This is to certify that the

thesis entitled

WHEAT YIELD AND BARLEY YELLOW DWARF VIRUS INFECTION AS AFFECTED BY PLANTING DATE AND CHEMICAL CONTROL

presented by

Salani Nkhori

has been accepted towards fulfillment of the requirements for

Master Of Science degree in Crop & Soil Sciences

Major professor

Date November 10, 1997

PLACE IN RETURN BOX
to remove this checkout from your record.
TO AVOID FINES return on or before date due.

DATE DUE	DATE DUE	DATE DUE

WHEAT YIELD AND BARLEY YELLOW DWARF VIRUS INFECTION AS AFFECTED BY PLANTING DATE AND CHEMICAL CONTROL

By

Salani Nkhori

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Department of Crops and Soil Science

1997

ABSTRACT

WHEAT YIELDS AND BARLEY YELLOW DWARF VIRUS INFECTION AS AFFECTED BY PLANTING DATE AND CHEMICAL CONTROL.

By

Salani Nkhori

Improving grain production in small grain crops requires adequate information on how performance is influenced by management practices. A two-year study examined the main and interaction effects of planting date and insecticides application on winter wheat performance. In both years the treatments consisted of factorial combinations of planting date and insecticide application, assigned to experimental units in a split-plot design. Insecticide treatments in year 1 (1995/6) were 1) none, 2) Imidacloprid (GAUCHO) as a seed treatment, and 3) GAUCHO (seed treatment) plus Dimethoate (CYGON) sprayed in spring, and in year 2 (1996/7) were none and GAUCHO + CYGON.

In both years, the latest planting resulted in the lowest grain yields. The last plantings produced the lowest test weight in year 1 but highest in year 2. Kernel weight decreased with delayed planting in a fashion similar to grain yield declines in year 1, but not in year 2. Maximum grain yield was obtained where both GAUCHO and CYGON were applied in both years. Barley yellow dwarf virus infection was heaviest from early-planted wheat. Levels of BYDV were reduced from some early plantings treated with GAUCHO in year one.

To my parents, wife, sons, and daughter.

ACKNOWLEDGEMENTS

I would like to take this opportunity to thank Dr Richard Ward for his support, friendship, and serving as my major professor. I would also like to thank Dr Patrick Hart and Dr Richard Harwood for their support as well as serving on my guidance committee. I am not forgetting the Wheat Breeding staff who helped me with my field experiments. I would like to thank Mike Kalishek for helping me with the extraction of barley yellow dwarf virus from plant samples. Special thanks are dedicated to my wife Hildah who was patient enough with my long stay away from home.

TABLE OF CONTENTS

LIST OF TABLES

1.0 INTRODUCTION

Wheat (*Triticum sp.*) is an important worldwide crop; one that is harvested somewhere every month of the year (Oleson, 1994; Smith, 1995). The crop is capable of growing over a wide range of agrogeographical regions (Briggle and Curtis, 1987). Of all wheat species, common wheat (*Triticum aestivum* L. em. Thell) is the most widely cultivated. It has ranked as the number one crop for human consumption, leading all other cereals in production and trade worldwide (Briggle and Curtis, 1987). World wheat production has been inconsistent, fluctuating from one year to the other. Over the last seven years (1990–1996), the largest world harvest (592 million metric tons) occurred in 1990, while the lowest (528 million metric tons) occurred in1994. During the same period the area harvested decreased only by 0.4% from 231 to 230 million hectares (FAO, 1997). Despite annual production fluctuations, consumption, primarily as human food, increased each year (FAO, 1997). Demand increased by over 34 million metric tons between 1990 to 1994 (FAO, 1997).

Increased crop production can be achieved in two major ways; (i) expansion of area planted, and (ii) improvement of yield per unit area (Briggle and Curtis, 1987; Evans, 1993). A combination of improved varieties; agronomic practices and expansion of the area under cultivation during the 1960's did increase wheat production. But the availability of new land for agriculture is now drastically reduced (CIMMYT, 1995). Improving the yield per unit of area planted remains the only alternative way to increase wheat yields. This can be achieved in two ways; (i) improved wheat varieties, and (ii) by using improved agronomic practices (Briggle and Curtis, 1987).

The crop season for wheat is the period of time and associated circumstances starting at sowing and ending at harvest. Strategic decisions by farmers, coupled with circumstances influencing access to land, dictate the beginning of a crop season. Crop response to the accumulated effect of the unfolding season determines the end of the crop season. By definition, therefore, change of planting date alters the nature of the ensuing crop season. A constant planting date employed for a period of years will also result in a set of distinct crop seasons. Another major farmer controlled factor influencing crop season is the choice of variety, which can dramatically influence the timing of flowering and harvest. This work focused on the relationship of planting date to performance in winter wheat as measured primarily by yield.

1.1 Wheat Planting Dates

Wheat planting date affects the physiological growth and development of wheat plants. Under temperature and moisture limiting conditions, it determines plant stand establishment, which influence grain yield (Dahlke et. al, 1993; Fowler, 1982). Planting winter wheat at optimum times enables the plants to develop strong root systems, achieve high winter survival, escape from other stress factors, and maximize grain yields (Paulsen, 1987).

Optimum planting dates for wheat vary by production area, intended purpose of the crop (Smith, 1995), and crop season (Coventry et. al, 1993). There are several underlying principles behind the choice of planting date that apply in all cases. Grain yield is one of the major criterion for selecting optimum planting dates for wheat (Paulsen, 1987), although in areas where grazing is practiced, vegetative biomass become an important criterion. In other areas, for example, Michigan and Southwestern Ontario, the previous crop planted influence optimum planting dates. Selection of planting date for wheat is also governed by the need to avoid temperature and moisture extremities. Both low and high temperatures have detrimental effects on winter wheat during the critical early developmental stages.

Planting wheat too early results in excessive growth in fall, uses up soil moisture and gives growth leading to increased lodging, susceptibility to winterkill (Smith, 1995; Fowler, 1983), and high pressure from diseases and insect pests. On the other hand, planting late tends to limit plant development resulting in poorly established plants with a lower winter-survival potential (Fowler, 1983). Such plants do not develop sufficient foliage to trap snow, which helps in the regulation of ground temperature during the winter. Late plantings of winter wheat also tend to have their grain filling period shifted into periods of higher temperatures. High temperatures shorten the duration of grain filling, hence reducing grain yields (Evans, 1980).

Optimum planting dates in many parts of the world have been arrived at through research and grower's experience. In Ontario, for example, a 2-wk optimum planting period for winter wheat has been proposed (Bootsma et al, 1993). The optimum seeding date estimation ranged from as early as 21 August in the north around Kapuskasing to as late as 15 October for the Windsor area though varying from one year to the other within the location. In Michigan, according to Wiese (1979) wheat can be planted 10 days after the hessian fly-free date (FFD). Hessian fly-free date is the date after which the Hessian fly, a pest of wheat, is no longer a threat to wheat plants (Wiese, 1979). In Ingham County, for example, the hessian fly-free date is 17 September and planting 10 days later means that planting begins 27 September.

Reports on the relationship between planting date-induced variations in crop season and performance reveal several patterns. A progressive decline in yields occurred with each delay in planting in several studies (McLeod et. al., 1992; Andrews et. al., 1992; Coventry et. al., 1992). In central Alberta, however, early-planted wheat produced the lowest yields compared to all subsequent plantings (Jedel and Salmon 1994). Another predominant pattern is where grain yield is low with early dates, increasing to maximum at mid-planting dates, and then declining with subsequent delays in planting (Dahlke et. al., 1993; Rourke, 1983; Wiese, 1979).

1.2 Barley Yellow Dwarf Virus.

Barley yellow dwarf, an important aphid-transmitted disease, is the most economically damaging virus disease of cereal crops worldwide (Gary et. al, 1996). Oswald and Houston (1951) were the first to recognize this disease in California, USA. The disease is caused by barley yellow dwarf luteoviruses

(BYDV), which can be subdivided into nine distinct viral groups (Duffus et. al, 1990). Several viral strains have been identified, and the most common worldwide are PAV (vector non-specific), RMV (transmitted efficiently by *Rhopalosiphum maidis*. Fitch.), RPV (efficiently transmitted by *Rhopalosiphum padi*. L.), SGV (transmitted effectively by *Schizaphis graminun*. Rondani) and MAV (efficiently transmitted by *Sitobium avenae*. W.) strains. Nomenclature of these strains was based on the aphid vector most efficiently transmitting the virus (Rochow, 1969). More recently, however, classification has been based on serological properties and deoxyribonucleic acid (DNA) sequence comparisons (Martin and D'Arcy, 1995).

Transmission of the virus is persistent, i.e. once the virus is acquired by an aphid, the aphid will transmit the virus for the rest of its life (Burnett, 1990). The virus is phloem-limited and contains a positive-sense genomic ribonucleic acid (RNA) (Mathews, 1991; Webster and Granoff, 1994). Symptoms caused by the virus range from stunted plant growth, leaf tip and margin yellowing, and reddening depending on variety. Symptoms are more pronounced in barley (*Hordeum vulgare* L.) and oats (*Avena sativa* L.) than wheat (*Triticum aestivum* L.) (Carrigan et. al, 1981). Because several factors influence BYDV epidemiology, development of effective control strategies remains a major problem for both wheat growers and agronomists.

Diagnosis of barley yellow dwarf virus (BYDV) based on symptoms under field conditions can be difficult. Symptoms are often not sufficiently developed to allow visual identification of infected plants. They can easily be confused with damage due to frost, wet weather, nutrients, and non-infectious agents (Conti et. al, 1990). Furthermore, the presence of BYDV in most cereals can often be masked by other cereal diseases (Burnett, 1990). Visual diagnosis should be confirmed with other diagnostic methods such as serological or hybridization assays.

Symptoms develop in a period of 7-20 days after inoculation (D'Arcy, 1995), and as a result, wheat growers and experienced agronomists often realize the presence of BYDV when it is too late to treat the current year's crop. Knowledge on vector population dynamics relative to host crop availability is an essential factor in developing control strategies. Scouting and monitoring for aphids could be used to predict BYDV presence. The best control for BYDV will be to control the vector that transmits the virus.

In most parts of the world where BYDV is a problem, its control is usually by a single method, using insecticides, relying on biological control, or utilizing genetic resistance (Plumb and Johnstone, 1995). Little success has yet been realized in breeding for BYDV resistance in wheat (Gourmet et. al, 1996). Application of insecticides to kill aphids vectors in cereals is a promising strategy for decreasing BYDV damage (McKirdy et al, 1996). The application of insecticides either as sprays or granules to control aphids that transmit BYDV in Australia resulted in large increases in yields (Plumb and Johnstone, 1995). Studies conducted at the University of Illinois using Imidacloprid (GAUCHO) as a seed-treatment insecticide indicated a yield increase of as much as 21%, and that the percentage of plants infected with BYDV was significantly reduced

(Gourmet et al, 1996). Imidacloprid is a nitroguanidine insecticide (Gourment, 1996). Biological control involves the use of natural enemies such as parasites and predators to control aphids. It has been used successfully in indirectly controlling BYDV as a result of controlled aphids vectors (Plumb and Johnstone, 1995). While biological control has been found to reduce the incidence of BYDV in Australasia and South America, introduction, rearing, and maintenance of predators and parasites populations can be difficult.

In Michigan and similar environments, adult aphid populations dramatically decline in the period that winter wheat is traditionally planted. Crop season will vary in season aphid pressure. Studies in the Midwest, U.S, indicated that winter wheat planted early and emerging before the first killing frost, was infested with a complex of viruses, resulting in lower yields (Dahlke et al. 1993). Another contributing factor to high infestation is the duration of exposure of plants to aphids. The earlier the planting date, the longer the plants are exposed to aphids, increasing the threat to BYDV infestation (McGrath et al. 1990). Altering time of planting the crop is consequently a likely means of escaping early infection by barley yellow dwarf virus.

Previous studies (Wiese, 1979; Ward, unpublished data) suggest that the pattern of relationship between planting dates (i.e., initiation of the crop season) and yield of winter wheat in Michigan is curvilinear. Yields appear to be highest with crop seasons initiated at a point several days after the fly free date. Yields from crop seasons initiated 20 to 30 days before or after a year's maximum are lower than the maximum. The work reported here sought to further refine our understanding of the relationship of crop season onset and performance environments. The major research hypotheses were 1) crop seasons initiated between early September and late October will vary in performance; 2) the pattern of relationship between crop season onset and performance is curvilinear with a single maximum after the fly-free date; 3) year affects the properties of the planting date/yield relationship including the date of the maximum, and the rates of decline in performance on either side of the optimum; and 4) insecticide control of fall aphid infection can reduce the penalty of planting before the maximum yield date.

2.0 MATERIAL AND METHODS

Field trials were conducted at Michigan State University's campus in East Lansing, Michigan during a two-year period. Trials were conducted on a capac loam (Aeric Endoaguals, fine-loamy, mixed, mesic) soil. The soft white winter wheat cultivar 'Harus' (Teich, 85) was used in all trials. Fields were prepared by conventional tillage. Land was tilled immediately before each planting event. Seed was sown at a rate of 1.8 million seeds per acre in experimental plots comprised of 7 rows spaced 7 inches apart and 11.0 feet long. A Wintersteiger research plot cone drill was used for planting. Weeds were controlled both manually and with herbicides during the spring. The previous crop in both years was soybeans that were chopped and plowed under as green manure. No fall fertilizer was applied. A single early spring application of N (as Urea 46-0-0) was applied at a rate of 80 lbs N/A each year.

In both years the treatments consisted of factorial combinations of planting date and insecticide application. In year 1 (planted in the fall of 1995, harvested in the summer of 1996), six planting dates (Table 1) and three insecticide treatments were employed. The insecticide treatments for year 1 were 1) none, 2) Imidacloprid (GAUCHO) as a seed treatment (1 fl oz/100lbs seed), and 3) GAUCHO as a seed treatment plus spring foliar application of Dimethoate (CYGON). The spring foliar application began at Feeke's scale 6 (first application was on 5/8/96) and was repeated at intervals of 10 – 14 days until booting (Feeke's scale 10) at a rate of half a pint per acre.

In year 2 (planted in the fall of 1996, harvested in the summer of 1997), four dates (Table 1) and two insecticide treatments were employed. The two insecticide treatments were 1) none and 2) GAUCHO + CYGON. CYGON was first applied on 5/13/97 at a rate and interval similar to that in year 1. Several other seed treatments were included in year 2, but data for those treatment combinations were excluded from all analyses.

Treatments were assigned to experimental units in a split-plot design where dates were confounded with main plots. Seed treatments were randomly assigned to sub-plots within main plots. Outer rows of the main plots were bordered by untreated Harus.

Dates of initiation of stem elongation and anthesis were assessed each spring. Data are presented as day of year, i.e., days from the first of January. In year 2 plant stand count at emergence was taken. Fifteen plots were selected at random within a replication for each planting date. A total of sixty plots were selected before subjected to stand count. In early spring, a second plant count was performed on the last planting date using the same procedure. Other planting dates had developed too many tillers to allow for stand count.

Table 1-Dates of planting Harus winter wheat.

	Planting year	
Planting event	**1995**	**1996**
1	12 Sept	21 Sept
2	18 Sept	30 Sept
3	25 Sept	11 Oct
4	05 Oct	21 Oct
5	09 Oct	---
6	17 Oct	---

Plant samples were acquired for BYDV analysis on four different dates. The first sample was collected at the onset of the winter and the other three samples were collected in the spring. Plants were selected at random within plots. A total of three plants were collected per plot during each sampling event. All above ground tissue was included in samples. No sampling was done after booting (Feeke's scale 10) had commenced. Samples were frozen immediately after their removal from the field. Double antibody sandwich - enzyme-linked immunosorbent assay (DAS-ELISA) technology was used to quantify BYDV and wheat spindle streak mosaic virus (WSSMV). This was done at the Plant and Soil Science Building's Plant Clinic at Michigan State University. Kits used for detecting the virus were produced by the Agdia Inc. Company.

A 36.6ft^2 area from each plot was harvested in August each year with a small plot research harvester. Grain was dried to a constant moisture content estimated at 11 percent. Grain yield was determined before a sub-sample of the grain from each plot was removed for determining test weight (AACC approved method 55-10, 1995). An electric seed counter was used to obtain thousand seeds for kernel weight determination. Data were analyzed using Proc. GLM of SAS (SAS Institute Inc. 1988) and means were separated using Fisher's protected least significance difference (LSD) with p-values < 0.05 considered significant.

3.0 RESULTS

3.1 Crop Development.

The 1995-96 trial (Year 1) was exposed to the harshest winter conditions in recent history in Michigan (C.R. Olien, pers. Comm.). Rate of growing degree day (GDD) accumulation was reduced to near zero by October 10, 1995. Scab (Gibberela zeae), and glume blotch pressures were both severe in that year. The 1996-97 trial (Year 2) exhibited very little winter kill damage and disease pressures were light. The average wheat yield for all of Michigan in Year 1 was 38 bu/acre, compared to the record setting yield of 62 bu/acre Michigan farmers experienced in Year 2. Plant density data were not collected for Year 1, but it was clear that the last planting event (10/17/96) suffered from poor emergence and excessive winterkill. Plant density data for the last planting in Year 2 are tabulated in Appendix A. Some loss of plants (up to 14%) during the winter was evident. However, winterkill did not appear to be a factor in Year 2 based on grain yields obtained from the 21 October planting (Table 6).

Table 2-Timing of initiation of stem elongation (SE) and 50% anthesis (A) for 'Harus' winter wheat planted at different dates in two years.

			Day of Year	
Trial	Planting event	Planting date	SE	A
Year 1	1	9/12/95	128	162
	2	9/18/95	134	163
	3	9/25/95	134	163
	4	10/5/95	137	167
	5	10/9/95	140	173
	6	10/17/95	149	179
Year 2	1	9/21/96	126	162
	2	9/30/96	131	163
	3	10/11/96	136	166
	4	10/21/96	143	169

The days of year of initiation of stem elongation (Feeke's scale 6.0) and anthesis (Feeke's scale 10.5) increased as planting date was delayed (Table 2). The difference in days between the onset of stem elongation and anthesis decreased as planting was delayed in 1997. In 1996, those intervals exhibited no relationship to planting date. Even though the dates of first stem elongation and anthesis varied, plants matured within a narrow time span in both years and all plots in a trial were harvested on a single day (8/1/96 for Year 1, and 7/30/97 for Year 2).

Table 3-Summary of the significance of F tests from separate analyses of variance for Year 1 and Year 2 of a split plot design of a factorial combination of planting date and insecticides.

	1996			**1997**		
Source	**Grain yield**	**Test weight**	**1000-kernel weight**	**Grain yield**	**Test weight**	**1000-kernel weight**
Replication	*	*	NS	NS	*	*
Planting date, PD	*	*	*	*	*	*
Insecticides, IN	*	NS	*	NS	NS	NS
PD*IN	NS	NS	NS	NS	NS	NS

*, NS = Significant at $p < 0.05$, and not significant, respectively.

3.2 Planting date and grain yield

Statistical comparisons could not be made across years because planting dates varied with year. Analysis of variance showed that planting date was a signficant factor in determining grain yield (Table 3). Generally, the earliest and latest plantings decreased yields, while intermediate plantings produced the highest yields (Table 4). In both years, a quadratic model explained considerably more variation in the combined yield data (inclusive of all insecticide treatments) than a simple linear model. The adjusted R^2's for the quadratic models, including all treatments and replications, were 0.54 and 0.37 for Year 1 and Year 2, respectively. If mean yield values are used, the R^2 values increased to 0.79 and 0.62 for year 1 and 2 respectively (Appendix H). The quadratic equations predicted that the maximum yields in Year 1 and Year 2 would have been 61.7 bu/acre and 83.8 bu/acre respectively. Those maxima correspond with planting on 9/23/95 (day of year =266), and 10/5/96 (day of year=278). The maximum and minimum days of year predicted to provide a yield no more than 5.0 bu/acre below the predicted maximum were 258 (9/15/95) and 273 (9/30/95) for Year 1, and 269 (9/26/96) and 286 (10/13/96) for Year 2.

Planting date affected test weight somewhat differently in the two years. In 1996, the response was similar to that observed with grain yields. However, only the last planting (17 October) resulted in a significant reduction in test weight in 1996 (Table 4a). In 1997, both early and late plantings increased test weight significantly compared to intermediate planting dates (Table 4b). Averaged across insecticide treatments, planting dates that maximized grain yields resulted in the highest test weight in 1996. In 1997, the opposite was true.

Table 4. Grain yield, test weight, and 1000-kernel weight of winter wheat variety Harus as affected by planting dates in year 1 (a) and year 2 (b)

(a)

Trial	Planting date	Yield (bu/acre)	Test weight (lbs/bu)	1000-kernel weight (ounce)
Year 1	12 Sept	55.6 ab*	56.5 a	1.18 ab
	18 Sept	49.6 b	53.3 a	1.14 ab
	25 Sept	62.4 a	57.2 a	1.23 a
	05 Oct	49.2 b	56.3 a	1.12 b
	09 Oct	49.9 b	56.9 a	1.20 ab
	17 Oct	6.2 c	26.9 b	0.64 c

(b)

Trial	Planting date	Yield (bu/acre)	Test weight (lbs/bu)	1000-kernel weight (ounce)
Year 2	21 Sept	70.8 bc	59.3 ab	1.45 a
	30 Sept	87.7 a	58.9 bc	1.36 b
	11 Oct	79.1 ab	58.3 c	1.38 b
	21 Oct	67.8 c	59.6 a	1.42 ab

* Means followed by a letter in common are not significantly different, $p < 0.05$, according to least significant difference.

Table 5 Mean BYDV absorbance, grain yield, test weight and 1000-kernel weight of 'Harus' winter wheat as affected by planting date and insecticide treatments in 1996.

Planting Dates (1995)	Insecticide Treatments	ELISA values Sample Time 18 Jan '96	08 May'96	27 May'96	04 Jun '96	Yield (Bu/A)	TW‡ (lbs./Bu)	1000-KW§ (ounce)
12 Sept	Control	0.089	0.375	0.758	0.251	45.5	56.4	1.12
	Gaucho	0.078	0.017*	0.298*	0.135	52.7	55.7	1.18
	Gaucho + Cygon	†	0.126	0.666	0.073	68.8*	57.3	1.22
18 Sept	Control	0.050	0.172	0.184	0.591	49.8	54.9	1.12
	Gaucho	0.024	0.026	0.654*	0.048	47.3	47.9	1.09
	Gaucho + Cygon	†	0.035	0.651*	0.025	51.8	57.2	1.21
25 Sept	Control	0.027	0.023	0.399	0.046	53.7	56.9	1.24
	Gaucho	0.028	0.027	0.193	0.067	63.0	57.5	1.22
	Gaucho + Cygon	†	0.030	0.705*	0.066	70.5*	57.1	1.27
05 Oct	Control	0.050	0.034	0.061	0.039	47.9	56.1	1.10
	Gaucho	0.020	0.024	0.017	0.056	46.8	55.7	1.05
	Gaucho + Cygon	†	0.026	0.073	0.053	52.9	57.1	1.19
09 Oct	Control	0.162	0.029	0.108	0.036	46.4	56.5	1.17
	Gaucho	0.078	0.033	0.042	0.045	47.6	56.9	1.15
	Gaucho + Cygon	†	0.008	0.095	0.027	55.9	57.3	1.25
17 Oct	Control	0.329	0.022	0.039	0.026	3.9	20.3	0.57
	Gaucho	0.161	0.036	0.026	0.048	6.8	20.5	0.58
	Gaucho + Cygon	†	0.022	0.022	0.026	7.9	36.6*	0.74*

*Significantly different from control at $p<0.05$.
†Cygon was not yet applied.
‡TW = Test weight.
§1000-KW = Thousand kernel weight.

Table 6 Mean BYDV absorbance, grain yield, test weight and 1000-kernel weight of 'Harus' winter wheat as affected by planting date and insecticide treatments in 1997

Planting dates(1996)	Insecticide treatments	ELISA values Sample Time				Yield (Bu/A)	Test weight (lbs./Bu)	1000-kernel weight (ounce)
		30 Nov '96	13 May'97	31 May'97	11 Jun '97			
	Control	0.171	0.078	0.009	0.205	67.2	59.3	1.45
21 Sept	Gaucho + Cygon	†	0.232	0.012	0.691*	71.0	59.3	1.45
	Control	0.263	0.151	0.328	0.680	85.0	58.7	1.35
30 Sept	Gaucho + Cygon	†	0.240	0.004	0.417	88.6	59.0	1.37
	Control	0.144	0.192	0.095	0.216	77.8	58.3	1.38
11 Oct	Gaucho + Cygon	†	0.147	0.025	0.184	80.5	58.2	1.37
	Control	0.444	0.130	0.035	0.140	67.8	59.5	1.43
21 Oct	Gaucho + Cygon	†	0.107	0.027	0.238	67.7	59.7	1.41

* Significantly different from no seed treatment ($P = 0.05$).
†Cygon was not yet applied.

As with test weight, kernel weight responded somewhat differently to planting dates. In 1996, the trend in kernel weight, averaged across insecticide treatments, was similar to that observed with grain yields. The response was significantly different among planting dates (Table 3). Planting dates that maximized grain yields did maximize kernel weight (Table 4a). In 1997, kernel weight response to planting dates was different significantly ($P<0.05$) (Table 3). The highest 1000 kernel weight was obtained from wheat planted on the first planting date (Table 4b).

3.3 Insecticide treatments and grain yield

Insecticides in year 1 (Table 3) affected grain yields differently. Planting dates x insecticide interactions were not significant in the analysis of variance (Table 3). However, pre-planned comparisons and inspection of the relationship of grain yield and planting date within insecticide treatments suggested an interaction did exist. With no insecticide applied, yields increased with planting date, reaching maximum on 25 September then decreasing with further delay in planting (Table 5). The GAUCHO and GAUCHO + CYGON treatments showed less of a decline with the earliest planting. Maximum grain yield with these treatments was also found with the 25 September planting. Although grain yields from the 18 September planting were lower than with the 12 September planting for GAUCHO and GAUCHO + CYGON treatments, the effects of GAUCHO and CYGON application was prevalent on 12 and 25 September plantings. The influence of both insecticides then decreased with any further delay in planting beyond 25 September (Table 5). In 1996, 25 September resulted in the maximum grain yield. The apparent rate of decline in yield was faster after optimum planting date (6.6 Bu - control, 15 Bu - GAUCHO, and 16 Bu - GAUCHO + CYGON) than before. A very steep difference was observed between the two last planting dates with both insecticide treatments (Table 5).

Grain yields in Year 2 were considerably higher than in Year 1. A curvilinear grain yield response was observed for both the control and GAUCHO + CYGON treatments (Table 6). Maximum grain yields were obtained when wheat was planted on 30 September for both treatments. Yield differences between the two insecticide treatments were not significantly different as a main effect or for any single planting date (Table 3 and Table 6). Minimum decline in grain yields between planting dates was similar for both insecticide treatments (17 Bu and 10 Bu) before and after the optimum planting date respectively. Unlike in 1996, the fastest rate of decline was before the optimum planting date rather than after.

Kernel weight responded to the effects of insecticide treatments differently when compared to grain yield in 1996. There were no significant differences among insecticide treatments for the first five planting dates. Differences occurred on the last planting date with the GAUCHO + CYGON treatment resulting in high 1000-kernel weight (Table 5). At all planting date, except the last, kernel weight due to GAUCHO treatment was always lower than from other insecticide treatment. Test weight response to the effect of insecticide treatments did not vary with planting date except for the last planted wheat. Like

1000-kernel weight, the GAUCHO + CYGON treatment resulted in the greatest test weight. In 1997, both kernel and test weights did not differ significantly among insecticide treatments within planting dates (Table 6), a similar response to that observed for grain yield.

3.4 Planting date and BYDV infection

ELISA results indicated that two BYDV strains were present. These were the RMV isolate, transmitted effectively by a corn leaf aphid (*Rhopalosiphum maidis*), and PAV isolate which is vector non-specific. However, the concentration of the PAV isolate was below levels regarded as adequate for quantitative analysis in both years and the data was not used in the analysis. All references to barley yellow dwarf virus (BYDV) will refer to the RMV isolate unless otherwise indicated.

Table 7. Mean BYDV absorbance of sample plants averaged across sampling dates for the years 1996 (a) and 1997 (b) field plots.

(a)

	Treatment		
Planting date	**Control**	**Gaucho**	**Gaucho+Cygon**
12 Sept	0.368 (44)†	0.132 (13)	0.232 (25)
18 Sept	0.249 (25)	0.188 (18)	0.188 (19)
25 Sept	0.124 (25)	0.079 (13)	0.212 (19)
05 Oct	0.046 (0)	0.030 (0)	0.043 (0)
09 Oct	0.100 (0)	0.050 (0)	0.076 (6)
17 Oct	0.104 (18)	0.068 (13)	0.086 (0)

LSD $_{0.05}$ =0.195

(b)

	Treatment	
Planting date	**control**	**Gaucho+Cygon**
21 Sept	0.129 (18)	0.297 (44)
30 Sept	0.364 (56)	0.247 (25)
11 Oct	0.140 (18)	0.115 (13)
21 Oct	0.201 (31)	0.188 (19)

LSD $_{0.05}$ = NS

† Percentage of positives out of sixteen samples tested for barley yellow dwarf virus (BYDV) by ELISA serological test

ELISA results for all sampling times and treatment combinations are presented in Table 5 and 6 for 1996 and 1997 respectively. In year 1, there was large variation in BYDV levels at different sampling times averaged across insecticide and planting date treatments. There was a significant difference among planting dates with respect to BYDV concentration. The concentration of BYDV (mean absorbance) decreased with planting date, reaching a minimum at the fourth planting date (Table 7a). For Year 1, wheat planted on 12 September had the greatest BYDV concentrations (Table 7a). In Year 2, no trend or pattern was observed with respect to BYDV concentration and planting date (Table 7b), and Barley yellow dwarf virus concentration was not significantly different among planting dates. High concentration levels of BYDV were detected from wheat planted on the 30 September (Table 7b) planting date.

3.5 Insecticide treatments and BYDV infection

High levels of BYDV were detected late in the season from the earliest planted wheat and early from their late-planted counterpart (Table 5 & 6). In year 1, ELISA values differed significantly among insecticide treatments within a sampling date. High concentrations of BYDV were obtained from the 27 May sampling in 1996 (Table 5). Except for the first planting date (12 September), means ELISA values across sampling dates were not significantly different among insecticide treatments at any planting date (Table 7a). Across planting and sampling dates, the GAUCHO treatment significantly reduced BYDV concentration (Table 8) in year 1. The effect of GAUCHO + CYGON treatment was not different significantly from the control treatments. Inexplicably, the incidence of BYDV was increased by the application of CYGON in the spring (Table 5).

In 1997 the GAUCHO treatment was inadvertently omitted. The only significant difference among insecticide treatments was observed from the 11 June sampling on the first planting date (Table 6). Insecticide treatments were not significantly different within any planting date (Table 7b). Across planting dates and sampling times, there was no significant difference among insecticide treatments either (Table 8).

Out of sixteen samples collected over time and tested for BYDV using ELISA from each planting date and insecticide treatment, a high percent infection was observed from the 12 September planted wheat where no insecticide was applied in 1996 (Table 7a). Wheat planted on 5 and 9 October 1995 showed zero percent infection. Less infection occurred where GAUCHO was applied than with other insecticide treatments (Table 7a). In 1997, although the second planting date resulted in high percent infection, within insecticide treatments, infection was similar (Table 7b). Percent infection, based on samples that tested positive for BYDV, was determined on a 0.2 ELISA values positive cutoff point. Any ELISA values 0.2 and above was considered positive, while those less than 0.1 were negative. Values between 0.2 and 0.1 are ambiguous. This recommendation was obtained from the Agdia Inc, company from where the kits used in determining BYDV were obtained (pers. Comm.). These results are similar to those analyzed statistically. GAUCHO +CYGON and the control treatments in both years, resulted in more BYDV positive samples.

Table 8. Mean BYDV absorbance averaged across planting and sampling dates, as influenced by insecticide treatments.

Trial	Insecticide event	Insecticide treatment	Mean BYDV (Absorbance)
Year 1	1	Control	0.162 a*
	2	Gaucho	0.091 b
	3	Gaucho + Cygon	0.152 ab
Year 2	1	Control	0.208 a
	3	Gaucho + Cygon	0.194 a

*Means followed by a letter in common are not significantly different, $p < 0.05$, according to least significant difference.

3.6 Planting date and Wheat spindle streak mosaic virus

In sample 1 in Year 1, levels of wheat spindle streak mosaic virus (WSSMV) were signficantly higher for the 25 September and 5 October dates than all other dates. In later samples, virus incidence decreased (Table 9a). The virus concentration levels did not vary significantly (P = 0.05) among planting dates. Because of this, differences in grain yield, test weight, and kernel weight may not be attributed to virus infection.

In 1997, except for the last two planting dates and during the second sampling time, virus concentrations also decreased with sampling time (Table 9b). Within planting dates high levels of WSSMV was obtained from the last two planting dates. Therefore, yield reductions recorded from the latest planted wheat may be associated with these high levels of the virus.

Table 9. Mean WSSMV absorbance detected at three sampling times in 1996 (a) and 1997(b) field plots.

(a)	ELISA values		
	Samplin Date		
Planting date	18 Jan '96	27 May'96	4 Jun '96
12 Sept	0.023	0.140	0.066
18 Sept	0.331	0.107	0.189
25 Sept	0.496*	0.072	0.153
05 Oct	0.704*	0.032	0.146
09 Oct	0.048	0.036	0.053
17 Oct	0.059	0.023	0.037

(b)	ELISA values		
	Sampling Date		
Planting date	30 Nov '96	13 May '97	11 Jun '97
21 Sept	0.113	0.056	0.026
30 Sept	0.136	0.059	0.034
11 Oct	0.093	1.374	0.036
21 Oct	0.733*	2.035*	0.050

*Significantly different at P = 0.05

4.0 DISCUSSION

Wheat crop seasons initiated in the month of September and October exhibited a range of yields. The relationship between planting date and yield was curvilinear with a single maximum after the fly free date. The penalty associated with late planting was substantial in year one. Generally, yields decreased as planting was delayed beyond September 30 in both years (Table 5). Planting later than the date, which maximized yields both, decreased grain yields and increased days to anthesis. Wiese (1979) suggested that Michigan farmers use the local hessian fly-free date as their target for planting wheat. In year 1, planting earlier than this time did not reduce yields dramatically (Table 5). As observed by other researchers (Knapp and Knapp, 1978; Martin, 1926; Coventry et. al, 1993), the latest planting dates decreased yields more severely than did earliest and intermediate planting dates.

A major factor contributing to the reduction in yield from the latest planted wheat was stand lose resulting from winterkill. Visual observations in both years and plant stand count conducted in spring 1997 after growth had resumed indicated that late planting did reduce plant population (data presented in appendix A). Increased seeding rate might have reduced this effect. In 1996, there was less snow cover and some frequent freezing and thawing conditions were observed. Repeated freezing and thawing are reported to increase winter injury than either condition alone (Gusta and Chen, 1987).

A comparison of planting dates 18, 25 September, 5 and 17 October from 1996 with the four planting dates in 1997 (Table 5), a similar pattern of increase and then subsequent decline in yield as planting progressed from the first to the last date was observed. Based on this comparison, the yields of wheat as affected by planting date followed the trend observed by several researchers (Rourke, 1983; Dahlke et al. 1993), who found yields to gradually increase, reaching maximum at mid-plantings, and then declining as planting date was delayed.

Year had a large effect on the planting date–yield relationship. In year 1, the observed maximum yield occurred on 25 September, while in year 2 it was five days later (30 September). The quadratic model based prediction of the maximum yield planting dates were 9/23/95 and 10/5/96 for years 1 and 2 respectively.

The 17 October planting date caused a significant reduction in test weight in 1996 while the 21 October did not in 1997. These different responses were likely due to winterkill. Evans et al, (1971) and Knapp and Knapp (1978) reported similar findings that planting date affected test weight differently in different years on winter barley and wheat respectively. Pittman and Andrews, (1961) however, found that the highest test weight came from the intermediate planting dates. The result of Pittman and Andrews, (1961) only agrees with those from year one of this study, where high-test weights coincided with maximum grain yield.

Although kernel weight is reported to decrease, as planting is delayed (Wiegand and Cuellar, 1981; Andrews et. al, 1992; Dahlke et. al, 1993), in this study the decrease was not pronounced. Other studies found kernel weight to increase with delayed planting (Rocheford et. al, 1988), and concluded that the increase in kernel weight was a compensatory physiological response to reduction in other components. This, therefore, suggest that kernel weight become relatively important in contributing to yield as planting is delayed.

Grain yield was increased in treatments where insecticides were applied both in fall and spring in both years (Table 5). However, those differences were significant only with the 12 and 25 September plantings in year 1. The effects of insecticide application on test weight and thousand-kernel weight were not as pronounced as on grain yield except for 17 October planting in year one (Table 5). The low-test weight from GAUCHO treatment (Table 5) on the first two planting dates could be attributed to abiotic factors other than biotic ones such as heat stress during grain filling period.

When GAUCHO was applied alone, BYDV incidence was reduced from wheat planted on the first planting date in both years. Although GAUCHO reduced BYDV levels, covariance analysis did not reveal a significant relationship between mean BYDV at all samplings to grain yield (data not shown). Applying CYGON in spring did not seem to have an effect on BYDV. This could have been because infection had occurred in spring already before spraying with CYGON. Several studies (Gourmet et. al. 1996; Gary et. al, 1996) found that GAUCHO significantly reduced the incidence of BYDV from treated plots as compared to untreated plots. These results support the findings of this study during the first year. The increase in grain yield from plots where CYGON was applied could be associated with its action on other wheat pests than the vectors of barley yellow dwarf virus. The effect of GAUCHO on early-planted wheat may indicate that grain yield can be increased if BYDV is controlled, but further exploration of this issue needs to be done before concrete recommendations can be made.

It is apparent from this study that both planting date and insecticide treatments influenced grain yield of winter wheat. Several factors influence the optimum planting date, which vary from year to year and location to location. Most experiments conducted on planting date do not encompass all these possible factors. Furthermore, the nature of crop seasons and consequently the optimum planting dates are not known until harvest. Resolution of useful extension messages will require knowledge of the frequency distribution of peak performance planting dates for a given production zone. Such distributions might be generated empirically through field experimentation and alternatively crop modeling may be useful.

5.0 REFERENCES.

American Association of Cereal Chemists. 1995. Approved methods. 9th ed. Vol. 2: St Paul, MN.

Andrews, C. J., M. K. Pomeroy, W. L. E Seaman, and G. Hoekstra. 1992. Planting dates and seeding rates for soft white winter wheat in eastern Ontario. Can. J. Plant Sci. 72: 391 - 402.

Boostma, A., C. J. Andrews, G. J. Hoekstra, W. L. Seaman, and A. E. Smid. 1993. Estimated optimum planting dates for winter wheat in Ontario. Can. J. Plant. Sci. 73: 389-396

Briggle, L. W and B. C. Curtis, 1987. Wheat worldwide. p. 1-32. In E. G. Heyne (ed.) Wheat and wheat improvement. Agron. Monogr. 13. ASA and SSSA, Madison, WI.

Burnett, P. A, 1990. Preface. In P.A. Burnett (ed.) World perspectives on barley yellow dwarf. CIMMYT, Mexico, D. F.

Carrigan, L. L., H. W. Ohm, J. E. Foster, and F. L. Patterson. 1981. Response of winter wheat to Barley Yellow Dwarf Virus infection. Crop Sci. 21: 377 – 380.

CIMMYT, 1995. CIMMYT world wheat facts and trends supplement 1995. Ongoing research at CIMMYT: Understanding wheat genetic diversity and international flows of genetic resources. Mexico, D.F.: CIMMYT. 11-16.

Conti, M., D'Arcy, C. J., Jedlinski, H., and P.A. Burnett. (1990). The 'yellow plaque' of cereals, barley yellow dwarf virus. P. 1-6. In P.A. Burnett (ed.) World perspectives on barley yellow dwarf. CIMMYT, Mexico, D.F., Mexico.

Coventry, D. R., T. G. Reeves, H. D. Brooke, and D. K. Cann. 1993. Influence of genotype, sowing date, and seeding rate on wheat development and yield. Aust. J. Exp. Agric. 33: 751 – 757.

Dahlke, B. J., E. S. Oplinger, J. M. Gaska, and M. J. Martinka. 1993. Influence of planting date and seeding rate on winter wheat grain yield and yield components. J. Prod. Agric. 6: 408 - 414.

D'Arcy, C. J. 1995. Symptomatology and host range of barley yellow dwarf. p. 9-28. In D'Arcy, C. J., and P. A. Burnett (ed.) Barley yellow dwarf. 40 years of progress. APS Press. St Paul. Mn.

Duffus, J. E, B. W. Falk, and G. R. Johnstone. 1990. Luteoviruses-One system, many variations. p. 86-104. In P.A. Burnett (ed.) World perspectives on barley yellow dwarf. CIMMYT, Mexico, D.F., Mexico.

Evans, L. T., I. F. Wardlaw, and R. A. Fischer. 1980. Wheat. p. 101-150. In L.T. Evans (ed.) Crop physiology -some case histories. Cambridge University Press. 101 - 149.

Evans, L. T. 1993. Crop evolution, adaptation and yield. Cambridge University Press.

Evans, R. G., K. E. Bohnenblust, B. J. Kolp, G. P. Roehrkasse. 1971. Yields and yield components of winter barley as affected by variety and planting date. WY. Agric. Exp. Stn. Res. J. 49: 1-10.

FAO, 1997. FAOSTAT Database/PC production, primary crops. Rome, Italy.

Fowler, D. B. 1982. Date of seeding, fall growth, and winter survival of winter wheat and rye. Agron. J. 74: 1060 - 1063.

Fowler, D. B. 1983. The effect of management practices on winter survival and yield of winter wheat produced in regions with harsh winter climates. p. 238-282. In Fowler et al (ed.) New frontiers in winter wheat production. Div. Ext. Comm. Rel., University of Saskatchewan, Saskatoon. SK.

Gary, S. M, G. C. Bergstrom, R. Vaughan, D. M. Smith, and D. W. Kalb, 1996. Insecticidal control of cereal aphids and its impact on the epidemiology of the barley yellow dwarf luteoviruses. Crop protection. 15: 687 – 697.

Gourmet, C., K. L. Kolb, C. A. Smyth, and W. L. Pedersen. 1996. Use of Imidacloprid as a seed-treatment insecticide to control Barley Yellow Dwarf Virus (BYDV) in Oat and Wheat. Plant Disease. 80: 136 - 141.

Gusta, L. V., and T. H. H. Chen. 1987. The physiology of water and temperature stress. In E. G. Heyne (ed.) Wheat and wheat improvement. p. 115-150. Agron. Monogr. 13. ASA and SSSA, Madison, WI.

Jedel, P. E., and D. F. Salmon. 1994. Date and rate of seeding of winter cereals in central Alberta. Can. Plant Sci. 74: 447-453.

Knapp, W. R., and J. S. Knapp. 1978. Response of winter wheat to planting date and fall fertilization. Agron. J. 70: 1048 – 1053.

Martin, J. H. 1926. Factors' influencing results from rate and date of seeding experiments with wheat in the Western US. J. Am. Soc. Agron. 18: 193 - 225.

Martin, R.R., and J. D'Arcy. 1995. Taxonomy of barley yellow dwarf viruses. p 203 – 214. In D'Arcy, C. J., and P.A. Burnett (ed.) Barley Yellow Dwarf: 40 years of progress. APS Press. St. Paul, Mn.

Mathews, R. E. F, 1991. Plant virology. 3rd ed. Academic Press, Inc. San Diego. California.

McGrath, P. F. and J. S. Bale, 1990. The effects of sowing date and choice of insecticide on cereal aphids and barley yellow dwarf virus epidemiology in Northern England. Annals of Applied Biology. 117: 31 – 43.

McKirdy, S. J. and R. A. C. Jones, 1996. Use of Imidacloprid and newer generation synthetic pyrethroids to control the spread of barley yellow dwarf luteoviruses in cereals. Plant disease.80: 895 – 901.

McLeod, J. G., C. A. Campbell, F. B. Dyck, and C. L. Vera. 1992. Optimum seeding date for winter wheat in Southwestern Saskatchewan. Agron. J. 84: 86 –90.

Oleson, B.T., 1994. World wheat production, utilization and trade. In Bushuk, W., and V. F. Rasper (ed.) Wheat production, properties and quality. Blackie Academic in Professional. Glasgow.

Oswald, J. W and B. R. Houston, 1951. A new virus disease of cereals, transmissible by aphids. Plant disease reporter. 35: 471 – 475.

Paulsen, G. M. Wheat stand establishment. p. 384-389. In E. G. Heyne (ed.) Wheat and wheat improvement. Agron. Monogr. 13. ASA and SSSA, Madison, WI.

Pittman, U. J., and J. E. Andrews. 1961. Effect of date of seeding on winter survival, yield, and bushel weight of winter wheat grown in Southern Alberta. Can. J. Plant Sci. 41: 71-80.

Plumb, R. T, and G. R. Johnstone, 1995. Cultural, chemical, and biological methods for the control of barley yellow dwarf. p. 307-320. In D'Arcy, C. J., and P.A. Burnett (ed.) Barley Yellow Dwarf: 40 years of progress. APS Press. St. Paul, Mn.

Rochford, T. R., D. J. Sammons and P. S. Baenziger. 1988. Planting date in relation to yield and yield components of wheat in the Middle Atlantic Region. Agron. J. 80: 30-34.

Rochow, W. F. 1969. Biological properties of four isolates of barley yellow dwarf virus. Phytopathology 59: 1580 – 1589.

Rourke, D. R. S. 1983. Winter wheat agronomy. p. 359-380. In Fowler et al (ed.) New frontiers in winter wheat production. Div. Ext. Comm. Rel., University of Saskatchewan, Saskatoon. SK.

SAS Institute Inc. SAS/STAT User's Guide, Release 6.03 Edition. Cary, NC: SAS Institute Inc., 1988.

Smith C W 1995. Crop Production: evolution, history and technology. John Wiley & Sons,Inc

Teich, A. H. 1985. Harus soft white winter wheat. Can. J. Plant Sci. 66: 161-163.

Webster, R.G, and A. Granoff. 1994. Encyclopedia of virology. Academic Press. 2: 792–798.

Wiegand, C. L., and J. A. Cuellar. 1981. Duration of grain filling and kernel weight of wheat as affected by temperature. Crop Sci. 21: 95-101.

Wiese, M. V., R. Loria, K. Dimoff, and N. Klimer. 1979. A derivation of optimal planting dates for winter wheat in Michigan. Farm Sci. Res. Report. 387: 1-7.

APPENDICES

APPENDIX A

PLANT EMERGENCE DATA BEFORE AND AFTER THE WINTER FROM THE LAST PLANTING DATE IN YEAR 2.

APPENDIX A

Rep	Plot	Emer Fall†	Emer Spring‡	Rep	Plot	Emer Fall	Emer Spring	Rep	Plot	Emer. Fall	Emer. Spring	Rep	Plot	Emer. Fall	Emer. Spring
1	1	45	40	2	1	28	39	3	1	40	36	4	1	31	28
1	2	37	33	2	2	31	38	3	2	31	32	4	2	40	28
1	3	50	45	2	3	41	37	3	3	42	52	4	3	44	39
1	4	33	36	2	4	32	27	3	4	29	49	4	4	31	31
1	5	28	35	2	5	49	30	3	5	24	29	4	5	37	46
1	6	29	27	2	6	37	21	3	6	39	31	4	6	36	28
1	7	45	39	2	7	25	26	3	7	26	29	4	7	37	34
1	8	22	45	2	8	30	24	3	8	30	27	4	8	33	37
1	9	30	29	2	9	33	19	3	9	34	36	4	9	41	43
1	10	34	25	2	10	35	30	3	10	42	38	4	10	29	38
1	11	42	25	2	11	54	29	3	11	42	24	4	11	21	22
1	12	39	38	2	12	35	31	3	12	44	20	4	12	38	40
1	13	27	25	2	13	52	25	3	13	30	36	4	13	41	22
1	14	34	24	2	14	36	25	3	14	36	23	4	14	37	32
1	15	42	18	2	15	41	23	3	15	45	28	4	15	33	32

†Emer. Fall =stand count 4-wks after emergence, ‡Emer. Spring = stand count 24-wks after planting.

APPENDIX B

GRAIN YIELD, TEST WEIGHT, AND THOUSAND-KERNEL WEIGHT DATA OBTAINED DURING THE FIRST YEAR (1995/6).

APPENDIX B

Replication	Planting date†	Insecticide Treatment‡	Grain yield (Bu/A)	Test weight (lbs./Bu)	1000-kernel weight (grams)
1	1	3	91.1	57.4	34.0
1	1	1	44.5	56.7	31.5
1	1	2	49.0	57.5	35.0
1	3	1	51.0	56.4	34.5
1	3	3	79.8	57.9	36.5
1	3	2	59.3	58.5	36.0
1	6	2	13.1	21.3	15.0
1	6	1	6.0	.	14.0
1	6	3	10.5	21.3	17.5
1	5	2	70.8	57.6	34.5
1	5	3	57.4	57.8	38.0
1	5	1	56.4	57.4	33.5
1	2	2	70.6	56.8	36.5
1	2	3	60.4	57.9	35.5
1	2	1	55.7	56.8	34.5
1	4	2	70.5	56.8	34.5
1	4	1	48.3	56.7	32.5
1	4	3	53.3	57.1	33.0
2	6	3	1.5	.	23.5
2	6	2	0.3	.	.
2	6	1	0.3	.	13.0
2	2	1	53.7	55.7	32.0
2	2	3	20.0	54.7	31.0
2	2	2	10.3	23.0	22.5
2	5	3	50.4	56.1	35.0
2	5	2	34.5	55.4	30.0
2	5	1	32.3	55.9	34.5
2	4	1	48.0	54.8	32.0
2	4	3	42.5	56.4	33.0
2	4	2	31.2	55.7	29.0
2	3	3	50.5	55.8	34.0
2	3	1	46.9	56.7	36.5
2	3	2	48.1	54.4	32.5
2	1	2	47.7	55.2	33.5
2	1	1	34.3	56.1	33.5
2	1	3	40.5	55.4	29.5
3	3	3	77.1	56.4	36.5
3	3	2	73.0	58.3	33.5
3	3	1	61.3	57.5	34.0

3	4	1	50.2	56.7	30.0
3	4	2	58.2	56.8	31.5
3	4	3	65.8	57.9	36.0
3	6	1	7.9	20.3	15.0
3	6	3	4.3	.	16.5
3	6	2	10.8	19.7	15.0
3	1	3	74.5	58.1	35.0
3	1	2	74.6	57.6	36.0
3	1	1	52.3	57.6	33.5
3	5	3	59.3	57.8	33.5
3	5	1	56.1	57.4	34.0
3	5	2	41.7	57.4	31.0
3	2	3	78.8	58.5	34.0
3	2	1	65.1	57.9	38.5
3	2	2	67.5	57.6	36.0
4	3	3	74.4	58.3	38.5
4	3	1	55.7	57.2	37.0
4	3	2	71.6	58.6	37.0
4	6	2	3.0	.	20.0
4	2	1	1.6	.	23.0
4	6	3	15.3	51.9	27.0
4	1	1	50.7	55.1	30.0
4	1	3	68.9	581	40.6
4	2	1	24.6	49.0	23.0
4	2	2	40.8	54.0	29.0
4	2	3	48.1	57.6	37.5
4	4	3	50.2	57.1	33.5
4	4	2	27.2	53.6	25.0
4	4	1	45.1	56.1	30.5
4	5	1	40.9	55.2	31.0
4	5	2	43.3	57.4	36.0
4	5	3	56.4	57.5	36.5

† Planting dates 1 = 12 September; 2 =18 September; 3 = 25 September; 4 = 5 October; 5 = 9 October; and 6 = 17 October.

‡ Insecticide treatments: 1 = no insecticide (control); 2 = GAUCHO; and 3 = GAUCHO + CYGON.

APPENDIX C

GRAIN YIELD, TEST WEIGHT, AND THOUSAND-KERNEL WEIGHT DATA OBTAINED DURING THE SECOND YEAR (1996/7).

APPENDIX C

Replication	Planting date	Insecticide Treatment	Grain yield (Bu/A)	Test weight (lbs./Bu)	1000-kernel weight (ounce)
1	3	1	67.4	58.1	1.37
1	3	2	67.6	67.9	1.33
1	1	2	55.7	59.1	1.48
2	1	2	68.0	59.2	1.43
2	2	2	93.3	58.5	1.37
1	4	1	65.2	58.3	1.30
2	2	1	85.0	58.1	1.37
2	3	1	88.2	58.5	1.40
1	2	2	91.2	58.8	1.37
2	4	2	72.6	59.2	1.43
2	4	1	75.0	59.7	1.48
2	3	2	91.8	58.8	1.43
2	1	1	63.4	59.2	1.48
1	2	1	.	58.2	1.30
1	4	2	57.6	59.1	1.30
1	1	1	68.2	59.3	1.40
3	1	1	77.1	59.2	1.43
3	4	1	67.3	60.1	1.43
4	1	1	60.2	59.3	1.48
4	3	1	74.9	58.9	1.37
3	3	2	76.6	58.1	1.33
3	2	2	87.6	58.8	1.40
3	2	1	82.4	59.1	1.40
3	3	1	80.4	59.5	1.37
3	1	2	84.7	60.2	1.51
4	2	1	87.6	59.3	1.33
4	1	2	89.3	59.5	1.43
4	3	2	86	58.1	1.37
3	4	2	63.3	60.5	1.51
4	4	1	63.8	59.9	1.48
4	4	2	77.4	60.1	1.43
4	2	2	86.9	59.5	1.33

† Planting dates 1 = 21 September; 2 =30 September; 3 = 11 October; and 4 = 21 October.
‡ Insecticide treatments: 1 = no insecticide (control); 2 = GAUCHO + CYGON

APPENDIX D

ELISA VALUES (ABSORBANCE) FROM PLANT SAMPLES COLLECTED OVER TIME IN THE FIRST YEAR.

APPENDIX D

Replication	Planting date	Insecticide Treatment	Sample 1 (18 Jan'96)	Sample 2 (13 May'96)	Sample 3 (27May'96)	Sample 4 (4Jun'96)
			Absorbance			
1	1	3	0.049	0.005	1.605	0.069
1	1	1	0.076	0.155	1.413	0.422
1	1	2	0.111	0.000	0.706	0.109
1	2	2	0.034	0.010	0.003	0.053
1	2	3	0.065	0.043	1.086	0.038
1	2	1	0.142	0.222	0.076	0.068
1	3	1	0.006	0.031	0.220	0.035
1	3	3	0.008	0.021	0.967	0.048
1	3	2	0.038	0.026	0.093	0.063
1	4	2	0.032	0.027	0.000	0.089
1	4	1	0.011	0.035	0.017	0.005
1	4	3	0.000	0.054	0.174	0.044
1	5	2	0.000	0.038	0.054	0.063
1	5	3	0.215	0.001	0.022	0.034
1	5	1	0.179	0.057	0.143	0.009
1	6	2	0.255	0.125	0.015	0.051
1	6	1	0.226	0.035	0.098	0.036
1	6	3	0.336	0.026	0.037	0.031
2	1	2	0.017	0.000	0.090	0.166
2	1	1	0.191	0.011	0.132	0.036
2	1	3	0.059	0.010	0.398	0.099
2	2	1	0.016	0.024	0.030	0.127
2	2	3	0.027	0.029	0.031	0.012
2	2	2	0.043	0.078	1.307	0.034
2	3	3	0.073	0.032	0.144	0.026
2	3	1	0.042	0.004	0.345	0.080
2	3	2	0.041	0.012	0.246	0.002
2	4	1	0.082	0.036	0.100	0.034
2	4	3	0.056	0.011	0.070	0.023
2	4	2	0.018	0.009	0.019	0.047
2	5	3	0.066	0.003	0.060	0.027
2	5	2	0.126	0.005	0.061	0.046
2	5	1	0.158	0.014	0.057	0.060
2	6	3	0.011	0.038	0.002	0.014
2	6	2	0.100	0.002	0.024	0.017
2	6	1	0.057	0.008	0.017	0.035

3	1	3	0.046	0.470	0.561	0.086
3	1	2	0.021	0.063	0.309	0.165
3	1	1	0.079	0.235	0.605	0.357
3	2	3	0.038	0.030	0.785	0.035
3	2	1	0.001	0.309	0.163	2.100
3	2	2	0.000	0.000	0.878	0.042
3	3	3	0.081	0.046	0.497	0.142
3	3	2	0.009	0.053	0.167	0.059
3	3	1	0.042	0.035	0.771	0.069
3	4	1	0.072	0.045	0.117	0.023
3	4	2	0.000	0.042	0.007	0.051
3	4	3	0.000	0.005	0.005	0.101
3	5	3	0.102	0.016	0.290	0.041
3	5	1	0.115	0.017	0.175	0.024
3	5	2	0.141	0.055	0.029	0.058
3	6	1	0.739	0.038	0.022	0.006
3	6	3	0.490	0.010	0.036	0.034
3	6	2	0.233	0.003	0.030	0.062
4	1	1	0.010	1.097	0.880	0.190
4	1	2	0.162	0.006	0.085	0.098
4	1	3	0.088	0.017	0.100	0.039
4	2	1	0.040	0.131	0.466	0.068
4	2	2	0.019	0.015	0.431	0.064
4	2	3	0.032	0.038	0.703	0.016
4	3	3	0.026	0.022	1.213	0.049
4	3	1	0.019	0.021	0.260	0.063
4	3	2	0.025	0.017	0.264	0.144
4	4	3	0.035	0.032	0.041	0.043
4	4	2	0.030	0.019	0.041	0.037
4	4	1	0.036	0.021	0.009	0.092
4	5	1	0.194	0.026	0.057	0.049
4	5	2	0.048	0.033	0.022	0.013
4	5	3	0.030	0.011	0.006	0.007
4	6	2	0.059	0.015	0.033	0.061
4	6	1	0.295	0.005	0.020	0.027
4	6	3	0.260	0.013	0.011	0.023

† Planting dates: 1 = 12 September; 2 =18 September; 3 = 25 September; 4 = 5 October; 5 = 9 October; and 6 = 17 October.

‡ Insecticide treatments: 1 = no insecticide (control); 2 = GAUCHO; and 3 = GAUCHO + CYGON

APPENDIX E

ELISA VALUES (ABSORBANCE) FROM PLANT SAMPLES COLLECTED OVER TIME IN THE SECOND YEAR.

APPENDIX E

Replication	Planting date	Insecticide Treatment	Sample 1 (30 Nov'96)	Sample 2 (13 May'97)	Sample 3 (31 May'97)	Sample 4 (11 Jun'97)
			Absorbance			
1	3	1	0.076	0.097	0.086	0.049
1	1	2	0.253	0.211	0.000	0.081
1	3	2	0.051	0.212	0.000	0.091
1	2	2	0.103	0.151	0.054	0.071
1	4	1	1.221	0.104	0.000	0.004
1	2	1	0.171	0.145	1.292	0.329
1	4	2	0.811	0.147	0.063	0.280
1	1	1	0.214	0.178	0.034	0.077
2	1	2	0.298	0.216	0.000	0.598
2	2	2	0.153	0.062	0.000	1.071
2	2	1	0.261	0.129	0.012	1.236
2	4	2	0.176	0.108	0.072	0.131
2	3	1	0.183	0.181	0.009	0.287
2	4	1	0.159	0.133	0.033	0.056
2	1	1	0.142	0.025	0.000	0.137
2	3	2	0.145	0.137	0.000	0.006
3	1	1	0.273	0.043	0.000	0.535
3	2	2	0.562	0.639	0.024	0.382
3	4	1	0.217	0.219	0.112	0.186
3	2	1	0.426	0.228	0.017	0.747
3	3	2	0.266	0.094	0.016	0.192
3	3	1	0.103	0.232	0.090	0.297
3	1	2	0.376	0.225	0.000	0.000
3	4	2	0.180	0.165	0.030	0.304
4	2	2	0.332	0.171	0.000	0.209
4	1	2	0.223	0.230	0.000	0.321
4	1	1	0.137	0.130	0.000	0.133
4	3	2	0.201	0.064	0.001	0.366
4	3	1	0.128	0.173	0.106	0.141
4	2	1	0.229	0.137	0.025	0.442
4	4	2	0.129	0.080	0.018	0.311
4	4	1	0.231	0.118	0.050	0.369

† Planting dates 1 = 21 September; 2 =30 September; 3 = 11 October; and 4 = 21 October.

‡ Insecticide treatments: 1 = no insecticide (control); 2 = GAUCHO + CYGON

APPENDIX F

DAYS OF YEAR OF INITIATION OF STEM ELONGATION AND ANTHESIS IN YEAR 1.

APPENDIX F

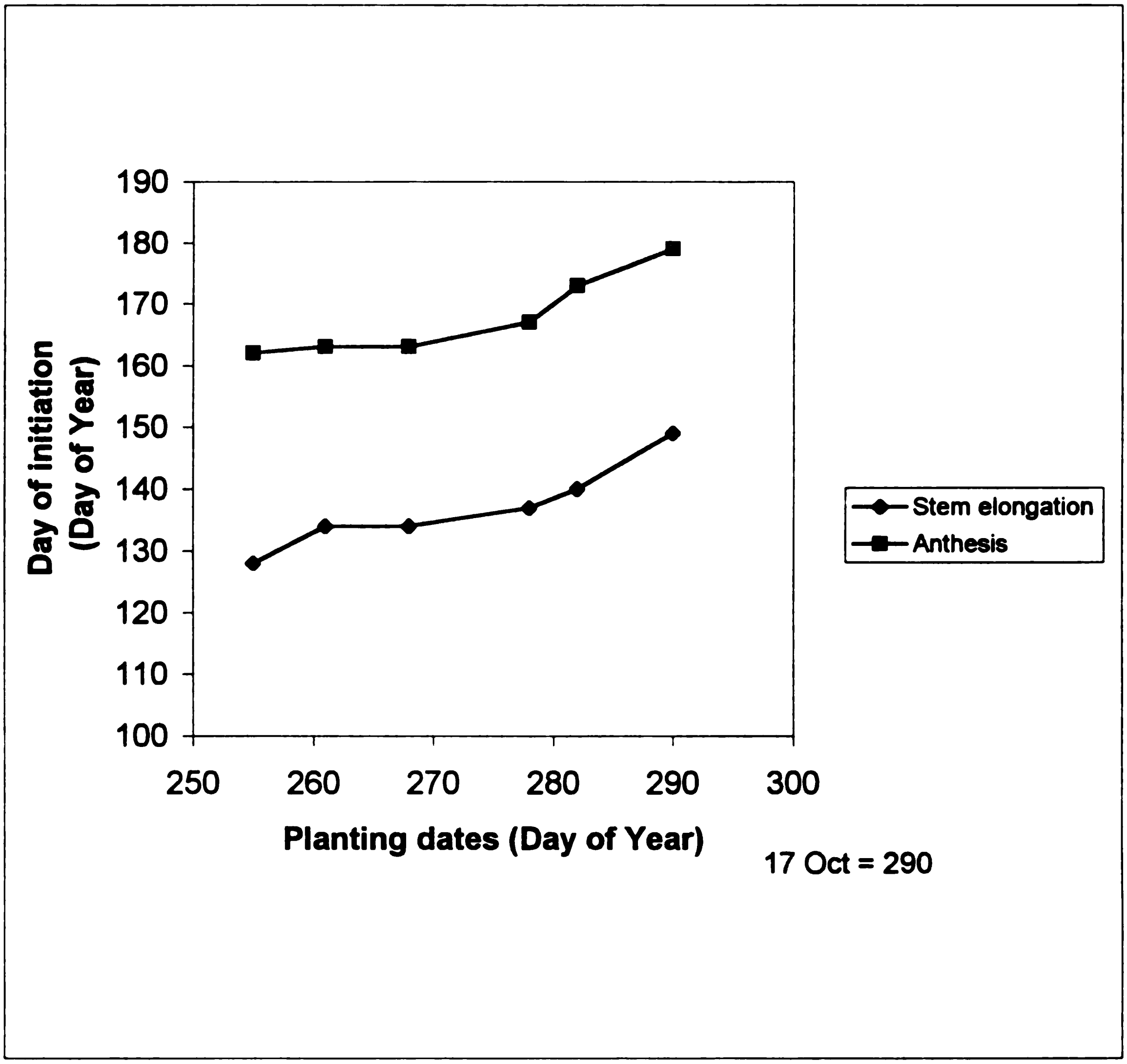

Figure 1 - Days of year of initiation of stem elongation and anthesis in Year 1.

APPENDIX G

DAYS OF YEAR OF INITIATION OF STEM ELONGATION AND ANTHESIS IN YEAR 2.

APPENDIX G

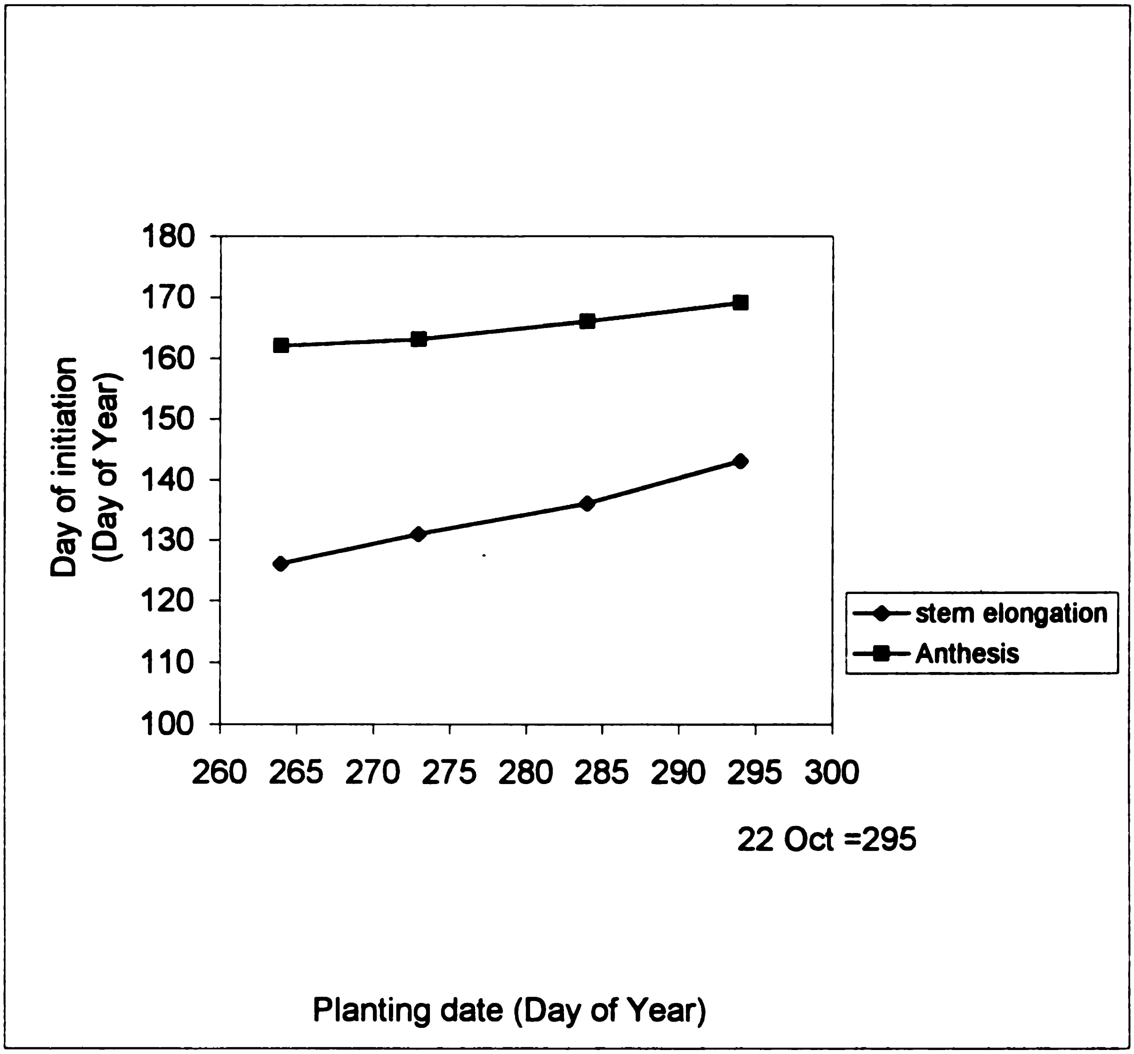

Figure 2 - Days of year of initiation of stem elongation and anthesis in year 2.

APPENDIX H

THE EFFECT OF PLANTING DATE ON GRAIN YIELD OF WINTER WHEAT VARIETY 'HARUS' IN YEAR 1 AND YEAR 2.

APPENDIX H

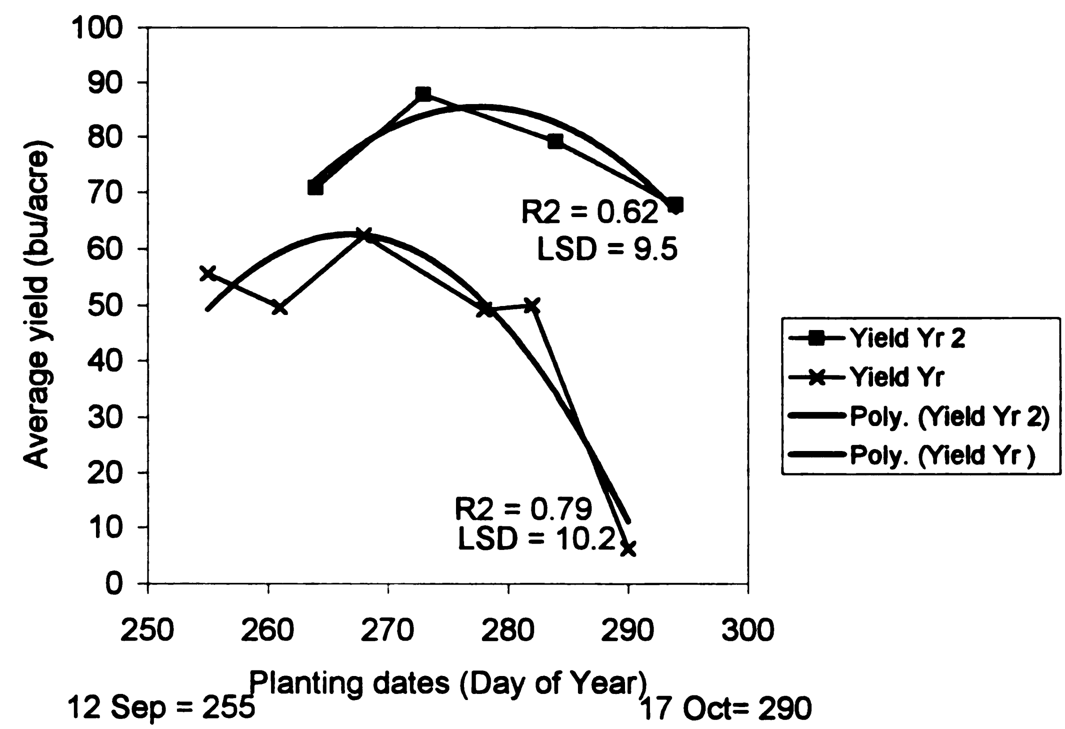

Figure 3 - Effect of planting date on grain yield of winter wheat variety 'Harus' in year 1 and year 2.

APPENDIX I

THE EFFECT OF PLANTING DATE ON TEST WEIGHT OF HARUS WINTER WHEAT IN YEAR 1 AND YEAR 2.

APPENDIX I

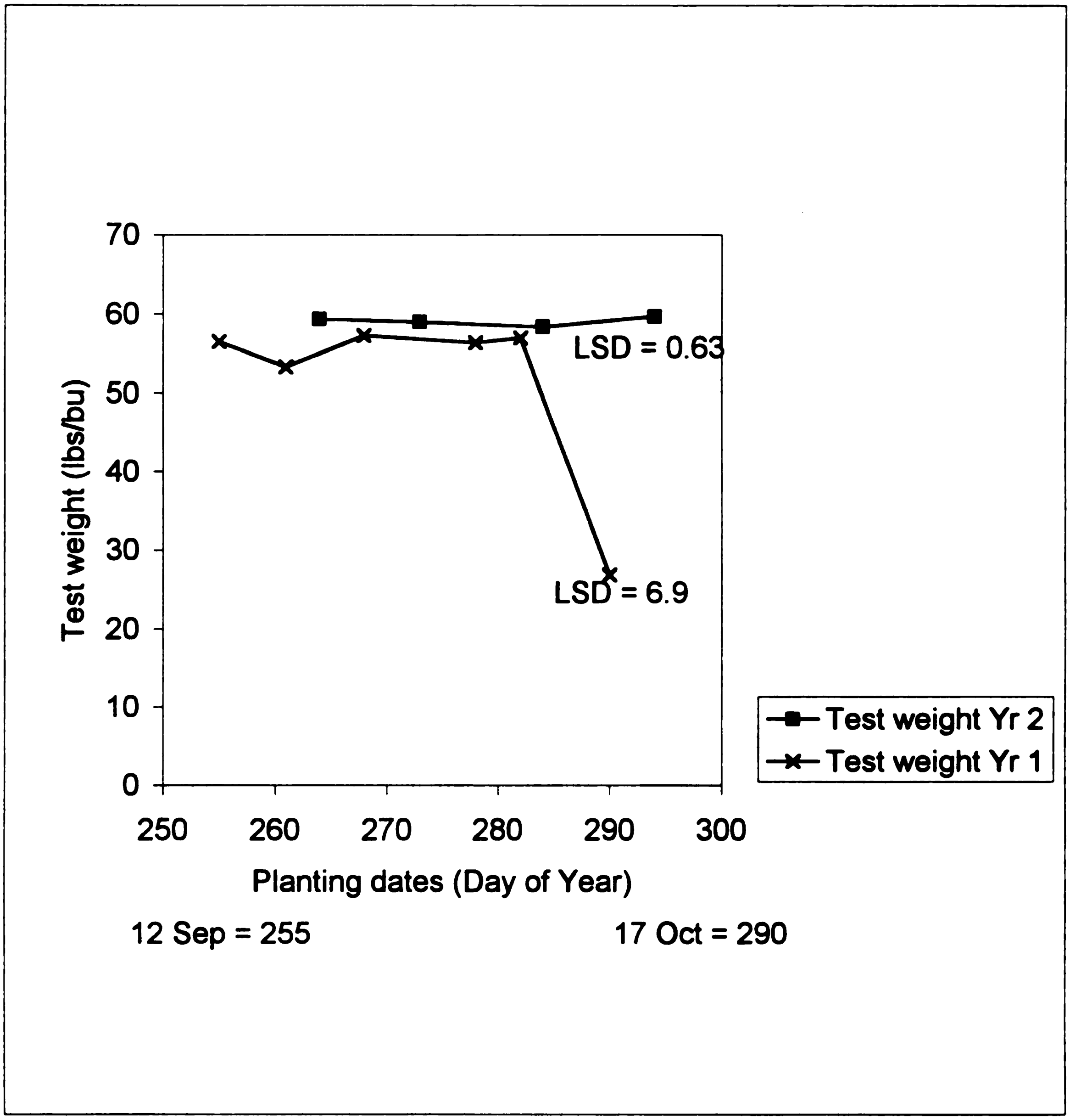

Figure 4 - The effect of planting date on test weight of Harus winter wheat in year 1 and year 2.

APPENDIX J

THE EFFECT OF INSECTICIDE TREATMENTS ON GRAIN YIELD OF HARUS WINTER WHEAT IN YEAR 1 AND YEAR 2.

APPENDIX J

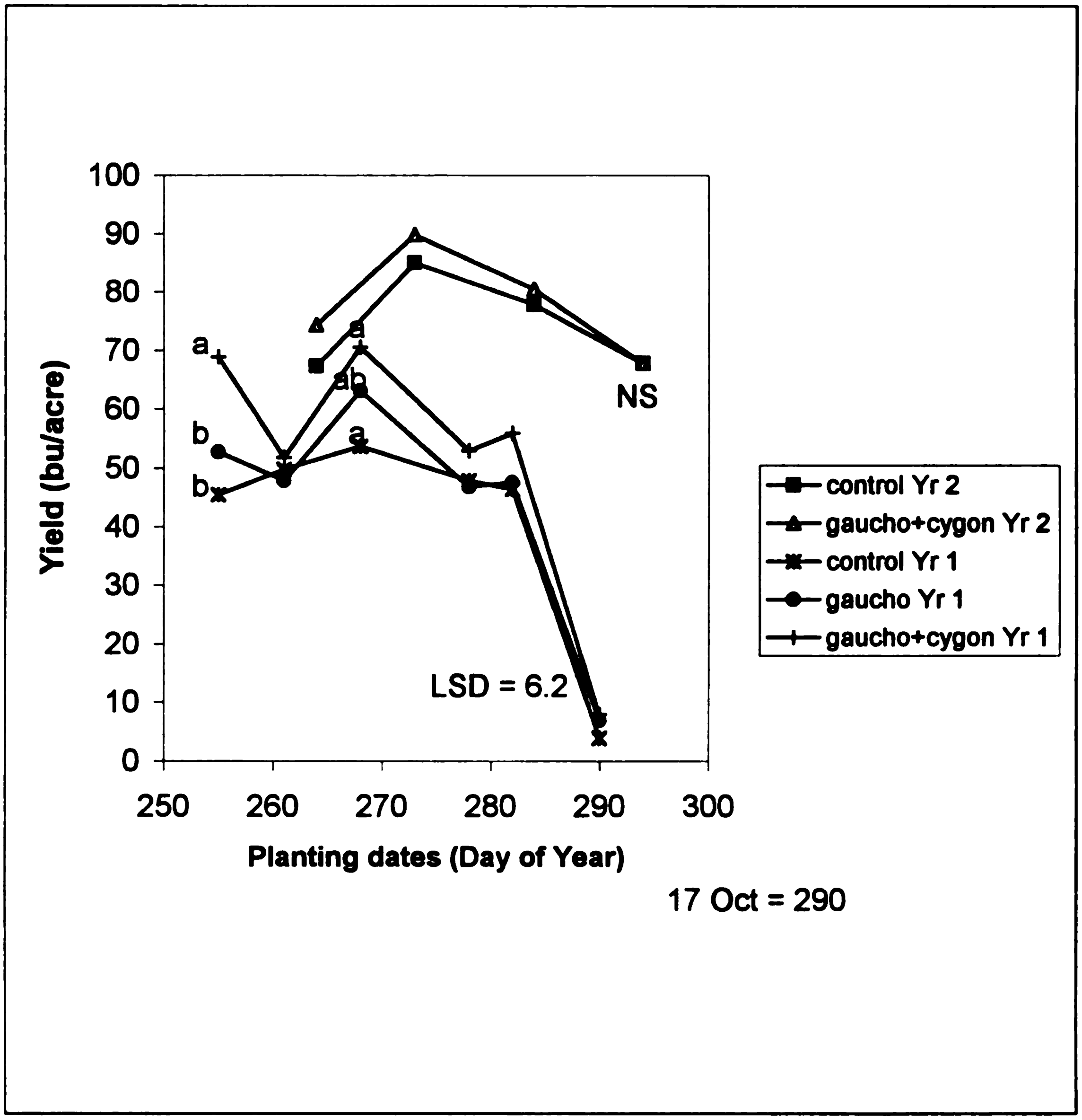

Figure 5 - The effect of insecticide treatments on grain yield of Harus winter wheat in Year 1 and Year 2.

APPENDIX K

TEST WEIGHT OF WINTER WHEAT VARIETY HARUS AS INFLUENCED BY INSECTICIDE TREATMENTS IN YEARS 1 AND 2.

APPENDIX K

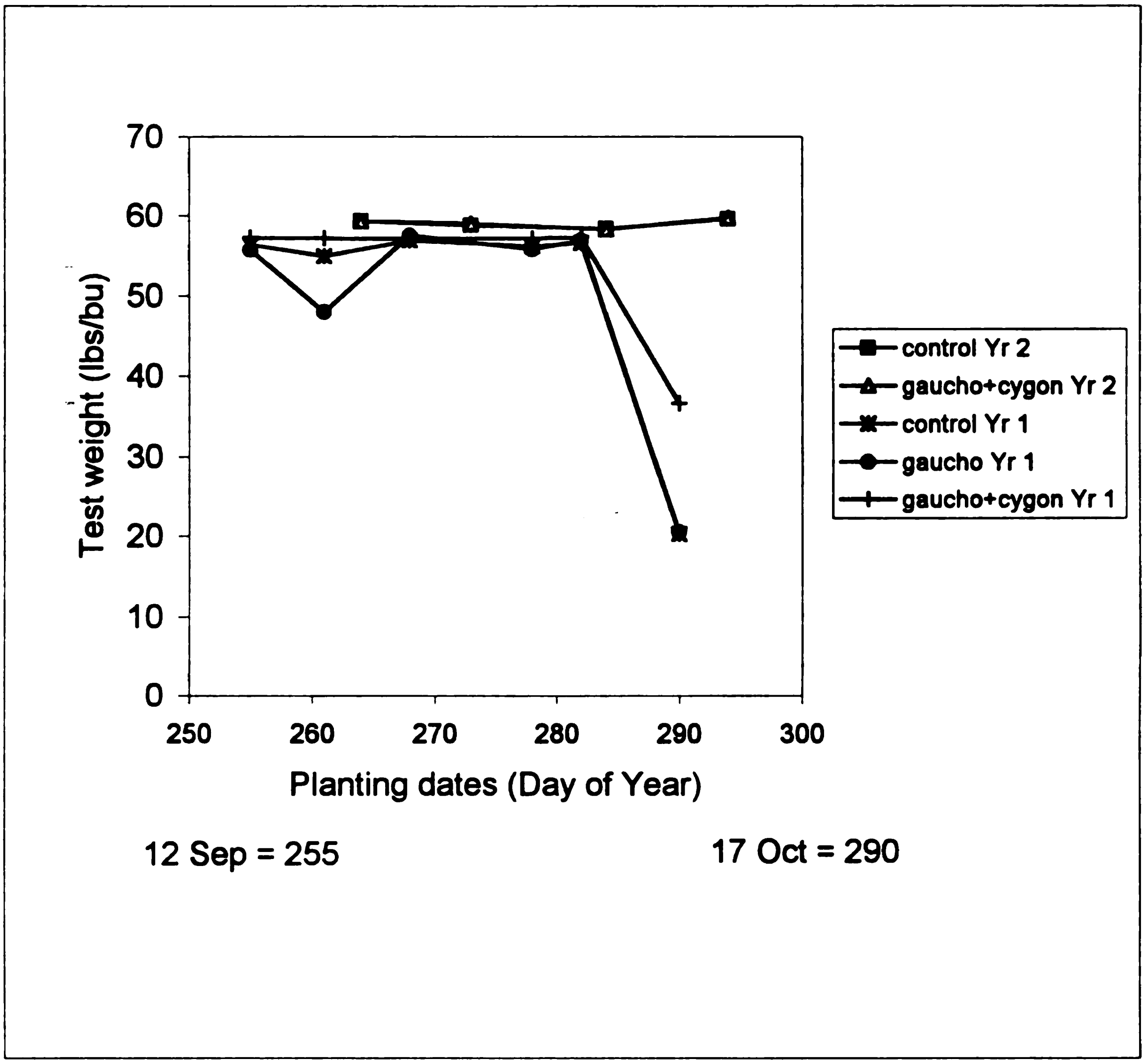

Figure 6 - Test weight of winter wheat variety Harus as influenced by insecticide treatments in years 1 and 2.

APPENDIX L

THE RELATIONSHIP BETWEEN PLANTING DATE AND BARLEY YELLOW DWARF VIRUS CONCENTRATION FROM WINTER WHEAT IN YEAR 1 AND YEAR 2.

APPENDIX L

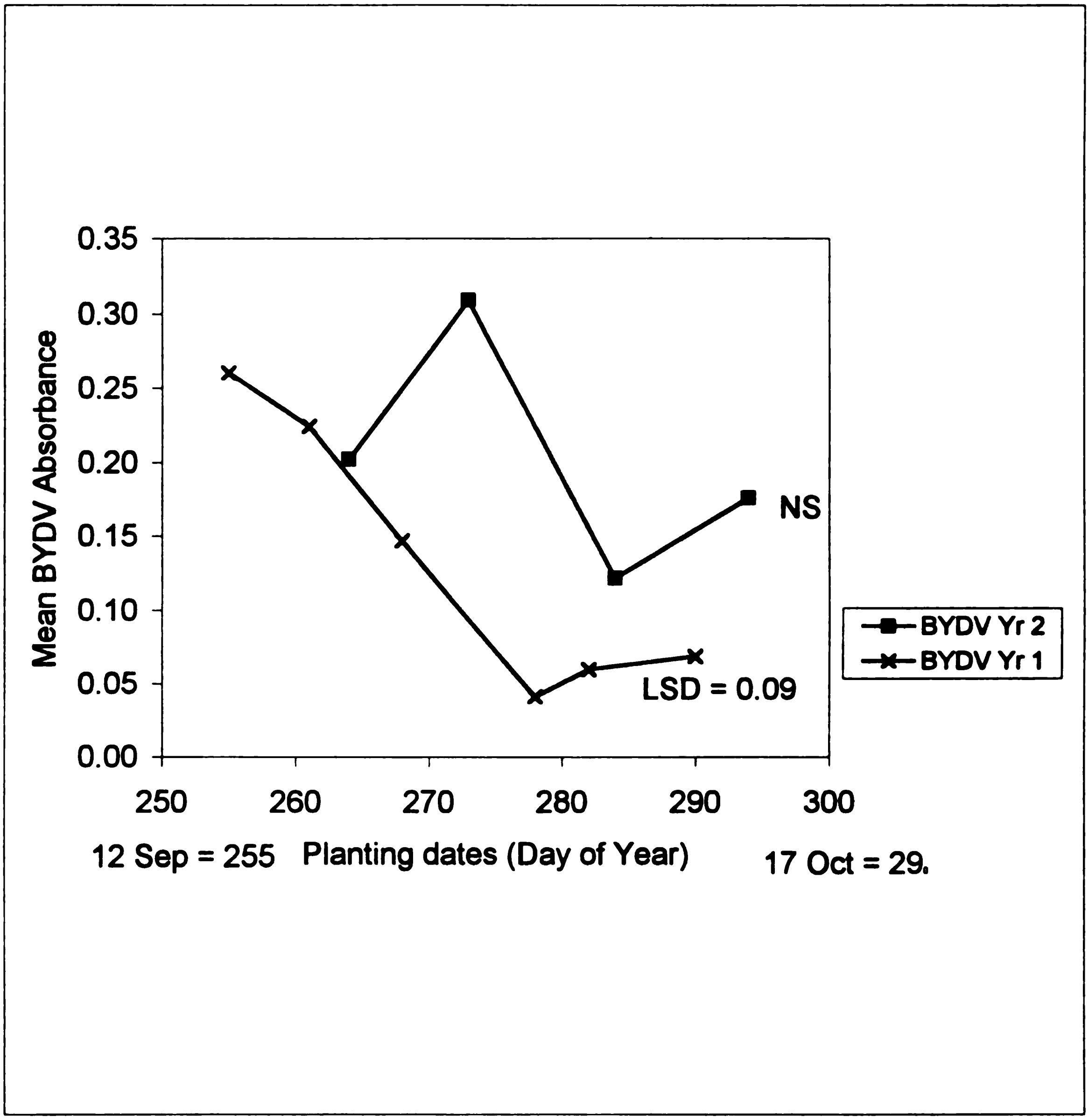

Figure 7 - The relationship between planting date and barley yellow dwarf virus concentration from winter wheat in year 1 and year 2.

APPENDIX M

A COMPARISON OF INSECTICIDE TREATMENTS IN RELATION TO THE CONTROL OF BARLEY YELLOW DWARF VIRUS ON HARUS WINTER WHEAT IN YEAR 1.

APPENDIX M

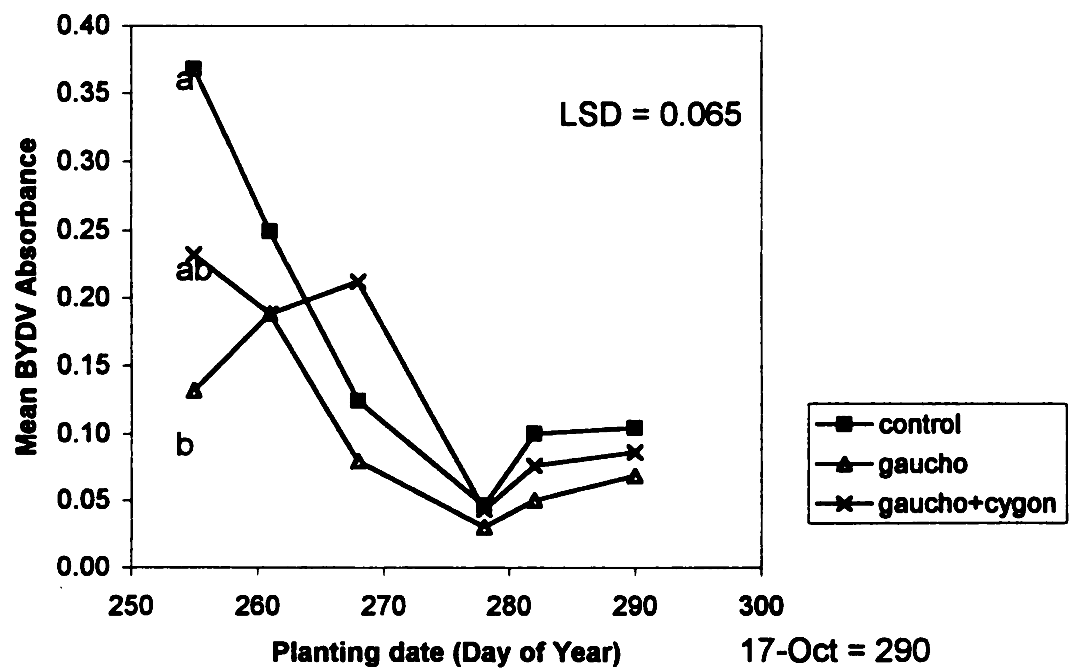

Figure 8 - A comparison of insecticide treatments in relation to the control of barley yellow dwarf virus on Harus winter wheat in Year 1.