treatment Nonprotected	Difference
	(kg/plot)		
Fumigated	4.08	2.79	1.29**
Nonfumigated	4.23	3.51	0.72**
Difference	-0.15	-0.72**	

*Significant at the 5 percent probability level.
**Significant at the 1 percent probability level.

Table 5. Grain yield differences between foliar treatments. Mean values for five wheat varieties sown in nonfumigated plots and two planting dates at Hyslop Agronomy Farm 1983-84.

Variety	Foliar Treatment Protected	Foliar Treatment Nonprotected	Difference
	(kg/plot)		
Stephens	4.25	3.34	0.91**
Yamhill	4.22	3.35	0.87**
Daws	4.10	3.35	0.75**
Lewjain	4.42	3.85	0.57**
Hill	4.18	3.68	0.50**

*Significant at the 5 percent probability level.
**Significant at the 1 percent probability level.

Table 6. Grain yield differences between foliar treatments. Mean values for five wheat varieties sown in fumigated plots and two planting dates at Hyslop Agronomy Farm in 1983-84.

Variety	Foliar Treatment: Protected	Foliar Treatment: Nonprotected	Difference
	(kg/plot)		
Stephens	4.34	2.74	1.60**
Daws	4.11	2.60	1.51**
Lewjain	3.76	2.31	1.45**
Hill	4.45	3.21	1.24**
Yamhill	3.72	3.09	0.63**

*Significant at the 5 percent probability level.
**Significant at the 1 percent probability level.

protection were detected in all the varieties in both the nonfumigated and fumigated treatments.

Due to the presence of the SxVxF interaction, the grain yield associated with the soil treatments was also compared within each variety and foliar treatment. Table 7 shows that an increase in grain yield for all varieties was found with the nonfumigation treatment; however, differences were observed only for the varieties Lewjain, Daws and Stephens.

The average grain yield for the soil treatments was also compared when all varieties were protected with fungicide (Table 8). It can be observed that two of the five varieties, Lewjain and Yamhill, showed differences favoring nonfumigated plots with only Lewjain being significantly different. The varieties Stephens and Hill showed differences favoring the fumigation treatment; however, these were not significant.

The presence of the PxS interaction implies that differences between soil treatments were not constant between planting dates. The analysis of this interaction may clarify the negative effect of soil fumigation on grain yield observed when the SxF interaction was analyzed.

The difference in grain yield between fumigated and nonfumigated plots within each planting date is presented in Table 9. This difference showed that the negative effect soil fumigation had on grain yield existed only in the first planting date. However, a slight difference also favoring fumigated plots occurred in the second planting date. Table 9 also reflects that a difference in

Table 7. Grain yield differences between soil treatments. Mean values for five wheat varieties not protected with foliar fungicide sown in two planting dates at Hyslop Agronomy Farm in 1983-84.

Variety	Soil Treatment		Difference
	Fumigated	Nonfumigated	
	(kg/plot)		
Lewjain	2.31	3.85	-1.54**
Daws	2.60	3.35	-0.75*
Stephens	2.74	3.34	-0.60*
Hill	3.21	3.68	-0.47
Yamhill	3.09	3.35	-0.26

*Significant at the 5 percent probability level.
**Significant at the 1 percent probability level.

Table 8. Grain yield differences between soil treatments. Mean values for five wheat varieties protected with foliar fungicide and sown in two planting dates at Hyslop Agronomy Farm in 1983-84.

Variety	Soil Treatment		Difference
	Fumigated	Nonfumigated	
	(kg/plot)		
Lewjain	3.76	4.42	-0.66*
Yamhill	3.72	4.22	-0.50
Daws	4.11	4.10	0.01
Stephens	4.34	4.25	0.09
Hill	4.45	4.18	0.27

*Significant at the 5 percent probability level.
**Significant at the 1 percent probability level.

Table 9. Grain yield differences between soil treatments and between planting dates. Mean values from five wheat varieties sown at Hyslop Agronomy Farm in 1983-84.

Planting Date	Soil Treatment		Difference
	Fumigated	Nonfumigated	
	(kg/plot)		
10/19/83	3.06	3.97	-0.91**
11/08/83	3.81	3.78	0.03
Difference	-0.75**	0.19	

**Significant at the 1 percent probability level.

grain yield existed between planting dates when these were compared within soil treatments. This difference suggests that a higher yield resulted in the first planting date when the comparison was carried out within nonfumigated plots; however, within fumigated plots, this comparison favored the second planting date.

Comparisons between soil treatments within varieties and planting dates are presented in Tables 10 and 11. The difference in grain yield favored nonfumigated plots for all the varieties in the first planting date (Table 10). This difference, however, was not significant for Hill.

A similar comparison for the second planting date is found in Table 11. Nonsignificant differences in grain yield between soil treatments were also detected. These differences demonstrated that soil fumigation had a negative effect on grain yield for the varieties Lewjain and Daws. The varieties Stephens, Hill and Yamhill showed a positive grain yield response to soil fumigation.

As with soil treatments, the magnitude of the difference in grain yield between foliar treatments was influenced by planting date. Table 12 shows the difference between foliar protection and nonprotection treatments. This comparison significantly favored the foliar protection treatment in the two planting dates with a larger difference noted in the second planting date. Estimated grain yields in Kg/ha for all varieties in each treatment are reported in Appendix Table 9.

Table 10. Grain yield differences between soil treatments. Mean values for five wheat varieties sown at the first planting date at Hyslop Agronomy Farm in 1983-84.

Variety	Soil Treatment Fumigated	Soil Treatment Nonfumigated	Difference
	(kg/plot)		
Lewjain	2.44	4.27	-1.83**
Yamhill	2.86	3.90	-1.04**
Stephens	3.14	3.82	-0.68*
Daws	3.28	3.85	-0.57*
Hill	3.57	4.01	-0.44

*Significant at the 5 percent probability level.
**Significant at the 1 percent probability level.

Table 11. Grain yield differences between soil treatments. Mean values for five varieties sown in the second planting date at Hyslop Agronomy Farm in 1983-84.

Variety	Soil Treatment Fumigated	Soil Treatment Nonfumigated	Difference
	(kg/plot)		
Lewjain	3.64	3.99	-0.35
Daws	3.42	3.60	-0.18
Stephens	3.94	3.76	0.18
Hill	4.10	3.85	0.25
Yamhill	3.95	3.67	0.28

Table 12. Grain yield differences between foliar treatments and between planting dates. Mean values from five wheat varieties sown at Hyslop Agronomy Farm in 1983-84.

Planting Date	Foliar Treatment		
	Protected	Nonprotected	Difference
	(kg/plot)		
10/19/83	3.98	3.05	0.93**
11/08/83	4.33	3.25	1.08**
Difference	-0.35	-0.20	

**Significant at the 1 percent probability level.

As indicated by the observed mean square values in the combined ANOVA (Table 1), the number of fertile spikes was influenced by both soil and foliar treatments. However, the presence of a significant SxF interaction suggested the comparison should be made for soil treatments within foliar treatments (Table 13). An increase in the number of fertile spikes was noted involving both foliar treatments. The comparison between foliar treatments, also in Table 13, significantly favored the protection treatment in fumigated plots, while no difference in the number of fertile spikes was detected in the nonfumigated plots. The comparison of the number of fertile spikes between soil treatments within varieties is presented in Table 14. Results favored the fumigation treatment in all the varieties for the number of fertile spikes.

The measurement of the grain weight of ten spikes was included in the analysis, (Table 1). For this trait, the effects of foliar and soil treatments were studied according to the SxF interaction. The difference between protection and nonprotection treatments as well as fumigation and nonfumigation treatments is presented in Table 15. Foliage protection clearly resulted in a significant increase in the grain weight of ten spikes in both soil treatments. For the soil treatments, a significant reduction of the grain weight of ten spikes occurred as a result of sowing the varieties in fumigated soil.

The comparison between foliar treatments within varieties and nonfumigated plots is presented in Table 16. All the varieties showed a greater ten-spike grain weight when their foliage was protected; however, this difference was not significant in the

Table 13. Fertile spikes per 60 cm differences between foliar treatments and between soil treatments. Mean values from five wheat varieties sown in two planting dates at Hyslop Agronomy Farm in 1983-84.

Foliar Treatment	Soil Treatment		
	Fumigated	Nonfumigated	Difference
Protected	71.2	54.7	16.5**
Nonprotected	66.8	55.9	10.9**
Difference	4.4**	-1.2	

**Significant at the 1 percent probability level.

Table 14. Fertile spikes per 60 cm differences between soil treatments. Mean values for five wheat varieties sown in two planting dates at Hyslop Agronomy Farm in 1983-84.

Variety	Soil Treatment		
	Fumigated	Nonfumigated	Difference
Lewjain	92.2	70.8	21.4**
Yamhill	66.0	48.5	17.5**
Stephens	70.8	53.4	17.4**
Hill	61.1	48.0	14.1**
Daws	66.1	55.9	10.2**

**Significant at the 1 percent probability level.

Table 15. Ten-spike grain weight differences between foliar treatments and between soil treatments. Mean values from five wheat varieties sown in two planting dates at Hyslop Agronomy Farm in 1983-84.

Soil Treatment	Foliar Treatment Protected	Nonprotected	Difference
	(gr)		
Fumigated	21.98	15.70	6.28**
Nonfumigated	26.16	21.96	4.20**
Difference	-4.18**	-6.26**	

**Significant at the 1 percent probability level.

Table 16. Ten-spike grain weight differences between foliar treatments. Mean values for five wheat varieties sown in nonfumigated plots and two planting dates at Hyslop Agronomy Farm in 1983-84.

Variety	Foliar Treatment Protected	Nonprotected	Difference
	(gr)		
Yamhill	30.20	23.30	6.90**
Stephens	26.40	21.50	4.90**
Daws	26.60	22.00	4.60**
Lewjain	20.80	18.30	2.50
Hill	26.80	24.70	2.10

**Significant at the 1 percent probability level.

varieties Lewjain and Hill. When sown in fumigated plots, all varieties showed a significant increase in the grain weight of ten spikes due to protection of the foliage (Table 17).

Difference in the grain weight of ten spikes between soil treatments was tested within each variety and foliar treatment. In the nonprotected plots, the comparison significantly favored the nonfumigation treatment in all varieties with the exception of Yamhill (Table 18). When carried out within foliarly protected plots and varieties, the same comparison detected differences consistently favorable to the nonfumigation treatment (Table 19).

The difference in ten spike grain weight between soil treatments presented in Table 20 was not homogeneous in the two planting dates as noted by the presence of the PxS interaction. Though significant in the two planting dates, the difference between soil treatments showed that the negative effect of sowing in fumigated soils was almost twice as much in the first planting date.

As a result of the PxSxV interaction, the comparison between soil treatments was conducted within each planting date and variety. Results in Tables 21 and 22 show that a difference in the grain weight of ten spikes occurred as a result of the negative effect soil fumigation had on this trait in all the varieties.

As shown by the observed mean square values for biological yield in the combined ANOVA (Table 2), the difference between foliar protection and nonprotection, as well as between soil fumigation and nonfumigation, was large. However, as suggested by the SxF

Table 17. Ten-spike grain weight differences between foliar treatments. Mean values for five wheat varieties sown in fumigated plots and two planting dates at Hyslop Agronomy Farm in 1983-84.

Variety	Foliar Treatment: Protected	Foliar Treatment: Nonprotected	Difference
	(gr)		
Lewjain	18.00	9.40	8.60**
Daws	23.00	14.90	8.10**
Stephens	21.40	14.90	6.50**
Hill	22.90	17.30	5.60**
Yamhill	24.60	22.00	2.60*

*Significant at the 5 percent probability level.
**Significant at the 1 percent probability level.

Table 18. Ten-spike grain weight differences between soil treatments. Mean values for five wheat varieties not protected with fungicide and sown in two planting dates at Hyslop Agronomy Farm in 1983-84.

Variety	Soil Treatment: Fumigated	Soil Treatment: Nonfumigated	Difference
	(gr)		
Lewjain	9.40	18.30	-8.90**
Hill	17.30	24.70	-7.40**
Daws	14.90	22.00	-7.10**
Stephens	14.90	21.50	-6.60**
Yamhill	22.00	23.30	-1.30

**Significant at the 1 percent probability level.

Table 19. Ten-spike grain weight differences between soil treatments. Mean values for five wheat varieties protected with foliar fungicide and sown in two planting dates at Hyslop Agronomy Farm in 1983-84.

Variety	Soil Treatment		Difference
	Fumigated	Nonfumigated	
	(gr)		
Yamhill	24.60	30.20	-5.60**
Stephens	21.40	26.40	-5.00**
Hill	22.90	26.80	-3.90**
Daws	23.00	26.60	-3.60**
Lewjain	18.00	20.80	-2.80*

*Significant at the 5 percent probability level.
**Significant at the 1 percent probability level.

Table 20. Ten-spike grain weight differences between soil treatments and between planting dates. Mean values from five wheat varieties sown at Hyslop Agronomy Farm in 1983-84.

Planting Date	Soil Treatment		Difference
	Fumigated	Nonfumigated	
	(gr)		
10/19/83	18.16	25.02	-6.86**
11/08/83	19.59	23.05	-3.46**

**Significant at the 1 percent probability level.

Table 21. Ten-spike grain weight differences between soil treatments. Mean values for five wheat varieties sown in the first planting date at Hyslop Agronomy Farm in 1983-84.

Variety	Soil Treatment Fumigated	Nonfumigated	Difference
	(gr)		
Hill	18.80	27.90	-9.10**
Stephens	17.00	23.70	-6.70**
Lewjain	13.10	19.70	-6.60**
Yamhill	22.10	28.50	-6.40**
Daws	19.80	25.30	-5.50**

**Significant at the 1 percent probability level.

Table 22. Ten-spike grain weight differences between soil treatments. Mean values for five wheat varieties sown in the second planting dates at Hyslop Agronomy Farm in 1983-84.

Variety	Soil Treatment Fumigated	Nonfumigated	Difference
	(gr)		
Daws	18.10	23.10	-5.00**
Lewjain	14.43	19.35	-4.92**
Stephens	19.30	24.20	-4.90**
Hill	21.03	23.60	-1.97**
Yamhill	24.50	25.00	-0.50**

**Significant at the 1 percent probability level.

interaction, a differential response to foliar and soil treatments was detected in the analysis of this trait.

Differences in biological yield between foliar treatments when varieties were sown in either fumigated or nonfumigated plots are presented in Table 23. This difference detected a positive effect of foliar protection on avoiding reduction in biological yield as a result of the attack by foliar diseases. This table also shows that the beneficial effect of protection of foliage was larger in fumigated plots.

The comparison between soil treatments shows that sowing the five varieties of wheat in fumigated soil increased the biological yield only when plots were kept free of foliar diseases (Table 23).

As suggested by the PxS interaction in the combined ANOVA for biological yield (Table 2), a differential response to soil treatment for this trait occurred between planting dates. Table 24 shows that the positive effect of soil fumigation on increasing the total biological yield in the second planting date. Though nonsignificant, a negative response to the same treatment was observed in the first planting date.

A difference in biological yield between planting dates also existed. This difference showed that a greater biological yield was produced in the first planting date when the comparison was carried out in nonfumigated plots. However, the same comparison within fumigated plots resulted in a highly significant increase for this trait in the second planting date (Table 24).

Table 23. Biological yield differences between foliar treatments and between soil treatments. Mean values from five wheat varieties sown in two planting dates at Hyslop Agronomy Farm in 1983-84.

Soil Treatment	Foliar Treatment Protected	Nonprotected	Difference
	(gr/60 cm row)		
Fumigated	341.20	278.40	62.80**
Nonfumigated	309.90	285.60	24.30**
Difference	31.30**	-7.20	

**Significant at the 1 percent probability level.

Table 24. Biological yield differences between soil treatments and between planting dates. Mean values from five wheat varieties grown at Hyslop Agronomy Farm in 1983-84.

Planting Date	Soil Treatment Fumigated	Nonfumigated	Difference
	(gr/60 cm row)		
10/19/83	294.60	303.60	-9.00
11/08/83	362.00	291.10	70.90**
Difference	-67.40**	12.50	

**Significant at the 1 percent probability level.

The comparison of the effect of foliar treatments on biological yield was also influenced by planting date. This is reflected by the large mean square value observed for the PxF interaction, (Table 2). Table 25 provides results of the difference between foliar treatments within each planting date. Foliar protection was found to have a positive effect on biological yield in the two planting dates. When carried out within protected plots, the comparison of the effect of planting dates showed that a larger amount of biomass was produced by the varieties in the second planting date.

The combined ANOVA for harvest index detected differences between foliar treatments as well as between foliar treatments (Table 2). The analysis of the SxF interaction for this trait is presented in Table 26. When comparing foliar treatments, harvest index values were high in the protected plots for both soil treatments. This contrast was more evident within fumigated plots.

A comparison of harvest index between soil treatments is also presented at the bottom of Table 26. Fumigation treatment had a negative effect on harvest index in both foliar treatments.

The comparison between foliar treatments within soil treatments and varieties is presented in Tables 27 and 28. The difference in harvest index between foliar treatments when the varieties were sown in nonfumigated plots is presented in Table 27. Protection of the foliage prevented a reduction in the harvest index in all the varieties. Harvest index was not influenced by foliar protection for the variety Hill.

Table 25. Biological yield differences between foliar treatments and between planting dates. Mean values from five wheat varieties grown at Hyslop Agronomy Farm in 1983-84.

Planting Date	Foliar Treatment: Protected	Nonprotected	Difference
	(gr/60 cm row)		
10/19/83	314.68	283.52	31.16**
11/08/83	336.60	280.60	56.00**
Difference	-21.92*	2.92	

*Significant at the 5 percent probability level.
**Significant at the 1 percent probability level.

Table 26. Harvest index differences between foliar treatments and between soil treatments. Mean values from five wheat varieties sown in two planting dates at Hyslop Agronomy Farm in 1983-84.

Soil Treatment	Foliar Treatment: Protected	Nonprotected	Difference
	(percent)		
Fumigated	38.38	30.40	7.98**
Nonfumigated	43.29	39.93	3.36**
Difference	-4.91**	-9.53**	

**Significant at the 1 percent probability level.

Table 27. Harvest index differences between foliar treatments. Mean values for five wheat varieties sown in nonfumigated soil and two planting dates at Hyslop Agronomy Farm in 1983-84.

Variety	Foliar Treatment Protected	Foliar Treatment Nonprotected	Difference
	(percent)		
Daws	44.52	39.61	4.91**
Stephens	44.49	39.91	4.58**
Yamhill	43.24	39.12	4.12**
Lewjain	42.92	40.05	2.86*
Hill	41.26	40.93	0.33

*Significant at the 5 percent probability level.
**Significant at the 1 percent probability level.

Table 28. Harvest index differences between foliar treatments. Mean values for five wheat varieties sown in fumigated plots and two planting dates at Hyslop Agronomy Farm in 1983-84.

Variety	Foliar Treatment Protected	Foliar Treatment Nonprotected	Difference
	(percent)		
Lewjain	36.95	24.93	12.02**
Daws	39.82	28.62	11.20**
Stephens	40.18	30.81	9.37**
Hill	37.39	32.58	4.81**
Yamhill	37.54	35.04	2.50

**Significant at the 1 percent probability level.

Table 28 shows the results when the varieties were sown in fumigated soil. With the exception of Yamhill, all the varieties showed a large reduction in harvest index when not protected.

The comparison of the harvest index between soil treatments was also tested within each variety and foliar treatment. A difference in harvest index between soil treatments was detected in all the varieties at either foliar treatment (Table 29 and 30). Moreover, this difference also reflected the negative effect of soil fumigation on this trait.

The difference in harvest index between soil treatments changed in magnitude between planting dates. This difference was significant when tested on either planting date as shown in Table 31. This table also shows that the negative effect of fumigation on harvest index was larger when the varieties were sown on the first planting date.

As it can be observed in the combined ANOVA, the weight of 300 kernels was greatly affected by the foliar and soil treatments (Table 3). Moreover, these factors showed a strong interaction. The comparison of the 300-kernel weight between foliar treatments within soil treatments is presented in Table 32. The results suggest that foliar protection prevented a reduction in the weight of 300 kernels.

The comparison of the 300-kernel weight between soil treatments is also presented in Table 32. These results demonstrate that soil fumigation had a detrimental effect on this trait regardless of whether the varieties were foliarly protected or not.

Table 29. Harvest index differences between soil treatments. Mean values for five wheat varieties not protected with foliar fungicide and sown in two planting dates at Hyslop Agronomy Farm in 1983-84.

Variety	Soil Treatment Fumigated	Soil Treatment Nonfumigated	Difference
	(percent)		
Lewjain	24.93	40.06	-15.13**
Daws	28.62	39.61	-10.99**
Stephens	30.81	39.91	- 9.10**
Hill	32.58	40.93	- 8.35**
Yamhill	35.04	39.12	- 4.08**

**Significant at the 1 percent probability level.

Table 30. Harvest index differences between soil treatments. Mean values for five wheat varieties protected with foliar fungicide and sown in two planting dates at Hyslop Agronomy Farm in 1983-84.

Variety	Soil Treatment Fumigated	Soil Treatment Nonfumigated	Difference
	(percent)		
Lewjain	36.95	42.92	-5.97**
Yamhill	37.54	43.29	-5.75**
Daws	39.82	44.52	-4.70**
Stephens	40.18	44.49	-4.31**
Hill	37.39	41.26	-3.87**

**Significant at the 1 percent probability level.

Table 31. Harvest index differences between soil treatments and between planting dates. Mean values from five wheat varieties grown at Hyslop Agronomy Farm in 1983-84.

Planting Date	Soil Treatment: Fumigated	Soil Treatment: Nonfumigated	Difference
	(percent)		
10/19/83	32.26	40.38	-8.12**
11/08/83	36.64	42.90	-6.26**
Difference	-4.38**	-2.52**	

**Significant at the 1 percent probability level.

Table 32. Three-hundred kernel weight differences between foliar treatments and between soil treatments. Mean values from five wheat varieties sown in two planting dates at the Hyslop Agronomy Farm in 1983-84.

Soil Treatment	Foliar Treatment: Protected	Foliar Treatment: Nonprotected	Difference
	(gr)		
Fumigated	13.98	10.40	3.58**
Nonfumigated	15.06	12.97	2.09**
Difference	-1.08**	-2.57**	

**Significant at the 1 percent probability level.

The difference between foliar treatments was not consistent among varieties. Tables 33 and 34 present the comparison between foliar treatments within soil treatments and varieties. These tables show that protecting the foliage increased 300-kernel weight.

The comparison of the 300-kernel weight between soil treatments within foliar treatments and varieties is presented in Tables 35 and 36. All detected a negative effect of soil fumigation on kernel weight in most of the varieties. The one exception was for the variety Yamhill, where a difference was not detected between the soil treatments in either the nonprotected or protected plots.

Results presented in Table 37 show differences in 300-kernel weight existed when planting dates were compared across soil treatments. This difference resulted in a negative effect due to soil fumigation. The difference was numerically twice as large in the first planting date.

Plant height was affected by both foliar and soil treatments as demonstrated by the significant observed mean square value for each of these sources of variation in the combined ANOVA (Table 3). Table 38 indicates that all varieties were taller when sown in fumigated soil.

The presence of PxS interaction showed a change in the magnitude of the difference between soil treatments when they were compared within planting dates (Table 39). In this table, an increase in plant height can be observed as a result of sowing varieties in fumigated plots in both planting dates. However, the effect was

Table 33. Three-hundred kernel weight differences between foliar treatments. Mean values for five wheat varieties sown in nonfumigated soil and two planting dates at the Hyslop Agronomy Farm in 1983-84.

Variety	Foliar Treatment		Difference
	Protected	Nonprotected	
	(gr)		
Yamhill	15.64	12.62	3.02**
Stephens	17.84	14.86	2.98**
Daws	15.47	13.42	2.05**
Lewjain	13.00	11.59	1.41**
Hill	13.36	12.36	1.00**

**Significant at the 1 percent probability level.

Table 34. Three-hundred kernel weight differences between foliar treatments. Mean values for five wheat varieties sown in fumigated plots and two planting dates at Hyslop Agronomy Farm in 1983-84.

Variety	Foliar Treatment		Difference
	Protected	Nonprotected	
	(gr)		
Stephens	16.28	11.16	5.12**
Daws	14.27	9.81	4.46**
Lewjain	12.08	7.63	4.45**
Yamhill	15.03	13.02	2.01**
Hill	12.26	10.39	1.87**

**Significant at the 1 percent probability level.

Table 35. Three-hundred kernel weight differences between soil treatments. Mean values for five wheat varieties not protected with foliar fungicide and sown in two planting dates at Hyslop Agronomy Farm in 1983-84.

Variety	Soil Treatment		
	Fumigated	Nonfumigated	Difference
	(gr)		
Lewjain	7.63	11.59	-3.96**
Stephens	11.16	14.86	-3.70**
Daws	9.81	13.42	-3.61**
Hill	10.39	12.36	-1.97**
Yamhill	13.02	12.63	0.39

**Significant at the 1 percent probability level.

Table 36. Three-hundred kernel weight differences between soil treatments. Mean values for five wheat varieties protected with fungicide and sown in two planting dates at Hyslop Agronomy Farm in 1983-84.

Variety	Soil Treatment		
	Fumigated	Nonfumigated	Difference
	(gr)		
Stephens	16.28	17.84	-1.56**
Daws	12.26	15.47	-1.20**
Hill	12.26	13.63	-1.37**
Lewjain	12.08	13.00	-0.92*
Yamhill	15.03	15.64	-0.61

*Significant at the 5 percent probability level.
**Significant at the 1 percent probability level.

Table 37. Three-hundred kernel weight differences between soil treatments and between planting dates. Mean values for five wheat varieties grown at Hyslop Agronomy Farm in 1983-84.

Planting Date	Soil Treatment		
	Fumigated	Nonfumigated	Difference
	(gr)		
10/19/83	11.75	13.99	-2.24**
11/08/83	12.65	14.04	-1.39**
Difference	-0.90	-0.05**	

**Significant at the 1 percent probability level.

Table 38. Plant height differences between soil treatments. Mean values for five wheat varieties sown in two planting dates at Hyslop Agronomy Farm in 1983-84.

Variety	Soil Treatment		
	Fumigated	Nonfumigated	Difference
	(cm)		
Yamhill	134.72	126.25	8.47**
Hill	132.86	124.75	8.11**
Stephens	120.50	114.75	5.75**
Daws	126.75	121.30	5.45**
Lewjain	116.00	110.85	5.15**

**Significant at the 1 percent probability level.

Table 39. Plant height differences between soil treatments and between planting dates. Mean values from five wheat varieties grown at Hyslop Agronomy Farm in 1983-84.

Planting Date	Soil Treatment		Difference
	Fumigated	Nonfumigated	
	(cm)		
10/19/83	127.00	122.40	4.60**
11/08/83	125.20	116.10	9.10**
Difference	1.80**	6.30**	

**Significant at the 1 percent probability level.

greater in the second date. Also, Table 39 shows that varieties were taller when planted in the first planting date. This last comparison was greater in the nonfumigated plots.

With regard to the effect of foliar treatments on plant height, the combined ANOVA in Table 3 did not detect them to significantly interact with any other factor in the study. On the average, foliar protection decreased the plant height by 1.19 cm.

The ANOVA results for heading date did not show any significant effect for either soil or foliar treatments (Appendix Tables 5 and 8). All differences detected occurred among varieties (Table 40).

Table 40. Heading date for five wheat varieties sown in two planting dates at Hyslop Agronomy Farm in 1983-84.

Variety	Planting Date 10/19/83	11/08/83
	Julian Days (1)	
Stephens	148	151
Yamhill	149	153
Daws	151	158
Hill	151	158
Lewjain	158	162

(1) Days after January 1.

DISCUSSION

Key components to economic wheat production are adapted varieties, appropriate management practices and favorable markets. Of these components, the plant breeder must be concerned foremost with developing adapted varieties. Such varieties, however, must be designed to fit into a package of management practices and provide an end product accepted in the market place. To be adapted, a variety must have resistance or tolerance to many abiotic and biotic factors which can limit potential grain yield. The breeders' dilemma is that as more traits are required for a variety to be successful, the less likely it is of finding progeny in segregating populations which possess all the desired attributes. Therefore, it is important for the breeder to establish priorities as to which traits are more important to the well being of the wheat plant.

It was the objective of this study to assess the yield reduction caused by both soil- and foliar-borne biotic factors. Since breeding for disease resistance is a major activity of most wheat breeding programs, it is important to determine if such expenditure of resources is justified. To obtain such an assessment, soil and foliar protective treatments were applied individually and in different combinations to five commercial wheat varieties. These varieties were selected as being adapted to the Willamette Valley; however they differ in their reaction to various diseases and in yield potential. An additional variable introduced was two planting dates.

Foliar diseases were first observed in the first planting date. A differential response to Septoria Leaf Blotch in the unprotected plots was observed with Stephens being the most susceptible followed by Daws, Lewjain and Hill. Yamhill was the least affected; however it was the most susceptible to Stripe Rust. Leaf Rust was noted and appeared to infect all five varieties. This disease appeared late in the growing season making it difficult to evaluate as the two previously mentioned diseases had already become established. These observations were similar in the second planting date where only the time of symptoms expression was delayed.

Some pycnidia of Septoria Leaf Blotch were present in the foliar protected plots; however the disease never reached the upper four leaves of the plants. The lack of complete protection may have resulted from the rainy conditions which prevailed just after the first application of the fungicide.

Soil-borne biotic complexes were not sampled. Observations carried out up to physiological maturity did not detect any visual damage associated with soil-borne diseases.

The effect of soil and foliage protection will be emphasized in this discussion. Also, the role of planting dates, varieties and the interaction between these factors will be discussed as they influenced the results concerning the effect of various biotic factors on yield and the yield components of wheat.

Soil-Borne Biotic Factors

It was not possible to visually identify any of the biotic soil borne factors as they represent a complex of different organisms. The most commonly found root diseases of wheat in the Willamette Valley are Eyespot Root Rot and Take-All. Soil fumigation was chosen as a means to protect the plants from being weakened by biotic soil factors.

Even though soil disease symptoms were not observed in the nonfumigated treatment a superior stand was established in the fumigated plots. The plants in the fumigated plots had a more rapid early growth rate, were taller and had more fertile spikes per unit area. These observations were particularly true for the first planting date. This indicated that soil fumigation likely eliminated competitors or other limiting factors in the soil, and favored plant development. Similar results were reported by Cook and Haglund (1982). Using fumigation they found that wheat planted in fumigated plots produced 20-25 percent more tillers which increased yield by 15-20 percent. These results were expected as the early elimination of any constraint permitted plants to grow vigorously. However in this study some of the yield components including grain yield per se were negatively affected by soil fumigation.

Grain weight of 10 spikes, weight of 300 kernels, harvest index and grain yield were reduced in fumigated plots. These negative effects were the result of the luxuriant growth which resulted in severe lodging in the fumigated plots. No lodging was observed in the nonfumigated plots with the exception of Lewjain which lodged just prior to harvest. Lodging was more extensive in the first planting date, but was also a factor in the second planting date in the fumigated plots.

Lodging in fumigated plots reduced the ability of plants to capture light necessary for photosynthesis. This likely disrupted the equilibrium of the physiological processes in the plants, mainly that between photosynthesis and respiration. Because it occurred at the grain filling stage, lodging also influenced the partition of dry matter into the grain which was shrivelled thus resulting in lighter weight.

In addition the more favorable growing conditions associated with fumigation also favored the development of Septoria Leaf Blotch. This disease, which moves up from the crown of the plant, is influenced by plant height according to Tavella (1978) and Danon et al. (1982). Thus lodging made the upper portion of the plants more accessible to infection. This in turn further reduced grain yield in the soil fumigated plots.

Biological yield tended to increase for all varieties when sown in fumigated plots. Contributing to this was the increase in plant height and the number of fertile spikes. Again, this reflected the more favorable growing conditions in the fumigated plots prior to lodging.

Little or no effect was observed for heading date when soil fumigated and nonfumigated treatments were considered for any of the varieties. This finding is contrary to that reported by Cook and

Haglund (1982) who observed that plants in fumigated plots headed earlier.

Foliar-Borne Biotic Factors

As suggested by the variability associated with foliar treatments, foliar diseases reduced harvest index and grain weight of ten spikes. However, the greatest reductions were observed for biological yield, weight of 300 kernels and grain yield. The magnitude of the effect of foliar diseases in reducing kernel weight agrees with the findings of Backmann (1962), Kelman and Cook (1977), Ziv and Eyal (1978), and Forrer and Zadoks (1983). Undoubtedly, the presence of foliar diseases enhanced the magnitude of the interaction between all factors considered in this study, especially when lodging was involved. Reductions in the number of fertile spikes, grain weight of ten spikes, biological yield, harvest index, weight of 300 kernels and grain yield caused by foliar diseases, were always greater in fumigated plots.

The effect of foliar diseases also varied depending on the variety, however reductions in grain yield and the yield components occurred in all varieties when left unprotected.

The more complex interaction between foliar treatments, varieties, and soil treatments was also present in the analysis of grain weight of ten spikes, harvest index, weight of 300 kernels, and grain yield. Despite this interaction, the results showed that almost all the varieties suffered greater reductions from foliar diseases in fumigated plots. As previously stated Septoria Leaf

Blotch progressed faster due to lodging and the resulting microenvironmental conditions created by soil fumigation. Yamhill was the only variety where a reduction was of a lower magnitude in fumigated versus nonfumigated plots.

With regard to the reaction of the varieties to Septoria Leaf Blotch, both Stephens and Daws, the most susceptible, showed heavy spike infection in the fumigated plots when these were left without foliar protection. Hill, which tends to avoid Septoria Leaf Blotch due to its increased height and later flowering period, was less affected in either soil treatment, but its relative yield reduction was considerably higher in fumigated plots due to lodging.

Stripe and Leaf Rust did not appear to play a major role in influencing any of the traits measured. Since Septoria Leaf Blotch was the first and by far the most extensive foliar disease, the rusts, even on susceptible varieties, did not develop to any degree in fumigated plots. Stripe Rust in the nonfumigated plots was a problem only on Yamhill. Leaf Rust infection was so late in the growing season that it never became established in any of the treatments.

Protection from foliar diseases had little influence on the number of fertile spikes in nonfumigated plots. When fumigated plots are considered, protection of the foliage did increase the number of fertile spikes. Thus both soil borne factors and foliar pathogens reduced the number of fertile spikes with the soil borne factors being the most important. Spikes with no grain were never found in protected plots, which suggests that foliar diseases may have greatly influenced the formation of spikes as the development of these diseases was strongly enhanced under soil fumigated growing conditions.

The reduction in plant height associated with foliage protection was not expected. Although the average reduction in plant height in protected plots was only 1.19 cm, this was statistically significant. No report was found in the literature on the effect on plant height by the fungicide used in this study. It could be speculated on a possible growth regulating effect of the fungicide, or perhaps on a natural response by the wheat plants to grow taller as a response to the attack by foliar diseases.

Heading date was not affected by foliar diseases. There was a tendency for the straw of diseased plants to senescence more slowly prior to physiological maturity of the grain. However, because of high temperatures at the end of the cycle, diseased and nondiseased plants reached physiological maturity and completed senescence at the same time.

Varieties

Despite the effect of soil treatments on plant height, the effect of varieties for this trait was comparable. Also, the interaction between soil treatments and varieties was present for plant height. Even though the ranking of varieties was the same in both fumigated and nonfumigated plots, the presence of the interaction was likely due to the larger differences in plant height detected between soil treatments for the two tallest varieties, Hill and Yamhill. The comparison of plant height among varieties also explains the presence of such interaction. In fact, differences in plant height between the two tallest varieties and the other varieties were greater in the fumigated plots. The short varieties grew at least 5 cm taller and the tall ones at least 8 cm taller. This indicates that the expression of plant height varies according to the environmental conditions with plants growing taller, as nutrients become more available and parasites are eliminated.

Stephens, Hill, and Yamhill showed a positive yield response to soil fumigation in the second planting date. The favorable response to soil fumigation observed in these varieties may be related to less lodging observed in that date of planting. Lewjain, the most susceptible to lodging, had the largest yield reduction in fumigated plots when compared to the other varieties even in the second date of planting.

Variation in heading date can be explained by differences among varieties. In both planting dates, Stephens was the first variety to head and Lewjain the last. Septoria Leaf Blotch appeared to be associated to earliness as Stephens being the first to head also was the most susceptible variety to that disease. This is in agreement with the findings of Danon, et. al. (1982), and Tavella (1978) who also reported such an association between severity of this disease and date of heading.

None of the varieties lodged in nonfumigated plots, except Lewjain which lodged slightly prior to harvest. Under this situation, Lewjain was attacked by Septoria Leaf Blotch to a lesser extent than it was by Leaf Rust, which appeared later. Hill, being tall, was able to escape the attack of Septoria Leaf Blotch. This explains why under normal soil growing conditions these two varieties had the lowest reduction of weight of 300 kernels, harvest index, grain weight of 10 spikes, and grain yield caused by foliar diseases.

Grain yield increases in wheat are recognized to be obtained as the result of an increase in the number of fertile spikes per unit area. In this study, protection from soil-borne diseases increased fertile spikes. However, the microenvironmental conditions resulting from the excessive vegetative growth and subsequent lodging in fumigated plots enhanced the development of foliar diseases, and may have disrupted some physiological processes causing yield reductions.

Planting Date

Planting date is recognized as an important factor in the development of winter wheat. According to Stoskopf (1981), winter wheat is recommended to be planted early in the fall because this favors the vigorous development and tillering of wheat plants. These characteristics permit winter wheat to stand and avoid damage by low winter temperatures. However in the Willamette Valley, earlier fall planting dates are thought to favor both soil and foliar diseases. Because of this, planting date was introduced as a factor in this study. Foliar diseases significantly reduced grain yield and biological yield in both planting dates, but the reduction of these traits was greater in the second planting date. These results might have been caused by the higher initial inoculum in the second planting date coming from diseased plots in the first date.

Assessment

In final analysis it would appear that wheat breeders must continue to regard disease resistance as a major objective in their programs. In this study Septoria Leaf Blotch appeared to be the major limiting factor to grain yield. It is apparent, however, that Stripe and Leaf Rust in the absence of Septoria Leaf Blotch could substantially reduce grain yield.

Since it is not economically practical for wheat producers to fumigate their fields, resistance must be sought to the soil borne pathogens and other limiting factors found in the soil.

The results of this study clearly suggest that as the breeder develops more resistant varieties, it will be necessary to also breed into such varieties greater straw strength especially under irrigated or high rainfall conditions where lodging can be a problem.

SUMMARY AND CONCLUSIONS

The focus of this study was to assess the effect of soil- and foliar-borne biotic factors on grain yield and the components of yield. Five soft white winter wheat varieties represented the experimental material. Data were collected from two dates of planting where fumigated and foliage protected treatments and appropriate checks were employed. The following conclusions were based on the measurements made for eight traits:

1. Both soil and foliar treatments had an apparent strong influence on grain yield and the components of yield.

2. Due to the luxuriant growth in fumigated plots, lodging prevented a reliable estimate of the effect of the biotic soil borne complex.

3. An increase in the number of fertile spikes and plant height were observed in the fumigated plots. Biological yield was increased in all varieties in the second planting date.

4. Reduction in kernel weight, ten spike weight, harvest index and grain yield were found with fumigation. In the second date, increases in grain yield were observed for Stephens, Hill and Yamhill.

5. Foliar fungicide treatments prevented grain yield reduction. Even though the foliar treatment strongly interacted with soil treatments and varieties, grain yield was always superior when compared to the nonprotected plots.

6. Foliar fungicide treatment also increased harvest index, spike weight, kernel weight, biological yield, and the number of fertile spikes; however, a reduction in plant height was noted.

7. A faster development of foliar diseases was noted in fumigated, nonprotected plots. Comparisons between foliar treatments within fumigated plots showed a larger difference for grain yield and the components of yield.

8. Septoria Leaf Blotch was first and the most prevalent disease observed in both planting dates. The comparison between foliarly protected and nonprotected plots under nonfumigated conditions showed that Stephens was the most susceptible variety with the greatest grain yield reduction.

9. Septoria Leaf Blotch development was faster in fumigated plots. Under these conditions Yamhill had the lowest grain yield reduction when foliar protection was not carried out. However, in nonfumigated, foliarly unprotected plots, this variety was the most susceptible to Stripe Rust.

10. Under nonfumigated conditions where lodging did not occur, Hill suffered the least grain yield reduction when it was not foliarly protected. The absence of lodging under these conditions enabled this variety to escape from the attack of Septoria Leaf Blotch perhaps due to its greater height.

11. Even though foliar diseases caused significant grain yield reductions in the two planting dates, losses were greater in the second date. Probably the proximity of experiments in the field increased the inoculum pressure in the second date.

12. With regard to grain yield losses, it can be concluded that foliar diseases caused an average 24.1% grain yield reduction.

13. The major factor influencing grain yield in fumigated plots was lodging. It also enhanced the infection by Septoria Leaf Blotch due to the reduction in the height of the canopy. This was particularly true for the first planting date.

14. Lewjain was more susceptible to lodging than the other varieties. It was also the first variety to lodge before heading occurred. This variety had the greatest grain yield reduction in fumigated plots in the two planting dates.

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APPENDIX

Appendix Table 1. Percentage of tissue infected by three foliar diseases on five winter wheat varieties sown on October 19, 1983. 1/

Variety	Plot	Soil Treatment	Below Flag Leaf: Septoria Leaf Blotch	Below Flag Leaf: Stripe Rust	Below Flag Leaf: Leaf Rust	Flag Leaf: Septoria Leaf Blotch	Flag Leaf: Stripe Rust	Flag Leaf: Leaf Rust
Daws	10	NF	80		20	40		60
	13	F	100			100		
	30	F	100			100		
	33	NF	75		25	25		75
	42	F	100			100		
	59	NF	100			60		40
	61	NF	100			50		50
	78	F	100			95		5
	89	F	100			100		
	96	NF	75		25		20	80
Lewjain	5	NF	5		95			100
	14	F	100			50		50
	23	F	100			90		10
	38	NF	10		90			100
	47	F	75		25	5		95
	55	NF	5		95			100
	70	NF	20		80			100
	75	F	100			70		30
	86	F	100			90		10
	91	NF			100			100

1/ Obseravations correspond to foliarly unprotected plots and were taken just prior to physiological maturity when there was some green color in the leaves.

Appendix Table 1. (continued)

Variety	Plot	Soil Treatment	Below Flag Leaf: Septoria Leaf Blotch	Below Flag Leaf: Stripe Rust	Below Flag Leaf: Leaf Rust	Flag Leaf: Septoria Leaf Blotch	Flag Leaf: Stripe Rust	Flag Leaf: Leaf Rust
Stephens	6	NF	100			20		80
	20	F	100			100		
	24	F	100			100		
	36	NF	100			50		50
	46	F	100			100		
	53	NF	100			50		50
	63	NF	100			25		75
	80	F	100			100		
	87	F	100			100		
	97	NF	100			25		75
Hill	2	NF	75		25	10		20
	18	F	100			95		5
	25	F	100			80		20
	39	NF	75		25	5		25
	45	F	100			100		
	57	NF	90		10			20
	66	NF	50		50			10
	71	F	100			90		10
	85	F	100			90		10
	92	NF	50		50			20

Appendix Table 1. (continued)

Variety	Plot	Soil Treatment	Below Flag Leaf: Septoria Leaf Blotch	Below Flag Leaf: Stripe Rust	Below Flag Leaf: Leaf Rust	Flag Leaf: Septoria Leaf Blotch	Flag Leaf: Stripe Rust	Flag Leaf: Leaf Rust
Yamhill	8	NF	5	90	5		70	30
	12	F	25	30	15	25	25	50
	22	F	25	25	15	5	30	50
	37	NF	10	60	30		70	30
	44	F	10	30	50	20	10	60
	56	NF	5	60	35		50	50
	68	NF	5	59	45		50	50
	74	F	25	50	25	10	40	60
	83	F	5	50	45		40	60
	95	NF		60	40		70	30

Appendix Table 2. Percentage of tissue infected by three foliar diseases on five winter wheat varieties sown on November 8, 1983. 1/

Variety	Plot	Soil Treatment	Below Flag Leaf: Septoria Leaf Blotch	Below Flag Leaf: Stripe Rust	Below Flag Leaf: Leaf Rust	Flag Leaf: Septoria Leaf Blotch	Flag Leaf: Stripe Rust	Flag Leaf: Leaf Rust
Daws	4	NF	70	10	30	10		90
	19	F				95		5
	30	F	100			100		
	40	NF	90		10	25		75
	44	F	100			100		
	56	NF	20		80	20		80
	66	NF	20	20	60	10		85
	71	F	100			100		
	82	F	100			95		
	96	NF	50		50	15		85
Lewjain	5	NF	80		20	100		
	15	F	100			40		60
	25	F	75		25	25		75
	50	F	100			80		20
	54	NF	10		90			95
	65	NF	5		95	100		
	72	F	100			90		10
	90	F	100			80		
	93	NF			100			100

1/ Obseravations correspond to foliarly unprotected plots and were taken just prior to physiological maturity when there was some green color in the leaves.

Appendix Table 2. (continued)

Variety	Plot	Soil Treatment	Below Flag Leaf: Septoria Leaf Blotch	Below Flag Leaf: Stripe Rust	Below Flag Leaf: Leaf Rust	Flag Leaf: Septoria Leaf Blotch	Flag Leaf: Stripe Rust	Flag Leaf: Leaf Rust
Stephens	1	NF	50		50	25		75
	18	F	100			95		5
	23	F	100			85		15
	34	NF	75		25	20		80
	43	F	100			100		
	58	NF	50		50	5		95
	64	NF	50		50	10		90
	75	F	100			90		5
	81	F	100			80		10
	97	NF	50		50	15		80
Hill	3	NF	25		75	20		75
	20	F	100			85		5
	27	F	100			50		50
	39	NF	50		50	10		90
	42	F	100			75		25
	60	NF	30		50	10		80
	69	NF	50		20			30
	76	F	100			60		5
	88	F	100			80		
	100	NF	50	30		10		75

Appendix Table 2. (continued)

Variety	Plot	Soil Treatment	Below Flag Leaf Septoria Leaf Blotch	Below Flag Leaf Stripe Rust	Below Flag Leaf Leaf Rust	Flag Leaf Septoria Leaf Blotch	Flag Leaf Stripe Rust	Flag Leaf Leaf Rust
Yamhill	7	NF	5	80	15		40	60
	13	F	50	30	20	10	50	40
	37	NF	5	80	15	10	50	40
	45	F	5	60	35	5	30	65
	57	NF	5	50	45		40	60
	67	NF	5	60	35		20	80
	79	F	5	60	35	20		20
	83	F	5	50	45	10		20
	95	NF	5	60	35			60

Appendix Table 3. Observed mean square values for grain yield per plot, spikes per 60 cm and ten-spike grain weight recorded from a split-plot design for a factorial arrangement of two soil and two foliar treatments, and five soft-white winter wheat varieties sown in October 19, 1983 at Hyslop Agronomy Farm.

Source of Variation	D.F.	Observed Mean Squares		
		Yield Per Plot	Spikes per 60 cm	Ten-Spike Grain Weight
Replications (R)	4	0.240	38.922	15.085
Soil treatments (S)	1	20.878*	4,422.219**	1,176.492**
Error (a)	4	1.018	39.789	3.265
Varieties (V)	4	0.620**	3,050.325**	231.285**
Foliar treatments (F)	1	21.381**	0.063	542.891
SxV	4	1.568**	189.680*	8.965
SxF	1	1.725**	580.875**	15.207
VxF	4	0.599**	37.266	22.615*
SxVxF	4	0.219*	55.336	25.836*
Error (b)	67	0.079	72.449	7.492

* Significant at the 5 percent probability level.
** Significant at the 1 percent probability level.

Appendix Table 4. Observed mean square values for biological yield per 60 cm row, harvest index and 300-kernel weight recorded from a split-plot design for a factorial arrangement of two soil and two foliar treatments, and five soft-white winter wheat varieties sown in October 19, 1983 at Hyslop Agronomy Farm.

Source of Variation	D.F.	Observed Mean Squares		
		Biological Yield Per 60 cm Row	Harvest Index	300-Kernel Weight
Replications (R)	4	865.25	20.461	1.202
Soil treatments (S)	1	2,025.00	1,648.703**	125.242**
Error (a)	4	1,810.75	1.348	0.165
Varieties (V)	4	2,063.25	36.168*	51.500**
Foliar treatments (F)	1	24,274.00**	810.766**	208.731**
SxV	4	2,165.25	28.992*	5.457**
SxF	1	12,859.00**	148.328**	14.051**
VxF	4	597.25	53.266**	6.999**
SxVxF	4	209.50	37.020**	5.112**
Error (b)	67	1,721.81	10.722	0.801

* Significant at the 5 percent probability level.
** Significant at the 1 percent probability level.

Appendix Table 5. Observed mean square values for heading date and plant height recorded from a split-plot design for a factorial arrangement of two soil and two foliar treatments, and five soft-white winter wheat varieties sown in October 19, 1983 at Hyslop Agronomy Farm.

Source of Variation	D.F.	Observed Mean Squares	
		Heading Date	Plant Height
Replications (R)	4	0.00	44.00
Soil treatments (S)	1	0.00	528.88**
Error (a)	4	0.06	7.78
Varieties (V)	4	306.44**	1,007.09**
Foliar treatments (F)	1	0.00	36.00**
SxV	4	0.06	39.69**
SxF	1	0.00	0.25
VxF	4	0.06	1.66
SxVxF	4	0.00	10.56
Error (b)	67	0.04	7.40

** Significant at the 1 percent probability level.

Appendix Table 6. Observed mean square values for grain yield per plot, spikes per 60 cm and ten-spike grain weight recorded from a split-plot design for a factorial arrangement of two soil and two foliar treatments, and five soft-white winter wheat varieties sown in November 8, 1983 at Hyslop Agronomy Farm.

Source of Variation	D.F.	Observed Mean Square		
		Yield Per Plot	Spikes Per 60 cm	Ten-Spike Grain Weight
Replications (R)	4	0.702	284.938	28.716
Soil treatments (S)	1	0.062	5,069.438**	306.250**
Error (a)	4	1.153	138.711	4.225
Varieites (V)	4	0.573**	1,374.734**	166.790**
Foliar treatments (F)	1	29.432**	190.438	882.090**
SxV	4	0.427*	123.367	27.101*
SxF	1	2.205**	1.969	50.410*
VxF	4	0.047	38.969	3.141
SxVxF	4	0.506**	94.531	20.311
Error (b)	67	0.122	69.71	10.338

* Significant at the 5 percent probability level.
** Significant at the 1 percent probability level.

Appendix Table 7. Observed mean square values for biological yield per 60 cm row, harvest index and 300-kernel weight recorded from a split-plot design for a factorial arrangement of two soil and two foliar treatments, and five soft-white winter wheat varieties sown in November 8, 1983 at Hyslop Agronomy Farm.

Source of Variation	D.F.	Observed Mean Squares		
		Biological Yield Per 60 cm Row	Harvest Index	300-Kernel Weight
Replications (R)	4	6,729.25	42.813	1.352
Soil treatments (S)	1	29,929.00**	955.953**	47.076**
Error (a)	4	2,598.25	13.043	1.811
Varieties (V)	4	2,837.25	8.641	46.011**
Foliar treatments (F)	1	73,875.00**	851.625**	194.801**
SxV	4	1,918.25	23.059*	6.139**
SxF	1	5,685.00	127.453**	14.383**
VxF	4	933.00	30.406**	3.258**
SxVxF	4	4,222.75*	21.277*	2.468**
Error (b)	67	1,621.37	6.822	0.614

* Significant at the 5 percent probability level.
** Significant at the 1 percent probability level.

Appendix Table 8. Observed mean square values for heading date and plant height recorded from a split-plot design for a factorial arrangement of two soil and two foliar treatments, and five soft-white winter wheat varieties sown in November 8, 1983 at Hyslop Agronomy Farm.

Source of Variation	D.F.	Observed Mean Squares	
		Heading Date	Plant Height
Replications (R)	4	2.31	3.44
Soil treatments (S)	1	3.25	2,016.00**
Error (a)	4	0.75	7.03
Varieties (V)	4	419.50**	1,155.16**
Foliar treatments (F)	1	1.00	34.63
SxV	4	1.88	11.31
SxF	1	0.50	0.00
VxF	4	2.44	7.41
SxVxF	4	4.19	4.19
Error (b)	67	3.21	12.32

** Significant at the 1 percent probability level.