INTENSIVE MANAGEMENT
OF BARLEY
IN SASKATCHEWAN

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by

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ABSTRACT

Two experiments were conducted in barley to assess the feasibility of Intesive Cereal Managment (ICM) and to evaluate plant growth regulator (PGR) type, rate and time of application. The first experiment consisted of ten tests assessing ICM with three levels of N (0, 50 and 100 kg ha^{-1}) above soil test recommendations, two levels of ethephon (0 and 0.24 kg ha^{-1}) and two levels of propiconazole (0 and 0.125 kg ha^{-1}). Varieties used in ICM tests were Bonanza, Samson, Leduc, Virden, Johnston and Heartland. The second experiment, comprised of nine tests, compared two PGRs (ethephon and ethephon + CCC) at two rates and two stages of application (ZGS 31-33 and ZGS 48-51). Varieties in the PGR experiment were Johnston, Leduc, Bonanza and Virden. Both experiments were conducted in 1986 and 1987 on dryland in the thin-black soil zone near Speers, Sask. and under irrigation in the dark brown soil zone near Outlook, Sask.

In the ICM experiment, only one test resulted in a yield increase (13%) due to N addition above the soil test recommendation (50 kg N ha^{-1}). This occurred in irrigated Leduc barley in 1987. There was no yield response to incremental increases of N in all other tests. Grain protein increases with higher levels of N were observed in all tests. There was an average 28% increase in harvested grain yield in five of the ICM tests when ethephon was used to control lodging. In the other four tests, where no lodging occurred, grain yield was unaffected by ethephon. Ethephon reduced crop height an average 10% in all tests and the number of kernels

head^{-1} was reduced in seven tests. Samson barley was not as prone to lodging as the other varieties tested. Propiconazole increased grain yield by an average of 10% in Bonanza and Samson barley. Control of leaf diseases by propiconazole resulted in an increase in kernel mass and grain yield.

In two of the nine PGR tests all PGRs depressed barley yield in the absence of lodging under dryland conditions. The PGRs in four out of the five irrigated experiments improved grain yield by an average of 56%. Where severe lodging occurred, late application of PGR resulted in higher yield increases than early application. PGRs reduced lodging and increased harvestable grain yield. PGRs significantly reduced crop heights in all tests.

Certain ICM inputs such as PGRs to control lodging can be profitable. Positive yield response is more reliable under irrigation as compared to rain-fed systems. Financial profit from integration of N, PGR and fungicide is unlikely under prairie conditions. Current management practices of using N at levels recommended by the Saskatchewan Soil Testing Laboratory, choosing disease resistant cultivars and occasionally using PGRs and foliar fungicides under certain conditions are more profitable than adopting the entire ICM package.

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1. INTRODUCTION

Intensive Cereal Management, or ICM, originated in West Germany in 1965. From there it spread to other countries of Western Europe and is now a common practice in member countries of the EEC.

From 1970 when ICM started, to 1985, West German winter wheat yields have doubled from 3 to 6 T ha (Stewart, 1985). Other member nations of the EEC have also realized similar increases in grain yield. The adoption of ICM has converted the EEC from a significant importer to an exporter of small grains.
Subsidized grain prices for EEC growers encouraged ICM since artificially high grain prices make ICM inputs a profitable expenditure. The result is over-production which depresses the world market price of small grains. This puts Canadian cereal growers in a difficult financial position unless they are either subsidized by government, or they can reduce their cost of production, or both.

The increase in yield from ICM observed in tests in the Canadian maritime provinces inspired people in other regions of Canada to consider it. In the prairies, results from ICM have generated variable responses, largely due to climatic limitations (Hopkins, 1988). Current ICM research efforts in Europe involve refinement of techniques which contribute to higher yields, however, marginal increases in yield have occurred at a slower pace than during the first 26 years. Efforts to develop more effective PGRs and fungicides, improved fertility management practices and better varieties continue to result in increases in yield.

The reason that farmers would consider ICM in Canada would be to lower their cost per unit of small grain production. This would make Canada a more competitive vendor of small grains on the world market. The value of extra production from ICM would have to exceed the cost of the additional inputs. This is more difficult for the prairie grower than for the EEC grower, since the prairie grower will have to cope with lower grain prices, given that cereal prices for a grower on the Canadian prairies are not subsidized to the extent they are in the EEC. In comparison to the EEC, the prairie grower also faces other limitations including climatic restrictions and a narrower selection of chemical inputs.

ICM increases production by integrating techniques such as higher seeding rates, higher fertility and the use of plant growth regulators (PGRs) to reduce lodging that can be induced by higher fertility. Foliar fungicides keep the crop healthy and minimize yield losses due to diseases. Cultivars are chosen on the basis of their yield potential with less regard to lodging and disease resistance. Of interest to the prairie grower is whether the proceeds from extra production will exceed the cost from deployment of these techniques. Furthermore, the synergistic interaction of ICM inputs would be an additional benefit of this management system.

The purpose of this project was to study the viability of ICM techniques in irrigated and dryland barley production in Saskatchewan. ICM was compared to conventional production methods to see if economic returns from ICM exceed those of conventional practices. The study was conducted in two areas of Saskatchewan where ICM responses were most likely to occur, irrigated barley in the Dark Brown Soil Zone (Outlook, Sask.) and dryland barley in the Black Soil Zone (Speers, Sask.). ICM techniques were also studied to see if there was any synergistic interaction on yield which may contribute to sustainable ICM. An additional study assessed two plant growth regulators, each applied at two rates and crop growth stages to assess their effects on barley under Saskatchewan conditions.

2. LITERATURE REVIEW

2.1 Intensive Crop Management

Good management is essential to maximize yield in either an Intensive Cereal Management (ICM) or conventional system of production. Central to ICM strategy is keeping the crop healthy, well nourished and standing (Stewart, 1985). As compared to a conventional production system, ICM requires the use of higher rates of N fertilizer. Plant growth regulators (PGRs) are used to minimize lodging losses and fungicides are applied as required to protect the crop from yield losses due to diseases.

Other techniques employed in an ICM system differ from conventional management (Stewart, 1985). Seeding is more precise, the objective being to establish a specific number of spikes per square meter. The cultivar selected may differ between conventional and ICM systems. In a conventional system the cultivar may be more resistant to lodging and disease whereas in an ICM system the use of PGRs and fungicides may compensate for lack of genetic resistance (Wilkins, 1984).

Barley grain yield in an ICM system will usually respond to higher levels of N than in a conventional production system. The use of PGRs in ICM systems will reduce or prevent lodging whereas, in a conventional system, lodging induced by high amounts of N can reduce harvestable grain yield. The lush, compressed canopy, greater leaf area (as a result of higher N rates) and shortened crop (due to PGRs) can make the crop more susceptible to foliar diseases. Fungicides can be applied to minimize yield losses due to diseases. In Europe, "tramlining" facilitates frequent application of N top dressings, PGRs and fungicides without damaging the crop (Hopkins, 1988). Tram lines are missing drill runs that are used by the grower to indicate to the applicator where to position the tires of the application equipment while applying treatments to the crops (BASF, 1984). With applications of fertilizers, fungicides, PGRs and other pesticides, tram lines ensure that these multiple applications to the crop are made accurately and uniformly without missing strips or overlapping.

All components of ICM are managed in an integrated manner. Thus, ICM is sometimes referred to as integrated cereal management. If yield is to be maximized, the effectiveness of each input component depends upon the proper management of other components.

2.2 Nitrogen Fertilizer Use in Barley

2.2.1 Amount of N Fertilizer

Barley responds well to fertilizer N. Stanberry and Lowrey (1965) determined that in irrigated barley at Yuma, Arizona, barley yield was significantly higher when supplemental N was used because of significant increases in the number of heads per plant and seeds per head. Needham and Boyd (1976) found that in 17 fertilizer N response experiments conducted on commercial farms in south-western England, yield and tiller population density increased with increasing N up to 100 kg N/ha. Atkins et. al. (1955) and Gately

(1971) found significant grain yield increases in response to added of N fertilizer. In the prairie provinces of Canada, significant increases in barley yield due to N fertilizer is well documented (Soper et al. 1971, Nuttall 1973, Heapy et al. 1976a, McGill 1976, Nyborg and Malhi 1986, Kucey 1987, Harapiak 1989).

Boyd et. al. (1976) dicovered that the effect of N on barley grain yield was represented by two intersecting lines. The first line represents the increase of barley yield as N fertilizer increased up to an optimum. The second line represented a more gradual decrease in barley yield when more than optimum N fertilizer was applied. Less or greater than optimum N fertilizer amounts can depress barley grain yield. Higher than optimum N fertilizer usually results in lodging (Pinthus 1973), greater disease development (Boyd et al. 1976), delays in maturity or other factors (Fiddian, 1970). McGill (1976) reported that application of 300 lb N ac^{-1} resulted in uneven emergence, delays in crop maturity and yield depression of barley in trials conducted across Saskatchewan.

Rate of N fertilizer can affect grain quality. Thousand kernel weight can be increased (Atkins et al. 1955, Gately 1971) by applying N fertilizer. Harapiak (1989) reported a positive response in protein concentration to each 30 kg N ha^{-1} increment of N up to 90 kg N ha^{-1}. However kernel mass declined slightly with each increment of N fertilizer in the same experiments. The positive effect of fertilizer N rate on grain protein has been reported extensively in the literature (Atkins et al. 1955, Calder and Mcleod 1974, Bole and Pittman 1978, Varvel 1982).

The most economic rate of N fertilizer to use is determined by soil tests and N response curves (Kucey and Schaalje 1986). Soper et al. (1971) found a highly significant correlation between nitrate nitrogen and barley yield in Manitoba. From this information, they developed an equation to estimate potential barley yield based on nitrate-N soil tests and N fertilizer rates. Nuttall et. al. (1971) developed barley yield equations as functions of available N in both the ammonium ion and nitrate ion forms based on work done in northeastern Saskatchewan. Nutall's equations are not influenced as much by variations in climate and soil types as Soper's method (Nutall 1973). Heapy et. al. (1976a) developed a barley yield equation for central Alberta explaining barley yield as a function of soil N and P. They also introduced a moisture stress term (1976b). The amount of N fertilizer recommended on the basis of soil tests will vary depending upon moisture conditions. Barley yield continues to respond to higher fertilizer N levels with increasing soil moisture (Stanberry and Lowrey 1965). Henry (1989) concluded that the interaction between N and soil moisture is as large as or larger than the individual effects of either N or soil moisture.

2.2.2 N Fertilizer Type, Timing and Method of Application

Nyborg and Malhi (1986) compared the effects of fall applied urea to spring applied urea on barley yield in Alberta and Saskatchewan. They concluded that fall applied urea resulted in lower barley yields than spring applied urea due to a lower recovery of soil mineral N from the fall treatment. The loss of mineral N from the fall application was due to denitrification and immobilization. Bole et al. (1984) found that urea broadcast and incorporated in the fall at 99 sites in Alberta increased yields an average of 76% compared to the same application in the spring. Harapiak (1989) suggested that with the advent of improved application techniques such as deep banding, over-winter losses may be reduced by using such techniques. Kucey (1987) compared various forms of spring and fall applied N fertilizers and banding versus broadcast methods of application. Time of application of banded or broadcast ammonium nitrate had no significant effect on barley yield.

Placement of N fertilizer can influence barley yield response. Hartman (1987) demonstrated that barley yield was not as responsive to broadcast as to banded N. In experiments conducted in Alberta, he also found that broadcast N treatments resulted in lower yield increases than banded N when precipitation was limited. Harapiak (1989) reported that yield advantages for banding over broadcast N ranged from 430 to 1345 kg ha^{-1} in trials conducted in Central Alberta.

Three forms of N fertilizer commonly used by prairie barley growers are ammonium nitrate, urea and anhydrous ammonia. Ammonium nitrate has about half of its N in the ammonium form and the other half in the nitrate form. Urea is quickly converted to ammonium when applied to soil or plant material. Ammonium N can be used directly by the plant (Spratt and Gasser 1970) or it may be converted to nitrate N by soil micro-organisms and then taken up by the plant. Kucey (1987) compared spring and fall treatments of ammonium nitrate, urea and anhydrous ammonia and found no differences in yield response when all 3 forms were banded, however broadcast urea resulted in significantly lower yields than broadcast ammonium nitrate or anhydrous ammonia.

One of the features of the ICM system in Europe is split applications of N fertilizer where most of the N fertilizer is applied as a "top-dress" after crop emergence. Timing of N application is synchronized with various developmental stages of the crop to maximize efficiency and minimize N losses in the soil. Experimental results from top dressing and split applications of N in Europe have been variable. Widdowson et al. (1961) found that dividing N application on barley between planting and late April or early May gave a slight yield advantage over applying all the N in the seedbed. However, Widdowson and Cooke (1958) found that split applications between seedbed and mid-May top dressing resulted in lower yield responses than the same amount of N all applied in the seedbed. Split applications increased lodging, reduced grain quality and delayed maturity.

Easson (1984) studied the effect of split applications at various intervals in spring barley as compared to the same amount of N applied in the seedbed. He found grain yields declined progressively with top dressings from the first node (40 days after emergence) and onwards. Top dressing at 40 days after emergence was found to increase tiller survival, but this effect was not expressed in increased yield because there were fewer kernels per head. He concluded that in most situations, splitting application of N with part of it applied as a top dressing is unlikely to improve yields if compared to applying all the N fertilizer in the seedbed. The exception is under circumstances of early seeding followed by high rainfall which would contribute to leaching losses of soil N. Gately (1971) reported that a split application of N fertilizer did not increase grain yield as much as a single application of N fertilizer applied early.

Top dressing applications of N applied near anthesis can increase grain protein content without compromising yield (Turley and Ching, 1986). In an intensive management system in northeastern Ontario, Skepasts (1985) found that splitting N application resulted in no yield benefit compared to applying the same amount of N at seeding. However, late application of N increased grain protein.

2.2.3 Other Factors Affecting Nitrogen Efficiency in Barley

Other factors can influence the response of barley yield to increasing amounts of N. Nuttall (1973) found significant N X phosphate fertilizer interactions in yield of Conquest barley in northeastern Saskatchewan. He found that the application of phosphate had a greater positive effect on Conquest barley yield at higher rates of N fertilizer (67 and 134 kg ha^{-1}) than at lower rates (22 and 45 kg ha^{-1}).

Kirby (1968) found no effect of barley cultivar on yield response to N at the Plant Breeding Institute, Cambridge. At Charlottetown, PEI, Calder and Mcleod (1974) found a differential cultivar yield response to fertilizer N and that soil pH can influence barley yield response to N fertilizer. Rahman and Goodman (1984) studied the effect of top dressing N fertilizer on six cultivars of spring barley. They found that there was no N by cultivar interaction on grain yield but there was a significant cultivar by N interaction on harvest index. McFadden (1970) found that Conquest and Olli barley responded equally to N fertilizer at different seeding rates at Lacombe, Alberta. Dubetz and Wells (1968) found cultivar X N interactions in barley in greenhouse pot trials. Cultivar X N interactions in the field were reported by Pendleton, et. al. (1953).

Briggs (1991) found no N or P_2O_5 X cultivar interaction when he tested two semidwarf and three conventional height barley cultivars in Central Alberta. Grant et. al. (1991) tested six semidwarf and conventional barley cultivars in southern Manitoba and found no N X cultivar interaction on grain yield under low or moderate moisture supply. Under high moisture conditions, they found the feed grain cultivars to yield higher than the malting variety Bonanza.

2.3 Lodging in Barley

2.3.1 Cause and Effect of Lodging in Barley

Pinthus (1973) reviewed the cause and effects of lodging in cereals. Lodging occurs when bending force due to wind, rain or hail combined with the weight of the head exceeds the strength of the culm. Neenan and Spencer-Smith (1975) reported that lodging in wheat and barley occurs by buckling rather than loss of anchorage and that the force of raindrops was not a significant factor in lodging. Root rots and foot rots may contribute to lodging, particularly "eyespot" foot rot caused by <u>Cercosporella herpotrichoides</u>. Use of higher rates of N fertilizer may increase head weight and culm length making barley more susceptible to lodging (Pinthus 1973). Stanca, et al. (1979) found a positive correlation between lodging susceptibility and plant height in eight spring barley cultivars.

Susceptibility to lodging varies among varieties (Pinthus 1973). Berbinger (1968) reported the creation of commercial semi-dwarf cultivars with the goal of improving lodging resistance. However, a reduction in culm length will not always increase lodging resistance. In order for short strawed varieties to infer better lodging resistance, they must have an adequate root system and the straw must still be elastic.

Anatomical features of the culm can influence lodging resistance of barley cultivars (Ceccarelli and Falcinelli 1978). Cenci et al. (1984) studied the anatomical characteristics of barley varieties and found that short culms did not always offer better standing power than long culms. However they found that varieties with culms constructed of thicker sclerenchyma cells offered better lodging resistance. They concluded that better lodging resistance is possible by combining a short culm and thicker sclerenchyma cells in the same genotype. Dunn and Briggs (1988) studied the differences in culm anatomy of five registered barley cultivars recommended for use on the Canadian prairies, including two semi-dwarf varieties, Samson and Duke. They found no differences in sclerenchyma cell walls amongst the varieties, however they agreed with Jezowski (1981) that lodging resistance is increased by a shorter culm, shorter basal internodes, thicker culm wall and a thicker sclerenchyma ring.

Briggs (1990) assessed lodging effects on six row cultivars commonly grown in western Canada. He found that lodging at the milk stage caused greater yield depression than later lodging. Johnston barley had the poorest lodging resistance and the greatest inability to recover from early lodging. Duke was superior in lodging resistance and ability to recover from lodging as compared to Samson. Both semidwarf cultivars lodged less than Leduc, Klondike or Johnston. Lodging reduced kernel weight and hectolitre weight. In some of the trials, incidence of leaf disease was increased by lodging. Helm (1986) reported that artificially induced lodging at the milk stage depressed yield by 40% whereas only 8% yield depression was recorded from artificial lodging induced just prior to harvest in central Alberta.

Pinthus (1973) cited a report by Baumgartner (1969) who concluded that in a lodged crop, harvest capacity could be reduced by up to 25% and unthreshed head loss may be doubled. Harvesting a lodged barley crop is more difficult than one that is standing.

Losses occur because heads lying below the cutter bar are missed by the harvesting equipment and does not feed into the threshing equipment properly. In the subsequent crop, the volunteer barley infestation may be greater as a result of grain that escaped harvesting operations (O'Donnovan, et. al. 1987).

2.3.2 Lodging Control with Plant Growth Regulators

The effects of chlormequat chloride (CCC) as a plant growth regulator were first published by Tolbert (1960a, 1960b). The biological effects of ethephon in plants were first discovered by Amchem in 1965 (Wilde 1971). Both CCC and ethephon reduce lodging in barley by shortening internodes (Jung and Rademacher 1983). In western Canada, the only commercially available plant growth regulator is ethephon which is sold under the trade name Cerone (Anon. 1991a). A preformulated mixture of CCC and ethephon marketed under the commercial name, Terpal C, is currently being reviewed by the Pesticides Directorate of Agriculture Canada for registration in barley and may be available soon (BASF, Personal Communication).

Humphries (1968) reviewed the effectiveness of CCC as an anti-lodging treatment in barley. It was more effective in wheat than in barley. CCC was found to be ineffective in barley because it is quickly metabolized and transported to the roots as a quaternary base (Skopik and Cervinka 1967).

Lord and Wheeler (1981) found greater mobility of CCC in wheat leaves than in barley leaves. Larter et al. (1965) found that CCC was more effective as a soil drench than a foliar application.

There is a differential response amongst barley cultivars to CCC (Larter et al. 1965, Larter 1967, Clark and Fedak 1977, Waddington and Cartwright 1986). The use of CCC has increased yield in barley in the absence of lodging by increasing the number of tillers (Koranteng and Matthews 1982). Conversely, Waddington and Cartwright (1986) did not find CCC effective in increasing barley yield in the absence of lodging. Clark and Fedak (1977) reported no effect of CCC on disease incidence.

Ethephon can increase barley yield by reducing lodging (Dahnous et al. 1982, Moes and Stobbe 1991a, Simmons et. al. 1988). In the absence of lodging, ethephon has been shown to reduce yield (Moes and Stobbe 1991a). When ethephon suppresses yield of barley it is due to a reduction in the number of kernels per head (Moes and Stobbe 1991c). Ethephon can also delay barley maturity (Moes and Stobbe 1991a).

Simmons et. al. (1988) reported varietal differences in height reduction due to ethephon application. Dahnous et. al. (1982) reported a greater reduction in barley height when ethephon was applied at the late boot stage than when applied at early heading. Moes and Stobbe (1991b) found that ethephon increased the number of fertile tillers per plant due to late tiller production and survival. When CCC was applied with ethephon it reduced the detrimental effects on barley yield that were noted with ethephon alone (Caldwell et al. 1988).

2.4 Foliar Diseases in Barley

2.4.1 Extent and Effect of Leaf Diseases in Western Canada

Weller and Rossnagel (1990) surveyed 30 locations in Saskatchewan and bordering areas for barley leaf diseases in 1989. They found spot form net blotch (*Pyrenophora teres* f. *maculata*) in moderate to heavy amounts at five locations and light infections at eight locations. Scald (*Rhyncosporium secalis*) occurred in heavy amounts at one location and in moderate to light infections at five locations. Spot blotch (*Cochliobolus sativus*) occurred at five locations in light to moderate amounts and net-form net blotch (*Pyrenophora teres* f.*teres*) occurred in light amounts at three locations. Septoria (*Septoria spp.*) was present in light amounts at two locations. No other diseases were present in yield-threatening amounts. Mueller and Tekauz (1990) surveyed 25 Manitoba fields in the same year finding net blotch (*Pyrenophora teres*) in 72% of the locations and spot blotch in 84% of the fields surveyed.

Tekauz et. al. (1989) listed net blotch, scald and stem rust (*Puccinia graminis*) as the most important foliar diseases infecting barley on the Canadian prairies based on frequency and degree of damage to barley. Other diseases such as leaf rust (*Puccinia hordei*), spot blotch, Septoria, powdery mildew (*Erysiphe graminis*) and bacterial or viral infections may be widespread, but generally occur in non-threatening amounts.

Tekauz (1989) estimated that the average annual yield loss in barley due to disease is about 8%. This differs from an earlier estimate by Buchannon and Wallace (1962) whom estimated yield losses due to leaf diseases at 20%.

Piening and Kaufmann (1968) compared the effects of net blotch and leaf removal on the yield of barley. They found that upper leaf removal caused the same yield depression as leaf infection irrespective of fertilizer regime. In contrast, infection of lower leaves caused greater yield loss than removal of lower leaves at the lower fertility regime. The results suggest that yield loss due to net blotch is due to a combination of photosynthetic area loss and a toxic effect. The toxigenic effect can be reduced by higher fertility. Cook (1980) found that late season leaf disease infection can reduce kernel size by diverting carbohydrates that would otherwise be contributing to kernel development.

2.4.2 Control of Foliar Disease

Tekauz (1989) emphasised the importance of disease resistant cultivars to minimizing losses. Rowling and Jones (1976) reported that the mechanism of varietal tolerance to scald is yield component compensation. Lehnackers and Knooge (1989) determined that scald infection in resistant cultivars was lower because the plant inhibited spore germination on the leaf surface and the development of subcuticular stroma was prevented.

Currently, the only fungicide registered and commercially available for foliar disease control in barley in Canada is propiconazole, or Tilt (Anon. 1991c). Van Den Berg and Rossnagel (1990) found propiconazole effective in controlling spot blotch, however the effective period was limited. Yield increases were attributed to increased kernel weight. Entz et al. (1990) found significant increases in yield and kernel size due to control of net blotch with propiconazole in barley. Johnston and McLeod (1987) found propiconazole to control net blotch and increase overall protein and grain yield in P.E.I.

Cook (1980) reported a 21% increase in winter wheat yield due to a late season application of captafol. The yield increase could not be explained by control of identifiable disease. Hill and Lacey (1983) reported slight increases in barley yield as a result of late season fungicide treatment which controlled superficial microflora.

2.5 Interaction Between N, PGR and Fungicide

Use of a PGR and fungicide will permit barley to respond fully to N fertilizer where climate is not a limiting factor. Jordan and Stinchcombe (1986) found that barley leaf size and disease intensity increased with the amount of N fertilizer applied. Use of a foliar fungicide suppressed disease and increased yield. Use of a growth regulator also increased yield. Jenkyn et al. (1983) reported that increasing the rate of N fertilizer increased the incidence of powdery mildew infection in barley. Yield response to N fertilizer was greatest when a fungicide was used. Couture and Isfan (1986) correlated severity of scald infection to the rate of N fertilizer. Johnston and McLeod (1987) concluded that a healthy standing crop is a prerequisite to benefit from supplemental use of N fertilizer in intensive barley management. Crop health is improved by use of fungicide and the structural integrity of the plant is ensured with use of PGRs. Skepasts (1985) found no benefit from fungicide use in conjunction with N fertilizer, however ethephon prevented lodging. Pearson et. al. (1989) reported that winter barley grain yield increased more with N when ethephon was used as compared to N alone in one of two years under an irrigated system in an arid environment. Dahnous (1982) found no interaction of N rate and PGR on barley yield. Zebarth and Sheard (1991) compared the yield response of Leger barley to eight rates of N under each of high management (use of PGR and foliar fungicide) and low management (no foliar fungicide or PGR used) systems in southern Ontario. They found no difference in yield response to N between high management or low management systems. They did, however, find that maximum economic yield occurred at a higher N rate (90 kg N ha^{-1}) in the high management system as compared to a lower N rate (71 kg N ha^{-1}) in the low management system.

2.6 Potential of ICM in Saskatchewan

Hopkins (1988) concluded that specific components of ICM on wheat may have economic benefit in more humid climates. The entire ICM package per se was not economically feasible in wheat. Increased N levels sometimes gave a positive yield response and improved grain protein for which a premium price may be received. PGRs and fungicides occasionally improved yields and grain quality. Furthermore, Hopkins concluded that current spring wheat management practices adopted by growers gave the highest MEY, or Maximum Economic Yield.

The threat of lodging and disease losses is greater in barley than wheat. Thus the use of PGRs and fungicide inputs may be practical under certain circumstances. Increasing grain protein with N fertilizer is of little economic benefit for feed barley production since no price premium is associated with higher levels of protein. If malting barley is grown, higher than recommended levels of N fertilizer could result in grain protein levels too high for malt eligibility. In 1991, the feed varieties of barley grown in Saskatchewan totalled less than 10% of the total barley planted (Western Producer, 1992). Generally growers plant malt eligible varieties with the hope of achieving malt grade of the grain. Few growers intentionally sow feed varieties with the sole intention of harvesting feed grain.

3. METHODS AND MATERIALS

3.1 General Description of Trials

Two field experiments were conducted under dryland and irrigated conditions in each of two years. The first experiment evaluated the effects of additional fertilizer N, growth regulator (ethephon[1]) and fungicide (propiconazole[2]) in barley (hereafter referred to as ICM trials). These are inputs commonly used by growers who practice ICM in Europe. The second experiment focused on the effect of plant growth regulator type, rate and stage of application on barley (hereafter referred to as PGR trials). A complete listing of seeding rates and dates, P_2O_5 rate and placement, herbicides used, treatment application dates and weather at application is presented in Appendix A. Barley varieties registered and used by growers in the Canadian prairies were used. Their agronomic characteristics are described in Appendix B.

3.2 Site Locations

Trials were centred around two locations in Saskatchewan in 1986 and 1987. All irrigated trials were conducted near Outlook, Saskatchewan on Bradwell silt loam soil. The dryland trials were conducted in the Speers-Keatley, Saskatchewan area on Blaine Lake silty clay loam soil. Outlook is in the Dark Brown Soil Zone of

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[1]Trade name Cerone (TM HOECHST Canada Inc.)

[2]Trade name Tilt (TM Ciba-Giegy Canada Inc.)

Saskatchewan whereas the Speers-Keatley area is in the Thin Black Soil Zone. The climate at Outlook is semiarid; that at Speers-Keatley subhumid. Table 3.1 lists the barley variety, year, location, type of trial and soil N level.

Table 3.1. Year, trial type, location, variety and soil N to 60 cm depth (total of soil N plus applied fertilizer N).

Year	Experiment	Location	Barley Variety	0 - 60 cm Available[a] Soil N kg ha^{-1}
1986	ICM	Outlook	Samson	234
		Outlook	Bonanza	112
		Keatley	Bonanza	126
		Speers	Samson	110
1987	ICM	Outlook	Virden	340
		Outlook	Leduc	340
		Outlook	Heartland	286
		Speers	Leduc	118
		Speers	Johnston	122
		Speers	Samson	118
1986	PGR	Outlook	Leduc	330
		Outlook	Johnston	330
		Speers	Bonanza	114
		Speers	Johnston	210
1987	PGR	Outlook	Leduc	340
		Outlook	Johnston	286
		Outlook	Virden	340
		Speers	Johnston	227
		Speers	Leduc	227

[a] NO_3-N as determined by Sask. Soil Testing Laboratory.

The N level shown in Table 3.1 is based on soil tests taken from the control plots of the tests at Zadok's GS 21 to 32.

The Saskatchewan Soil Testing Laboratory N recommendations deemed to be sufficient for barley production in the black soil zones and for irrigation are shown in Table 3.2.

Table 3.2 Saskatchewan Soil Testing Laboratory N levels deemed to be sufficient for barley production[a].

Soil Zone	Moisture	NO_3-N to 60 cm lb. ac^{-1}	NO_3-N to 30 cm lb. ac^{-1}
Brown	Dry	46 - 50	28 - 30
	Normal	61 - 65	37 - 39
	Wet	86 - 90	52 - 54
Dark brown	Dry	61 - 65	37 - 39
	Normal	81 - 85	49 - 51
	Wet	100 +	60+
Thin, thick black	Dry	91 - 95	61 - 63
	Normal	106 - 110	71 - 73
	Wet	121 - 125	80+
Irrigation, All zones	Irrigated	140+	97+

a. Taken from "Nutrient Requirement Guidelines for Field Crops in Saskatchewan, 1990" published by the Saskatchewan Soil Testing Laboratory.

3.3 Treatments

3.3.1 Chemicals

The fungicide applied was propiconazole formulated as an emulsifiable concentrate containing 250 g ai L^{-1}. The two PGRs used were ethephon and a preformulated mixture of ethephon + CCC[3], (hereafter referred to as eth+CCC). The ethephon formulation was a 480 g ai L^{-1} aqueous solution. The preformulated eth+CCC product was an aqueous solution containing 305 g ai L^{-1} of CCC and 155 g ai L^{-1} ethephon. All chemicals used are described in Appendix C. All chemicals were applied in 110 L ha^{-1} of water at a pressure of 275 kPa using a hand held plot sprayer. The sprayer was equipped with

[3]Trade name Terpal C (TM of BASF Canada Inc.)

six 8001SS Tee-Jet nozzles spaced 50 cm apart and held 50 cm above the crop canopy.

3.3.2 ICM Experiment

In the ICM tests, additional N was added to some treatments. The 0 rate of N shown in Table 3.1 represents soil N plus the N fertilizer added according to SSTL recommendations to bring the soil available N up to the level deemed sufficient by SSTL. The 50 and 100 kg ha^{-1} rates are 50 and 100 kg above the amounts indicated in Table 3.1. In 1986, all the fertilizer N was added as a post-emergent application of ammonium nitrate when the crop was at the early tillering (Zadok's GS 21-23) stage of development. In the 1987 dryland ICM tests, the additional N treatments were applied as ammonium nitrate in the seedbed prior to planting. In the 1987 irrigated ICM tests, the additional N was applied as liquid 28-0-0 applied in 200 L ha^{-1} of water at the early stem elongation stage of crop development (Zadok's GS 31-32).

The PGR used was ethephon applied at two levels: 0 and 0.24 kg ha^{-1}. The fungicide used was propiconazole applied at 2 levels: 0 and 0.125 kg ha^{-1}. For treatments which had propiconazole and ethephon in common, the two products were tank-mixed and applied simultaneously. All chemicals were applied to the crop at Zadok's GS 48-50. Crop growth stages were determined using the system developed by Zadoks et al. (1974).

3.3.3 PGR Experiment

Each PGR was applied at two stages of crop growth. The early timing was when the crop was at Zadok's GS 31-33 and the late timing was applied at Zadok's GS 48-50. Each PGR was applied at two rates. The application rates[4] used for ethephon were 0.24 kg ha^{-1} and 0.40 kg ha^{-1}. Eth+CCC was applied at 0.46 kg ha^{-1} and 0.69 kg ha^{-1}.

3.4 Experimental Design

Each trial was arranged in a randomized complete block design. Plots had a breadth of 3 m and a length of 6 m and were replicated four times. The ICM trials were a 2 X 2 X 3 factorial design testing three levels of N (0, 50 and 100 kg ha^{-1}), 2 levels of ethephon (0 and .24 kg ha^{-1}) and 2 levels of propiconazole (0 and .125 kg ha^{-1}).

3.5 Assessments

Grain yield was determined in every test using a Kincaid small plot grain harvester cutting a 7.8 m^2 portion of each plot. Grain protein was determined by analyzing a 200 gram grain sample from each plot in the ICM tests. Analysis was done using the Udy dye method (Udy, 1971).

Grain moisture was determined in 1986 trials by retaining a 200 gram grain sample from each plot at harvest and drying it in forced air at 45° C for a period of two days. In 1987, grain moisture was determined using a Labtronics Model 919 grain moisture

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[4]Rates of all chemicals are as suggested by the manufacturer

tester immediately after harvesting.

The number of kernels head^{-1} was determined by randomly selecting 20 heads in each plot when the crop was at Zadok's GS 85. These samples were subsequently dried and retained for kernel counts.

The number of heads meter row^{-1} was counted in each plot with the exception of the 1987 Heartland barley test at Outlook. This trial was cross seeded and heads were counted in two randomly placed sampling quadrats (0.5 m^2) per plot.

The grain samples were cleaned and dried before the kernels were taken. Thousand kernel weight was determined by weighing 250 kernels per plot.

Crop height was determined in all plots when the crop was at Zadok's GS 80-85 by holding a measuring stick in the centre of each plot and determining the mean height. Where lodging occurred, it was visually assessed using the Belgian Lodging Scale (Oplinger et. al. 1985).

Where leaf diseases occurred, they were identified and rated according to James (1971). Leaf disease assessments were determined by randomly selecting 10 penultimate leaves from main stems in each plot at Zadok's GS 75-85.

3.6 Statistical analysis and mean separation

With the exception of the visual lodging scores, all field data were analyzed using analysis of variance. Each test was analyzed separately. Tables of observed F tests for all experiments are in Appendix D. Statistical analysis was performed using the of the ICI Field Trial Information System[5] statistical package and Pesticide Research Manager[6]. Missing values were estimated by using Yate's method[7].

3.6.1 ICM

ICM tests were analyzed as a 3 X 2 X 2 factorial design. Each test was analyzed for significant main effects and interactions between main factors. Mean separation was performed by LSDs calculated at the P=0.05 level of probability.

3.6.2 PGR

Grain yield and crop height data from PGR tests was analyzed for treatment effects using orthogonal contrasts.

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[5]FTIS programme developed by ICI Agrochemicals, Jealott's Hill Research Station, Bracknell, Berkshire, England.

[6]Developed by Fran Gylling, Gylling Data Management Inc., Brookings, South Dakota, USA.

[7]In "Principles and Procedures of Statistics, A Biometric Approach, Second Edition". 1980. R.G.D. Steel and J.H. Torrie.

4. RESULTS AND DISCUSSION

4.1 Climatic Conditions During the Growing Season

4.1.1 Precipitation, Irrigation and Temperature

The continental climate of Saskatchewan features fluctuations in rainfall and temperature that greatly influence crop development and yield. It is therefore essential to consider the temperature and precipitation patterns during crop development when interpreting the results from experiments.

Table 4.1 lists the actual monthly May to September precipitation for 1986 and 1987 and the long term average for each site.

Table 4.1. Monthly May to September precipitation during 1986 and 1987 at the test sites as compared to the 1951 - 1980 means.

Location	Year	Monthly Average Precipitation (mm) May	June	July	Aug.	Total
Outlook[1]	1986	77	32	111	17	237
	1987	27	49	93	60	229
	1951-1980 Mean	33	64	50	33	180
Speers[2]	1986	61	96	170	65	392
	1987	29	61	17	83	190
	1980-1985 Mean	40	71	69	52	232

[1]Outlook information from Sask. Irrigation Dev. Centre weather station.
[2]Speers information from Environment Canada monthly summaries for Hafford, 16 km east.

Irrigation was applied to all the Outlook experiments in 1986 and 1987. The summary of all irrigation information is indicated in Table 4.2.

Table 4.2. Irrigation information for all irrigated tests, Outlook

				Water Applied		
Year	Experiment	Barley Variety	Irrigation Method	Irrigation mm	Prec.[1] mm	Total[2] mm
1986	ICM	Bonanza	Centre Pivot	140	237	377
	ICM	Samson	Wheel Move	205	237	442
	PGR	Leduc	Wheel Move	205	237	442
	PGR	Johnston	Wheel Move	205	237	442
1987	ICM & PGR	Leduc	Wheel Move	133	229	362
	ICM & PGR	Virden	Wheel Move	133	229	362
	ICM	Heartland	Flood	118	229	347
	PGR	Johnston	Wheel Move	156	229	385

[1] Precipitation taken from Table 4.1.
[2] Total = irrigation water (mm) + precipitation water (mm)

The dryland experiments at Speers received above normal precipitation in 1986 and below normal precipitation in 1987. In 1986 the trials at Speers received adequate precipitation throughout the growing season. At Speers, the month of July, 1986 was a particularly wet month with 246% of normal precipitation. This was a contributing factor to late lodging in some crops in the area and provided conditions conducive to late season leaf diseases such as scald (Rhynchosporium secalis). In 1987, the growing season at Speers was drier than normal. Precipitation in May, 1987 was 73% of normal which contributed to spotty crop germination in some fields. July 1987 precipitation at Speers was 25% of normal which negatively influenced crop development during anthesis and grain filling. August, 1987 precipitation was 160% of normal.

Precipitation at Outlook during 1986 and 1987 was above average. All the trial sites received significantly less irrigation in 1987 than in 1986 because precipitation during August, 1987 was higher than normal.

4.1.2 Soil Moisture Status

Soil moisture was not quantitatively measured at any of the locations. The crop at all irrigation sites was planted into soil with good moisture in both years. This contributed to good germination and even emergence at all irrigated sites.

Soil moisture status at Speers at planting was generally good in both years. However, soil moisture was generally better in 1986 than in 1987. Precipitation over 1985 and the winter of 1985-86 was normal. The heavy rain in 1986 was somewhat offset by below normal autumn precipitation and below normal snowfall over the winter of 1986-87. Furthermore, precipitation in April and May 1987 was below normal so soil moisture was not as good in 1987 as in 1986.

4.1.3 Air temperature

Mean daily, monthly maximum and minimum air temperatures for all trial locations for 1986 and 1987 as compared to the long term averages are given in Table 4.3.

Table 4.3. 1986 and 1987 mean monthly minimum and maximum daily temperatures and 5 year average mean daily maximum and minimum temperatures at Speers and Outlook.

Location	Year	Mean Daily Maximum, °C				Mean Daily Minimum, °C			
		May	June	July	Aug.	May	June	July	Aug.
Speers[1]	1986	18.8	22.5	22.2	23.8	3.5	7.9	10.6	8.1
	1987	20.1	24.4	22.3	19.6	5.7	10.3	10.1	6.4
	Mean 1980-1985	16.5	21.4	24.3	23.0	3.9	8.1	10.6	9.1
Outlook[2]	1986	18.6	25.5	24.1	26.0	4.3	10.8	11.8	9.6
	1987	21.3	25.8	24.3	20.9	6.1	11.3	11.8	8.3
	Mean 1951-1980	19.6	22.3	25.4	24.2	4.2	8.9	11.5	10.1

[1]Speers information from Environment Canada monthly summaries for Hafford, 16 km east.
[2]Outlook maximum and minimum information from SIDC weather records. Outlook 30 yr average from Environment Canada.

In general, the daily maximum and minimum temperatures at Speers were lower than those experienced at Outlook. There was no frost recorded at any time between crop emergence and harvest in either year at either location.

Mean monthly temperatures over the 1986 and 1987 growing seasons at Speers and Outlook are summarized in Table 4.4.

Table 4.4. Mean monthly temperatures over 1986 and 1987 growing seasons at Speers and Outlook, Saskatchewan

Location	Year	Mean Daily Temperature in °C				
		May	June	July	August	September
Speers[1]	1986	12.2	15.2	16.4	16.0	8.4
	1987	12.9	17.4	17.1	13.0	13.6
	1980-1985	10.5	14.8	17.5	16.1	9.2
Outlook[2]	1986	18.6	25.5	24.1	26.0	14.0
	1987	13.7	18.6	18.1	16.0	17.0
	1951-1980	11.5	16.1	18.9	17.8	11.2

[1]Speers information from Environment Canada monthly summaries for Hafford, 16 km east.
[2]Outlook maximum and minimum information from SIDC weather records. Outlook normal information from Environment Canada.

Temperatures at both locations were generally higher than normal for May and June in both years. August 1986 was particularly warmer than normal at Outlook contributing to accelerated crop maturity.

4.2 Results and Analysis of the ICM Experiment

Significant yield response to ICM inputs was identified in all 5 irrigated ICM tests and in only one of five dryland tests (Bonanza barley, 1986). There were no interactions of main factors on grain yield in any of the ICM experiments.

Significant responses of disease, yield components and grain protein to ICM inputs occurred frequently. There were occasional main factor interactions on yield components, disease and grain protein.

4.2.1 Irrigated Tests at Outlook, 1986

4.2.1.1 Grain yield and protein

Grain yield and protein information is presented in Table 4.5. Additional N did not affect grain yield in either Samson or Bonanza barley. The use of ethephon prevented lodging in Bonanza barley and resulted in increased grain yield. The use of ethephon did not influence grain yield in Samson barley, probably because lodging was not a problem in Samson barley. Yield of Samson barley was increased due to application of propiconazole which controlled powdery mildew (*Erysiphae graminis*).

Table 4.5. Effect of nitrogen rate, ethephon and propiconazole on grain yield and grain protein content of irrigated barley at Outlook, Saskatchewan, 1986.

Main Factor	Level ($kg\ ha^{-1}$)	Yield $g\ m^{-2}$ Bonanza	Yield $g\ m^{-2}$ Samson	Percent Grain Protein Bonanza	Percent Grain Protein Samson
Nitrogen	0	556	732	14.5	13.4
	50	484	739	15.4 **	13.8 **
	100	512	728	16.0 **	14.0
	LSD (P=0.05)	195	21	0.3	0.3
Ethephon	0	394	727	15.4	13.6
	.24	640 **	739	15.1 *	13.8
	LSD (P=0.05)	159	17	0.3	0.3
Propiconazole	0	489	711	15.3	13.7
	.125	545	755 **	15.3	13.8
	LSD (P=0.05)	159	17	0.3	0.3
Mean		517	733	15.3	13.7

*, ** = significantly different from the check or preceding level at p=0.05 and p=0.01 respectively.

Grain protein increased with incremental N in both Bonanza and Samson barley. The use of ethephon in Bonanza barley reduced grain protein. This result is difficult to explain, particularly since ethephon also decreased kernel mass in the same test. This is the only occurrence of ethephon affecting grain protein in all ICM tests. Given this, and the fact that the decrease is slight (less than 2%), the importance of this observation should be minimized.

4.2.1.2 <u>Lodging and crop height</u>

Crop height and lodging scores are reported in Table 4.6. Shorter culm length has always been associated with reduced lodging (Pinthus, 1973).

Table 4.6. The effect on N rate, propiconazole and ethephon on crop height and lodging scores for 1986 irrigated Bonanza and Samson barley at Outlook

Main Factor	Level (kg ha^{-1})	Crop Height (cm) Bonanza	Crop Height (cm) Samson	Belgian Lodging Score Bonanza	Belgian Lodging Score Samson
Nitrogen	0	129	94	3.1	0.3
	50	130	94	3.7	0.4
	100	127	94	4.3	0.7
	LSD (P=0.05)	4	3		
Ethephon	0	137	97	7.0	0.7
	.24	121 **	92 **	0.4	0.3
	LSD (P=0.05)	3	2		
Propiconazole	0	130	95	3.7	0.5
	.125	127 *	94	3.6	0.4
	LSD (P=0.05)	3	2		
Mean		129	94	3.7	0.5

*, ** = significantly different from the check or preceding level at p=0.05 and p=0.01 respectively.

The lodging scores indicate that lodging seriously depressed harvestable yield in Bonanza barley and it is for this reason that a highly significant yield response to ethephon was detected. Lodging was less of a factor in the semi-dwarf variety Samson, in which case ethephon did not influence yield (Table 4.5). Samson is shorter than Bonanza, reflecting its semi-dwarf growth habit. This may intrinsically make Samson more resistant to lodging than longer strawed varieties.

Ethephon reduced height in both Bonanza and Samson barley. Straw was shortened by 11% in Bonanza but only 5% in Samson. Moes and Stobbe (1991a) found a differential cultivar response to ethephon. They found height of Argyle barley was more responsive to use of ethephon than Samson.

Propiconazole reduced crop height in Bonanza barley. There was an interaction between ethephon and propiconazole on crop height as indicated in Table 4.7.

Table 4.7. Propiconazole X ethephon interaction on Bonanza barley height, 1986

Rate ethephon ($kg\ ha^{-1}$)	Crop height (cm) Rate propiconazole ($kg\ ha^{-1}$) 0	0.125	
0	137	136	
.24	125	118	LSD (P=0.05) = 4

Propiconazole is a fungicide belonging to the triazole family. Most triazole fungicides, including propiconazole, have been shown to reduce the length of internodes. An analogue of propiconazole called paclobutrazol is a common PGR and has been demonstrated to reduce internode length in barley (Morrison, 1985).

Ethephon is more effective in reducing crop height in the presence of propiconazole. Both ethephon and propiconazole were applied simultaneously as a tank-mix. Winberg and Arnold (1984) reported surfactant enhancement of ethephon activity in barley. It is possible that the surfactant and solvent system in the commercial propiconazole formulation may have contributed to the biological activity of ethephon. Another possibility is that propiconazole itself may be a synergist to ethephon. There was no interaction of this sort in any of the other nine tests, so its relevance should be minimized.

4.2.1.3 Yield Components

The effect of the rate of N, propiconazole and ethephon on yield components is reported in Table 4.8.

Table 4.8. Effect of main factors on yield components, 1986 ICM irrigation sites at Outlook.

Main Factor	Level ($kg\ ha^{-1}$)	Bonanza Heads m^{-1}	Bonanza TKW(g)	Bonanza Kernels $Head^{-1}$	Samson Heads m^{-1}	Samson TKW(g)	Samson Kernels $Head^{-1}$
Nitrogen	0	51	41.7	52	83	41.5	47
	50	51	39.6 **	52	84	41.8	50
	100	52	37.3	51	85	41.1	49
	LSD (P=0.05)	2	1.9	2	3	1.4	3
Ethephon	0	50	39.4	54	84	41.5	50
	.24	52 *	37.7 *	50 **	84	41.4	47 *
	LSD (P=0.05)	1	1.6	2	2	1.1	2
Propiconazole	0	52	38.4	52	81	40.7	48
	.125	50	38.6	51	87 **	42.2 *	49
	LSD (P=0.05)	1	1.6	2	2	1.1	2
Mean		51	35.5	52	84	41.5	48

*, ** = significantly different from the check or preceding treatment at p=0.05 and p=0.01.

The number of heads meter row^{-1} was not affected by N rate, however, the number of heads meter row^{-1} was increased by ethephon in Bonanza and by propiconazole in Samson barley. The increase in the number of spikes meter row^{-1} with ethephon has been noted by North American authors Moes and Stobbe (1991a, 1991b) and Simmons et. al. (1988). An increase in the number of heads meter row^{-1}

associated with the use of propiconazole was observed in only one of all the ICM tests. Jenkyn et. al. (1983) reported increases in spikes m^{-2} in spring barley when the fungicide tridemorph was used. Tridemorph and propiconazole are both triazole fungicides which have a similar mode of action. However, this effect is reported rarely in the literature and the majority of authors report no effect of fungicide on spike numbers per unit area.

Ethephon depressed the number of kernels $head^{-1}$ in both Bonanza and Samson barley. This effect was observed in 8 out of the 10 ICM trials conducted over both years. Ethephon has been reported by Moes and Stobbe (1991a, 1991c) to reduce the number of kernels $spike^{-1}$ in Samson and Argyle barley. The cause may be related to the gametocidal properties of ethephon which was first reported by McMurray and Miller (1969).

Kernel mass decreased with increasing N rate or ethephon use in Bonanza barley. Associated with the decrease in kernel mass was an increase in grain protein with increasing N, however, this is not the case with ethephon. One possible reason for reduced kernel mass with increasing N is the higher disease infection with higher N rates. Another possibility is that N or ethephon caused delays in maturity causing kernel mass to be reduced because of high temperatures during kernel development. The use of ethephon increased the number of heads meter row^{-1} and the extra heads are usually late tillers as reported by Moes and Stobbe (1991b). These late tillers may have contributed a higher proportion of smaller kernels which would explain the depression in kernel mass.

4.2.1.4 <u>Leaf disease</u>

The effect of main factors on the incidence of leaf disease (powdery mildew) in Samson barley is shown in Table 4.9.

Table 4.9. Effect of N rate, propiconazole and ethephon on powdery mildew infection in irrigated Samson barley at Outlook, Sask., 1986

Main Factor	Level (kg ha^{-1})	% Powdery Mildew (penultimate leaf)
Nitrogen	0	18
	50	19
	100	23 *
	LSD (P=0.05)	4
Ethephon	0	18
	.24	22 *
	LSD (P=0.05)	3
Propiconazole	0	31
	.125	9 **
	LSD (P=0.05)	3
Mean		20

*, ** = significantly different from the check or preceding treatment at p=0.05 or p=0.01, respectively.

There was no leaf disease noted in Bonanza barley, however, there was a significant infestation of powdery mildew on Samson barley. The use of both N and ethephon increased the incidence of powdery mildew. Increases in powdery mildew infection with increasing N in spring barley have been reported by Jenkyn et. al. (1983). Ethephon resulted in a more compressed crop canopy which could have promoted mildew development.

Propiconazole suppressed powdery mildew. This could explain the positive yield response and increase in kernel mass observed where propiconazole was applied.

4.2.2 Irrigated Tests at Outlook, 1987

4.2.2.1 Yield and Grain Protein

Grain yield and grain protein are presented in Table 4.10.

Table 4.10. Barley grain yield and percent protein from 1987 irrigated trials under ICM at Outlook, Saskatchewan

Main Factor	Level ($kg\ ha^{-1}$)	Yield ($g\ m^{-2}$) Virden	Leduc	Heartland	Grain Protein (%) Virden	Leduc	Heartland
Nitrogen	0	508	408	596	13.5	12.2	13.4
	50	506	459 *	574	13.8 **	13.2 **	13.6
	100	523	444	589	13.9	13.4	14.4 **
	LSD (P=0.05)	39	38	31	0.2	0.3	0.3
Ethephon	0	483	414	568	13.7	13.0	13.8
	.24	542 **	460 **	605 **	13.7	13.1	13.8
	LSD (P=0.05)	32	31	25	0.1	0.2	0.3
Propic.	0	502	437	591	13.7	13.0	13.9
	.125	523	438	582	13.7	13.1	13.7
	LSD (P=0.05)	32	31	25	0.1	0.2	0.3
Mean		512	437	586	13.7	13.0	13.8

*, ** = significantly different from the check or preceding level at p=0.01 and p=0.05 respectively.

There was a highly significant yield increase due to ethephon application in all 1987 irrigated ICM trials. Lodging was a factor in all tests. The use of ethephon reduced lodging which in turn increased grain yield. The use of higher N rates increased grain yield of Leduc barley, but not in any of the other tests. The yield response of Leduc barley to higher N rates is difficult to explain, particularly since the amount of available N in the Virden barley test was the same (340 kg ha^{-1}) as in the Leduc barley test at the 0 N level. A further complication is that the increase in yield in Leduc barley is not associated with any yield component response to N. This is the only ICM test where there was a positive yield response to higher levels of N, thus the relevance of this yield increase due to N should be minimized. There were no detectable leaf diseases present during the growing season. The use of propiconazole did not influence crop yield.

Grain protein increased when the rate of N was increased from 0 to 50 kg ha^{-1} in Virden and Leduc barley, however, no additional increase in grain protein was observed when N was increased from 50 to 100 kg ha^{-1}. In contrast, protein increased in Heartland barley with the highest rate of N. Heartland barley was flood irrigated as where as Leduc and Virden barley were sprinkler irrigated. Excess water from flood irrigation may have removed more available N as compared to sprinkler irrigation. This may explain the differential response of grain protein content to incremental N.

4.2.2.2 Lodging and Crop Height

Neither N nor propiconazole affected crop height. Crop heights and Belgian lodging scores are summarized in Table 4.11.

Table 4.11. The effect of N rate, propiconazole and ethephon on barley height and lodging scores from 1987 irrigated trials at Outlook, Sask.

Main Factor	Level ($kg\ ha^1$)	Crop Height (cm) Virden	Leduc	Heartland	Belgian Lodging Score Virden	Leduc	Heartland
Nitrogen	0	100	94	97	0.9	0.4	0.5
	50	101	94	97	0.8	0.6	0.6
	100	101	95	97	1.1	0.5	0.6
	LSD (P=0.05)	2	2	2			
Ethephon	0	105	98	100	1.5	0.7	0.8
	.24	96 **	90 **	94 **	0.4	0.3	0.3
	LSD (P=0.05)	2	1	1			
Propic.	0	100	94	97	0.9	0.5	0.5
	.125	101	94	97	1.0	0.5	0.6
	LSD (P=0.05)	2	1	1			
Mean		101	94	97	0.9	0.5	0.5

*, ** = significantly different from the check or preceding level at p=0.01 and p=0.05, respectively.

Ethephon reduced crop height and lodging in all three tests. Lodging in general was light, though it did affect harvestable yield in all three tests.

Ethephon appeared to minimize grain losses due to lodging. Virden was the tallest variety and was more prone to lodging than the other two varieties, as indicated by lodging scores. This may explain why it was the most responsive cultivar to ethephon at this location.

4.2.2.3 Yield Components

The number of heads meter row^{-1} and kernel mass were not influenced by any main factors or interactions. However, the number of kernels spike^{-1} was reduced in Heartland barley in response to ethephon application. This was not observed in Leduc and Virden barley. The effect of N rate, propiconazole and ethephon on kernels spike^{-1} in Heartland barley is reported in Table 4.12.

Table 4.12. Main factor effect on kernels per spike, irrigated Heartland barley, 1987

Main Factor	Level (kg ha^{-1})	Kernels spike^{-1}
Nitrogen	0	48
	50	48
	100	48
	LSD (P=0.05)	3
Ethephon	0	50
	.24	45 **
	LSD (P=0.05)	2
Propiconazole	0	48
	.125	47
	LSD (P=0.05)	2
Mean		48

*, ** = significantly different from the check or preceding treatment at p=0.01 or p=0.05, respectively.

The fact that ethephon reduced the number of kernels spike^{-1} of Heartland but not Leduc and Virden warrants further discussion. Moes and Stobbe (1991b) indicated that, though slight, there were varietal differences to ethephon influence on kernels spike^{-1}. They found that Argyle barley was more prone to head blasting due to ethephon use than Samson barley but concluded that differential cultivar response to ethephon is not fully understood.

4.2.3 Dryland Tests at Speers, 1986

The Bonanza and Samson barley tests differed in two ways. Firstly, the space between rows in the Bonanza barley was 17.8 cm as compared to a 15.2 cm space between rows in the Samson barley. Secondly, the Bonanza barley was planted later than the Samson barley and, as a consequence, the tests responded differently to heavy rains that fell in July. Grain yield of Bonanza barley was higher than Samson barley and, furthermore, the Bonanza barley was more responsive to ICM inputs. Another result of the late seeding of Bonanza was that the crop had a higher incidence of scald infection. Scald infections are more prevalent in later seeded barley as compared to early seeded barley.

4.2.3.1 Grain Yield and Protein

Yield and grain protein data from both tests is summarized in Table 4.13. Grain yield of Samson was unaffected by any of the main factors, but the yield of Bonanza increased due to both propiconazole and ethephon. The positive yield response due to ethephon was due to lodging control. The positive yield response to propiconazole was due to control of scald.

Grain protein content of Bonanza barley increased in response to 50 kg of N ha^{-1} but no further increase was noted at 100 kg of N ha^{-1}. Grain protien content of Samson barley increased when 50 or 100 kg of N ha^{-1} were applied.

Table 4.13. The effect of N rate, propiconazole and ethephon on barley grain yield and percent protein from 1986 dryland trials at Speers.

Main Factor	Level (kg ha^{-1})	Yield ($g\ m^{-2}$) Bonanza	Yield ($g\ m^{-2}$) Samson	Percent Grain Protein Bonanza	Percent Grain Protein Samson
Nitrogen	0	443	512	12.8	13.1
	50	479	521	13.0 **	13.2 **
	100	442	514	13.1	13.3 *
	LSD (P=0.05)	65	80	0.1	0.1
Ethephon	0	368	541	12.9	13.2
	.24	542 **	490	13.0	13.2
	LSD (P=0.05)	53	66	0.1	0.1
Propiconazole	0	426	509	13.0	13.2
	.125	484 *	523	13.0	13.2
	LSD (P=0.05)	53	66	0.1	0.1
Mean		455	516	13.0	13.2

*, ** = significantly different from the check or preceding level at p=0.01 and p=0.05, respectively.

There was a significant N X propiconazole interaction on grain protein in Bonanza barley, shown in Table 4.14.

Table 4.14. Propiconazole X N interaction on grain protein in Bonanza barley, Speers, 1986.

Nitrogen kg ha^{-1}	Percent Protein, Rate propiconazole kg ha^{-1}: 0	0.125	Mean %	
0	12.8	12.9	12.8	
50	13.1	12.9	13.0	
100	13.0	13.0	13.0	LSD (P=0.05) = 0.1
Mean % Protein	13.0	13.0	13.0	

Protein increased when N was increased from 0 to 50 kg ha^{-1} in the absence of propiconazole, whereas it did not increase in the presence of propiconazole. This is associated with a significant increase in kernel mass with use of propiconazole which controlled scald.

4.2.3.2 Lodging and Crop Height

The effect of N rate, propiconazole and ethephon on lodging and crop height is shown in Table 4.15.

Table 4.15. The effect of N rate, ethephon and propiconazole on crop height and lodging of Bonanza and Samson barley at Speers, Sask., 1986.

Main Factor	Level ($kg\ ha^{-1}$)	Crop Height (cm)		Belgian Lodging Score	
		Bonanza	Samson	Bonanza	Samson
Nitrogen	0	113	97	2.2	0.3
	50	114	98	3.5	0.3
	100	117 **	98	3.2	0.4
	LSD (P=0.05)	3	2		
Ethephon	0	122	101	5.0	0.5
	.24	107 **	95 **	0.9	0.2
	LSD (P=0.05)	2	2		
Propiconazole	0	114	97	2.4	0.4
	.125	115	98	3.5	0.3
	LSD (P=0.05)	2	2		
Mean		115	98	2.9	0.4

*, ** = significantly different from the check or preceding level at p=0.01 and p=0.05, respectively.

The application of increasing amounts of N to Bonanza barley increased crop height. There was serious lodging in Bonanza barley, whereas lodging was very slight in Samson barley. The use of ethephon reduced crop height in both tests and reduced lodging in Bonanza barley which contributed to an increase in harvestable grain.

There was a significant N by ethephon interaction on the height of Bonanza barley as shown in Table 4.16.

Table 4.16. Ethephon X N interaction on crop height in Bonanza barley, Speers, 1986.

Nitrogen ($kg\ ha^{-1}$)	Height (cm) Rate ethephon $kg\ ha^{-1}$ 0	0.24	Mean height (cm)	
0	119	106	113	
50	121	108	114	
100	127	108	117	LSD (P=0.05) = 4
Mean height (cm)	122	107	115	

In the absence of ethephon, crop height increased when N was increased from 50 to 100 kg ha^{-1}. When ethephon was used, crop height did not increase with incremental N. This suggests that the internode shortening effects of ethephon were not influenced by increasing N.

4.2.3.3 Leaf Disease

The severity of scald was influenced by ICM inputs in Bonanza barley (Table 4.17).

Table 4.17. The effect of ICM inputs on scald infection, Bonanza barley at Speers, 1986

Main Factor	Level (kg ha^{-1})	% Scald (penultimate leaf)
Nitrogen	0	14
	50	16
	100	22 **
	LSD (P=0.05)	4
Ethephon	0	16
	.24	19
	LSD (P=0.05)	3
Propiconazole	0	27
	.125	8 **
	LSD (P=0.05)	3
Mean		18

** = significantly different from the check or preceding treatment at P=0.01.

Propiconazole reduced scald severity in Bonanza barley from 27% to 8%. This reduction in disease severity was associated with an increase in grain yield.

Scald infection increased with higher rates of N. This observation is in agreement with Couture and Isfan (1986) who found a strong positive correlation between N rate and scald severity.

The yield increase due to scald control with propiconazole is a result of increased kernel mass. Scald could have interfered with kernel filling, thus reducing scald severity with propiconazole probably increased carbohydrate flow into the kernel later in the season. Entz et. al. (1990) found that late season propiconazole application significantly increased kernel plumpness due to leaf disease control in barley.

There was a significant N X propiconazole interaction on the severity of scald infection, as shown in Table 4.18.

Table 4.18. Propiconazole X N interaction on scald severity in Bonanza barley, Speers, 1986.

Nitrogen ($kg\ ha^{-1}$)	% Scald Rate propiconazole $kg\ ha^{-1}$ 0	 0.125	Mean % Scald	
0	21	8	15	
50	24	7	16	
100	36	8	22	LSD (P=0.05) = 6
Mean % scald	27	8	18	

The severity of scald increased when N rate was increased by 50 or 100 $kg\ ha^{-1}$ without propiconazole. However, when propiconazole was used, increasing N rate did not increase scald severity. Propiconazole was effective regardless of N regime.

4.3.3.4 Yield Components

There were effects of N rate, propiconazole and ethephon on yield components. These are presented in table 4.19. Increased N rate increased the number of heads meter row^{-1} and kernel mass in Samson barley. Ethephon reduced the number of kernels $spike^{-1}$ in Samson and Bonanza barley. The space between rows in the Bonanza barley was 17.8 cm as compared to 15.2 cm in Samson barley. This may explain the occurrence of more heads meter row^{-1} in Bonanza barley as compared to Samson barley.

Table 4.19. Effect of N rate, ethephon and propiconazole on yield components of Bonanza and Samson barley at Speers, Saskatchewan, 1986.

Main Factor	Level (kg ha^{-1})	Bonanza Heads m^{-1}	Bonanza TKW(g)	Bonanza Kernels $Head^{-1}$	Samson Heads m^{-1}	Samson TKW(g)	Samson Kernels $Head^{-1}$
Nitrogen	0	80	43.0	50	73	38.2	37
	50	80	42.0	51	75 *	39.4	40
	100	82	43.7	51	77 **	40.0 *	39
	LSD (P=0.05)	3	2.4	2	1	1.2	4
Ethephon	0	82	41.5	52	75	39.3	41
	.24	79 *	44.3 **	49 **	75	39.1	37 *
	LSD (P=0.05)	2	2.0	1	1	1.0	3
Propiconazole	0	81	41.5	51	75	39.3	39
	.125	80	44.3 **	50	74	39.2	39
	LSD (P=0.05)	2	2.0	1	1	1.0	3
Mean		81	42.9	51	75	39.2	39

*, ** = significantly different from the check or preceding treatment at p=0.01 and p=0.05.

Kernel mass of Bonanza barley increased when ethephon or propiconazole was applied. The increase in kernel mass with use of propiconazole in Bonanza barley was associated with disease control. The increase in kernel mass with use of ethephon in Bonanza barley is due to reduced lodging. Lodging can interfere with translocation of carbohydrate to the kernel, hence reducing lodging can increase kernel plumpness.

There was an interaction between N and propiconazole on kernel mass in Bonanza barley, as shown in Table 4.20.

Table 4.20. Propiconazole X N interaction on TKW on Bonanza barley, Speers, Saskatchewan, 1986.

Nitrogen ($kg\ ha^{-1}$)	Thousand kernel weight (g) Rate propiconazole $kg\ ha^{-1}$ 0	0.125	Mean TKW (g)	
0	43.6	42.4	43.0	
50	39.6	44.7	41.9	
100	41.7	45.8	43.8	LSD (P=0.05) = 3.4
Mean TKW	41.5	44.3	42.9	

Thousand kernel weight decreased when N was increased from 0 to 50 kg ha^{-1} in the absence of propiconazole, probably because scald severity increased with higher rates of N. Kernel mass increased when N rate was increased from 0 to 100 kg ha^{-1} in the presence of propiconazole. Increasing the N rate from 50 to 100 kg ha^{-1} in the presence of propiconazole did not result in an increase in kernel mass. In the absence of propiconazole, the fact that kernel mass at the 100 kg ha^{-1} rate of N did not differ from 0 kg ha^{-1} rate of N cannot be explained.

4.2.4 Dryland Tests at Speers, 1987

4.2.4.1 Grain Yield and Grain Protein

Grain protein and grain yield data are shown in Table 4.21.

Table 4.21. Barley grain yield and percent protein, Speers, 1987.

Main Factor	Level (kg ha^{-1})	Yield (g m^{-2}) Johnston	Leduc	Samson	Grain Protein (%) Johnston	Leduc	Samson
Nitrogen	0	337	342	383	13.2	13.4	13.3
	50	332	354	386	13.6 **	13.6	13.9 **
	100	344	353	378	13.7	13.8 *	14.0 *
	LSD (P=0.05)	47	39	36	0.2	0.3	0.1
Ethephon	0	337	345	380	13.5	13.7	13.7
	.24	337	354	385	13.5	13.6	13.8
	LSD (P=0.05)	38	32	29	0.1	0.2	0.1
Propic.	0	353	344	387	13.5	13.6	13.7
	.125	322	355	378	13.5	13.7	13.8
	LSD (P=0.05)	38	32	29	0.1	0.2	0.1
Mean		338	350	382	13.5	13.6	13.7

*, ** = significantly different from the check or preceding level at p=0.01 and p=0.05 respectively.

N rate, propiconazole or ethephon did not affect grain yield. Grain protein was increased in all three tests when N was increased. Grain protein was increased in Leduc and Samson barley when the N was increased from 50 to 100 kg ha^{-1}. The reason that Johnston barley protein did not respond to the additional increment of N (whereas Samson and Leduc barley did) cannot be explained. The increases in grain protein are slight and not of practical importance.

4.2.4.2 Lodging and Crop heights

Crop height of Johnston, Leduc and Samson barley is reported in Table 4.22.

Table 4.22. The effect of N rate, ethephon and propiconazole on height of Johnston, Leduc and Samson barley Speers, Saskatchewan, 1987.

Main Factor	Level (kg ha^{-1})	Crop Height (cm) Johnston	Leduc	Samson
Nitrogen	0	56	52	44
	50	59 *	55	49
	100	65 **	55	49
	LSD (P=0.05)	3	5	4
Ethephon	0	62	60	51
	.24	58 **	49 **	44 **
	LSD (P=0.05)	2	4	3
Propic.	0	60	55	47
	.125	60	53	48
	LSD (P=0.05)	2	4	3
Mean		60	54	47

*, ** = significantly different from the check or preceding level at p=0.01 and p=0.05, respectively.

There was no appreciable lodging and crop height was reduced by ethephon in all three tests. Increasing N rate increased the height of Johnston barley. There were no main factor interactions on crop height.

4.2.4.3 Yield components

Main factors did not affect kernel mass (data not shown). Yield components that were influenced by main factors are presented in Table 4.23.

Table 4.23. Effect of ICM inputs on the number of kernels head^{-1} and heads meter row^{-1} in 1987 trials at Speers, Sask.

Main Factor	Level (kg ha^{-1})	Kernels head $^{-1}$ Johnston	Kernels head $^{-1}$ Leduc	Heads m^{-1} row Johnston
Nitrogen	0	48	35	45
	50	51	34	41 *
	100	50	34	46
	LSD (P=0.05)	3	2	4
Ethephon	0	51	35	44
	.24	48 **	33 **	44
	LSD (P=0.05)	2	1	3
Propic.	0	49	34	44
	.125	50	35	44
	LSD (P=0.05)	2	1	3
Mean		50	34	44

*, ** = significantly different from the check or preceding level at p=0.01 and p=0.05, respectively.

The use of ethephon reduced the number of kernels head^{-1} in Johnston and Leduc barley, but not in Samson barley. A similar differential cultivar response in the number of kernels head^{-1} to use of ethephon was observed in 1987. Increasing N rate from 0 to 50 kg ha^{-1} resulted in fewer heads meter row^{-1} in Johnston barley, however, at 100 kg ha^{-1} the number of heads meter row^{-1} row did not differ from the 0 level. This relationship is not possible to explain.

There was a N X ethephon interaction on the number of kernels head^{-1} in Leduc barley. This interaction is shown in Table 4.24.

Table 4.24. Ethephon X N interaction on kernels head^{-1} in Leduc barley, Speers, 1987.

Nitrogen (kg ha^{-1})	Kernels head^{-1} Rate ethephon (kg ha^{-1}) 0	0.24	Kernels head^{-1}	
0	35	35	35	
50	36	32	34	
100	35	33	34	LSD (P=0.05) = 2
Mean	35	33	34	

Ethephon caused a reduction in the number of kernels head^{-1} when N was increased. This phenomenon is difficult to explain in that the interaction was not observed in Samson or Johnston barley. From a practical perspective, the importance of this interaction is minimal considering there were no main effects or interactions on the other 2 yield components or yield in Leduc barley.

4.2.4.4 Leaf Disease

The effect of main factors on scald severity is presented in Table 4.25. Even though there was no effect of propiconazole on grain yield or kernel mass, there were differences in scald severity observed in all three tests. The probable reason that scald did not affect yield or kernel mass was that the level of infection was too low.

Table 4.25. Main factor effects on scald infection, Johnston, Leduc and Samson barley at Speers, 1987

Main Factor	Level (kg ha^{-1})	% Scald (penultimate leaf) Johnston	Leduc	Samson
Nitrogen	0	5	3	4
	50	3	6 **	5
	100	4	6	8 **
	LSD (P=0.05)	4	2	2
Ethephon	0	4	4	4
	.24	4	6 *	6 *
	LSD (P=0.05)	3	1	1
Propiconazole	0	7	9	9
	.125	2 **	1 **	1 **
	LSD (P=0.05)	3	1	1
Mean		4	5	5

*,** = significantly different from the check or preceding treatment at p=0.01 or p=0.05 respectively.

Scald severity was reduced with propiconazole in all three tests. Increasing the rate of N or ethephon increased scald incidence in Samson and Leduc barley.

4.3 General Discussion on ICM Trials

4.3.1 Barley Response to N

Increased levels of N increased grain yield in irrigated Leduc barley grown in 1987. All other ICM tests did not produce any yield response to increasing the rate of N.

Grain protein was increased in all ICM tests when N was increased. In two tests, increasing N rate increased crop height. In one-half of the ICM trials there were detectable levels of leaf disease. Increasing N rate increased disease severity in four out of these five trials.

In conclusion, increasing N levels over what the Saskatchewan Soil Testing Laboratory recommends is unlikely to increase grain yield. However, it will increase grain protein. Higher rates of N may contribute to greater leaf disease severity.

4.3.2 Barley Response to Ethephon

Yield increases in response to main factors were observed in six out of ten trials. In five of these trials, the main factor causing the positive yield response was ethephon. The yield response due to the use of ethephon was always associated with a reduction in lodging. In seven out of ten ICM trials, the use of ethephon reduced the number of kernels head^{-1}. In those trials where lodging was not a problem, the reduced number of kernels head^{-1} associated with the use of ethephon did not result in reduced yield. The use of ethephon reduced crop height in all ICM trials.

The higher yield associated with ethephon use is due to an increase in harvestable grain. When harvesting lodged plots, all the grain was not harvested because heads lying below the cutter bar could not be recovered. Yield differences may have been exaggerated because the tests were straight cut. Swathing lodged crop with pickup reels may reduce harvest losses.

4.3.3 Barley Response to Propiconazole

The use of propiconazole increased grain yield in two out of the ten ICM tests. This was attributed to leaf disease control. The higher yield resulted from increased thousand kernel weight in both tests.

In three out of ten tests, propiconazole reduced leaf disease, but no increase in kernel mass or yield was observed. The disease severity was below a threshold that would affect yield or kernel mass.

4.3.4 Dryland Versus Irrigated Tests

There was a positive yield response to ICM inputs in every irrigated test. Conversely, under dryland conditions there was a positive yield response to ICM inputs in only one out of five tests conducted. Barley grain yield response to ICM inputs is more likely under irrigation as compared to dryland conditions.

In the dryland test that showed positive yield response to ICM inputs, precipitation in late June and July was 247% of the 6 year average. Both lodging and disease were factors in yield determination and both were controlled by ICM inputs. Under normal rainfall, ICM under dryland conditions did not increase yield over normal practice.

The wide difference in barley response to ICM in the dryland tests is indicative of the wide variation in climatic conditions that occur in Saskatchewan. If ICM were to be adopted in rain-fed cropping systems, the decision whether to proceed with any given input in the ICM package would have to be re-assessed depending upon crop condition and soil moisture at the time the input is normally applied. It is impossible to predict future climatic conditions and the only variable that can influence a grower's decision is seed-bed moisture at planting. Lodging and disease are not usually important factors in dryland crop production.

4.3.5 1986 Versus 1987 Dryland Tests

Barley grain yield from all 1986 ICM dryland tests was 36% greater than grain yield in all 1987 ICM dryland tests. The reason for this is that precipitation was greater in 1986 than in 1987, particularly in July. All dryland ICM tests received below average rainfall in May, June and July of 1987.

4.3.6 1986 Versus 1987 Irrigated Tests

Grain yield from 1987 ICM tests under irrigation was 22% lower than irrigated tests conducted in 1986. This is because irrigation was restricted in late July and August of 1987. ICM under irrigation will increase yield more reliably because water will be available to the crop in a more predictable pattern as compared to dryland situations.

4.3.7 Integration of N, Ethephon and Propiconazole in ICM

There were no interactions between N, ethephon or propiconazole and grain yield in any of the tests. Each of these inputs occasionally interacted on yield components, crop height or disease severity, but this did not influence yield. Interaction of ICM inputs on grain protein bear little practical significance since their effects were very slight. Differences in grain protein were small and were not of practical importance.

Given that there were no interactions of ICM inputs on yield, each input can be considered independently when trying to increase barley yield in Saskatchewan.

4.3.8 Barley Varieties

Samson barley tended to be less prone to harvestable yield losses due to lodging. This is demonstrated by the fact that there was a positive yield response to use of ethephon in all irrigated trials except Samson barley. However, Samson is the only cultivar that had a powdery mildew infection at levels that reduced yield. Samson was also the highest yielding barley of all varieties tested.

4.4 Plant Growth Regulator Experiment

4.4.1 Dryland PGR Tests

4.4.1.1 Grain Yield

Yield data from the 1986 dryland tests conducted near Speers, Saskatchewan are shown in Table 4.26.

Table 4.26. Treatment means for grain yield from Bonanza and Johnston barley in dryland PGR trials at Speers, Sask., 1986.

Treatment	Rate (kg ha^{-1})	Application Growth stage Zadok's	Grain yield (g m^{-2}) Bonanza	Johnston
Ethephon	0.24	31-33	459	493
Ethephon	0.40	31-33	474	513
Eth + CCC	0.16 + 0.30	31-33	480	513
Eth + CCC	0.23 + 0.46	31-33	475	476
Ethephon	0.24	48-51	454	503
Ethephon	0.40	48-51	492	443
Eth + CCC	0.16 + 0.30	48-51	463	470
Eth + CCC	0.23 + 0.46	48-51	471	462
Untreated Control		-	536	563
Value of F (Treatments)			1.3 (ns)	2.3 (ns)
LSD (P=0.05)			63	68
Test mean			478	493

The LSDs for both tests in Table 4.26 cannot be used to make all pairwise comparisons of treatment means without risk of a Type I error means because of a non-significant observed F.

Orthogonal contrasts from the 1986 trials were tested for significance, the results of which are presented in Table 4.27.

Table 4.27. Orthogonal contrasts of yield from Bonanza and Johnston barley in PGR trials conducted under dryland at Speers, Sask. in 1987.

Contrast			Significance	
			Bonanza	Johnston
PGRs	vs.	Untreated	--	--
Early PGRs	vs.	Late PGRs	ns	ns
Ethephon (early)	vs.	eth + CCC (early)	ns	ns
Ethephon (late)	vs.	eth + CCC (late)	ns	ns
Low eth. (early)	vs.	High eth. (early)	ns	ns
Low eth + CCC (early)	vs.	High eth+CCC (early)	ns	ns
Low eth. (late)	vs.	High eth. (late)	ns	ns
Low eth + CCC (late)	vs.	High eth + CCC (late)	ns	ns

-- means significant decrease of former over the latter at P=0.01

There was no lodging of barley in any of the 1986 dryland PGR trials. Yield was not affected by crop growth stage at PGR application, rate or type of PGR.

Grain yield due to all PGR treatments was reduced as compared to untreated Johnston and Bonanza barley. The means for this contrast are summarized in Table 4.28.

Table 4.28. Yield comparisons from PGRs vs. untreated contrast in Bonanza and Johnston barley from dryland tests conducted at Speers, Sask. in 1986.

Variety	Yield ($g\ m^{-2}$)		% Change
	All PGRs	Untreated	From Untreated
Bonanza	471**	536	-12
Johnston	484**	563	-14

** = significantly different from the check at p=0.01

Yield reduction due to PGRs has been reported by many North

American authors. Simmons et. al. (1988), Caldwell et. al. (1988) and Dahnous et. al. (1982) all reported depression of barley yield when the crop was treated with PGRs where lodging was not a problem. In the ICM experiments, a reduction in the number of kernels head^{-1} was associated with PGR use. This could explain the yield reduction observed in Table 4.28.

The 1987 dryland tests were subjected to the same contrast analysis as the 1986 tests. There were no differences determined. Grain yield for the 1987 dryland tests is indicated in Table 4.29.

Table 4.29. Average grain yield of Leduc and Bonanza barley from dryland PGR tests conducted at Speers, Sask. in 1987.

Variety	Yield (g m^2)	Observed F (Treatments)	LSD (P=0.05)
Leduc	312	< 1	27
Johnston	332	< 1	50

Grain yield was less in 1987 than 1986 due to the drier conditions over May, June and July in 1987 as compared to the same period in 1986.

4.4.1.2 Plant Height and Lodging

PGRs affected crop height in all tests conducted under dryland in 1986 and 1987. The crop height for each treatment is shown in Table 4.30.

Table 4.30. Crop height for all PGR tests conducted under dryland conditions at Speers, Sask. in 1986 and 1987.

Treatment	Rate ($kg\ ha^{-1}$)	Application Growth stage Zadok's	Crop height (cm) 1986 Bonanza	1986 Johnston	1987 Leduc	1987 Johnston
Ethephon	0.24	31-33	118	115	58	64
Ethephon	0.40	31-33	116	115	57	65
Eth + CCC	0.16 + 0.30	31-33	112	111	59	65
Eth + CCC	0.23 + 0.46	31-33	111	106	57	66
Ethephon	0.24	48-51	107	107	53	61
Ethephon	0.40	48-51	101	107	52	59
Eth + CCC	0.16 + 0.30	48-51	106	109	55	62
Eth + CCC	0.23 + 0.46	48-51	106	106	51	60
Untreated Control		-	119	120	60	68
Value of F (Treatments)			19.8**	11.8**	14.4**	11.7**
LSD (P=0.05)			4	4	2	3
Test mean			111	111	56	63

Crops were shorter in 1987 than 1986 due to the drier conditions over May, June and July in 1987 as compared to the same period in 1986.

The results of analysis of orthogonal contrasts comparing crop height from all dryland tests is presented in Table 4.31. In all four trials, PGRs reduced crop height. Late PGR applications caused greater crop height reductions than early PGR applications in all tests.

Table 4.31. Orthogonal contrasts comparing crop height from all dryland PGR tests conducted at Speers, Sask. in 1986 and 1987.

Contrast			Significance			
			1986		1987	
			Bon.	John.	Led.	John.
PGRs	vs.	Untreated	--	--	--	--
Early applied PGRs	vs.	Late applied PGRs	++	++	++	++
Ethephon (early)	vs.	eth + CCC (early)	++	++	ns	ns
Ethephon (late)	vs.	eth + CCC (late)	ns	ns	ns	ns
Low eth. (early)	vs.	High eth. (early)	ns	ns	ns	ns
Low eth + CCC (early)	vs.	High eth+CCC (early)	ns	+	ns	ns
Low eth. (late)	vs.	High eth. (late)	++	ns	ns	ns
Low eth + CCC (late)	vs.	High eth + CCC (late)	ns	ns	++	ns

-- means significant decrease of former over the latter at P=0.01
+ , ++ means significant increase of former over the latter at P=0.05 & P=0.01, respectively.

Stobbe et. al. (1986) found that ethephon was more effective in reducing culm length at ZGS 45-47 than at ZGS 32-33. However, eth+CCC was just as effective applied at ZGS 32-33 as the corresponding application applied at ZGS 45-47. In both 1986 tests, the early applications of ethephon alone were less effective in reducing culm length than eth+CCC. Mean crop height for early applications of ethephon and eth+CCC in 1986 tests is presented in Table 4.32.

Table 4.32. Crop height comparison of early applied ethephon vs. early applied eth+CCC in Bonanza and Johnston balrey at Speers, Sask., 1986.

Variety	Mean crop height in cm		
	Early ethephon	Early eth + CCC	Control
Bonanza	117	111	119
Johnston	115	108	120

In three out of the four dryland PGR tests, the rate of PGR affected crop height. In comparing the rates of late applied ethephon in 1986 Bonanza barley, the low rate of ethephon (mean crop height 107 cm) was not as effective in reducing crop height as the high rate of ethephon (mean crop height 101 cm). In 1986 the early applied low rate of eth+CCC (mean crop height 111 cm) was not as effective in reducing crop height in Johnston barley as the high rate of eth+CCC (mean crop height 106 cm). In 1987, the higher rate of eth+CCC applied late (mean crop height 51 cm) was more effective in reducing crop height in Leduc barley than the lower rate of eth+CCC (mean crop height of 55 cm).

4.4.2 Irrigated PGR Tests

4.4.2.1 Grain Yield

Grain yield for all irrigated PGR tests in both 1986 and 1987 is shown in Table 4.33.

Table 4.33. Treatment means for yield from all irrigated PGR trials conducted in 1986 and 1987 at Outlook, Saskatchewan.

Treatment	Rate ($kg\ ha^{-1}$)	Application Growth stage Zadok's	Grain yield ($g\ m^{-2}$) 1986 John.	1986 Leduc	1987 Vir.	1987 Leduc	1987 John.
Ethephon	0.24	31-33	517	561	575	453	449
Ethephon	0.40	31-33	562	461	566	445	460
Eth + CCC	0.16 + 0.30	31-33	478	476	573	443	437
Eth + CCC	0.23 + 0.46	31-33	528	450	564	455	451
Ethephon	0.24	48-51	459	610	589	465	497
Ethephon	0.40	48-51	538	702	602	479	525
Eth + CCC	0.16 + 0.30	48-51	488	741	589	435	489
Eth + CCC	0.23 + 0.46	48-51	487	647	593	474	514
Untreated Control		-	244	324	506	415	394
Value of F (Treatments)			3.0*	15.3**	0.7ns	0.7ns	3.7*
LSD (P=0.05)			157	101	99	71	64
Test mean			478	552	573	452	468

There were differences in grain yield due to treatments in three of five tests. The yield improvements were due to lodging control which increased harvestable yield. Results from the analysis of orthogonal contrasts of grain yield are shown in Table 4.34. There were no grain yield differences due to the type or rate of PGR used.

Table 4.34. Results of analysis of orthogonal contrasts (grain yield) from 1986 and 1987 irrigated PGR trials at Outlook.

Contrast			Significance 1986		1987		
			John.	Led.	Vir.	Led.	John.
PGRs	vs.	Untreated	+	++	+	ns	++
Early applied PGRs	vs.	Late applied PGRs	ns	--	ns	ns	--
Ethephon (early)	vs.	eth + CCC (early)	ns	ns	ns	ns	ns
Ethephon (late)	vs.	eth + CCC (late)	ns	ns	ns	ns	ns
Low eth. (early)	vs.	High eth. (early)	ns	ns	ns	ns	ns
Low eth + CCC (early)	vs.	High eth+CCC (early)	ns	ns	ns	ns	ns
Low eth. (late)	vs.	High eth. (late)	ns	ns	ns	ns	ns
Low eth+CCC (late)	vs.	High eth+CCC (late)	ns	ns	ns	ns	ns

-- means significant decrease of former over the latter at P=0.01
+ , ++ means significant increase of former over the latter at P=0.05 & P=0.01, respectively.

Mean yields for all PGRs vs. the untreated control is presented in Table 4.35.

Table 4.35. Yield comparison of all PGRs vs. the untreated control in irrigated PGR trials, Outlook, 1986 and 1987.

Variety	Year	Yield $g\ m^{-2}$ All PGRs	Untreated Control	% Increase in grain yield
Johnston	1986	507	244	+108
Leduc		581	324	+79
Virden	1987	581	506	+15
Johnston		477	394	+21

Use of PGRs in 1986 resulted in greater yield increases as compared to PGR use in 1987 because lodging was more severe in 1986 than in 1987. Leduc barley in 1987 was the only test in which grain yield was not increased by PGR use. Lodging did not occur in this test to an extent that would adversely affect harvestable yield.

In two of the tests conducted, late application of PGRs produced higher grain yield than early application. In Leduc barley in 1986, early application of PGRs produced a mean grain yield of 487 gm m^{-2} as compared to a mean grain yield of 675 gm m^{-2} when PGRs were applied late. In Johnston barley in 1987, the early application of PGRs yielded an average of 449 gm m^{-2} of grain as compared to 506 gm m^{-2} when the PGRs were applied late. Late application of PGRs on barley is more effective in preventing grain yield losses than when applied at an earlier crop growth stage because the later applied PGRs provided better lodging control than earlier applied PGRs.

4.4.2.2 Crop Height and Lodging

PGRs reduced crop height in all irrigated tests over both years as shown in Table 4.36.

Table 4.36. Crop heights from all irrigated PGR tests, Outlook, 1986 and 1987.

Treatment	Rate ($kg\ ha^{-1}$)	Application Growth stage Zadok's	Crop height (cm) 1986 John.	Leduc	1987 Vird.	Leduc	John.
Ethephon	0.24	31-33	113	105	103	97	109
Ethephon	0.40	31-33	111	103	101	95	107
Eth + CCC	0.16 + 0.30	31-33	116	105	102	96	111
Eth + CCC	0.23 + 0.46	31-33	114	100	105	96	109
Ethephon	0.24	48-51	116	103	97	92	105
Ethephon	0.40	48-51	109	98	95	89	98
Eth + CCC	0.16 + 0.30	48-51	109	99	100	94	108
Eth + CCC	0.23 + 0.46	48-51	105	98	96	92	101
Untreated Control		-	121	109	111	100	111
Value of F (Treatments)			13.4**	5.5**	6.6**	2.8*	7.6**
LSD (P=0.05)			4	5	6	6	5
Test mean			113	102	101	95	107

Results from analysis of orthogonal contrasts comparing crop height is shown in Table 4.37.

Table 4.37. Analysis of orthogonal contrasts comparing crop height of all irrigated PGR tests conducted in 1986 and 1987 at Outlook, Sask.

Contrast			Significance 1986 John.	Leduc	1987 Vird.	Leduc	John.
PGRs	vs.	Untreated	--	--	--	--	--
Early applied PGRs	vs.	Late applied PGRs	++	++	++	++	++
Ethephon (early)	vs.	eth + CCC (early)	+	ns	ns	ns	ns
Ethephon (late)	vs.	eth + CCC (late)	++	ns	ns	ns	ns
Low eth. (early)	vs.	High eth. (early)	ns	ns	ns	ns	ns
Low eth + CCC (early)	vs.	High eth+CCC (early)	ns	+	ns	ns	ns
Low eth. (late)	vs.	High eth. (late)	++	+	ns	ns	++
Low eth + CCC (late)	vs.	High eth + CCC (late)	+	ns	ns	ns	++

-- means significant decrease of former over the latter at P=0.01
+ , ++ means significant increase of former over the latter at P=0.05 & P=0.01, respectively.

In all trials, crop height was reduced by PGRs. Furthermore, late application of PGRs resulted in greater culm shortening than early application. The mean crop height of the contrasts comparing PGRs vs. untreated and early vs. late application of PGRs is shown in Table 4.38.

Table 4.38. Crop height comparison of all PGRs vs. the untreated control in all irrigated PGR trials at Outlook, Sask. in 1986 and 1987.

		Crop height (cm)			
		PGRs vs. Untreated		PGR Application timing	
Variety	Year	All PGRs	Control	Early	Late
Johnston	1986	111	121	113	109
Leduc		101	109	103	99
Virden	1987	99	111	102	97
Leduc		93	100	96	92
Johnston		106	111	109	103

There was a difference between the effect of ethephon and eth+CCC on crop height in only one of the five tests. In 1986, Johnston barley was shortened more with the early application of ethephon (mean height 112 cm) than with the early application of eth+CCC (mean height 115 cm). Conversely, late application of eth+CCC (mean height 107) shortened the crop more than the late application of ethephon (mean height 112). This contradicts findings in the 1986 dryland tests which found that early application of eth+CCC was more effective in culm shortening than early applications of ethephon. Caldwell et. al. (1988) reported that the results from PGR application on barley are dependent on cultivar and year, indicating that both genetic and environmental factors can influence the effect PGRs have on crop height.

Belgian lodging scores for all treatments from all irrigated PGR tests are given in Table 4.39.

Table 4.39. Belgian lodging score for all irrigated PGR tests conducted at Outlook, Sask. in 1986 and 1987.

		Application	Mean Belgian Lodging Score				
	Rate	Growth stage	1986		1987		
Treatment	(kg ha^{-1})	Zadok's	John.	Leduc	Vird.	Leduc	John.
Ethephon	0.24	31-33	3.8	6.1	3.8	1.3	3.3
Ethephon	0.40	31-33	2.2	6.4	0.8	1.2	2.3
Eth + CCC	0.16 + 0.30	31-33	3.1	6.3	2.3	1.5	3.6
Eth + CCC	0.23 + 0.46	31-33	2.0	5.7	1.4	1.2	3.0
Ethephon	0.24	48-51	3.3	0.9	0.5	0.6	0.9
Ethephon	0.40	48-51	0.8	0.5	0.2	0.2	0.5
Eth + CCC	0.16 + 0.30	48-51	1.2	1.2	0.7	1.1	1.2
Eth + CCC	0.23 + 0.46	48-51	0.3	0.6	0.5	0.4	0.7
Untreated Control		-	7.5	8.8	3.4	3.0	4.2

The most serious lodging occurred in 1986. Trends can be identified with respect to lodging scores. In 1986 tests (especially Leduc barley), late application of PGRs resulted in better lodging control than early application. Application of PGRs irrespective of type, timing or rate always reduced lodging with the exception of early applied ethephon at the low rate in Virden barley in 1987.

4.4.3 General Discussion on PGR Experiment

Irrigated barley is more prone to grain yield losses due to lodging than barley produced under dryland conditions. Yield in four of the five irrigated tests was increased by using PGRs to reduce lodging. Yield from dryland tests in 1986 was reduced due to PGR use whereas it was not affected in 1987. Lougheed and Franklin (1972) reported a higher rate of ethylene release from ethephon at higher temperatures. Moes and Stobbe (1991a) found that higher temperatures during the week following ethephon application to barley resulted in a greater reduction in kernels spike^{-1} than lower temperatures in the same week. A positive yield response to PGRs is more likely under conditions of higher moisture and high fertility.

In most cases, using the higher rate of PGR was more effective in preventing lodging. Later applications of PGRs were generally better with regards to lodging control than early applications. Ethephon is a reliable anti-lodging product if applied at Zadoks GS late 40's. Eth+CCC may facilitate earlier application in barley, however in one test it was determined that ethephon was better than eth+CCC at early application.

PGRs will improve harvestable yield only if lodging occurs. Water is a factor in whether a barley crop will lodge, and barley grown in an irrigated setting is more likely to lodge. PGR application in the absence of lodging can cause yield depression.

4.5. Economic Analysis of ICM in Barley

There was a positive yield response to one or more of the ICM inputs in six out of the ten ICM tests. There were no interactions between any of the ICM inputs on yield, thus the economic benefit of each input can be assessed independently.

The economic assessments do not correct for extra costs of application and include only the variable cost of the input itself. Also not considered are costs of handling and storing the extra grain production.

4.5.1 Benefit of Additional N

There was a positive yield response to additional N fertilizer in only one of the 10 ICM tests. The test that benefited from the additional N fertilizer was Leduc barley in 1987 grown under irrigation at Outlook. The economic consequences of the effect of N in this test are given in Table 4.40.

Table 4.40. Economic analysis of additional N input in irrigated Leduc barley under ICM at Outlook, 1987.

Level N (kg ha^{-1})	Grain Yield (T ha^{-1})	Variable Product Cost of extra N \$CDN ha^{-1}	Break Even Price For Barley \$CDN T^{-1}
0	4.08	0[a]	
50	4.59	18.92	37.09
100	4.44	37.84	105.11

a. Based on 82-0-0 at \$0.37 kg^{-1} (FOB Saskatoon) as quoted May, 1991.

When N was increased from 0 to 50 kg ha^{-1}, the break even price of barley was \$37.09 T^{-1}. In comparison, the initial price for #1 CW feed barley in the 1991-1992 crop year was \$86.00 T^{-1} (not including deductions for freight and elevator handling). Thus, expenditure on extra N was profitable. When N was increased to 100 kg ha^{-1}, the break even price of barley nearly tripled to \$105.11 T^{-1}, which exceeded the May 1991 initial price for barley.

This is the only test where additional N contributed to a profitable yield increase. Additional N resulted in higher grain protein in all ICM tests. Since no premium is associated with higher protein levels in feed barley, this is of no economic benefit. Returns from N fertilizer use in barley follow the law of diminishing marginal returns. Incremental increases in barley yield diminish as N increases.

Increasing N to levels higher than the Saskatchewan Soil Testing Laboratory recommendations is unlikely to result in reliable increases in yield. Current management practices appear to be adequate to maximize production. Furthermore, additional N over the recommended amounts will contribute to higher grain protein which would reduce the likelihood of eligibility for malting barley.

4.5.2 Fungicide

Two out of the ten ICM tests showed positive yield increases due to propiconazole. Samson barley under irrigation in 1986 demonstrated a positive yield response to propiconazole supression of powdery mildew. Bonanza barley grain yield grown under dryland conditions in 1986 responded to scald supression by propiconazole. Yield increases were due to higher kernel mass.

The economic assessment of these two tests is shown in Table 4.41.

Table 4.41. Economic analysis of propiconazole use in irrigated Samson barley and dryland Bonanza barley at Speers, 1986.

Variety	Location	Increase Grain Yield ($T\ ha^{-1}$)	Variable Product Cost of Propiconazole $CDN ha^{-1}	Break Even Price For Barley $CDN T^{-1}
Bonanza	Speers	0.58	29.88[a]	51.52
Samson	Outlook	0.44		67.91

a. Based on propiconazole manufacturer's suggested retail price of $239.00 per kg of active ingredient.

The break even prices of Samson and Bonanza barley to justify the expenditure on propiconazole are slightly less than the 1991 -

1992 Canadian Wheat Board initial price (\$86.00 T^{-1}) of #1 CW feed barley.

Propiconazole may have benefits other than yield increase. The plumper barley kernels associated with propiconazole use may have benefits in seed production (Entz et. al. 1990).

4.5.3 Ethephon

The most common yield response to any of the ICM inputs tested was a positive response to ethephon use. In five out of the ten ICM tests, ethephon improved harvestable yield. The increase in yield with ethephon was not due to increases in any one yield component, but to keeping the crop standing so that it intercepted the cutter bar during harvesting. Lodging losses may have been exaggerated due to straight cutting, as it is possible that more yield could have been recovered by using a swather with pick-up reels.

Economic benefits of ethephon use are summarized in Table 4.42. Only tests with significant yield responses were assessed.

Table 4.42. Economic analysis of ethephon use in ICM tests where significant yield response was detected, 1986 & 1987.

Variety	Location	Year	Increase Grain Yield (T ha^{-1})	Variable Product Cost of Ethephon \$CDN ha^{-1}	Break Even Price For Barley \$CDN T^{-1}
Bonanza	Speers	1986	1.74	28.12[a]	16.16
Bonanza	Outlook		2.46		11.43
Virden	Outlook	1987	0.59		47.66
Heartland	Outlook		0.37		76.00
Leduc	Outlook		0.46		61.13

a. Based on ethephon manufacturer's suggested retail price of \$117.19 per kg active ingredient.

Ethephon use was more profitable in 1986 than in 1987 because the severity of lodging in the 1986 tests was greater than in 1987. Ethephon can be used profitably if lodging is severe. It is, however, a double edged sword. PGRs depressed yield in the absence of lodging. Moes and Stobbe (1991a) found that in Manitoba, the potential for ethephon to cause yield reductions in barley restricts its use to situations where the risk of lodging is high. The decision to use ethephon is simpler under irrigation or heavy rainfall conditions. If water is not limiting to crop development and fertility is high, it may be advisable to consider ethephon. Alternatively, the selection of a shorter strawed cultivar may minimize lodging losses. The cultivar Samson did not respond to ethephon under irrigation, because lodging was not a serious problem. Other semi-dwarf cultivars such as Duke and Winchester may give growers the option of avoiding economic losses from lodging without using ethephon.

Ethephon may have other benefits. A standing crop is easier to harvest than one that is lodged. This may result in time savings and reduced wear and tear on harvesting equipment. Grain that cannot be harvested will contribute to increased volunteer barley weed populations in the following rotation. The grower may incur extra herbicide costs and crop yield may be depressed due to barley weed competition in the following crop (O'Donovan et.al., 1988).

5. SUMMARY AND CONCLUSIONS

The purpose of this project was to evaluate the feasibility of ICM practices for barley production in Saskatchewan. Tests evaluated the effect of three levels of N (0, 50 and 100 kg ha^{-1} above what SSTL deems sufficient), use of ethephon to prevent lodging and propiconazole to control foliar diseases. If yield improvements were detected as a result of one or more inputs, then yield component analysis helped to explain the source of the yield increase. Another experiment evaluated two PGRs, ethephon and eth+CCC, each at two rates and two timings in barley to assess their effectiveness as stem stabilizers in barley.

Ten ICM tests were conducted in 1986 and 1987. Half were under irrigation and half in dryland. The irrigated tests were conducted in the Dark Brown Soil Zone near Outlook, Sask. whereas the dryland tests were located in the Thin-Black Soil Zone near Speers, Saskatchewan. Increased yield due to one or more ICM inputs was observed in six out of the ten tests. Of those six tests with yield improvement, five were irrigated. Lack of water was a limiting factor in preventing higher yields in the dryland trials. Of the six tests showing positive yield response, three of them were due to ethephon only, one was due to ethephon and additional N, one was due to ethephon and propiconazole and one was due to propiconazole only. Yield responses were due to main factors only and there were no interactions of ICM inputs on yield. There were occasional interactions of ICM inputs on yield components. All

Bonanza barley trials had protein levels in excess of 12% which would diminish the possibility of the grain qualifying for malting grades. All other cultivars used were ineligible for malting grades.

In the one test where a positve yield response to N occurred, the 50 kg ha^{-1} increment of N generated a 13% increase in yield of Leduc barley under irrigation. The 100 kg ha^{-1} rate of N did not produce more yield than the 50 kg ha^{-1} rate. One reason for infrequent yield response to N in the ICM tests was that the 0 level of N was the same as or greater than that recommended by the Saskatchewan Soil Testing Laboratory. Increasing N rate resulted in significantly higher grain protein in all the ICM tests. On average, the grain protein at the 0 N level was 13.3%. Increasing N to 50 kg ha^{-1} and 100 kg ha^{-1} produced grain protein of 13.7% and 14.0% respectively. The differences are slight and when considering using ICM for feed barley production, there is no premium for higher protein feed barley. Thus, the improved grain protein is of little commercial benefit.

Four of the five ICM tests where ethephon use increased grain yield were irrigated. The one dryland test where yield was increased due to ethephon received abnormally high rainfall during the growing season. The yield increase with ethephon application in all tests was due to a reduction in lodging. In tests with significant positive yield response to ethephon, the average Belgian lodging score in the checks was 3.0 and in the ethephon treated plots it was 0.4. In the tests where yield was increased due to use of ethephon, the ethephon treated plots yielded an average 28% higher than the untreated. Yield increase was attributed to an increase in harvestable grain since spikes that were lying below the cutter bar at harvest did not contribute to yield. Ethephon reduced plant height by an average of 10% in all ICM tests.

The two tests where propiconazole use increased grain yield were conducted in 1986. Propiconazole reduced penultimate leaf scald by 70% in dryland Bonanza barley and reduced penultimate leaf powdery mildew by 71% in irrigated Samson barley. Yields were increased an average 10% across both trials. Yield increases were associated with higher thousand kernel weight in both tests.

Since there were no interactions of N, ethephon and propiconazole in the ICM tests, it is possible to consider the economic value of each of these inputs independently. The value of the yield increase associated with the one positive yield response to 50 kg ha^{-1} of N slightly exceeded the cost of the N. Adding N above levels recommended by the Saskatchewan Soil Testing Laboratory is unlikely to consistently improve yield and profitability.

In two of the five tests where yield was improved by ethephon, the profit margin was considerable. The return on ethephon investment in the other 3 trials was slightly positive and if application costs were considered, at best, ethephon resulted in a "break-even" position. Other benefits of ethephon might be to simplify harvesting operations and to reduce volunteer barley infestations in the following crop.

In both tests where yield increases occurred with use of propiconazole, economic analysis showed that the extra yield barely covered the cost of propiconazole.

In the PGR experiment, two out of nine tests demonstrated an average 13% yield depression due to PGR use. These two tests were in dryland in 1986 where no lodging occurred. Grain yield from 1987 dryland PGR tests was not affected by PGRs. In four out of five PGR tests conducted under irrigation, grain yields were improved an average of 56% with PGRs, due to lodging control. In two of these five trials, late application of PGRs resulted in higher yield than early application. This is because late application of PGRs provided better lodging control than early application. PGRs reduced crop height in all tests with late application resulting in greater crop height reduction than early application. In two tests, the early application of eth+CCC resulted in greater crop height reduction than the early application of ethephon.

In all the ICM tests conducted, the revenues generated from extra yield from all the inputs was not enough to pay for the extra input costs incurred. Specific inputs occasionally gave profitable responses, particularly ethephon where lodging was a problem. The entire ICM package including N, PGR and fungicide for prairie growers is not an economically feasible practice, but certain inputs may be feasible under certain conditions. Profitable use of N at levels above soil test recommendations is unlikely. Ethephon or propiconazole can be profitable under certain conditions. The challenge is to predict when ethephon and propiconazole will result in sufficient yield increase to be profitable. Proper cultivar selection may reduce the risk of disease and lodging. The ICM tests demonstrated a positive response to ethephon is more likely under irrigated conditions than under rain-fed conditions.

If the economics of ICM is compared to conventional management in barley production, the conclusion is that conventional management practices are more profitable than ICM given current barley prices and costs of N, fungicide and PGR. Certain components of ICM, such as PGR use, may be profitable under certain circumstances. The reliability of a positive cash return from using these inputs is greater under irrigation as compared to dryland situations.

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Appendix A

Management Practices at all Sites

Planting and Fertility Information for ICM Tests, 1986 and 1987.

			Planting Information				N Fertilizer			P205 Fertilizer			
Year	Location	Variety	Dated Seeded	Seeding Equipment	Seeding Rate kg ha^{-1}	Seeding Depth cm	Amount kg ha^{-1}	Type	Method of Application	Amount kg ha^{-1}	Type	Method of Application	Date Harvested
1986	Speers	Bonanza	May 23	Hoe-Drill	87	3.0	6.1 49.2	11-55-0 82-0-0	with seed deep band	31	11-55-0	with seed	Sept. 8
		Samson	May 3	Disc-drill	80	2.3	7.2 49.2	11-55-0 82-0-0	with seed deep band	35.8	11-55-0	with seed	Sept. 4
1986	Outlook	Bonanza	May 13	Hoe-drill	91	2.8	7.2 41.4	11-55-0 46-0-0	with seed broadcast	35.8	11-55-0	with seed	Sept. 3
		Samson	May 26	Disc-drill	85	3.0	6.6	11-55-0	with seed	33.0	11-55-0	with seed	Sept. 3
1987	Speers	Samson	May 6	Disc-drill	85	4.0	7.2 92.0	11-55-0 46-0-0	with seed broadcast	35.8	11-55-0	with seed	Sept. 10
		Johnston	May 6	Disc-drill	85	4.0	7.2 92.0	11-55-0 46-0-0	with seed broadcast	35.8	11-55-0	with seed	Sept. 10
		Leduc	May 6	Disc-drill	85	4.0	7.2 92.0	11-55-0 46-0-0	with seed broadcast	35.8	11-55-0	with seed	Sept. 11
1987	Outlook	Leduc	May 4	Disc-drill	105	3.0	5.0 55.0	11-48-0 34-0-0	with seed broadcast	22.0	11-48-0	with seed	Sept. 5
		Virden	May 4	Disc-drill	105	3.0	5.0 55.0	11-48-0 34-0-0	with seed broadcast	22.0	11-48-0	with seed	Sept. 5
		Heartland	May 6	Disc-drill	110	3.0	5.0 55.0	11-48-0 34-0-0	with seed broadcast	22.0	11-48-0	with seed	Sept. 6

Chemical Application Informtion for ICM Tests, 1986 and 1987.

Year	Location	Variety	Ethephon Date of Application	Ethephon Time	Ethephon Temp. °C	Propiconazole Date of Application	Propiconazole Time	Propiconazole Temp. °C	Other Chemical Applications
1986	Speers	Bonanza	July 9	17:30	20	July 15	18:00	17	Bromoxynil/MCPA at 0.56 kg ha^{-1} Tralkoxydim at 0.25 kg ha^{-1}
		Samson	June 23	09:20	17	July 4	17:00	18	Bromoxynil/MCPA at 0.56 kg ha^{-1} Tralkoxydim at 0.25 kg ha^{-1}
1986	Outlook	Bonanza	June 23	05:00	18	June 27	6:30	12	Bromoxynil/MCPA at 0.56 kg ha^{-1} Diclofop-methyl at 0.71 kg ha^{-1}
		Samson	June 27	07:30	14	July 7	8:00	16	Bromoxynil/MCPA at 0.56 kg ha^{-1} Tralkoxydim at 0.25 kg ha^{-1}
1987	Speers	Samson	June 19	06:30	14	June 19[a]	6:30	14	Bromoxynil/MCPA at 0.56 kg ha^{-1} Tralkoxydim at 0.25 kg ha^{-1}
		Johnston	June 19	07:30	14	June 19[a]	7:30	14	Bromoxynil/MCPA at 0.56 kg ha^{-1} Tralkoxydim at 0.25 kg ha^{-1}
		Leduc	June 19	08:00	14	June 19[a]	8:30	14	Bromoxynil/MCPA at 0.56 kg ha^{-1} Tralkoxydim at 0.25 kg ha^{-1}
1987	Outlook	Virden	June 23	07:00	28	June 23[a]	7:00	28	Diclofop-methyl 0.71 kg ha^{-1} Bromoxynil at 0.28 kg ha^{-1}
		Leduc	June 23	08:00	28	June 23[a]	8:00	28	Diclofop-methyl 0.71 kg ha^{-1} Bromoxynil at 0.28 kg ha^{-1}
		Heartland	June 23	08:00	28	June 23[a]	8:00	28	Diclofop-methyl 0.71 kg ha^{-1} Bromoxynil at 0.28 kg ha^{-1}

a. Applied as a tank-mix with ethephon. The propiconazole was added to the spray tank first.

Planting and Fertility Information for PGR Tests, 1986 and 1987.

			Planting Information				N Fertilizer			P205 Fertilizer			
Year	Location	Variety	Dated Seeded	Seeding Equipment	Seeding Rate kg ha^{-1}	Seeding Depth cm	Amount kg ha^{-1}	Type	Method of Application	Amount kg ha^{-1}	Type	Method of Application	Date Harvested
1986	Speers	Bonanza	May 27	Hoe-Drill	90	3.0	5.5 57.2	11-55-0 82-0-0	with seed deep band	28	11-55-0	with seed	Sept. 9
		Johnston	May 3	Disc-drill	80	2.5	7.7 49.2	11-55-0 82-0-0	with seed deep band	38.5	11-55-0	with seed	Sept. 9
1986	Outlook	Johnston	May 26	Disc-drill	85	2.0	7.2 82.3	11-55-0 46-0-0	with seed broadcast	35.8	11-55-0	with seed	Sept. 5
		Leduc	May 26	Disc-drill	85	3.0	7.2 82.3	11-55-0 46-0-0	with seed broadcast	35.8	11-55-0	with seed	Sept. 5
1987	Speers	Leduc	May 6	Disc-drill	85	4.0	7.2 92.0	11-55-0 46-0-0	with seed broadcast	35.8	11-55-0	with seed	Sept. 10
		Johnston	May 6	Disc-drill	85	4.0	7.2 92.0	11-55-0 46-0-0	with seed broadcast	35.8	11-55-0	with seed	Sept. 11
1987	Outlook	Leduc	May 4	Disc-drill	105	3.0	5.0 55.0	11-48-0 34-0-0	with seed broadcast	22.0	11-48-0	with seed	Sept. 6
		Virden	May 4	Disc-drill	105	3.0	5.0 55.0	11-48-0 34-0-0	with seed broadcast	22.0	11-48-0	with seed	Sept. 5
		Johnston	May 9	Disc-drill	85	3.0	7.2 55.0	11-48-0 34-0-0	with seed broadcast	35.8	11-48-0	with seed	Sept. 6

Chemical Application Information for PGR Tests, 1986 and 1987.

Year	Location	Variety	Early Application Timing: Date of Application	Early: Time	Early: Temp. °C	Late Application Timing: Date of Application	Late: Time	Late: Temp. °C	Other Chemical Applications
1986	Speers	Johnston	June 14	07:30	18	June 23	9:00	18	Bromoxynil/MCPA at 0.56 kg ha^{-1} Tralkoxydim at 0.25 kg ha^{-1}
		Bonanza	June 23	10:30	18	July 17	18:00	16	Bromoxynil/MCPA at 0.56 kg ha^{-1} Tralkoxydim at 0.25 kg ha^{-1}
1986	Outlook	Johnston	June 25	07:00	24	July 6	9:30	24	Bromoxynil/MCPA at 0.56 kg ha^{-1} Tralkoxydim at 0.25 kg ha^{-1}
		Leduc	June 25	08:00	24	July 6	8:30	24	Bromoxynil/MCPA at 0.56 kg ha^{-1} Tralkoxydim at 0.25 kg ha^{-1}
1987	Speers	Leduc	June 6	16:30	21	June 19	10:30	18	Bromoxynil/MCPA at 0.56 kg ha^{-1} Tralkoxydim at 0.25 kg ha^{-1}
		Johnston	June 19	17:30	21	June 19	11:00	18	Bromoxynil/MCPA at 0.56 kg ha^{-1} Tralkoxydim at 0.25 kg ha^{-1}
1987	Outlook	Virden	June 12	07:00	14	June 23	7:00	28	Diclofop-methyl 0.71 kg ha^{-1} Bromoxynil at 0.28 kg ha^{-1}
		Leduc	June 12	08:00	14	June 23	8:00	28	Diclofop-methyl 0.71 kg ha^{-1} Bromoxynil at 0.28 kg ha^{-1}
		Johnston	June 12	07:30	14	June 23	8:00	28	Diclofop-methyl 0.71 kg ha^{-1} Bromoxynil at 0.28 kg ha^{-1}

Appendix B

Characteristics of Barley Varieties Used in the Study

Main Characteristics of Varieties of Barley Used in all Tests.[1]

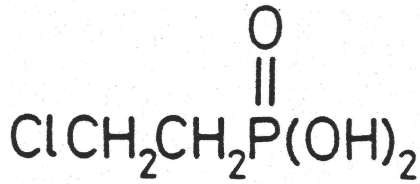
Type & Variety	2 or 6 row	Rough or Smooth Awns	Yield as % of Harrington: Irr Yield as % of Duke	Yield as % of Harrington: Soil Zone Dark Brown	Yield as % of Harrington: Soil Zone Black	Maturity in Days	k.wt.[2] g/1000 Seeds	Resistance to: Lodging	Shattering	Net Blotch	Stem Rust	Scald	Loose Smut	Other Smuts	Root Rot
Malting															
Harrington	2	R	-	100	100	92	42	G	VG	P	P	P	P	VP	G
Bonanza	6	S	-	91	93	89	36	G	VP	G	G	P	P	P	G
Feed															
Heartland	6	S	102	99	100	92	36	VG	F	VG	G	P	P	P	G
Johnston	6	S	-	106	107	94	36	VP	P	F	G	G	P	VP	P
Leduc	6	R	99	107	103	91	41	P	P	F	G	VG	F	G	F
Virden	6	S	-	102	105	95	43	VG	G	G	G	P	P	F	VG
Intensive Management															
Duke	6	R	100	-	-	93	38	VG	F	F	G	VG	P	F	VG
Samson	6	R	95	-	-	92	35	VG	F	F	G	P	P	F	G

1. Taken from "Varieties of Grain Crops in Saskatchewan, 1991".
2. K. wt. is thousand kernel weight taken from "Guide to Grain Varieties in Alberta, 1991".

Appendix C

Description of all Chemicals Used

ETHEPHON[8]



Nomenclature and development.

Common name ethephon (ANSI, Canada); chorethephon (New Zealand). Chemical name (IUPAC) 2-chloroethylphosphonic acid. (C.A.) (2-chloroethyl) phosphonic acid (8 & 9CI); Reg. No.[16672-87-0]. Introduced as a plant growth regulator by Amchem Products Inc. (now Union Carbide Agricultural Products Co. Inc.) and GAF Corp. (USP 3 879 188;3 896 163; 3 897 486) as trade marks 'Ethrel', .'Florel', 'Cerone' (all to Amchem), 'Cepha' (to GAF Corp.)

Properties.

It is a colourless waxy solid; m.p. 74-75 °C; d 1.58. Solubility: c. 1 kg/l water, short-chain alcohols, glycols; sparingly soluble in non-polar organic solvents; insoluble in kerosene, diesel oil. It is corrosive. It is stable at pH<3, decomposing to liberate ethylene at higher pH values.

Uses.

It is used to accelerate the pre-harvest ripening of fruit and vegetables including: apples, blackberries, black currants, blueberries, citrus and coffee; post-harvest ripening of fruit: bananas, citrus, mangoes. Also: yellowing of tobacco leaves and temporary growth inhibition of tobacco and tomato transplants; stimulation of latex flow in rubber trees and of resin flow in pine trees; acceleration of boll opening and of defoliation in cotton; prevention of lodging in cereals and maize; induction of hull split in walnuts, flower abscission in cloves, increase in fruit set and yield of cucumbers; induction of flowering in pineapples and ornamental Bromeliads; promotion of earlier defoliation of apple nursey stock, roses and tall hedge blackthorn; elimination of undesireable fruit on apples and crabapples; stimulation of lateral branching of azaleas, geraniums and roses; modification of sex expression in cucumbers and squash; shortening of stem length in forced daffodils. It acts by releasing ethylene within plant tissue.

Formulations.

'Ethrel' SL (240 or 480 g a.i./l); 'Ethrel C' (in the UK, ICI Plant Protection Division); 'Cerone', 'Prep', SL (480 g/l); 'Florel', (40g/l). Mixtures include: 'Terpal' (BASF), (Reg. No. [71587-73-0]), SL (ethephon + mepiquat chloride).

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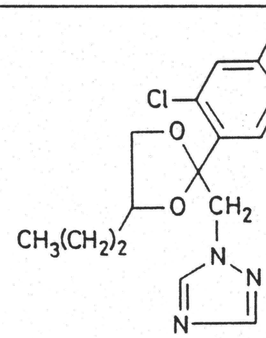
[8]Taken from "The Pesticide Manual: A World Compendium" Eight Edition. C.R. Worthing. 1987. Published by the British Crop Protection Council.

PROPICONAZOLE[9]



Nomenclature and development.

Common name propiconazole (BSI, E-ISO, (m) F-ISO). Chemical name (IUPAC) (±)-1-[2-(2,4-dichlorophenyl)-4-propyl-3, 3-dioxolan-2-ylmethyl]-1 H--1,2,4-triazole. (C.A.) 1-[[2-(2,4-dichlorophenyl)-4-propyl-1, 3-dioxolan-2-yl]methyl]-H-1,2,4--triazole (9CI); Reg.No. [60207-90-1]. Its fungicidal properties were decribed by Janssen Pharmaceutica. Developed by Ciba-Geigy AG and described by P. A. Urech et al. (Proc. Br. Crop Prot. Conf., 1979, 2, 508) (GBP 1 522 657; BEP 895 579 to Janssen Pharmaceutica) as code no. 'CGA 64 250'; trade marks 'Tilt' in Federal Republic of Germany 'Desmel' (both to Ciba-Geigy AG), 'Radar' (to ICI Pland Protection Division).

Properties.

Pure propiconazole is a yellowish viscous liquid; b.p. 180°C/0.1 mmHg; v.p. 0.133 mPa (20 °C); n ^{D}20 1.5468; density 1.27 g/cu. cm (20 °C): 110 mg/l water; completely miscible with acetone, methanol, propan-2-ol; 60 g/kg hexane. Hydrolysis is not significant; stable <320 °C.

Uses.

It is a systemic foliar fungicide with a broad range of activity. On cereals it controls, at 125 g a.i./ha with 1-2 applications, diseases caused by Erysighe graminis, Leptosphaeria nodorum, Pseudocercosporella herpotrichoides, Puccinia spp., Pyrenophora teres, Rhynchosporium secalis, Septoria spp. In some countries it is recommended against Uncinula necator on grapes.

Formulations.

'Tilt' 100, 'Tilt' 250, EC (100 or 250 g a.i./l); 'Tilt' 125, SL (125 g/l). Mixtures include: 'Hispor 45', 'Tilt' CB 45, WP (250 g propiconazole + 200 g carbendazim/(kg); 'Tilt C' 275, SC (125 g propiconazole + 150 g carbendazim/l); 'Tilt' CF' 72.5, WP (125 g propiconazole + 600 g captafol/kg); 'Tilt Turbo 375;', EC (125 g propiconazole + 250 g tridemorph/l).

[9]Taken from "The Pesticide Manual: A World Compendium" Eight Edition. C.R. Worthing. 1987. Published by the British Crop Protection Council.

CHLORMEQUAT CHLORIDE (CCC)[10]

$$Cl CH_2CH_2\overset{+}{N}(CH_3)_3$$

Nomenclature and development.

Common name chlormequat (BSI, E-ISO). Chemical name (IUPAC) 2-chloroethyltrimethylammonium; 2-chloroethyltrimethylammonium ion. (C.A.) 2-chloro-N,N,N-trimethylethanaminium (9CI); (2-chloroethyl) trimethylammonium (8C1); Reg. No. [7003-89-6] chlormequat; [999-81-5] chlormequat chloride. Trivial names for the chloride: chorocholine chloride; CCC. Introduced in collaboration with Michigan State University by American Cyanamid Co. (GBP 944 807; FP 1 264 866; BEP 593 961) as code no. 'AC 38 555'; trade mark 'Cycocel'.

Properties.

Chlormequat chloride is a colourless crystalline solid, with a fish-like odour; it begins to decompose at 245°C; v.p. 0.010 mPa (20°C). Solubility (20°C): >1 kg/kg water; < 1 g/kg chloroform; insoluble in cyclohexane; 320 g/kg ethanol. The technical grade is 97-98% pure. The solid is extremely hygroscopic but its aqueous solutions are stable though corrosive to unprotected metals. It may be stored in containers of glass or high-density plastic, or of metal lined with rubber or epoxy resin.

Uses.

Chlormequat chloride is a plant growth regulator which influences the habit of certain plants by shortening and strengthening the stem, e.g. in oats, rye wheat and poinsettias. It can also influence the developmental cycle resulting in increased flowering and harvest, e.g. in pears and tomatoes. An intensification of chlorophyll formation is often seen. The root system may also be increased, resulting in yield increases under dry conditions. Wheat is better protected against damage by Cercosporella herpotrichoides. Chlormequat chloride is rapidly degraded in soil by enzyme activity and there is no influence on soil microflora or fauna.

Formulations.

These include: 'Barleyquat' (Mandops), 'Cycocel' (Cyanamid), 'Farmacel' (Farm Protection), 'Hyquat' (Agrichem); 'Titan' (FBC Limited), SL (chlormequat chloride); DP (650 g/kg). Mixtures include: 'Arotex Extra' (ICI), 'BAS 06 200W'(BASF), '5C' (Atlas Interlates Ltd.), 'CCC Extra' (BASF), '5C Cycocel' (BASF), 'Cycocel 460' (American Cyanamid Co.).

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[10]Taken from "The Pesticide Manual: A World Compendium" Eight Edition. C.R. Worthing. 1987. Published by the British Crop Protection Council.

Appendix D

Values of F From ANOVA of all Tests

Grain Yield: Values for F from ANOVA for ICM Tests

	1 9 8 6				1 9 8 7					
	Dryland		Irrigated		Dryland			Irrigated		
Source	Bonanza	Samson	Bonanza	Samson	Johnston	Leduc	Samson	Virden	Leduc	Heartland
Nitrogen	< 1	< 1	1.88	< 1	< 1	< 1	< 1	< 1	4.04*	1.18
Ethephon	44.34**	2.43	63.50**	1.73	< 1	< 1	< 1	14.08**	9.27**	8.98**
Propiconazole	5.04*	< 1	3.23	27.69**	2.62	< 1	< 1	1.84	< 1	< 1
N X Eth.	1.09	< 1	< 1	< 1	< 1	< 1	2.62	< 1	1.61	< 1
Eth. X Prop.	< 1	< 1	< 1	< 1	< 1	< 1	2.87	< 1	< 1	< 1
N X Prop.	2.00	< 1	< 1	< 1	< 1	< 1	1.48	< 1	< 1	< 1
N X Eth. X Prop.	< 1	< 1	2.03	< 1	2.37	< 1	1.55	< 1	< 1	< 1
MSE	8178	12567	74278	856	4265	2795	2457	2940	2819	1810

Percent Grain Protein: Values for F from ANOVA for ICM Tests

	1 9 8 6				1 9 8 7					
	Dryland		Irrigated		Dryland			Irrigated		
Source	Bonanza	Samson	Bonanza	Samson	Johnston	Leduc	Samson	Virden	Leduc	Heartland
Nitrogen	18.35**	23.47**	46.04**	6.45**	12.99**	13.70**	41.99**	13.69**	34.00**	18.14**
Ethephon	3.33	< 1	5.59*	2.47	< 1	< 1	2.93	< 1	< 1	< 1
Propiconazole	< 1	1.29	3.23	< 1	< 1	1.55	1.30	1.55	< 1	< 1
N X Eth.	< 1	1.79	< 1	< 1	2.06	2.39	< 1	2.39	< 1	< 1
Eth. X Prop.	< 1	1.23	< 1	1.21	< 1	< 1	< 1	< 1	< 1	< 1
N X Prop.	5.23**	< 1	2.77	< 1	< 1	3.52*	< 1	< 1	< 1	1.99
N X Eth. X Prop.	< 1	< 1	< 1	1.10	< 1	< 1	< 1	< 1	< 1	1.00
MSE	0.013	0.013	0.209	0.237	0.069	0.059	0.041	0.059	0.123	0.206

Crop Height: Values for F from ANOVA for ICM Tests

	1 9 8 6				1 9 8 7					
	Dryland		Irrigated		Dryland			Irrigated		
Source	Bonanza	Samson	Bonanza	Samson	Johnston	Leduc	Samson	Virden	Leduc	Heartland
Nitrogen	6.33**	< 1	1.52	< 1	20.96**	1.46	3.26	< 1	< 1	< 1
Ethephon	179.18**	34.92**	131.02**	17.30**	8.86**	34.39**	21.99**	102.5**	124.8**	99.80**
Propiconazole	< 1	< 1	5.53*	1.61	< 1	< 1	< 1	1.54	< 1	< 1
N X Eth.	3.68*	< 1	1.11	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Eth. X Prop.	< 1	< 1	5.24*	1.10	1.50	< 1	< 1	< 1	< 1	< 1
N X Prop.	1.26	1.02	< 1	< 1	< 1	< 1	< 1	< 1	2.1	< 1
N X Eth. X Prop.	2.22	< 1	1.68	< 1	< 1	< 1	1.61	< 1	< 1	< 1
MSE	14.98	11.20	21.77	15.92	14.74	41.58	29.22	9.14	5.77	5.34

Heads m-1 Row: Values for F from ANOVA for ICM Tests

	1986				1987					
	Dryland		Irrigated		Dryland			Irrigated		
Source	Bonanza	Samson	Bonanza	Samson	Johnston	Leduc	Samson	Virden	Leduc	Heartland
Nitrogen	< 1	24.84**	< 1	1.83	3.67*	< 1	2.13	1.11	< 1	< 1
Ethephon	5.44*	< 1	5.58*	< 1	< 1	< 1	< 1	1.97	< 1	< 1
Propiconazole	1.36	3.45	2.13	27.22**	< 1	< 1	< 1	< 1	< 1	< 1
N X Eth.	< 1	< 1	< 1	< 1	< 1	< 1	1.84	< 1	< 1	< 1
Eth. X Prop.	< 1	1.94	< 1	< 1	< 1	< 1	< 1	< 1	< 1	1.73
N X Prop.	< 1	< 1	1.54	< 1	< 1	< 1	< 1	< 1	< 1	1.40
N X Eth. X Prop.	4.49*	< 1	2.51	< 1	< 1	< 1	1.13	< 1	< 1	< 1
MSE	17.69	3.47	6.58	17.45	26.55	13.54	7.38	12.21	12.12	874.28

a. The number of heads in the Heartland test was recorded per m²

Thousand kernel weight: Values for F from ANOVA for ICM Tests

	1986				1987					
	Dryland		Irrigated		Dryland			Irrigated		
Source	Bonanza	Samson	Bonanza	Samson	Johnston	Leduc	Samson	Virden	Leduc	Heartland
Nitrogen	1.14	4.67*	8.23**	< 1	2.11	< 1	< 1	< 1	< 1	< 1
Ethephon	8.64**	< 1	5.07*	< 1	< 1	< 1	< 1	< 1	< 1	1.11
Propiconazole	8.02**	< 1	< 1	8.00**	< 1	< 1	2.19	< 1	< 1	< 1
N X Eth.	1.22	1.92	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Eth. X Prop.	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
N X Prop.	4.41*	1.74	1.56	< 1	< 1	< 1	< 1	< 1	1.17	< 1
N X Eth. X Prop.	< 1	< 1	< 1	< 1	1.26	< 1	1.09	< 1	< 1	< 1
MSE	9.12	2.30	5.59	2.93	10.99	9.23	5.75	4.78	4.06	3.19

Kernels head-1: Values for F from ANOVA for ICM Tests

	1986				1987					
	Dryland		Irrigated		Dryland			Irrigated		
Source	Bonanza	Samson	Bonanza	Samson	Johnston	Leduc	Samson	Virden	Leduc	Heartland
Nitrogen	1.35	1.58	< 1	2.26	3.00	2.64	1.07	2.35	1.04	< 1
Ethephon	11.67**	5.17*	19.16**	9.08**	7.94**	11.09**	2.41	3.95	< 1	18.50**
Propiconazole	2.10	< 1	3.14	< 1	< 1	< 1	< 1	< 1	2.62	1.98
N X Eth.	< 1	1.30	2.94	1.84	< 1	4.18*	< 1	1.22	< 1	2.50
Eth. X Prop.	< 1	< 1	< 1	< 1	< 1	< 1	1.54	< 1	1.22	< 1
N X Prop.	1.79	1.34	< 1	< 1	1.11	< 1	< 1	< 1	< 1	< 1
N X Eth. X Prop.	3.97	< 1	< 1	< 1	< 1	< 1	< 1	1.66	< 1	< 1
MSE	6.58	36.84	9.97	16.63	12.86	4.88	13.92	26.55	15.42	15.15

Values for F from ANOVA of Orthogonal Contrasts on Grain Yield from PGR Tests, 1986 and 1987.

			1986				1987				
			Dryland		Irrigated		Dryland			Irrigated	
Contrast			Bonanza	Johnston	Leduc	Johnston	Leduc	Johnston	Virden	Leduc	Heartland
PGRs	vs.	Untreated	8.2**	10.3**	49.5**	21.5**	< 1	< 1	4.5*	2.6	13.1**
Early PGRs	vs.	Late PGRs	< 1	3.1	58.8**	< 1	< 1	< 1	< 1	< 1	13.5**
Ethephon (early)	vs.	eth + CCC (early)	< 1	< 1	1.9	< 1	< 1	< 1	< 1	< 1	< 1
Ethephon (late)	vs.	eth + CCC (late)	< 1	< 1	1.2	< 1	< 1	< 1	< 1	< 1	< 1
Low eth. (early)	vs.	High eth. (early)	< 1	< 1	4.2	< 1	< 1	< 1	< 1	< 1	< 1
Low eth + CCC (early)	vs.	High eth+CCC (early)	< 1	1.2	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Low eth. (late)	vs.	High eth. (late)	1.6	3.3	3.5	1.1	< 1	< 1	< 1	< 1	< 1
Low eth + CCC (late)	vs.	High eth + CCC (late)	< 1	< 1	3.7	< 1	< 1	< 1	< 1	< 1	< 1
MSE			1085	2180	4807	11618	345	1162	4557	2337	1932

Values for F from ANOVA of Orthogonal Contrasts on Crop Height from PGR Tests, 1986 and 1987.

			1986				1987				
			Dryland		Irrigated		Dryland			Irrigated	
Contrast			Bonanza	Johnston	Leduc	Johnston	Leduc	Johnston	Virden	Leduc	Heartland
PGRs	vs.	Untreated	42.3**	46.4**	20.3**	47.7**	30.3**	34.4**	30.9**	8.2**	7.9**
Early PGRs	vs.	Late PGRs	91.4**	18.9**	10.9**	16.9**	74.6**	40.4**	18.3**	8.8**	25.3**
Ethephon (early)	vs.	eth + CCC (early)	16.2**	19.7**	< 1	5.4*	< 1	1.3	< 1	< 1	1.5
Ethephon (late)	vs.	eth + CCC (late)	2.1	< 1	1.6	18.2**	< 1	1.3	1.1	1.5	3.3
Low eth. (early)	vs.	High eth. (early)	1.1	< 1	< 1	1.2	< 1	< 1	< 1	< 1	< 1
Low eth + CCC (early)	vs.	High eth+CCC (early)	< 1	5.8*	4.8*	1.2	< 1	2.6	1.2	< 1	< 1
Low eth. (late)	vs.	High eth. (late)	9.6**	< 1	4.8*	14.8**	< 1	2.6	< 1	1.1	8.9**
Low eth + CCC (late)	vs.	High eth + CCC (late)	< 1	2.1	< 1	4.8*	11.9**	2.6	2.2	< 1	8.9**
MSE			7.5	8.6	10.3	6.6	2.7	3.2	14.4	16.5	11.1