A STUDY OF SOME ASPECTS OF INTENSIVE MANAGEMENT OF SPRING BARLEY IN SOUTH WESTERN QUEBEC

BY

ELIZABETH WANGA MALOBA
PLANT SCIENCE DEPT.
MCGILL UNIVERSITY, MONTREAL
JANUARY 1991

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulmillment of the requirements for the degree of Master of Science in Plant Science.

(c) Elizabeth Wanga Maloba 1991.

ACKNOWLEDGEMENTS

My greatest thanks and appreciation go to God the Father, Son and Holy Spirit, who by His infinite grace and faithfulness provided the means by which I have been able to undertake this study.

To my supervisor Dr. Donald Smith who helped me with the details, patiently reviewed my work, was a source of numerous valuable suggestions, and provided the persistent encouragement that kept me going. I am very grateful.

I thank Drs. Bruce Coulman and Harold Klinck who were on my supervisory committee for their helpful comments and advice; Joan Kearvall, Sima Khosrhavi and Stewart Leibovitch whose technical know-how was of great help; my fellow students, Baoluo Ma, Patrick Bulman, Chantal Hamel and Ralph Martin for their assistance in the field work and for their valuable comments.

I also thank the Kenyan Government for offering me the scholarship that supported me during this work. I thank my employer, the Kenya Agricultural Research Institute for giving me leave of absence to study.

I extend my gratitude to my parents Professor and Mrs. Maloba for their commitment to providing their children with a good education. This is one of the fruits of that commitment.

I want to thank my husband Dankit whose unfailing love, encouragement and patience has been my support throughout my studies, and also my children Luseno and Manakhe whose time I used so freely.

Finally, to those others whom I have interacted with during my studies, I am thankful.

ABSTRACT

There may be potential to increase cereal yields in North America by the use of Intensive Cereal Management (ICM) practices similar to those that have been used successfully in Europe. High levels of nitrogen fertilizers applied along with plant growth regulators and fungicides at high seeding rates and in narrow row widths have resulted in large yield increases in Europe (Gallagher, 1984). Studies in North America indicate that higher yields are also possible (Fredrick and Marshall, 1985; Stobbe et al. 1985; Nafziger et al. 1985).

Three experiments were carried out at the E. A. Lods Research Centre of Macdonald College of McGill University in 1987 and 1988 to evaluate the applicability of some aspects of the intensive management system to barley production in Québec. In the first experiment, the effects of three levels of nitrogen fertilizer (0, 70, and 140 kg/ha) and ethephon (Cerone) on the performance of the cultivars Cadette, Laurier and Leger were tested. The aim of the second experiment was to test the effects of fungicide (Bayleton at 140 g a.i./ha) application and row width (10 and 20 cm) on the same cultivars as in the first experiment. In the third experiment, conventional and intensive management techniques were tested on three soil types on which four barley cultivars (Cadette, Laurier, Leger and Joly) were grown.

The application of high levels of nitrogen did not increase barley yields under dry weather conditions and when the soil nitrogen resources were high. The high levels of nitrogen increased the grain protein content and thus improved the feed quality of spring barley. Application of ethephon in the absence of lodging reduced plant height but also reduced yields by reducing the number of grains per head. Narrow row widths led to a higher tiller number but did not necessarily increase yields. A fungicide by row width interaction resulted in a reduced seed size and seed weight in the narrow rows and this may be responsible for the lack of yield response in these rows. The effects of intensive management on yield were inconsistent and were influenced to a large extent by the prevailing weather and soil conditions.

TABLE OF CONTENTS

LIST OF TABLES

HYPOTHESIS

Main Hypothesis:

Under the environmental conditions existing in southwestern Québec the application of intensive management techniques has the potential to increase barley yields and improve grain quality.

Sub-hypotheses:

1. The application of large amounts of nitrogen on high yielding cultivars will increase yields provided that lodging and diseases are controlled.
2. The application of ethephon will prevent lodging by reducing the height of the crop.
3. The application of the fungicide Bayleton will prevent and control powdery mildew and the leaf spot diseases.
4. The use of narrow row widths will increase yields by enhancing tiller numbers.
5. The use of an intensive management package will increase yields equally on all soil types.

OBJECTIVES

1. To determine the effects of nitrogen fertilizer levels and ethephon on the performance of three spring barley cultivars.
2. To determine the effect of using narrow row widths and a fungicide on the performance of three spring barley cultivars.
3. To determine the effect of intensive management on the performance of four spring barley cultivars grown on three soil types.

1. INTRODUCTION AND LITERATURE REVIEW

1.1 Culture and Use

Barley, Hordeum vulgare L. is second to wheat in importance as a cereal crop in Canada. It is the most widely grown small-grain cereal in Quebec, covering 160,000 hectares. All of the barley produced in Quebec is spring type. Barley is grown almost exclusively for use as a feed grain in Quebec; small amounts are occasionally used as pasture, silage or hay or as a source of malt. During the last five years the average yields of barley in Quebec have ranged from 2.6-3.4 tonnes per hectare. A high protein content is desirable for barley used as a feed. Nitrogen is a major requirement for high yields of barley.

1.2 Intensive Cereal Management

Intensive cereal management practises have been used with some success in Europe and trials in North America have indicated that a significant yield benefit may be derived from their use under certain climatic conditions (Fredrick and Marshall 1978). The management practices involve the use of responsive high yielding varieties grown with high levels of nitrogen fertilization, in narrower row spacings than are conventionally used and with the application of growth regulators and pesticides (herbicides and fungicides in particular).

1.3 Nitrogen Fertilizers

Positive responses to increasing levels of nitrogen fertilizers have been observed in increased numbers of tillers, increased plant height and increased yield (Bingham et al. 1969; Campbell et al. 1977).

For barley and wheat, nitrogen applied at seeding time increases yields more than later applications (Widdoson et al. 1976; Gracia et al. 1984). Split applications of nitrogen fertilizers have been shown to give the highest yields (Palmer 1986). In Britain, yields of 6.4 t/ha of grain have been obtained from winter wheat that received 120 kg/ha of nitrogen (Palmer 1986). The greatest effect of nitrogen on winter wheat was on the number of tillers (Gracia et al. 1984). Large numbers of tillers, resulting from high levels of nitrogen fertilizer application may lead to incomplete grain filling, and, as a result, smaller grain sizes and lower test weights (Needham et al. 1976; Ohm et al. 1976).

Late foliar applications of nitrogen have resulted in reduced grain size and increased storage proteins (grain protein) in barley. The degree of response is usually dependent on the cultivar. Hordein (which accounts for 35-50 % of the total grain protein) is increased by high nitrogen fertility in some cultivars but not at all in others (Turley et al. 1986; Kirkman et al. 1982). Nitrogen application increases grain protein content because the principal sink for the nitrogen available after anthesis is the developing seed. The increase in grain protein content can be in the range of 33 to 47% (Turley et al. 1986).

1.4 Fungicides

Cereal foliage diseases can reduce yields by as much as 25-50% (Moseman 1968) and their control is essential under intensive management conditions. The most important fungal pathogens in cereals are powdery mildew, the leaf rusts and leafspot diseases. Spring barley in eastern Canada is most affected by spot blotch and net blotch although the other diseases just listed do cause considerable damage when high levels of infestation occur (Clark, 1979; Martin et al. 1988). Severe spot blotch epidemics of 1-2 weeks have been found to cause yield reductions of 10-20% ; epidemics of 3-4 weeks may reduce yields by 20-30% and reduce grain size by 10-15% (Clark,1979). Where fungicides have effectively been used to control spot blotch 15-20% yield increases have been obseverd (Coutoure et al 1978).

Powdery mildew, <u>Erysiphe graminis</u> can cause damage at any growth stage. Early epidemics directly affect plant growth by causing chlorosis and the development of lesions which later result in a reduced leaf size (Lim et al. 1986). Late epidemics of powdery mildew have been associated with increased floret and grain abortion and reduced grain size (Brooks et al. 1972; Lim et al. 1986).

Several fungicides have been tested to determine which is most effective in controling spot blotch, net blotch and powdery mildew on cereals. Propiconzole and triadimefon seem to be the most promising and they also effectively control leaf rust and septoria leaf blotch (Caldwell et al. 1987; Wale et al. 1985, Coutoure et al 1978). No interactions were observed between nitrogen fertilizer and fungicides on spring wheat, but in spring barley, Jenkyns et al. (1983) found that at high levels of nitrogen, the use of tridemorph resulted in very high yields. They also noted that the percentage grain nitrogen did not change with increasing levels of nitrogen if a crop was infested with powdery mildew, but in a crop where the disease had been controlled, there was a significant increase in grain nitrogen as nitrogen fertility increased.

Generaly several applications of fungicides are nessacary in controlling spot blotch and net blotch (Mather,1982). Triadimefon at low concentration is effective when timed with prevailing weather conditions (Couture et al 1978). The use of a seed treatment and a later spray treatment were most effective in controlling powdery mildew. Treatments of fungicides which gave the highest control of mildew also gave the highest yields although the yield responses were not always closely related to the degree of mildew control achieved, suggesting that the amount of yield reduction is not proportional to the symptoms observed.

1.5 Growth Regulators

Growth regulators are applied to cereal crops to reduce lodging by reducing plant height and increasing the stem strength, though recently there has been more emphasis in the use of growth regulators to increase the number of grains and the grain yield in barley and wheat.

Cycocel the trade name for Chloronequat chloride-(2 chloroethytrimethyl ammonium chloride) has been used successfully in wheat to reduce height and lodging (Whitter et al. 1971). Plants treated with it exhibit short stiff straw similar to the genetic double and triple dwarfs produced by the International Maize and Wheat Improvement Centre (CIMMYT). Cycocel encourages redistribution of dry matter and a reduction of assimilates to underground parts so that plants with more upright leaves, thicker and stiffer stems and more tillers are produced. Spring barley did not respond as well as wheat when treated with the Cycocel (Later 1965; Bokarev 1977; Kuhn and Hofner 1980) which may be due to more rapid decomposition of CCC in barley plants than in wheat plants (Bokarev 1967).

Ethephon (2 chloroethyl phosphonic acid) has been reported to have various effects on grain yield. Dahnous et al. (1982), Simmons et al. (1988) and Cox et al. (1989) found that yield could be enhanced by as much as 13 percent, under conditions favourable to lodging. In contrast, Murray and Dixon (1970) and Nafziger et al. (1989) found that even where heights were reduced and lodging controlled, grain yields have either remained constant or been reduced.

Ethephon may affect grain yield through elimination of lodging related yield loss and (or) through enhancement of tiller survival. Ethephon-treated cereals tend to lodge less because their stems are shorter, heavier, and stronger. Simmons et al. 1988 989) found that mass per unit of crop height was greater for ethephon-treated spring wheat and barley plants. Improved tiller survival has been reflected in an increased spike numbers per unit area (Mathews et al. 1981; Cartwright and Waddington 1981; Simmons et al. 1988). The main effect of growth regulator treatments is to reduce the dominance of the main stem, thus encouraging the development of more florets and the faster growth of spikes in later formed shoots (Waddington et al. 1986).

1.6 Row widths

Several studies have shown that the response of small grain cereals to row spacing has been an increase in grain yields as row widths were reduced below conventional widths (Holliday et al. 1963; Finlay et al. 1966; Briggs 1974; Brinkman et al. 1979; Fredrick et al. 1985 and Marshall et al. 1987).

Holliday et al. (1963) summarised work done in Europe and reported that narrow rows resulted in yield increases of 5-7% for wheat, barley and oats. Much of this increase resulted from an increase in the number of tillers per square meter and/or an increase in the size of the heads. Finlay et al. (1966) found that narrower row spacings resulted in increased numbers of spikes per square meter and the high yielding barley cultivars demonstrated a greater yield response to narrow row spacings than did their lower yielding counterparts. They also found that the effect of row width on spring barley yields was dependent on growing conditions and that there were no differences in 11, 18, 23, 31 cm row spacings when growing conditions were poor and yields were 2500 kg/ha, but they obtained higher yields with narrower rows in a year when the growing conditions were good and the yield was greater then 3500 kg/ha.

Brinkman et al. (1979) observed that grain yields were highest in 7.5 cm rows and lowest in 30 cm rows. Across cultivars and environments, the 7.5 cm rows yielded 4% more grain than the 15 cm rows and 12% more grain than the 30 cm rows. Grain and straw yield improvements in rows narrower than 30 cm corresponded closely to increased tillering. Plant height did not change with the narrower row spacing. Lodging decreased by 4% as row spacing was reduced and it was suggested that the reason may be that plants that are not crowded within a row may develop stronger lower stems that resist lodging, or they may not lodge as readily because the "domino effect" is reduced.

Roth et al. (1984) observed that wheat yields often increased through the use of narrower rows and that the increase was consistently high. Similarly in oat Marshall (1987) observed yield increases of 8.2% as row spacing was reduced from 18 to 13 cm. Increased tiller number contributed 70% of the grain yield increase (Fredrick et al. 1985).

Holiday et al. (1963), among others pointed out that the efficiency of nutrient uptake by roots is not greater in narrower rows and suggested that increased plant productivity in narrower rows is probably due to more efficient use of light in photosynthesis. Because small grains seeded in narrower rows have a better spatial arrangement and tiller more profusely, they intercept more light earlier in the growing season, thus increasing total photosynthesis and ultimately plant productivity is increased.

2. MATERIALS AND METHODS

2.1 General procedures

Three experiments were sown at the Emil A. Lods Agronomy Research Centre of Macdonald College in 1987 and 1988. Treatments were designed to test the effects of a fungicide (Bayleton, a trade name of Triadimefon, manufactured by Bayer, Leverkusen, West Germany), a plant growth regulator (Cerone, a commercial formulation of ethephon, manufactured by Rhone-Poulenc, Research Triangle Park, N. Carolina), management level (intensive or conventional, as defined below) and the rate of nitrogen fertilizer on yield, biomass and grain protein content of spring barley. The cultivars used were Cadette, Laurier, Leger and Joly. Plots were 3.8 meters long at seeding and consisted of 5 rows at a 20 cm row spacing or 11 rows at a 10 cm row spacing. Prior to harvest these were trimmed back to 3.4 meters to eliminate edge effects along the sides of the pathways. Certified seed treated with Vitaflo-280 (Carbathim plus thiram) was seeded at a rate of 450 seeds/m2. Spray treatments were applied with a Roper Lawn tractor fitted with a 275 cm boom mounted at the front and an 80 litre tank mounted at the rear. Five tee jet type nozzles on the boom were used to spray.

2.2 Experiment 1

The first experiment was designed to test the effects of three levels of nitrogen fertilizer (0, 70, or 140 kg/ha) and two levels of ethephon [0 and 480 g active ingredient (a.i.)/ha] on Cadette, Laurier and Leger. The experiment was seeded on May 2nd 1987 and May 4th 1988 respectively, as a 3 x 3 x 2 split plot in a randomized complete blocks replicated four times. Nitrogen was the main plot factor and was applied as ammonium nitrate broadcast on each plot at seeding. The subplots consisted of a factorial arrangement of cultivars and plant growth regulator. Ethephon was applied at Zadoks' growth stage (ZGS) 39, when the flag leaf is just visible (Zadoks et al. 1974).

2.3 Experiment 2

The second experiment was sown on the 2nd of May 1987 and the 3rd of May 1988 on the same soil as the first experiment. It was designed to test the effects of row width [narrow (10 cm) versus wide (20 cm)] and fungicide (Bayleton) at a rate of 140 g/ha on the same cultivars as those used in the first experiment. This was laid out as a factorial in randomized complete blocks.

2.4 Experiment 3

The third experiment was sown on May 3rd 1987 and May 5th 1988 and was designed to test the effect of the type of management (intensive versus conventional) on the performance of Cadette, Leger, Laurier and Joly planted on three soil types. Intensive management treatment employed the use of narrow rows (10 cm), a high rate of nitrogen fertilizers (140 kg/ha) and an application of Ethephon at ZGS 39. Conventional management employed the use of wide rows (20 cm) and a lower rate of nitrogen fertilizers (70 kg/ha) only. The soil types used were sand (Chicot sandy loam), loam (St. Bernard loam) and Clay (Bearbrook Clay). The experiment was planted in a completely randomized split-split-plot layout with soil type being the main plot, cultivar the subplot and management the sub-sub-plot.

2.5 Variables measured

The variables measured were stand count, number of heads per meter, number of grains per head, plant height, days to heading and days to maturity, disease level, lodging, grain yield and percent protein of the grain and straw. Stand counts were made on samples of one meter of row, with three samples being taken per plot and averaged. The number of heads per meter was determined by counting the number of heads per three meter of row and converting to a m^2 basis. The number of grains per head were obtained from the mean of the number of grains from 10 randomly selected heads per plot. Plant heights were the mean of two samples per plot taken at ZGS 83. Days to heading were defined as the number of days from seeding to when 50% of the plot was in the swollen boot stage ZGS 45. Days to maturity were the number of days from seeding to hard dough and ripening, where hard dough indicates physiological maturity and ripening indicates harvest maturity and these are the ZGS 87 and 90.

Disease scores were taken for powdery mildew, Erysiphe graminis, spotblotch, Cochlibolus sativus and rust, Puccina hordei Otth. on the penultimate and flag leaves. The score was on a scale of 1 to 10, where 1 indicates that the disease being scored covers at least 1-10% of the leaf for 50% of all the infected leaves per plot, while a score of 10 indicates that the disease being scored covers at least 91-100% of the leaf for 50% of all the infected leaves per plot.

Lodging scores were determined by degree and by area lodged following the Belgian lodging scale (Wiersman et al. 1986). Lodging by degree was measured on a scale of 1 to 5. A score of 1 indicates a crop standing upright or at 90 degrees, while a score of 5 indicates a flattened crop or bent at an angle of 22 degrees or less. Lodging by area was measured on a scale of 1 to 10. One indicates that up to 10% of the plot has lodged and 10 indicates that between 91% and 100% of the plot had lodged. Harvesting was done using a Kincaid combine harvester. The grain samples were dried to a constant weight at 70oC, weighed, the moisture content determined and the subsequent yields per plot were converted to yields in kg/ha, corrected for moisture (14%).

Harvest index was obtained from one meter row samples that were collected at harvest, dried and separated into grain and straw. The grain and straw weights were used to determine the harvest index for each plot. Protein was determined by the Kjeldahl method using a Tecator analysis system (Tecator Co. Hoganas, Sweden).

2.6 ^{15}N Determination

In 1988 a 99% ^{15}N (ammonium nitrate) solution was applied at a rate of 2 kg N/ha to 20 x 50 cm subplots. ^{15}N was applied on May 8th, 1988. The subplots were bounded by a plastic border extending 15 cm into the soil. The procedure used for ^{15}N analysis was an adaptation of the Dumas method (Preston et al. 1981, Fiedler and Proksch 1975). An aliquot, containing 7 g of N was taken from a Kjeldahl distillation solution, added to a 6 mm diameter, 18 cm long glass tube, and dried. Previously heated CuO (catalyst) and CaO (drying agent) were then added, in excess, to each tube, and each tube was attached to a vacuum line and evacuated to a pressure of less than 0.006 mbar. The tubes were then sealed by closing them at about 12 cm from the bottom with an acetylene torch. The sealed tubes were baked over night at 500o C before being analyzed for percent ^{15}N on an emission spectrometer (^{15}N analyzer, Jasco Co. Easton, Maryland).

Table 1. Rainfall and temperature data for 1986, 1987 and 1988 in May, June, July and August.

	Rainfall (mm)	Average Temperature (C)

	1986	1987	1988	198€	1987	1988
May	49.0	71.6	47.0	13.7	13.1	15.4
June	121.9	115.6	74.8	16.3	18.9	18.2
July	134.1	105.4	36.6	19.7	20.5	22.5
August	130.5	58.3	113.4	18.2	18.5	20.9

2.7 Statistical Analysis

Statistical analyses were conducted with the SAS system (Ray 1982). comparisons between means were made with the Fisher's protected LSD, as described specifically for this purpose by Steel and Torrie (1980). As whole plot and model error terms were not significantly different the former was used to determine least significant difference and coefficient of variation values.

3. RESULTS

3.1 Experiment 1. Response to nitrogen, cultivar and ethephon

3.1.1 Yield and yield components

In both years, the level of nitrogen fertilizer applied did not affect the yield and there were no significant main effects of nitrogen on any of the yield components (Tables 2 and 3).

Ethephon application significantly reduced grain yields in both years. In 1987, ethephon application significantly reduced all of the yield parameters for the number of heads per square meter. In 1988, ethephon application significantly reduced hectolitre weight, the number of heads per square meter and the number of kernels per head.

In both years the effects of the applied treatments on the yield components varied among cultivars. Significant differences were observed between the cultivars for all the yield components except yield itself and the number of heads per square metre in 1987. In 1988, significant differences were observed for the yield, the 1000 grain weight and for the number of grains per head. Leger had the highest yield in 1988 while Cadette had the lowest. In both years, Laurier had the highest 1000-grain weight while Leger had the lowest. Laurier also had the highest number of grains per head and the highest hectolitre weight in 1987 while in 1988, it had the highest number of heads per square metre. The hectolitre weight was lowest in 1987 for Cadette. Leger had the highest number of grains per head in 1988 but for the same year, it had the lowest harvest index (Tables 2 and 3).

Table 2: Main effects of cultivar, nitrogen fertilizer and plant growth regulator on spring barley yield components in 1987.

	Yield (T/ha)	1000-grain weight (g)	Hectolitre weight (kg)	Harvest Index	Heads m^{-2}	Grains $head^{-1}$
Cultivar						
Cadette	5.430ab	40.213b	58.275c	0.536a	458b	30.522a
Laurier	5.514a	44.783a	62.825a	0.525a	494a	25.661b
Leger	5.164b	37.192c	60.704b	0.468b	442b	32.617a
Difference	ns	**	**	**	ns	**
N levels						
0	5.336a	40.483a	60.367a	0.516a	469a	29.121a
70	5.308a	40.704a	60.946a	0.512a	451a	30.675a
140	5.464a	41.000a	60.492a	0.501a	474a	29.005a
Difference	ns	ns	ns	ns	ns	ns
PGR						
No Ethephon	5.618a	41.231a	61.447a	0.539a	453a	31.148a
Ethephon	5.121b	40.228b	59.756b	0.479b	477a	28.052b
Difference	**	**	**	**	ns	*
CV (%)	9.8	3	2.1	10.3	16.7	20.5

ns, *, **, int: differences were not significant,or significant at the 5 % and 1% levels, respectively,or an interaction existed for the variable.

Values followed by the same letter are not significantly different from one another by the Duncan's new multiple range test.

Table 3: Main effects of cultivar,nitrogen fertilizer and plant growth regulator on spring barley yield components in 1988.

	Yield (T/ha)	1000-grain weight (g)	Hectolitre weight (kg)	Harvest Index	Heads m^{-2}	Grains $head^{-1}$
Cultivar						
Cadette	3.1502c	42.616b	63.042	0.437	396a	20.149b
Laurier	3.4055b	44.896a	65.970	0.463	378a	20.151b
Leger	3.7284a	35.478c	64.686	0.490	352a	31.450a
Difference	**	**	int	int	ns	**
N levels						
0	3.514a	40.725a	64.642	0.489	377a	24.109a
70	3.393a	41.358a	64.385	0.436	379a	23.482a
140	3.352a	41.204a	64.600	0.461	370a	23.688a
Difference	ns	ns	int	int	ns	ns
PGR						
No Ethephon	3.541a	41.700a	65.03a	0.468a	409a	26.144a
Ethephon	3.298b	40.492a	64.56b	0.456a	342b	21.375b
Difference	*	ns	**	ns	**	**
CV (%)	12.4	4.8	1.7	15.56	19.23	24.03

ns, *, **, int: differences were not significant,or significant at the 5 % and 1% levels, respectively,or an interaction existed for the variable.
Values followed by the same letter are not significantly different from one another by the Duncan's new multiple range test.

3.1.1.2 Nitrogen by Cultivar interaction

Nitrogen by cultivar interaction effects were noted for hectolitre weight and harvest index in 1988. The cultivar Cadette showed a higher hectolitre weight when nitrogen fertilizer was applied at 70 kg/ha than when none was applied. The reverse was true for cultivars Laurier and Leger. For all the three cultivars, 140 kg/ha of applied nitrogen resulted in the same hectolitre weight that were not different from those of the zero nitrogen fertilizer treatments. The harvest index of Cadette was reduced at the highest level of nitrogen (140 kg/ha) while Laurier and Leger showed a decrease at the intermediate level (70 kg/ha) (Table 4).

Table 4: Significant two way interactions of nitrogen fertilizer levels and cultivar on Hectolitre weight and harvest index (1988).

N Level	Cultivar	Hectolitre Weight	Harvest Index
0	Cadette	62.748d	0.461c
	Laurier	66.143ab	0.505a
	Leger	65.036b	0.503a
70	Cadette	63.760c	0.448c
	Laurier	65.468b	0.386d
	Leger	63.950c	0.479bc
140	Cadette	62.526d	0.410d
	Laurier	66.297a	0.496ab
	Leger	64.978b	0.487ab

Values within a column followed by the same letter are not different at the 5% level according to the protected l.s.d test.

3.1.2 Height, Heading and Maturity

There was a slight delay (2 days) in the maturity of the plants receiving the highest level of nitrogen (140 kg N/ha) in 1987 as compared to those receiving no nitrogen fertilizers (Table 4). Crop height and days to heading were not significantly affected by nitrogen fertilizer application. Crop heights were reduced by application of ethephon in both years. In both years, there were significant differences between the cultivars in height and days to maturity. Significant differences between the cultivars in days to heading were also observed in 1988. In both years, Leger was tallest while Cadette took longest time to head and the longest time to mature (Tables 5 and 6).

Table 5: Main effects of cultivar, nitrogen fertilizer and plant growth regulator on height, days to heading,and maturity of spring barley (1987).

		Height	Heading	Maturity
Cultivar				
	Cadette	61.333c	58.750	93.250a
	Laurier	70.583b	52.833	88.500c
	Leger	81.146a	56.958	89.833b
	Difference	**	int	**
N levels				
	0	69.917a	56.000a	89.583b
	70	71.125a	56.250a	90.708ab
	140	72.021a	56.292a	91.292a
	Difference	ns	ns	*
PGR				
	No Ethephon	76.306a	55.528	89.944b
	Ethephon	65.736b	56.833	91.111a
	Difference	**	int	*
	CV (%)	5.2	1.3	2.2

ns, *, **, int: differences were not significant,or significant at the 5 % and 1% levels, respectively,or an interaction existed for the variable.

Values followed by the same letter are not significantly different from one another by the Duncan's new multiple range test.

Table 6: Main effects of cultivar, nitrogen fertilizer and plant growth regulator on height, days to heading and maturity of spring barley (1988).

		Height	Heading	Maturity
Cultivar				
	Cadette	45.740b	47.840a	84.800a
	Laurier	45.413ab	44.083c	84.500b
	Leger	49.826a	46.348b	84.348b
	Difference	**	**	*
N levels				
	0	45.975a	46.166a	84.500a
	70	46.958a	46.166a	84.583a
	140	47.875a	46.000a	84.583a
	Difference	ns	ns	ns
PGR				
	No Ethephon	48.331a	46.056a	84.472a
	Ethephon	45.542b	46.167a	84.639a
	Difference	**	ns	ns
CV (%)		5.8	1.5	1.0

ns, *, **, int: differences were not significant,or significant at the 5 % and 1% levels, respectively,or an interaction existed for the variable.
Values followed by the same letter are not significantly different from one another by the Duncan's new multiple range test.

3.1.2.1 Ethephon by cultivar interaction

A significant interaction was observed between ethephon treatment and cultivar for days to heading in 1987. Laurier was most sensitive to ethephon applications and heading was delayed for three days (Table 7).

Table 7: Significant two-way interactions of plant growth regulator and cultivar on days to heading of spring barley (1987).

PGR	Cultivar	Heading
No Ethephon	Cadette	58.583a
	Laurier	51.583e
	Leger	56.416c
Ethephon	Cadette	58.916a
	Laurier	54.083d
	Leger	57.500b

Values within a column followed by the same letter are not significantly different at the 5% level according to the protected l.s.d test.

3.1.3 Protein content

Grain percentage protein increased with nitrogen application level in 1988. In both years, percentage straw protein increased with the level of nitrogen fertilizer application. The percentage straw protein was significantly different among cultivars in 1988 with Cadette having the highest level. Grain and straw protein was higher in plots treated with ethephon in 1987 but not in 1988 (Tables 8 and 9).

Table 8: Effect of cultivar, nitrogen fertilizer and plant growth regulator on % protein in the grains and straw of spring barley (1987).

		% Protein	
		Grain	Straw
Cultivar			
	Cadette	13.405	7.768a
	Laurier	13.708	7.565a
	Leger	13.464	7.728a
	Difference	int	ns
N levels			
	0	12.877	6.632b
	70	13.793	8.078a
	140	13.908	8.381a
	Difference	int	**
PGR			
	No Ethephon	13.305b	7.071b
	Ethephon	13.746a	8.381a
	Difference	**	**
	CV (%)	3.4	10.3

ns, *, **, int: differences were not significant,or significant at the 5 % and 1% levels, respectively,or an interaction existed for the variable.
Values followed by the same letter are not significantly different from one another by the Duncan's new multiple range test.

Table 9: Effect of cultivar, nitrogen fertilizer and plant growth regulator on % protein in the grain and straw of spring barley (1988).

		% Protein	
		Grain	Straw
Cultivar			
	Cadette	14.01a	8.355a
	Laurier	13.78a	7.899ab
	Leger	13.80a	7.475b
	Difference	ns	*
N levels			
	0	13.410b	6.788c
	70	14.026a	7.926b
	140	14.163a	9.051a
	Difference	**	**
PGR			
	No Ethephon	13.988a	8.056a
	Ethephon	13.746a	7.787a
	Difference	ns	ns
	CV (%)	4.8	13.7

ns, *, **, int: differences were not significant,or significant at the 5 % and 1% levels, respectively,or an interaction existed for the variable.
Values followed by the same letter are not significantly different from one another by the Duncan's new multiple range test.

3.1.3.1 Nitrogen by cultivar interaction

The nitrogen by cultivar interaction for grain protein percentage was significant in 1987. Grain protein content increased in all the cultivars between 0 and 70 kg/ha of applied nitrogen. Between 70 and 140 kg/ha of applied nitrogen, grain protein content increased in Laurier and Leger but not in Cadette (Table 10).

Table 10: Significant two-way interactions of nitrogen fertilizer levels and cultivar on % protein in grains in 1987.

N Level	Cultivar	% Protein
0	Cadette	12.745c
	Laurier	12.905c
	Leger	12.978c
70	Cadette	13.808b
	Laurier	13.785b
	Leger	13.784b
140	Cadette	13.661b
	Laurier	14.433a
	Leger	13.629a

Values within a column followed by the same letter are not different at the 5% level according to the protected l.s.d test.

3.1.4 Disease and lodging

Disease pressure was low for all treatments and cultivars in 1987, however treatment with ethephon increased the disease score for both Cadette and Laurier. Although there was very little lodging in 1987 (Table 11 and 12), the effect of ethephon in reducing lodging was significant and was most evident in the cultivars Laurier and Leger. There was no lodging in 1988.

Table 11: Main effects of cultivar, nitrogen fertilizer and plant growth regulator on lodging and disease of spring barley (1987).

	Lodging area	Lodging degree	Leaf spot on flag leaf	Rust on flag leaf
Cultivar				
Cadette	1.04	1.05	2.54a	3.42
Laurier	5.38	2.21	1.92b	2.42
Leger	2.79	1.70	1.88b	2.21
Difference	int	int	*	int
Nitrogen level				
0	2.85a	1.50a	2.16a	2.75a
70	3.44a	1.79a	2.13a	2.75a
140	2.88a	1.67a	2.04a	2.54a
Difference	ns	ns	ns	ns
PGR				
No Ethephon	4.19	1.94	1.69b	2.33
Ethephon	1.94	1.36	2.53a	3.03
Difference	int	int	**	int

ns, *, **, int: differences were not significant, or significant at the 5 % and 1% levels, respectively, or an interaction existed for the variable.
Values followed by the same letter are not significantly different from one another by the Duncan's new multiple range test.

Table 12: Significant two way interactions of plant growth regulator and cultivar on lodging and disease of spring barley (1987).

PGR	Cultivar	Lodging area	Lodging degree	Rust on flag leaf
No Ethephon	Cadette	1.08d	1.08d	3.16b
	Laurier	7.58a	2.58a	1.66d
	Leger	3.92b	2.17b	2.16cd
Ethephon	Cadette	1.00e	1.00d	3.66a
	Laurier	3.16b	1.83c	3.16b
	Leger	1.66c	1.25d	2.25c

Values within a column followed by the same letter are not significantly different at the 5% level according to the protected l.s.d test.

3.2 Experiment 2. Fungicide and row width.

3.2.1 Yield and yield components

In 1987, seeding barley in a 10 cm row width led to a lower grain yield than the 20 cm row width, because of the significant decrease in the number of grains per head, and in spite of the greater number of heads per square metre in the 10 cm row width treatment than in the 20 cm row width treatment. Fungicide treatment also decreased the number of grains per head (Table 13). In 1988, a significant row width fungicide interaction was observed for the thousand grain weight and for the hectolitre weight. Both parameters increased when the fungicide was added to the 10 cm rows but there was no change in the 20 cm rows (Tables 14 and 15).

Table 13: Main effects of cultivar, fungicide and Row width on the yield and yield components of spring barley (1987).

	Yield (T/ha)	1000-grain weight (mg)	Hectolitre weight (kg)	Harvest Index	Heads m^{-2}	Grains $head^{-1}$
Cultivar						
Cadette	5.839b	40.738b	57.85c	0.533ab	434a	33.91b
Laurier	6.429a	44.431a	62.08a	0.566a	459a	32.76b
Leger	6.197a	37.600c	59.23b	0.509b	413a	40.82c
Difference	**	**	**	*	ns	**
Fungicide						
Bayleton	6.238b	40.77a	59.86a	0.531a	437a	32.47b
No Bayleton	6.073a	41.07a	59.57a	0.530a	434a	35.58a
Difference	ns	ns	ns	ns	ns	**
Row width						
10 cm	5.880b	40.94a	59.73a	0.529a	459a	32.47b
20 cm	6.430a	40.90a	59.71a	0.542a	412b	39.19a
Difference	**	ns	ns	ns	*	**
CV (%)	7.0	2.9	2.1	15.9	9.1	19.5

ns, *, **, int: differences were not significant, or significant at the 5 % and 1% levels, respectively, or an interaction existed for the variable.
Values followed by the same letter are not significantly different from one another by the Duncan's new multiple range test.

Table 14: Main effects of cultivar, fungicide and row wiath on yield and yield components of spring barley (1988).

	Yield (T/ha)	1000-grain weight (mg)	Hectolitre weight (kg)	Harvest Index	Heads m^{-2}	Grains $head^{-1}$
Cultivar						
Cadette	2.063b	45.25b	61.74c	0.334b	511a	10.07c
Laurier	3.900a	50.78a	66.46a	0.446a	404b	19.87b
Leger	3.874a	41.69c	65.19b	0.441a	391b	25.73a
Difference	**	**	**	**	*	**
Fungicide						
Bayleton	3.298a	45.81	64.55	0.401a	457a	17.57a
No Bayleton	3.260a	46.00	64.38	0.413a	413a	19.54a
Difference	ns	int	int	ns	ns	ns
Row width						
10 cm	3.243a	45.53	64.19	0.399a	452a	17.75a
20 cm	3.322a	46.36	64.79	0.417a	415a	19.50a
Difference	ns	int	int	ns	ns	ns
CV (%)	15.6	3.1	1.7	16.0	28.2	32.9

ns, *, **, int: differences were not significant, or significant at the 5 % and 1% levels, respectively, or an interaction existed for the variable.
Values followed by the same letter are not significantly different from one another by the Duncan's new multiple range test.

Table 15: Significant two-way interactions of fungicide and row width on thousand-grain and hectolitre weight of spring barley (1988).

Fungicide	Row width	1000-grain weight (mg)	Hectolitre weight (kg)
No Bayleton	10 cm	45.26b	63.62b
	20 cm	46.88a	65.27a
Bayleton	10 cm	45.80a	64.74a
	20 cm	45.82a	64.31a

Values within a column followed by the same letter are not different at the 5% level according to the protected l.s.d test.

3.2.2 Height, Heading and Maturity

Height, heading and maturity were not significantly affected by row widths but maturity was significantly delayed by fungicide treatment in 1987 (Table 16). In 1988, heading was slightly later in 10 cm rows than in 20 cm rows. Fungicide also interacted with cultivar for the variable plant height in 1988 (Table 17). Fungicide application decreased the height of Cadette but not of the other cultivars (Table 18).

Table 16: Main effects of cultivar, fungicide and row width on some growth parameters of spring barley (1987).

	Height (cm)	Heading	Maturity
Cultivar			
Cadette	57.13c	58.75a	94.75a
Laurier	66.91b	52.63c	89.00b
Leger	80.72a	56.44b	89.13b
Difference	**	**	**
Fungicide			
Bayleton	68.48a	55.83a	90.91a
No Bayleton	68.02a	56.04a	91.00a
Difference	ns	ns	ns
Row width			
10 cm	67.39a	56.17a	91.00a
20 cm	69.10a	55.71a	90.92a
Difference	ns	ns	ns
CV (%)	4.5	1.5	1.6

ns, *, **, int: differences were not significant, or significant at the 5 % and 1% levels, respectively, or an interaction existed for the variable.
Values followed by the same letter are not significantly different from one another by the Duncan's new multiple range test.

Table 17: Main effects of cultivar, fungicide and row width on some growth parameters of spring barley (1988).

	Height (cm)	Heading	Maturity
Cultivar			
Cadette	47.12	51.88a	89.13a
Laurier	52.56	48.13c	85.69b
Leger	53.23	49.63b	84.44c
Difference	int	**	**
Fungicide			
Bayleton	51.23	49.75a	87.08a
No Bayleton	50.71	50.00a	85.75b
Difference	int	ns	**
Row width			
10 cm	50.25a	50.15a	86.38a
20 cm	51.82a	49.54b	86.45a
Difference	ns	*	ns
CV (%)	6.7	1.5	1.8

ns, *, **, int: differences were not significant, or significant at the 5 % and 1% levels, respectively, or an interaction existed for the variable.
Values followed by the same letter are not significantly different from one another by the Duncan's new multiple range test.

Table 18: Significant two-way interaction of fungicide and cultivar on height of spring barley (1988).

Fungicide	Cultivar	Height (cm)
No Bayleton	Cadette	48.25b
	Laurier	52.62a
	Leger	51.25a
Bayleton	Cadette	46.00c
	Laurier	52.50a
	Leger	55.19a

Values within a column followed by the same letter are not different at the 5% level according to the protected l.s.d test

3.2.3 Protein content

There were no significant effects of either row width or fungicide on grain protein in 1987 (Table 19), and neither did these treatments effect grain or straw protein content in 1988 (Table 20).

Table 19: Effect of cultivar, fungicide and row width on % protein in grains of spring barley (1987).

	% Protein
Cultivar	
Cadette	14.76a
Laurier	15.05a
Leger	14.38b
Difference	**
Fungicide	
Bayleton	14.76a
No Bayleton	14.70a
Difference	ns
Row width	
10 cm	14.69a
20 cm	14.79a
Difference	ns
CV (%)	3.4

ns, *, **, int: differences were not significant, or significant at the 5 % and 1% levels, respectively, or an interaction existed for the variable.
Values followed by the same letter are not significantly different from one another by the Duncan's new multiple range test.

Table 20: Effect of cultivar, fungicide and row width on % protein in grain and straw of spring barley (1988).

	% Protein	
	Grain	Straw
Cultivar		
Cadette	15.090a	8.505a
Laurier	14.609b	7.758ab
Leger	14.470b	7.318b
Difference	**	*
Fungicide		
Bayleton	14.765a	7.809a
No Bayleton	14.681a	7.912a
Difference	ns	ns
Row width		
10 cm	14.795a	8.178
20 cm	14.638a	7.484a
Difference	ns	ns
CV (%)	2.46	18.39

ns, *, **, int: differences were not significant,or significant at the 5 % and 1% levels, respectively, or an interaction existed for the variable.
Values followed by the same letter are not significantly different from one another by the Duncan's new multiple range test.

3.2.4 Disease and lodging

Fungicide application reduced lodging in 1987 and a row width by cultivar interaction was observed for the area lodged, with the score for Leger being significantly lower in the narrow rows, than in wide rows, but not changing with row width for other cultivars (Tables 21 and 22).

Table 21: Main effects of cultivar, fungicide and row width on lodging and disease of spring barley (1987).

	Lodging area	Lodging degree	Leaf spot on flag leaf	Rust on flag leaf
Cultivar				
Cadette	1.37	1.13c	2.75a	3.31a
Laurier	6.25	2.13a	1.75b	2.88a
Leger	4.25	1.63b	1.81a	3.19a
Difference	int	**	**	ns
Fungicide				
Bayleton	3.79a	1.67a	2.13a	3.29a
No Bayleton	4.12b	1.58a	2.08a	2.96a
Difference	*	ns	ns	ns
Row width				
10 cm	3.42	1.54a	2.08a	3.04a
20 cm	4.50	1.71a	2.13a	3.21a
Difference	int	ns	ns	ns

ns, *, **, int: differences were not significant, or significant at the 5 % and 1% levels, respectively, or an interaction existed for the variable.
Values followed by the same letter are not significantly different from one another by the Duncan's new multiple range test.

Table 22: Lodging as influenced by row width and cultivar (1987).

Row width	Cultivar	Lodging area
10 cm	Cadette	1.75a
	Laurier	6.13c
	Leger	2.38b
20 cm	Cadette	1.00a
	Laurier	6.38c
	Leger	6.13c

ns, *, **, int: differences were not significant,or significant at the 5 % and 1% levels, respectively,or an interaction existed for the variable.
Values followed by the same letter are not significantly different from one another by the Duncan's new multiple range test.

3.3 Experiment 3. Intensive and conventional management

3.3.1 Yield and yield components

Grain yields were lower under intensive management (140 kg/ha, ethephon applied, fungicide applied, narrow rows) than under conventional management (70 kg/ha, wide rows, no fungicide or ethephon applied) in 1987, on all three soil types, and this was associated with the decrease in the number of grains per head. This apparently offset an observed increase in the number of heads per square meter under intensive management (Tables 23, 24, and 25). In 1988, grain yields increased under intensive management on all soil types, as did the number of grains per head and the number of heads per square meter (Tables 26, 27 and 28).

Table 23: Main effects of cultivar and management on the yield and yield components of spring barley grown on clay (1987).

	Yield (T/ha)	1000-grain weight (mg)	Hectolitre weight (kg)	Harvest Index	Heads m^{-2}	Grains $head^{-1}$
Cultivar						
Cadette	6.113ab	42.083b	56.09b	0.617a	496a	30.286a
Laurier	6.463a	44.583a	59.51a	0.514a	477a	31.145a
Leger	6.086ab	38.667c	58.96a	0.561a	446a	40.381a
Joly	5.726b	38.667c	56.13b	0.508a	513a	34.039a
Difference	*	**	**	ns	ns	ns
Intensive	5.927b	40.75a	57.09b	0.624a	562a	28.14b
Conventional	6.266a	41.25a	58.22a	0.506a	399b	39.77a
Difference	*	ns	*	ns	**	**
CV (%)	4.7	1.8	1.6	25.7	16.6	23.3

ns, *, **, int: differences were not significant, or significant at the 5 % and 1% levels, respectively, or an interaction existed for the variable.
Values followed by the same letter are not significantly different from one another by the Duncan's new multiple range test.

Table 24: Main effects of cultivar and management on the yield and yield components of spring barley grown on loam (1987).

	Yield (T/ha)	1000-grain weight (mg)	Hectolitre weight (kg)	Harvest Index	Heads m^{-2}	Grains $head^{-1}$
Cultivar						
Cadette	5.676a	39.083b	55.675c	0.661a	363a	40.345a
Laurier	5.731a	42.833a	59.325a	0.765a	404a	36.955a
Leger	5.622a	39.167b	57.875b	0.463a	316a	47.860a
Joly	4.965a	38.333b	56.300c	0.463a	387a	36.961a
Difference	ns	ns	**	*	ns	ns
Management						
Intensive	5.103b	39.376a	57.117a	0.612a	435a	31.254b
Conventional	5.896a	40.333a	57.471a	0.644a	300b	49.807a
Difference	**	ns	ns	ns	**	**
CV (%)	11.7	6.1	1.6	39.4	20.9	26.6

ns, *, **, int: differences were not significant, or significant at the 5 % and 1% levels, respectively, or an interaction existed for the variable.
Values followed by the same letter are not significantly different from one another by the Duncan's new multiple range test.

Table 25: Main effects of cultivar and management on the yield and yield components of spring barley grown on sand (1987).

	Yield (T/ha)	1000-grain weight (mg)	Hectolitre weight (kg)	Harvest Index	Heads m^{-2}	Grains $head^{-1}$
Cultivar						
Cadette	4.893b	38.500b	54.608b	0.587a	420a	21.915b
Laurier	6.052a	42.416a	58.317a	0.662b	461a	32.670b
Leger	4.892a	37.833b	57.858a	0.561a	390a	45.420a
Joly	4.406b	34.917c	54.900b	0.594a	487a	26.907b
Difference	**	**	**	*	ns	*
Management						
Intensive	4.961a	38.958a	56.516a	0.616a	515a	25.469b
Conventional	5.593a	37.875a	56.325a	0.585a	366b	42.987a
Difference	ns	ns	ns	ns	**	**
CV (%)	12	3.1	1.4	14	19.6	25.9

ns, *, **, int: differences were not significant, or significant at the 5 % and 1% levels, respectively, or an interaction existed for the variable.
Values followed by the same letter are not significantly different from one another by the Duncan's new multiple range test.

Table 26: Main effects of cultivar and management on the yield and yield components of spring barley grown on clay (1988).

	Yield (T/ha)	1000-grain weight (mg)	Hectolitre weight (kg)	Harvest Index	Heads m^{-2}	Grains $head^{-1}$
Cultivar						
Cadette	3.8017a	41.417a	62.062a	0.457a	443a	26.72a
Laurier	3.7628a	39.317a	62.300a	0.478a	422a	31.64a
Leger	3.4878a	39.450a	61.813a	0.439a	421a	26.62a
Joly	3.8911a	40.292a	63.447a	0.441a	371a	30.64a
Difference	ns	ns	ns	ns	ns	**
Managment						
Intensive	3.937a	40.025a	62.762a	0.421b	538a	40.06a
Conventional	3.535b	40.212a	62.050a	0.486a	290b	17.75b
Difference	*	ns	ns	*	**	**
CV(%)	11.18	6.6	2.2	13.8	31.0	42.5

ns, *, **, int: differences were not significant, or significant at the 5 % and 1% levels, respectively, or an interaction existed for the variable.
Values followed by the same letter are not significantly different from one another by the Duncan's new multiple range test.

Table 27: Main effects of cultivar and management on the yield and yield components of spring barley grown on loam (1988).

	Yield (T/ha)	1000-grain weight (mg)	Hectolitre weight (kg)	Harvest Index	Heads m^{-2}	Grains $head^{-1}$
Cultivar						
Cadette	3.495a	43.01a	64.28a	0.364a	414a	22.91a
Laurier	3.423a	40.23b	62.62a	0.400a	484a	21.82a
Leger	3.068b	43.25a	62.90a	0.388a	465a	18.53a
Joly	2.812b	42.30a	63.66a	0.408a	520a	14.69a
Difference	**	**	ns	ns	ns	ns
Management						
Intensive	3.302a	42.31a	63.33a	0.385a	575a	23.19a
Conventional	3.097b	42.08a	63.40a	0.415a	367b	15.79b
Difference	*	*	ns	ns	*	*
CV (%)	6.23	3.12	2.05	21.6	38.89	33.15

ns, *, **, int: differences were not significant, or significant at the 5 % and 1% levels, respectively, or an interaction existed for the variable.
Values followed by the same letter are not significantly different from one another by the Duncan's new multiple range test.

Table 28: Main effects of cultivar and management on the yield and yield components of spring barley grown on sand (1988).

	Yield (T/ha)	1000-grain weight (mg)	Hectolitre weight (kg)	Harvest Index	Heads m^{-2}	Grains $head^{-1}$
Cultivar						
Cadette	3.068a	40.884a	63.173a	0.417a	446a	24.109a
Laurier	2.647a	39.492a	60.984a	0.426a	469a	14.324a
Leger	2.493a	41.725a	61.262a	0.401a	434a	14.119a
Joly	2.243a	41.500a	61.074a	0.366a	491a	14.119a
Difference	ns	ns	ns	ns	ns	ns
Management						
Intensive	2.799a	40.217a	61.644a	0.400a	569a	23.780a
Conventional	2.425a	41.564a	61.603a	0.405a	351b	12.268b
Difference	ns	ns	ns	ns	**	**
CV (%)	35.3	6.9	2.8	19.1	24	41

ns, *, **, int: differences were not significant, or significant at the 5 % and 1% levels, respectively, or an interaction existed for the variable.
Values followed by the same letter are not significantly different from one another by the Duncan's new multiple range test.

3.3.2 Height, Heading and Maturity

Intensive management significantly reduced plant height, delayed heading and delayed maturity on clay and sandy soil but had no effect on any of these parameters on loam soil in 1987 (Tables 29, 30 and 31), or on any of the soil types in 1988 (Tables 32, 33, and 34).

Table 29: Main effects of cultivar and management on the growth and development of spring barley grown on sand (1987).

Cultivar	Height	Heading	Maturity
Cadette	66.50c	55.92a	89.42a
Laurier	75.83b	49.92c	84.83c
Leger	88.50a	53.17b	86.83b
Joly	76.58b	54.25b	87.67b
Difference	**	**	**
Management			
Intensive	72.63b	54.13a	88.08a
Conventional	81.08a	52.50b	86.29b
Difference	**	**	**
CV (%)	2.2	1.8	1.4

ns, *, **, int: differences were not significant, or significant at the 5 % and 1% levels, respectively, or an interaction existed for the variable.
Values followed by the same letter are not significantly different from one another by the Duncan's new multiple range test.

Table 30: Main effects of cultivar and management on the growth and development of spring barley grown on loam (1987).

Cultivar	Height	Heading	Maturity
Cadette	61.58b	56.67a	91.00a
Laurier	68.42b	50.83c	86.67b
Leger	79.67a	54.33b	86.67b
Joly	71.17ab	54.17b	89.33a
Difference	**	*	**
Management			
Intensive	67.92a	54.33a	88.33a
Conventional	72.50a	53.67a	88.50a
Difference	ns	ns	ns
CV (%)	10.89	2.4	1.8

ns, *, **, int: differences were not significant, or significant at the 5 % and 1% levels, respectively, or an interaction existed for the variable.
Values followed by the same letter are not significantly different from one another by the Duncan's new multiple range test.

Table 31: Main effects of cultivar and management on the growth and development of spring barley grown on clay (1987).

Cultivar	Height	Heading	Maturity
Cadette	62.96c	56.25a	89.83a
Laurier	75.15b	50.08c	86.33b
Leger	85.17a	53.42b	86.67b
Joly	76.42b	53.33b	86.67b
Difference	**	**	**
Management			
Intensive	70.92b	54.04a	88.00a
Conventional	78.92a	52.50b	86.75b
Difference	**	**	**
CV (%)	3.91	1.9	1.2

ns, *, **, int: differences were not significant, or significant at the 5 % and 1% levels, respectively, or an interaction existed for the variable.
Values followed by the same letter are not significantly different from one another by the Duncan's new multiple range test.

Table 32: Main effects of cultivar and management on the growth and development of spring barley grown on sand (1988).

Cultivar	Height	Heading (days)	Maturity (days)
Cadette	48.36a	46.22a	87.33a
Laurier	44.17b	43.58a	80.92a
Leger	42.96a	48.00a	88.00a
Joly	46.75a	48.83a	86.67a
Difference	ns	ns	ns
Management			
Intensive	46.86a	47.58a	88.00a
Conventional	44.27a	45.74a	84.46a
Difference	ns	ns	ns
CV (%)	8.86	11.21	10.1

ns, *, **, int: differences were not significant, or significant at the 5 % and 1% levels, respectively, or an interaction existed for the variable.
Values followed by the same letter are not significantly different from one another by the Duncan's new multiple range test.

Table 33: Main effects of cultivar and management on the growth and development of spring barley grown on loam (1988).

Cultivar	Height	Heading (days)	Maturity (days)
Cadette	56.87a	47.00b	85.33d
Laurier	55.54ab	47.67a	87.33c
Leger	51.71b	47.33ab	88.17b
Joly	51.30b	47.33ab	89.33a
Difference	ns	ns	**
Management			
Intensive	55.16a	47.42a	87.58a
Conventional	52.55a	47.25a	87.50a
Difference	ns	ns	ns
CV (%)	6.7	0.86	0.23

ns, *, **, int: differences were not significant, or significant at the 5 % and 1% levels, respectively, or an interaction existed for the variable.
Values followed by the same letter are not significantly different from one another by the Duncan's new multiple range test.

Table 34: Main effects of cultivar and management on the growth and development of spring barley grown on clay (1988).

Cultivar	Height	Heading (days)	Maturity (days)
Cadette	53.96a	47.11c	86.00b
Laurier	53.45a	48.67b	86.50a
Leger	52.93a	49.33a	86.67a
Joly	50.72a	47.33c	86.67a
Difference	ns	**	**
Management			
Intensive	53.92a	48.08a	86.50a
Conventional	51.61a	48.17a	86.42a
Difference	ns	ns	ns
CV (%)	9.67	0.42	0.23

ns, *, **, int: differences were not significant, or significant at the 5 % and 1% levels, respectively, or an interaction existed for the variable.

Values followed by the same letter are not significantly different from one another by the Duncan's new multiple range test.

3.3.3 Protein content

On clay soils in 1987, grain and straw protein concentrations were higher under intensive management than under conventional management. On loam soils, there were no significant differences between the type of management for protein levels, while on sandy soil, conventional management resulted in a higher grain protein concentration and intensive management in a higher straw protein content (Tables 35, 36, and 37). In 1988 conventional management on loam soil resulted in a higher grain protein concentration while intensive management resulted in a higher straw protein content (Tables 39, 40, and 41).

Table 35: Main effects of cultivar and management on the % protein in the grain and straw of spring barley grown on clay (1987).

	% Protein	
	Grain	Straw
Cultivar		
Cadette	13.532a	7.136a
Laurier	13.673a	6.594a
Leger	13.571a	6.664a
Joly	12.790b	7.479a
Difference	*	ns
Management		
Intensive	13.761a	7.622a
Conventional	13.023b	6.314b
Difference	**	**
CV (%)	3.1	12.8

ns, *, **, int: differences were not significant, or significant at the 5 % and 1% levels, respectively, or an interaction existed for the variable.
Values followed by the same letter are not significantly different from one another by the Duncan's new multiple range test.

Table 36: Main effects of cultivar and management on the % protein in the grain and straw of spring barley grown on loam (1987).

	% Protein	
	Grain	Straw
Cultivar		
Cadette	14.564a	9.939a
Laurier	14.517a	9.216a
Leger	14.703a	8.358a
Joly	13.956a	10.481a
Difference	ns	ns
Management		
Intensive	14.625a	10.080a
Conventional	14.216a	8.917a
Difference	ns	ns
CV (%)	5.6	19.3

ns, *, **, int: differences were not significant, or significant at the 5 % and 1% levels, respectively, or an interaction existed for the variable.
Values followed by the same letter are not significantly different from one another by the Duncan's new multiple range test.

Table 37: Main effects of cultivar and management on the % protein in the grain and straw of spring barley grown on sand (1987).

	% Protein	
	Grain	Straw
Cultivar		
Cadette	13.867a	9.193a
Laurier	13.566a	6.867b
Leger	13.742a	7.621b
Joly	13.164a	8.309ab
Difference	ns	*
Management		
Intensive	14.073a	8.839a
Conventional	13.096b	7.156b
Difference	*	**
CV (%)	7	13.7

ns, *, **, int: differences were not significant, or significant at the 5 % and 1% levels, respectively, or an interaction existed for the variable.
Values followed by the same letter are not significantly different from one another by the Duncan's new multiple range test.

Table 38: Main effects of cultivar and management on the % protein in the grain and straw of spring barley grown on clay (1988).

	% Protein	
	Grain	Straw
Cultivar		
Cadette	14.113a	6.894a
Laurier	14.406a	6.615a
Leger	14.453a	6.105a
Joly	14.035a	7.282a
Difference	ns	ns
Management		
Intensive	14.255a	6.827a
Conventional	14.247a	6.621a
Difference	ns	ns
CV (%)	2.0	11.8

ns, *, **, int: differences were not significant, or significant at the 5 % and 1% levels, respectively, or an interaction existed for the variable.
Values followed by the same letter are not significantly different from one another by the Duncan's new multiple range test.

Table 39: Main effects of cultivar and management on the % protein in the grain and straw of spring barley grown on loam (1988).

	% Protein	
	Grain	Straw
Cultivar		
Cadette	14.978a	7.545b
Laurier	14.966a	8.347a
Leger	14.737a	7.111b
Joly	14.923a	8.461a
Difference	ns	**
Management		
Intensive	14.757b	8.190a
Conventional	15.044a	7.542b
Difference	**	**
CV (%)	1.6	5.5

ns, *, **, int: differences were not significant,or significant at the 5 % and 1% levels, respectively,or an interaction existed for the variable.
Values followed by the same letter are not significantly different from one another by the Duncan's new multiple range test.

Table 40: Main effects of cultivar and management on the % protein in the grain and straw of spring barley grown on sand (1988).

	% Protein	
	Grain	Straw
Cultivar		
Cadette	14.589a	7.947a
Laurier	14.612a	8.288a
Leger	15.111a	8.098a
Joly	15.038a	8.871a
Difference	ns	ns
Management		
Intensive	14.616a	8.475a
Conventional	15.059a	8.128a
Difference	ns	ns
CV (%)	3.47	11.08

ns, *, **, int: differences were not significant,or significant at the 5 % and 1% levels, respectively,or an interaction existed for the variable.
Values followed by the same letter are not significantly different from one another by the Duncan's new multiple range test.

3.3.4 ^{15}N (Nitrogen 15) Percentage

Intensive management had no effect on the nitrogen 15 uptake on any of the soil types in 1988 (Tables 41, 42, and 43).

Table 41: The nitrogen 15(%) in the grain and straw of spring barley cultivars grown on clay under two management systems (1988).

	% ^{15}N	
	Grain	Straw
Cultivar		
Cadette	1.693a	1.616a
Laurier	1.656a	1.609a
Leger	1.635a	1.639a
Joly	1.671a	1.607a
Difference	ns	ns
Management		
Intensive	1.758a	1.691a
Conventional	1.609a	1.573a
Difference	ns	ns
CV (%)	4.20	5.08

ns, *, **, int: differences were not significant,or significant at the 5 % and 1% levels, respectively, or an interaction existed for the variable.
Values followed by the same letter are not significantly different from one another by the Duncan's new multiple range test.

Table 42: The nitrogen 15 (%) in the grain and straw of spring barley cultivars grown on loam under two management systems (1988).

	% ^{15}N	
	Grain	Straw
Cultivar		
Cadette	1.639a	1.605a
Laurier	1.685a	1.538a
Leger	1.797a	1.684a
Joly	1.782a	1.589a
Difference	ns	ns
Management		
Intensive	1.767a	1.628a
Conventional	1.614a	1.541a
Difference	ns	ns
CV (%)	7.17	7.59

ns, *, **, int: differences were not significant,or significant at the 5 % and 1% levels, respectively, or an interaction existed for the variable.
Values followed by the same letter are not significantly different from one another by the Duncan's new multiple range test.

Table 43: The nitrogen 15 (%) in the grain and straw of spring barley cultivars grown on sand under two management systems (1988).

	% ^{15}N	
	Grain	Straw
Cultivar		
Cadette	1.654a	1.666a
Laurier	1.559a	1.560a
Leger	1.684a	1.565a
Joly	1.633a	1.598a
Difference	ns	ns
Management		
Intensive	1.693a	1.653a
Conventional	1.551a	1.534a
Difference	ns	ns
CV (%)	11.6	7.2

ns, *, **, int: differences were not significant, or significant at the 5 % and 1% levels, respectively, or an interaction existed for the variable.
Values followed by the same letter are not significantly different from one another by the Duncan's new multiple range test.

DISCUSSION

Two factors may have contributed to the lack of yield response to intensive management inputs in 1987. First, the crop preceding the barley experiments was alfalfa which may account for the apparent lack of response to the applied nitrogen fertilizer treatments. A green manure crop of alfalfa is capable of contributing between 168-224 kg/ha of nitrogen (Pieters 1927) which should be able to supply adequate nitrogen, even to treatments receiving no nitrogen fertilizer. Second, during the flowering and grain filling periods, the temperatures were high, which may have reduced the number of fertile florets and also interfered with grain filling, resulting in small grains (low thousand grain weight) (Nuttonson 1957).

Again, in 1988 there was little positive yield response to all of the applied treatments in experiments one, two and for barley grown on sand in experiment three (Tables 3, 14, and 28). In 1988, the weather was hot with less than average rainfall for the months of May, June and July (Table 1). In terms of plant development, this coincided with the period from shooting to shortly after heading, which is considered to be the most sensitive period to temperature and soil moisture conditions (Day et al. 1975).

The period from jointing to shortly after heading is considered to be the growth development period during which cereals are most sensitive to temperature and soil moisture conditions. High temperatures during the flowering period may adversely affect pollination and give rise to a reduced number of florets. The low number of seeds per head noted in this study (Tables 3, 14, 26-28) in 1988 may have been due to the high temperatures since under optimum weather conditions, high nitrogen levels would increase the count per head (Fredrick et al. 1985).

Although the total vegetative biomass was not measured, the low harvest index values obtained indicate there was a greater straw to grain ratio and it is possible that, under the low moisture conditions, the crop showed a response to nitrogen which was not reflected in grain yield. Pearman et al. (1978) have similarly noted a decrease in the harvest index with increasing nitrogen fertilizers for winter wheat grown under dry conditions.

In both years the protein content of both the grains and the straw was increased by nitrogen fertilizer application. Similar observations under conditions of limited soil moisture and high soil nitrogen levels (Luebs and Laag 1967) have been reported and indicated that nitrogen tended to accumulate in the plant. Campbell et al. (1977) also found that under dry conditions, grain protein concentrations were increased by nitrogen applied at rates greater than 61.5 kg/ha. They further found that under irrigation, as much as 123-164 kg/ha of nitrogen were required to bring the grain protein content to the same level (15.4%) as that of the unirrigated crop. Kramer (1979) pointed out that the major source of protein for cereal grain is the nitrogenous pool present in the vegetative tissues of the crop prior to the onset of grain filling. The remainder is absorbed from the soil during grain development.

Yields as well as the number of grains per head and the hectolitre weight of the grain were significantly reduced by the application of ethephon (Tables 2 and 3). Similar observations have been reported on spring barley and wheat (Simmons et al. 1988; Murray and Dixon 1970). In these studies, yield reductions were found to occur when lodging was not a factor. This was also apparent in our study. Simmons et al. (1988) suggested that where temperatures are high following ethephon application, there is an enhanced rate of production of ethylene. This causes the plants to respond as if under drought stress by reducing the number of grains in the spike and weight per grain.

In our study, there were high temperatures prevailing at the time immediately following ethephon application in both years, hence it is likely that ethephon enhanced the drought-like effect on the crop and this may have contributed to the yield reductions.

The increase in the number of heads per square metre following ethephon treatment suggests that ethephon effectively enhanced tiller survival in 1987. The reduction in head count per square metre on ethephon treated plots in 1988 may have been due to the inability of the late formed tillers to produce heads under the prevailing moisture stress conditions (Day et al. 1978).

Research on the effect of row width on yields of small grain cereals has shown that narrow row widths (less than 18-23 cm) have resulted in higher yields than when wider row widths are used. The increases in yield are related to an increase in the number of tillers per square metre when narrow row widths are used (Holliday 1963; Stoskopf 1967).

In this study, yields were not affected by narrow rows in 1988, while in 1987 the yields were lower in narrow rows than in wide rows, even though there was a significant increase in the number of spikes per plant due to the narrow row spacing (Tables 13 and 14). The dry summers that occurred in both years may have shortened the duration of grain filling leading to reduction in the thousand grain weight and the number of grains per head in the narrow rows. This was probably particularly severe for seeds developing on late formed tillers. The slower development of leaf area in wide rows as compared to narrow ows results in slower removal of soil water. This may allow more of the plants, and more spikelets of each plant to develop into and through the flowering and seed filling stages, resulting in higher yields under water limited conditions (Luebs and Laag 1967).

The barley crop responded to intensive cereal management by increasing tillering and head size although, it was only in 1988 when this increase was reflected in increased yields (Tables 26 and 27). This suggests that the management level, weather and soil conditions (including previous crop) played an important role in determining the final grain yield of the crop. In 1987, the highest level of applied nitrogen considerably enhanced vegetative growth, which probably resulted in an increase in water use and hence an earlier depletion of soil water as noted by Morgensen (1980).

The dry conditions at the end of the growing season probably interfered with grain filling thus eliminating the grain yield advantage that would be expected to result from the increases in the number of heads per square metre and seeds per head produced by intensive management. Day et al. (1975) has shown that moisture stress at the flowering and dough filling stages usually reduced barley grain yields more drastically than moisture stress at jointing. Moisture stress at jointing resulted in plants that tended to tiller more profusely and to be less tall. Morgensen (1980) also found that when drought occurs during and after heading, one stress day (a measure of the severity of water stress during a drought period) corresponds to one day without grain filling. He also noted that there was little or no yield reduction when drought occurred during the vegetative period.

Reports of intensive cereal management (ICM) systems used in West Germany, France and Belgium and trials carried out in Britain have indicated that ICM works well under the prevailing environmental conditions in those countries (Gallagher 1984). The regions in Europe where most work has been done on ICM experience relatively cool and wet climate with mild summers. Average summer temperatures in these regions range from 10 to 15 degrees centigrade for at least five months (Broekhuisen 1969). For instance in the south east and midlands region of England and, in the Schleswig-Holstein region of West Germany where cereals are the major crops, average daily temperatures of 16 to 18 degrees centigrade are common during the flowering and grain filling stages.

In France (North, North East and Paris Basin) and Belgium the average daily temperatures vary from 16 to 22 degrees centigrade during the same growth stages. The relatively mild winters experienced in these regions allow the production of winter cereals, which are exposed to a long growing season. In Quebec, winter conditions present more of a risk to the production of winter cereals. Some winter wheat is produced, but only spring types of barley can be grown.

ICM systems in Europe are based on winter cereals and this necessitates the use of split nitrogen applications, which have consistently resulted in higher yields. McEwen and Moffet (1979), working with winter wheat, reported that these systems produced average yields of 9.5 t/ha while a single N application at seeding resulted in only 9 t/ha.

In France, Germany, Belgium and Britain, typical yields vary from 8-10 t/ha. It is clear that the yield component making the largest contribution to these high yields is the number of heads per square metre (Gallagher, 1984). The emphasis on high seeding rates (500 ears/m2) to ensure a high population of mainstems and primary tillers, and the use of 3 or more applications of nitrogen (170-235 kg/ha) has consistently resulted in yields of more than 9 tonnes/ha under the systems used in West Germany (Gallaghar et al. 1984).

Research on ICM in Canada has produced varying results with reports from Western Canada showing that some benefit may be derived from the use of ICM systems with yield increases of between 12-42% (Stobbe et al. 1985; Rourke 1985). Stobbe et al. (1985) found that neither the seeding rate (500 ears/m2) nor the nitrogen levels of 150 kg/ha (applied all at once or split) had any beneficial effects on the grain yield of spring wheat. However, the use of fungicides played a major role in enhancing the yield in Manitoba and the highest yields were always obtained when the weather was cooler and wetter than is usual.

Rourke (1985) cited Briggs et al. (1985) as having found that on large scale winter and spring barley trials carried out in Alberta, intensive management resulted in higher yields (3502 kg/ha) than conventional management (2541 kg/ha). These yield increases were due to a large increase in the number of heads per square metre (320 under intensive management and 200 under conventional management).

Rourke (1985) also cited a study carried out in Quebec by the Coopérative Fédérée on spring barley and winter wheat in which yields increased by 12-25% under ICM, with the winter wheats having the highest yield increases.

It is thus apparent that ICM can significantly increase yields under conditions in Western Canada and Quebec. However, the average yield increases are not as large as those attained in Europe. It would appear that the high input systems need modification to be more effective in Western Canada and Quebec.

Eastern Canadian (Nova Scotia) findings indicate that ICM may be more promising there since the weather conditions are similar to those in Europe (Caldwell and Starrat, 1987).

The poor response of the spring barley crop to intensive cereal management inputs in 1987 and 1988 indicates that more studies need to be carried out on the response of spring barley on individual inputs under conditions prevailing in this South Western part of Quebec.

The net additional cost for using intensive management is $160.26 (Table 44). With the current per tonne price of barley at $120, a yield increase of at least 1.3 tonnes per hectare, due to ICM, is required for the system to be economical. None of the significant yield increases measured in this research were of this magnitude. As such intensive management is not beneficial to the farmer under conditions similar to those experienced during these experiments.

Table 44. Summary of input costs incurred using ICM.

Input	Cost($)
Nitrogen fertilizer (70 additional kg/ha) @$0.75/ha	52.50
Ethephon and one [1]tractor pass @$225/5L	53.00
Bayleton and one tractor pass @$167/kg	54.76
Total extra costs for ICM production	160.26

[1]estimated total cost of one tractor pass is $8 per ha.

The N15 determinations were aimed at assessing the extent to which ferilizer derived nitrogen is available to the crop in the different soil types and determining the distribution of the labelled nitrogen within the crop between the source and the sink.

The amount of nitrogen in the soil as fixed NH4+ is considerably high. Clay and clay loam soils generally contain more available NH4+ ions then silt loams which in turn contain larger amounts then sandy soils (Bartholomew et al 1965). The lack of response to N15 uptake by barley on the different soils may be because the labelled nitrogen was immobolized and not immediatly available the crop.

CONCLUSIONS

1. The application of high levels of nitrogen does not increase barley yields under dry weather conditions and when the soil nitrogen resources are high. The high levels of nitrogen do however increase the grain protein content and thus improve the feed quality of spring barley.
2. The application of ethephon (Cerone) in the absence of lodging reduces plant height and decreases yields by reducing the number of grains per head.
3. Narrow row widths lead to a higher tiller number but do not necessarily increase yields. A fungicide by row width interaction results in a reduced seed size and seed weight in the narrow rows and this may be responsible for the lack of yield response in these rows.
4. The effect of intensive management on yields was inconsistent and was influenced to a large extent by the prevailing weather and soil conditions.

LITERATURE CITED

Bartholomew, W.V. and F.E. Clark, Eds. 1965. Soil Nitrogen, American Society of Agronomy, Madison, Wisc.

Bingham, J. 1969. The physiological determinants of grain yield in cereals. Agric. Progr. 44: 30-42.

Blackman, J.A., J. Bingham and J.L. Davidson. 1978. Response of semi-dwarf and conventional winter wheat varieties to the application of nitrogen fertilizer. J. Agric. Sci. Camb. 90: 543-550.

Bokarev, K.S., L.D. Prusakova, S.A. Murave'er and S.I. Chizhora. 1977. Use of Growth regulators to increase resistance of spring barley to lodging. Fiziologiya Rastenii 24 (5): 1078-1084.

Briggs, K.G. 1975. Effects of seeding rate and row spacing on agronomic characteristics of Glenlea, Pitic 62 and Neepawa wheats. Can. J. Plant Sci. 55: 363-367.

Brinkman, M.A., T.M. Luk and J.J. Rutledge. 1979. Performance of spring barley in narrow rows. Agron. J. 71: 913-916.

Brooks, D.H. 1972. Observation of the effects of mildew (Erysiphe graminis) on growth of spring and winter barley. Ann. App. Biol. 70: 149-156.

Caldwell, C.D. and C.E. Starrat. 1987. Response of Max spring wheat to management practices. Can. J. Plant. Sci. 67: 645-652.

Caldwell, C.D., Mellish, D.R. and J. Norrie. 1988. A comparison of Ethephon alone and in combination with CCC or DPC applied to spring barley. Can. J. Plant Sci. 68: 941-946.

Campbell, C.A., H.R. Davidson and F.G. Warden. 1977. Effects of fertilizer N soil moisture on yield, yield components, protein contents and N accumulation in the above ground parts of spring wheat. Can. J. Soil Sci. 57: 311-327.

Cannell, R.Q. 1969. The tillering pattern in barley varieties. 1. Production, survival and contribution to yield by component tillers. J. Agric. Sci., Camb. 72: 405-422.

Cartwright, P.M. and S.R. Waddington. 1981. Growth regulators and Grain yield in spring cereals. p.61-70. in A.F. Hawkins and B. Jeffcoat (ed.) Opportunities for manipulation of cereal productivity. Mono. 7, British Plant Growth regulator Group, Wantage, England.

Clark, R.V. 1979. Yield losses in barley cultivars caused by spot blotch. Can. J. Plant Patho. 1: 113-117.

Couture, L and J.C. Sutton. 1978. Efficacies of fungicides in controlling spot blotch of barley. Can.J.Plant Sci. 58: 311-317.

Cox W.J. and D.J. Otis. 1989. Growth and Yield of Winter wheat as influenced by chlormequat chloride and ethephon. Agron J. 81: 264-270.

Dahnous, K., G.T. Vigue, A.G. Law, C.F. Konzak and D.G. Miller. 1982. Height and yield response of selected wheat, barley and triticale cultivars to Ethephon. Agron. J. 74: 580-582.

Dann, P.R. 1969. Response by wheat to phosphorous and nitrogen with particular reference to "haying off". Aust. J. Exper. Agric. Anim. Husb. 9: 625-629.

Day, A.D. and R.K. Thompson. 1975. Effects of moisture regimes on the growth of barley. Agron. J. 67: 430-433.

Ellis, R.P. and G. Russell. 1984. Plant development and grain yield in spring and winter barley. J. Agric. Sci. Camb. 102: 85-95.

Frederick, J.R. and H.G. Marshall. 1985. Grain yield and yield components of soft red winter wheat as affected by management practises. Agron. J. 77: 495-499.

Finlay R.C., E. Reinbergs and T.B. Daynard. 1971. Yield response of spring barley to row spacing and seed rate. Can. J. Plant Sci. 51: 527-

533.

Gallagher, E.J. (Ed). 1984. Cereal Production. Royal Dublin Society. Butterworths. pp. 247-285.

Gallagher, J.N., P.V. Biscoe and R.K. Scott. 1975. Barley and its environment. VI. Growth and development in relation to yield. J. Appl. Ecol. 12: 563-5?2.

Gracia del Moral, L.F., J.M. Ramos and L. Recalde. 1984. Tilling dynamics of winter barley as influenced by cultivar and nitrogen fertilizer. A Field Study. Crop. Sci. 24: 179-181.

Gracia del Moral, L.F., J.M. Ramos and L. Recalde. 1985. Relationships between vegetative growth, grain yield and grain protein content in six winter barley cultivars. Can. J. Plant Sci. 65: 523-532.

Holliday, R. 1963. The effect of row widths on the yield of cereals. Field Crop Abstr. 16: 71-81.

Hofner, W., W. Nau and D. Freutch. 1985. Influence of growth regulator CCC and ancymidol on the fertility of genetically uniculm spring barley (Hordeum vulgare). Field Crops Abstr. Vol. 40: Sec. 1815.

Jenkyn J.F., M.E. Finney and G.V. Dyke (1983). Effects of Nitrogen fertilization and tridemorph on mildew, growth and yield of spring barley 1975-77. J. Agri. Sci., Camb. 101: 517-546.

Jenkyn, J.F. and J.R. Moffat. 1975. The effect of ethirimol seed dressing on yield of spring barley grown with different amounts of nitrogen fertilizer. 1969-71. Plant Pathol. 24: 16-21.

Kirkman, M.A., P.R. Shewry and B.S. Miflin. 1982. The effect of nitrogen nutrition on the lysine content of and protein composition of barley seeds. J. Sci. Food Agr. 33: 115-127.

Kuhn, H. and W. Hofner. 1980. Shortening of spring barley by combining application of CCC and ancymidol. (Ger) Z. Pflanzenernaehr. Bodenkd 143: 250-252.

Larter, E.N., M. Samii and F.W. Sosulksi. 1965. The morphological and physiological effects of 2-chloroethyl-trimethylammonium chloride on barley. Can. J. Plant Sci. 45: 419-427.

Lim, L.G. and R.E. Gaunt. 1986. The effect of powdery mildew (Erysiphe graminis f. sp. hordei) and leaf rust (Puccina hordei) on spring barley in New Zealand. II. Apical development and yield potential. Plant. Pathol. 35: 54-60.

Linser H. 1968. Influence of CCC on lodging and behaviour of cereal plants. Euphytica 17(Supplement 1): 215-238.

Luebs, R.E. and A.E. Laag. 1967. Nitrogen effect on Leaf area, yield,and Nitrogen uptake of barley under moisture stress. Agron. J. 59: 219-222.

Mather, D.E. Ed. 1982 Compendium of Barley Diseases. American Phytopathological Society, St.Paul, Minn.

Matthews, S., G.O. Korateng and W.J. Thomson. 1981. Tillering and ear production: Opportunities for chemical regulation. pp. 88-96. In A.F. Hawkins and B. Jeffcoat (ed.) Opportunities for manipulation of cereal productivity. Mono. 7 British Plant Growth Regulator Group, Wantage, England.

Marshall, H.G., F.L. Kolb and G.W. Roth. 1987. Effects of nitrogen fertilizer rate, seeding rate and row spacing on semidwarf and conventional height spring oat. Crop. Sci. 27: 572-575.

Martin, R.A. and J.B. Sanderson. 1988. Yield of barley in response to propiconazole. Can. J. Plant Patho. 10: 66-72.

Moseman, J.G. 1968. Barley diseases and their control. p. 45-60. In Barley: Origin, botany, culture, winter hardiness, genetics, utilization and pests. Agric. Handbook 388. U.S. Dept. Agric.

Morgensen, V.O. 1980. Drought sensitivity at various growth stages of barley in relation to relative evapotranspiration and water stress. Agron. J. 72: 1033-1038.

Murray, R. and I.J. Dixon. 1970. Effects of 2-chloroethyl- phosphonic acid (Ethrel) on factors affecting yield in spring barley. Proc. 10th Brit. Weed Control Conf. 1: 266-274.

Nafziger, E.D., M.L. Wax and C.M. Brown. 1986. Response of five winter wheat cultivars to growth regulators and increased nitrogen. Crop Sci. 26: 767-770.

Needham. P, and D.A. Boyd. 1976. Nitrogen requirement of cereals. 2. Multi-level nitrogen tests with spring barley in south-western England. J. Agric. Sci. Camb. 87: 163-170.

Nuttonson, M.Y. (ed). 1957. Barley-climate relationships and the use of phenology in ascertaining the thermal and photo thermal requirements of barley. American institute of Ecology, Washington.

Ohm, H.W. 1976. Response of 21 oat cultivars to nitrogen fertilization. Agron. J. 68: 773-775.

Palmer G.M. and W.E.R. Madge. 1986. Spring barley, nitrogen and growth regulator management, 1983-1985. In seventy eighth annual report, 1985-86 Norfolk Agric. Station. Wymondham, Norfolk, U.K.

Pearman. I., S.M. Thomas and G.N. Thorne. 1978. Effect of nitrogen fertilizer in growth and yield of semidwarf and tall varieties of winter wheat. J. Agric. Sci. 91: 31-45.

Roth, G.W., H.G. Marshal, V.E. Hartly and R.R. Hill Jr. 1984. Effects of management practises on grains yield, test weight and lodging of soft red winter wheat. Agron. J. 76: 379-383.

Rourke, D. 1985. Highlights of Canada Grains Council, national intensive wheat management project. Union carbide ICM Seminar. Toronto.

SAS Institute. 1982. SAS User's Guide: Statistics. SAS Inc., Cary, N.C.

Simmons, S.R., E.A. Oelke, J.V. Wiersma, W.E. Lueschen and D.D. Warnes. 1988. Spring wheat and barley responses to ethephon. Agron. J. 80: 829-834.

Spiertz, J.H.J. and J. Ellen. 1978. Effects of nitrogen on crop development and grain growth of winter wheat in relation to assimilation and utilization of assimilates and nutrients. Neth. J. Agric. Sci. 26: 210-231.

Steel, R.G.D. and Torrie, J.H. 1980. Princples and Procedures of Statistics: A Biometrical Approach. MaGraw-Hill Co., New York, N.Y.

Stobbe, E.H., D.R.S. Rourke and R. Berard. 1985. Semidwarf vs. conventional height spring wheat cultivars response to ICM practices. (preliminary unpublished report).

Stoskopf, N.C. 1967. Yield performance of upright-leaved selections of winter wheat in narrow row spacings. Can. J. Plant. Sci. 47: 597-601.

Thorne, G.N. and J.C. Blacklock. 1971. Effects of plant density and nitrogen fertilizer on growth and yield of short varieties of wheat derived from Norin 10. Ann. Appl. Biol. 68: 93-111.

Turley, R.H. and T.M. Ching. 1986. Physiological responses of barley leaves to foliar applied urea-ammonium nitrate. Crop Sci. 26: 987-992.

Waddington S.R. and P. Cartwright. 1986. Modification of yield components and stem length in spring barley by the application of growth retardants prior to mainshoot stem elongation. J. Agric. Sci., Camb. 107: 367-375.

Warner, H.L. 1969. Ethylene evolution from 2-chloroethylphosphonic acid. Plant Physiol. 44: 156-158.

Wale S.J. and E.A. Hunter. 1985. A comparison of fungicides for the control of mildew on spring barley. J. Agri. Sci., Camb. 105: 573-579.

Widdowson, F.V, J.F. Jenkyn and A. Penny. 1976. Results from two barley experiments at Saxmundham, Suffolk, measuring effects of the fungicide benodanil on three varieties given three amounts of nitrogen at two times 1973-4. J. Agric. Sci. Camb. 86:271-280.

Wierman, D.W, E.S. Oplinger and S.O. Guy. 1986. Environment and cultivar effects on winter wheat response to ethephon growth regulator. Agron. J. 78: 761-784.

Zadoks, J.C., T.T. Chang, and C.F. Konzak. 1974. A decimal code for the growth stages of cereals. Weed Res. 14: 415-421.