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THE EFFECT OF PLANT GROWTH REGULATORS ON PLANT HEIGHT, LODGING AND YIELD IN BARLEY

BY

PETER JOHN ENTZ

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TABLE OF CONTENTS

Chapter | Page

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABSTRACT

Entz, Peter John. M.Sc., The University of Manitoba, February 1988. The Effect of Plant Growth Regulators on Plant Height, Lodging and Yield in Spring Barley. Major Professor; Dr. E. H. Stobbe.

The plant growth regulators (PGR's) ethephon and ethephon/mepiquat chloride were evaluated in several barley cultivars at several sites in Manitoba. These plant growth regulators were effective in reducing the plant height and internode length of all spring barley cultivars evaluated. Efficacy was influenced by cultivar, rate of PGR applied, stage of application and growing conditions. Ethephon applied to Bedford barley at 100 g ai/ha did not result in a reduction of plant height, whereas, ethephon applied at 600 g ai/ha resulted in a 22.3 cm reduction in plant height. The addition of mepiquat chloride to ethephon did not affect the plant height of barley, however, lodging was less when compared to an equal amount of ethephon applied alone. Internodes that were actively elongating at the time of ethephon application were most affected by the PGR treatment, these being internode 4, 5 and the peduncle. When lodging occurred, all rates of PGR applied to barley prevented or reduced lodging.

The ability of cultivars to resist lodging varied, as did their response to a PGR application. Johnston, a cultivar with fair lodging resistance, treated with 300 g ai/ha of ethephon had a lodging score of 7.2, at harvest, compared to Bedford, a cultivar with excellent lodging resistance, untreated, scoring 4.2 (Belgian lodging scale). At the same evaluation Bedford, treated with 300 g ai/ha of ethephon, did not lodge.

PGR's were effective in reducing or preventing lodging with all cultivars evaluated.

Yields, yield components and protein were unaffected by PGR application, except with Johnston barley at Teulon in 1984, where 300 g ai/ha of ethephon resulted in an increase in kernel weight.

Chapter 1

INTRODUCTION

In 1985, 4.8 million hectares of barley were seeded in the Canadian prairie region with 770,000 hectares seeded in Manitoba (Prairie Pools Inc., 1985). The most widely grown cultivar was Bonanza (fair lodging resistance) which constituted 30.8 percent of the barley sown in the province (Manitoba Agriculture, 1985; Anonymous c, 1984). Other cultivars, Bedford, Argyle, Conquest and Norbert, are less susceptible to lodging than Bonanza, but with certain environmental conditions, lodging can be a serious problem (Manitoba Agriculture, 1986).

Lush growth, coupled with heavy winds and precipitation, can cause lodging with any cultivar (Einarsson, 1983). Lodging can be the temporary bending, or a complete buckling of the barley culm. The intensity and time of lodging will dictate the severity of the problems associated with a lodged crop. These problems include negative effects on flowering and carbohydrate assimilation, uneven maturity, reductions in grain quality, difficulties in harvesting and an increased drying cost (Lasson, 1983). Permanent, early lodging of the barley crop can cause yield reductions of up to 38 percent. Lodging may not have a direct affect on grain yield, but harvesting losses may be more severe in a lodged crop. Lodging resistance of a plant can be increased by reducing the plant height or increasing the straw strength (Einarsson, 1983).

Studies were conducted to determine the effect of ethephon and ethephon/mepiquat chloride applied to spring barley on the ability of cultivars to resist lodging, influence plant height, length of culm internode, yield, yield components and kernel protein, and to determine the effect of ethephon on lodging in barley seeded with several levels of nitrogen fertilizer.

Chapter 2

LITERATURE REVIEW

2.1 Growth and Development of Cereals

In cereals, the rate of growth, measured as an increase in height over time, is slow during seedling establishment and tiller formation, accelerated during stem elongation and reduced again as the plant matures (Salisbury and Ross, 1978). Plants consist of 7 to 15 internodes of which only 5 or 6 elongate (Reilly, 1984; Briggs, 1978). Briggs (1978) describes the barley plant as being a hollow series of internodes, weak at the meristimatic tissue, separated by nodes, supported by unsheathing leaf bases and carrying extended leaf blades and a terminal ear, the whole system being anchored by a root system. The central tissue extending throughout the internode is hollow, resulting in a hollow cavity (Cook, 1962). The nodal region is where the leaf tissue is inserted and the leaf tissue offers support to the internode (Dennis *et al.*, 1984).

2.1.1 Plant Growth Stages

Although several scales are currently being used to identify the growth stages of cereals, in this study the Zadoks-Chang-Konzak (hereafter referred to as the Zadoks Scale) was used and it describes ten distinct segments of cereal growth (Zadoks *et al.*, 1974). The segments of development are germination, seedling growth, tillering, stem elongation, booting, inflorescence emergence, anthesis, milk development, dough development and ripening (Zadoks et al., 1974).

Tillering, the third event, is an important developmental period, as it determines the potential ears per unit area and will directly affect final grain yield (Dewey and Albrechtsen, 1985).

2.1.1.1 Tillering

Tillering is controlled at three levels: (1) genetics of the plant, (2) environmental factors and (3) agronomic practices. Typically barley plants will produce a mainstem and two or three tillers (Briggs, 1978; Kirby and Appleyard, 1982). More tillers are initiated, but not all survive (Cook, 1962).

Leopold (1949) reported that auxin, produced in the apical meristem, had an inhibitory effect on tiller bud release. In barley a three fold increase in tillering occurred upon removal of the apical meristem. In experiments with Lolium multiflorum, Clifford (1977) found that IAA (indol-acetic acid) synthesized in the ear and young leaves can exert an inhibitory effect on tiller bud initiation. Auxin is exported from the ear and young leaves to the elongating internode and the activity of the elongating internode controls tiller bud activity. Jinks and Marshall (1982) concluded that with the application of IAA, assimilate transport converged at the elongating internode, at the expense of transport to the tiller buds. Morris and Thomas (1974), working with intact Pisum sativum seedlings, suggested that auxin travelled from source, basipetally, via phloem transport. Auxins moving basipetally to the elongating internodes, inhibit tiller bud growth as the internodes are a large sink for nutrients (Clifford, 1977). Sharif and Dale (1980), reported IAA to inhibit tiller bud initiation only in treatments where mineral nutrients were added.

Morgan and Gausman (1966) concluded ethylene to inhibit the movement of auxin in cowpea and cotton. They concluded that ethylene caused a shortage of auxin in certain plant parts and surplus in others. Aqueous solutions of ethylene applied to the apices of Phaseolus vulgaris resulted in an outgrowth of basipetally situated axillary buds (Yeang and Hillman, 1979). The presence of glucose and sucrose stimulated the production of ethylene and indirectly affecting auxin levels, internode elongation and lateral bud growth (Meir et al., 1985; Philosoph-Hadas et al., 1985).

Aspinall (1961) observed two distinct phases of tillering in winter barley (cv. Proline). Tiller initiation and growth occurred for 8 weeks, prior to the boot stage, ceased from week 8 to 16, and resumed after after week 16, after ear emergence when the kernels were in the dough stage. Leopold (1949) suggested that development of the ear exerted control over the initiation of tiller buds via the synthesis and transport of auxin. Tillers developing after ear emergence may not mature and produce grain (Briggs, 1987).

Temperature and/or moisture stress have a two-fold effect on tillering: (1) the elimination of axillary bud growth and (2) the delay of axillary bud development into tillers (Jinks and Marshall, 1982). Levitt (1980) found that plant stress caused and immediate increase in growth inhibitors, along with a decrease in growth promoters. Stress inhibited tiller initiation and caused existing tillers to abort (Klepper et al., 1983). Mulder (1954) stated that rain, in association with heavy winds, caused bending of the main stem which disrupted the basipetal transport of auxin and caused a release of tiller buds.

Seeding depth can influence the number of fillers per plant. Briggs (1978) reported that an increase in seeding depth, increased the number of nodes available for tiller initiation. 1978). Dewey and Albrechtsen (1985) reported only 50 percent of the tillers initiated in the plant were seed bearing. A reduction in seeding rate produces more tillers, however, the tiller mortality was greater with the reduced seeding rates (Kirby and Appleyard, 1982). As seeding rate was increased, the tillers per plant decrease, the seeds per ear decreased, but the grain yield increased (Briggs, 1987). This trend continued until an optimal density was reached, which was cultivar dependant.

Tillering can be enhanced through the use of nitrogen fertility (Mulder, 1954; Aspinall, 1961). Aspinall (1961) reported two phases of tillering occurred in barley when nutrients were supplied solely before germination. The majority of tillering occurring prior to stem elongation. When nutrients were replaced weekly, the tillering rate was maintained throughout the life cycle of the plant.

2.1.1.2 Stem Elongation

Dry weight of the barley plant increases dramatically as the stem elongates (Briggs, 1978). Stem elongation is achieved by the ordered elongation of the culm internodes (Cook, 1962). Stem elongation consists of the developmental phase in which the plant has attained a pseudo-erect stature, up to the flag leaf becoming visible (Anonymous a, 1983). In this phase, the nodes and internodes become detectable and rapid elongation of the internodes is occurring (Briggs, 1978). This period of elongation is often termed as the grand period of growth, as the plant is now in a linear growth phase, when measuring height increases over time (Briggs, 1978; Reilly, 1984). Rapid stem elongation follows an ordered sequence from the base of the plant moving upwards. The rate of growth accelerates with favourable climatic conditions and occurs at the time when primordium initiation is almost complete. When an internode is half elongated, the next uppermost internode begins to elongate, and this continues in sequence, until the peduncle is fully elongated. The basal internodes reach their maximum length sooner than the higher internodes, while the internode length increases towards the apex.

The meristimatic region of the culm occurs at the basal section of each internode and remains non-lignified until the plant has flowered (Cook, 1962; Salisbury and Ross, 1978). The basal section of the internode is where the younger, actively elongating cells are derived. Auxin produced in the apex and younger leaves of the plant moves basipetally to the internodes where cell elongation is induced (Abeles and Rubinstein, 1964).

2.1.4 Maturation of the Plant

As the plant matures, the elongating peduncle will push the ear out of the boot and the grain filling period begins after anthesis. As the grain matures, the plant will senesce and its life cycle will be complete (Briggs, 1978).

2.2 Lodging of Cereals

Dennis *et al*. (1984) define lodging as the displacement of the culm from its upright position. Lodging of a crop is due to inadequate standing power, which is cultivar dependant and affected by the singular or combined forces of rain, hail and wind (Mulder, 1954; Neenan and Spencer-Smith, 1975; Anonymous c, 1984; Manitoba Agriculture, 1986). Lodging has a negative effect on flowering and carbohydrate assimilation, grain quality, grain yield, harvesting and grain drying (Lasson, 1983; Dennis *et al*., 1984). A reduction in quality can include, reduced kernel plumpness, reduced kernel weight and higher wort nitrogen content (Day and Dickson, 1957). Dennis *et al*. (1984) calculated that yield losses due to lodging can be 38 percent. Mulder (1954) concluded lodging to be the most limiting factor in attaining high grain yields through increased nitrogen fertilization.

2.2.1 Physical Characteristics of Lodging

Lodging can result from failure of the root system, occurrence of fungal diseases and/or weakness of the culm (Grafius *et al*., 1955; Neenan and Spencer-Smith, 1975). Weakness of the culm can cause the structure to bend, buckle or break (Mulder 1954). Dennis *et al*. (1984) reported lodged plants regained their erect stature through a positive geotrophic response of the lower internodes. In a hollow cylinder the most likely cause of failure is buckling (Neenan and Spencer-Smith, 1975). A lateral force exerted on the plant will cause bending of the culm and, as the force increases, buckling can occur. Lodging due to culm breakage only occurs with plants left in the field after maturity (Grafius *et al*. 1955; Dennis *et al*., 1984). Grafius *et al*. (1955) concluded oat cultivars that resisted lodging, in season, tended to resist stem breakage when left in the field after physiological maturity.

Neenan and Spencer-Smith (1975) used Young's modulus of rupture test to obtain a numerical value for the inherent bending resistance of a culm. Young's modulus of rupture test can be used to determine lodging resistance in plants as it measures the mechanical strength of the barley culm, that is, the maximum force per unit area that a culm could withstand prior to buckling. They determined the modulus of rupture value was proportional to the thickness of the culm wall. The plant will be more lodging resistant with a high modulus of rupture value. In barley, the force applied to the culm is transferred to the base of the plant, where the plant is mechanically stronger. The stress transferred to the base was greater with tall cultivars, as the force is proportional to the fourth power of the plant height (Pinthus, 1973).

2.2.2 Environmental Factors Affecting Lodging

A plant, that is susceptible to lodging can remain erect in the absence of adverse environmental conditions (Mulder,1954). These environmental factors are wind, rain and hail (Dennis *et al.*, 1984). Wind is the main component, but is usually associated with rain and/or hail. Environmental forces cause the deflection of the culm and when the elastic limit of the culm is exceeded, the plant will lodge. Neenan and Spencer-Smith (1975), in wind tunnel experiments, concluded barley culms would fail at a wind velocity of 55.4 km/hour. In the field, crop unevenness and the crop boundary layer would increase the velocity required to cause barley culms to lodge. Wind will exert a lateral force on the culm and it is often the strength of the basal internodes and the root system that determine if the plant will lodge (Mulder, 1954). Neenan and Spencer-Smith (1975) reported that the wall thickness of the internodes increased from the peduncle to the base of the plant, as did the breaking load per culm.

Raindrops will exert a vertical force on the plant. Raindrops coupled with wind will exert a strong lateral force on the plant culm. The retention of raindrops on the ear of the plant can increase the mass of the ear by 30 percent (Neenan and Spencer-Smith, 1975). The combined effects of rainfall can exert forces on the plant that will cause it to lodge. Moisture can also cause the plant to develop longer and weaker internodes. High levels of soil moisture can also result in poor anchorage for the root system of the plant.

2.2.3 Morphological Factors Affecting Crop Lodging

Tall plants are more likely to lodge than short plants (Mulder, 1954). Deflection of the culm due to external forces is proportional to the fourth power of plant height (Pinthus, 1973). A small change in plant height can have a strong influence on lodging. Stanca *et al.* (1979) reported a correlation between plant height and lodging. Cenci *et al.* (1984) concluded that taller cultivars had a thicker sclerenchyma cell wall in comparison to shorter stature cultivars, suggesting that the thicker sclerenchyma cell walls are responsible for the improved lodging resistance of some tall cultivars over shorter cultivars. Improved lodging resistance may be achieved by combining the reduced height of the short strawed cultivars with the thicker cell walls of the taller statured cultivars. Taller statured cultivars have a more elastic characteristic, whereas the shorter cultivars are stiffer, with stronger basal internodes.

Morphologic characteristics such as plant height, wall thickness and cell wall lignification can effect the ability of the plant to resist a lateral force. In studies reported by Stanca *et al.* (1979) a significant negative correlation between plant height and lodging was observed. However, he did not report a correlation between lodging and vascular bundles in the 8 cultivars of barley tested.

This observation would suggest that plant height is the most important component in determining the plants ability to resist lodging.

Lateral forces such as wind and rain will be intercepted by the plant. The greater the exposed surface area of the plant, the greater are the lateral forces it will intercept. Awned cultivars will, therefore, intercept more lateral forces than an awnless cultivar (Neenan and Spencer-Smith, 1975). They determined a 6 row awned barley spike having an area of 9.62 cm^2, compared to a 2 row awned barley having an area of 3.84 cm^2. A barley flag leaf can account for up to 15.4 cm^2 of leaf area and offer substantial resistance to air flow. Ear shape, leaf number, leaf area, plant height and internode length will all determine the architecture of the plant, and the plants response to the forces that cause lodging.

2.2.4 Growth Characteristics affected by Lodging

Lodging will alter plant development and growth and is affected by the severity of lodging, duration of lodging and the time of lodging (Mulder, 1954; Day and Dickson, 1957; Stanca _et al_., 1979). Stanca _et al_. (1979) reported permanent, early lodging to cause yield reductions of up to 38 percent. Early, temporary lodging, prior to anthesis, still resulted in a 25 percent yield reduction. Day and Dickson (1957) reported a detrimental yield and quality effect when lodging occurred ten or twenty days after heading. Barley kernel weight was reduced when ninety degree lodging occurred at any stage (Day and Dickson, 1957). When the barley was lodged at a forty-five degree angle little effect on yield was noted with the two cultivars tested.

Yield reductions are greatest when the lodging occurred during the short period of grain filling (Mulder, 1954) and are mostly a result of a reduction in grain weight (Stanca et al., 1979; Dennis et al., 1984).

Reduced grain weight can be a result of reduced photosynthesis caused by the shading effect of a lodged crop. Bending of the culm can also reduce the translocation of photosynthate throughout the plant, while respiration continues. Stanca et al. (1979), found the number of small kernel sievings, measuring less than 2.2mm, increased with the severity of lodging. The increase in small kernels may indicate that kernel filling was restricted. A reduction in plant growth can also leave the plant susceptible to attack by pathogens. Root diseases can also cause lodging by reducing the anchorage of the plant, provided by the root system (Neenan and Spencer-Smith, 1975).

2.2.5 The effect of nitrogen fertility on lodging

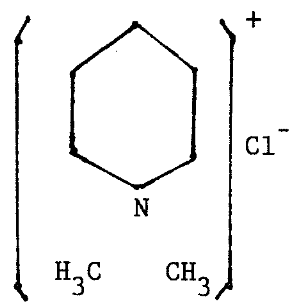
Lodging is often the main factor limiting the response of cereals to nitrogen (Dennis et al., 1985). The addition of nitrogen can cause an increase in overall plant height, along with thinner, weaker culms (Mulder, 1954; Dennis et al., 1984). Dennis et al. (1984), reported that the addition of 100 kg/ha of nitrogen caused the development of smaller culm diameters in the lower internodes and increased the length of the lower internodes by ten to fifteen percent. The addition of 100 kg/ha of nitrogen resulted in a 57 percent increase in lodging with Midas spring barley and resulted in a yield reduction of 0.14 tonnes/ha (Blackett and Taylor, 1982). Mulder (1954) concluded that rates of nitrogen as low as 30 kg/ha applied in the spring resulted in an increase in lodging of wheat and oats.

2.3 Plant Growth Regulators

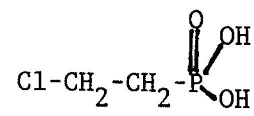
Plant growth regulators (PGR's) are phytohormones, that are exogenously applied to a growing plant. The effect is to alter the hormone balance within the plant, making the plant more suitable for high yield crop production. Some PGR's are used to protect the crop from lodging and to offer a degree of yield enhancement (Danhous *et al*., 1982; Jung, 1984). Plant growth regulators are currently being used in canola, winter wheat, winter barley, fall rye, spring wheat, spring barley and spring oats (Lasson, 1983; Einarsson, 1983). A PGR, such as ethephon, is effective in reducing plant height and may also increase the strength of the culm (Sachs and Hackett, 1972; Wunsche, 1977). Blomquist *et al*. (1973), showed that ethephon increased the lignin deposits in the stem of *Vicia faba*. Chemicals such as chlormequat chloride or mepiquat chloride also cause a reduction in plant height, but are not as effective as ethephon. Chlormequat chloride and mepiquat chloride are more effective than ethephon in increasing the strength of the culm (Anonymous d, 1985; Prusakova *et al*. 1973).

2.3.1 Ethephon

Ethephon has been used in field trials since 1966 and commercially on cereal crops since 1977 (Einarsson, 1983). Cerone, the commercial name of ethephon, is marketed by May and Baker in Canada as a liquid formulation containing 480 grams of ethephon per liter (Figure 1.1).



MEPIQUAT CHLORIDE



ETHEPHON

Figure 1.1 The chemical structure for ethephon and ethephon/mepiquat chloride.

Ethephon breaks down in the presence of a base to form ethylene, with an apparent release of chlorine and phosphate (Warner and Leopold, 1967; de Wilde, 1971; Jackson and Dobson, 1978). Ethephon provides a convenient method of applying ethylene to plants, without the need of a gas confining chamber (de Wilde, 1971; Salisbury and Ross, 1978). Warner and Leopold (1967) reported that ethephon applied to the cereal plant stimulated endogenous levels of ethylene in the plant. The application of ethephon resulted in similar responses to those known for ethylene.

Ethephon is is applied between the late boot and early flag leaf extension stage (Anonymous b, 1984). Brown and Early (1973) concluded that ethephon was most effective in reducing plant height when applied to the early boot stage. Thonke (1983) reported no difference in efficacy of ethephon when applied in water volumes of 30, 100 or 300 liters per hectare. However, he showed that spray retention was increased when the droplet size was decreased, thus improving the efficacy of ethephon. Ethephon applications should be restriced to when the plant is dry and the risk of precipitation is low, as ethephon can be washed off the leaves. Ethephon should not be applied when the crop is in a stress situation, as endogenous levels of ethylene increase in both root and stem tissue (Hall et al., 1977). This endogenous ethylene production is an adaptive feature to allow for reduced plant growth during periods of stress (Abeles, 1973; Levitt, 1980). Levitt (1980) reported that ethylene evolution increased with the severity of water stress in excised wheat leaves.

Prusakova et al. (1973) postulated that the application of exogenous ethylene increased the activity of endogenous auxin in barley, shifting the plant to a inhibitory growth response in the plant. Morgan and Gausman (1966) reported that stem elongation was mediated by ethylene levels, through its effect on auxin uptake and transport. Working with cowpea, they showed that exogenous ethylene caused a reduction in auxin uptake and transportation, causing local surpluses and shortages of auxin. Auxin is associated with active growth centers, therefore, if auxin transport to the basal meristematic zone of the internode is reduced, internode elongation is reduced (Schott and Rittag, 1982).

2.3.2 Ethephon/ Mepiquat Chloride

The combination of ethephon and mepiquat chloride is marketed as Terpal and contains 155 grams of ethephon and 305 grams of mepiquat chloride per liter (Figure 1.1). Mepiquat chloride was developed in 1975 by BASF Aktiengesellschaft in West Germany (Schott and Rittag, 1982; Lasson, 1983). Mepiquat chloride has a similar solubility in water as ethephon. Mepiquat chloride is taken up by the growing parts of the plant and translocated via phloem movement (Lasson, 1983). Mepiquat chloride inhibited the cyclization of geranylgeranyl pyrophosphate to coplyl pyrophosphate in the course of gibberellic acid synthesis (Jung, 1984). Gibberellic acid caused the elongation of detached internodes in Avena sativa (Sharif and Dale, 1980). Mepiquat chloride caused internode shortening, increased radial culm growth and an increased tiller production (Schott and Rittag, 1982; Lasson, 1983; Jung, 1984). Mepiquat chloride promoted thickening of the culm by increasing the number of vascular bundles and enhancing the formation of schlerechyma tissue.

Larson (1983) reported that mepiquat chloride was effective in strengthening the straw of winter barley. The addition of ethephon enhanced the ability of mepiquat chloride to reduce plant height. By affecting the plants straw strength and height, the plant was able to better resist lodging (Jinks and Marshall, 1982). Scheffer et al. (1983) concluded that the application of ethephon and mepiquat chloride resulted in increased yield, as a result of increased tillering, in the absence of lodging.

2.3.3 Agronomic Characteristics affected by Ethephon and Ethephon in combination with Mepiquat Chloride

Ethephon and ethephon in combination with mepiquat chloride reduced crop lodging by reducing plant height and increasing the straw strength of the plant (Brown and Early, 1973; Stanca et al., 1979; Lasson, 1983; Einarsson, 1983). In the absence of lodging, grain yields may not be increased following the application of ethephon alone or in combination with mepiquat chloride. When a yield increase is observed it appears to be due to an increase in ears per unit area (Provakova et al., 1973; Jung, 1984). A decrease in kernel weight has frequently been observed when the ears per unit area was increased due to the PGR application.

2.3.3.1 Plant Height

A reduction in plant height is the most consistent parameter affected by ethephon. Wunsch (1977) reported significant reductions in plant height, when compared to the untreated check, with ethephon applied to barley at rates of 1.3, 3.9 and 11.7 kg ai/ha, at a height of 20-25 cm. This concurs with Aigner (1982) who applied ethephon to barley at Zadoks growth stage 37-49. Dahnous et al. (1982) reported ethephon applied at rates of 550 and 850 g ai/ha significantly reduced the the total plant height by significantly reducing the length of the peduncle. Einasson (1983) also concluded that ethephon reduced peduncle length, by 25 per cent when compared to the untreated check and total plant height by 14 per cent. Brown and Early (1973) added that ethephon applied at 560 g ai/ha significantly reduced the length of the peduncle and second last internode, which resulted in a significant reduction of overall plant height.

Ethephon in combination with mepiquat chloride (Terpal) applied at 2.0 l/ha was more effective in reducing plant height than applications at 1.0 l/ha (Lasson, 1983). Terpal, applied at the 3.0 l/ha rate to winter barley, significantly reduced the length of internodes 2, 3, 4 and 5 and the peduncle, when compared to the untreated plants.

The application timing of growth regulators is critical, as it will determine the developmental stage of the plant when the exogenous growth substance is applied. Applications of ethephon applied at GS 32-37 were more effective in reducing the elongation of the lower internodes, whereas later applications were more effective in reducing the elongation of the higher internodes (Schott and Rittag, 1982). Schott and Rittag (1982) and Dahnous _et al_. (1982) reported no significant differences in final plant height when varying the time of ethephon application, however, applications at GS 45 resulted in greater plant height reductions than applications at GS 50.

Terpal applied to _Avena sativa_ at GS 45 resulted in the greatest height reductions when compared to Terpal applied at other timings. Terpal, at a rate of 2.0 l/ha, applied to spring barley at GS 42 resulted in the shortening of the top four internodes (Stanca _et al_., 1979). Lasson (1983) reported that the 2.0 l/ha. rate of Terpal resulted in greater plant height reductions when applied at GS 39 and 45. The recommended application of Terpal is between GS 32 and 45 (Anonymous d).

2.3.3.2 Tillering

Yield increases associated with the application of ethephon resulted from an increase in ears per unit area (Roth _et al_., 1984). The increase in ears per unit area was attributed to an increase in tiller survival. Prusakova _et al_. (1973) reported a slight increase in lateral shoot development with a 2.0 kg ai/ha application of ethephon and a 1.5 fold increase with ethephon applied at 4.0 kg ai/ha. Ripening of the tillers was severely delayed. Wunsche (1977) concluded that ethephon applied at 0.43, 1.3, 3.9 and 11.7 kg ai/ha increased tillering by up to 1.3 tillers per plant, however, mature ears per plant were not affected.

2.3.3.3 Yield and Yield Components

The number of ears per unit area, the number of seeds per ear and the weight of the seeds are the components that make up the total yield (Yoshida, 1972). Ethephon and ethephon/mepiquat chloride can effect final grain yield by affecting one of more of the yield components.

Einarsson (1983) reported no effect in final yield when increasing the rate of ethephon from 380 to 720 g ai/ha, although Wunsche (1973) showed that ethephon applications of 1.3, 3.9 and 11.7 kg ai/ha increased the number of tillers per plant, but not the number of mature ears per unit area. Prusakova et al. (1973) reported yield reductions with ethephon applied at 2.0 and 3.0 kg ai/ha and were a result of a reduction in seeds per head.

Scheffer et al. (1983) applied 1.0 and 2.0 l/ha of Terpal at GS 32 and 37 to mechanically supported barley, cultivar Villa, and concluded that yield increases were a result of increases in the number of heads per unit area. Application of Terpal at GS 37 were more effective in increasing the yield of Villa barley, than applications of Terpal at GS 32. They concluded that applications of Terpal at a rate of 1.5

l/ha increased yield when compared to the untreated plots by increasing the ears per unit area and kernel weight. Stanca et al. (1979) reported that Terpal at a rate of 2.0 l/ha, applied to eight spring barley cultivars, increased the overall yield, but reduced the kernel weight. Blackett and Taylor (1982) also reported that Terpal applied at 2.0 l/ha to spring barley increased yield by 0.01 tonnes/ha, however, kernel weight was decreased. Schott and Rittag (1982) reported that application of mepiquat chloride increased the number of kernels per ear. Barley, cultivar Carina, yielded significantly more when treated with mepiquat chloride, however, plant height was not affected (Jinks and Marshall, 1982). The application of a growth regulator to a crop can result in a variable yield response.

2.3.3.4 Lodging

Ethephon alone and in combination with mepiquat chloride protected or reduced the incidence of crop lodging (Prusakova et al., 1973; Aigner, 1982; Lasson, 1983; Einarsson, 1983; Gaiser and Thiel, 1984). The degree of lodging protection was greater when the growth regulators were applied at higher rates (Roth et al., 1984). Lodging protection was achieved through a reduction in plant height and/or increased straw strength (Mulder, 1954; Cenci et al., 1984; Neenan and Spencer-Smith, 1975).

The use of a PGR, to protect the crop from lodging, is only effective if there is a potential for the crop to lodge (Anonymous b, 1984). Aigner (1982) reported lodging to increase from anthesis to maturity, regardless of ethephon treatment, however, the degree of lodging was less in plots treated with 384, 480 and 576 g ai/ha of ethephon when compared to the untreated plots.

Stanca et al. (1979) reported that Terpal applied at 2.0 l/ha eliminated lodging in 6 of the 8 cultivars of spring barley tested. In cultivars with weak straw, lodging was reduced, but not eliminated.

Chapter 3

MATERIALS AND METHOD

3.1 General Procedures

Field experiments were conducted in Manitoba for two years. In 1984, experiments were conducted at Teulon on a Tarno clay soil and at Portage la Prairie, Portage, on a Dugald clay loam soil. In 1985, experiments were conducted at Winnipeg on a Riverdale clay loam soil and at Portage. The climatic data for these locations are present in Tables 3.1 to 3.8. Prior to seeding the experimental sites were cultivated and harrowed to establish a good seedbed. Certified seed was used in all experiments. Weeds were controlled using herbicides or plots were hand weeded. Experimental layouts and details concerning establishment are included in Table 3.9.

In 1984 a handheld CO_2 sprayer with a four nozzle (TeeJet 8003) boom was used to apply the plant growth regulators. In 1985 a handheld CO_2 sprayer with a six nozzle (TeeJet 8002) boom was used. The spray output was 200 l/ha in 1984 and 214 l/ha in 1985 at 275 Kpa. The plant growth regulators were applied at a specific growth stage using the Zadoks Scale (Table 3.10). To determine growth stages precisely, the main stem of the barley plants were sectioned longitudinally by hand to ascertain the internode number and extent of elongation.

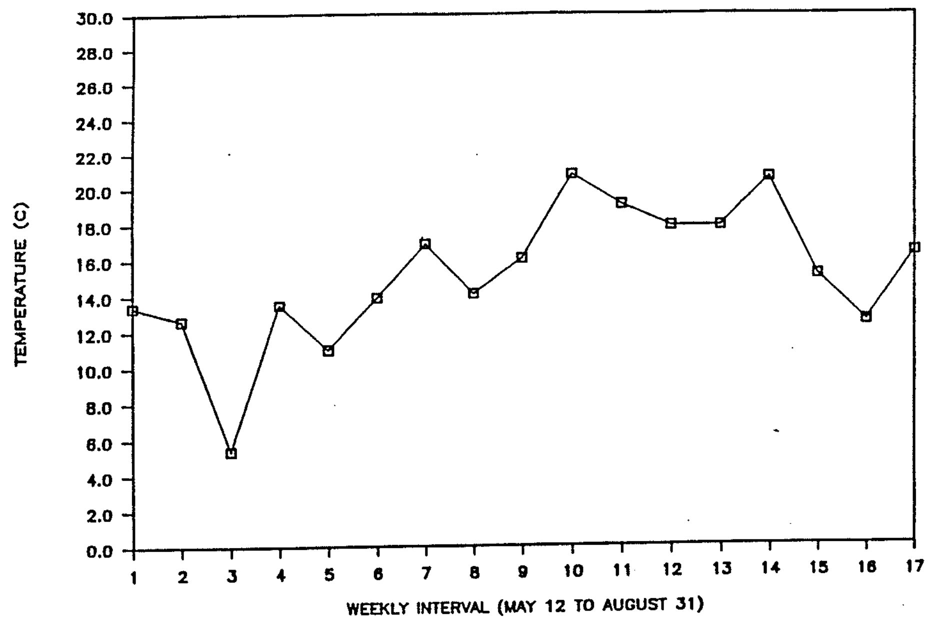


Table 3.1. Weekly temperature data, Portage la Prairie, 1985

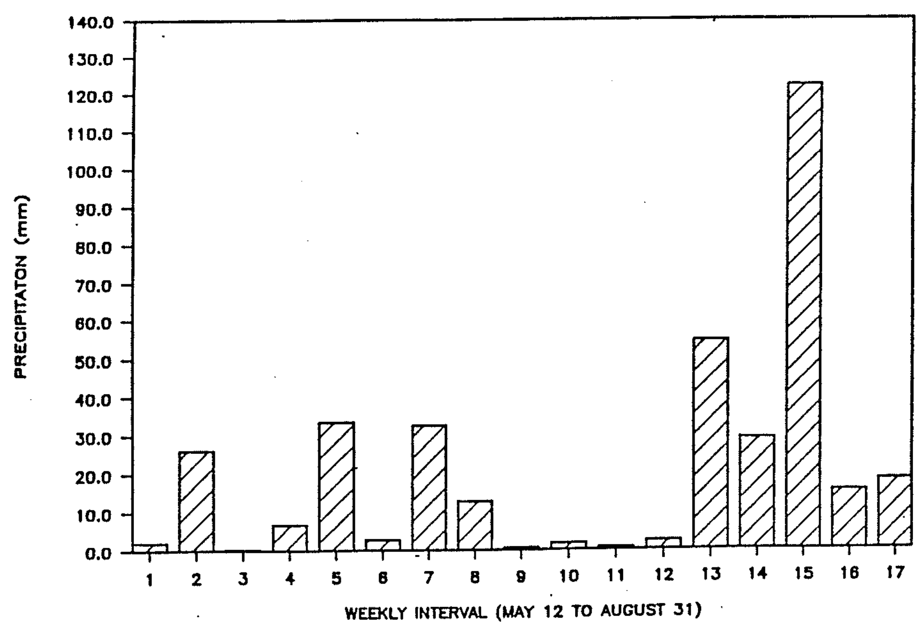


Table 3.2. Weekly precipitation data, Portage la Prairie, 1985

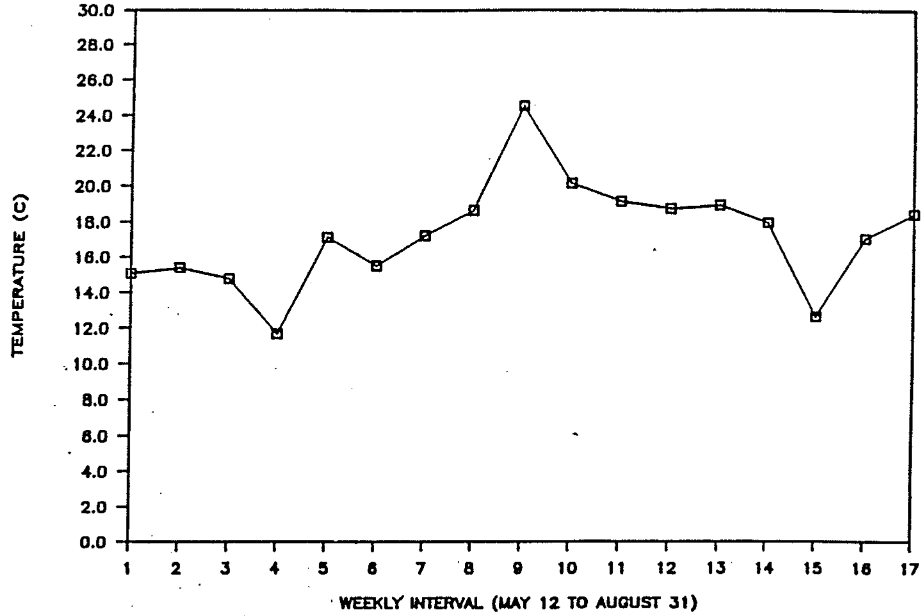


Table 3.3 Weekly temperature data, Winnipeg, Campus, 1985

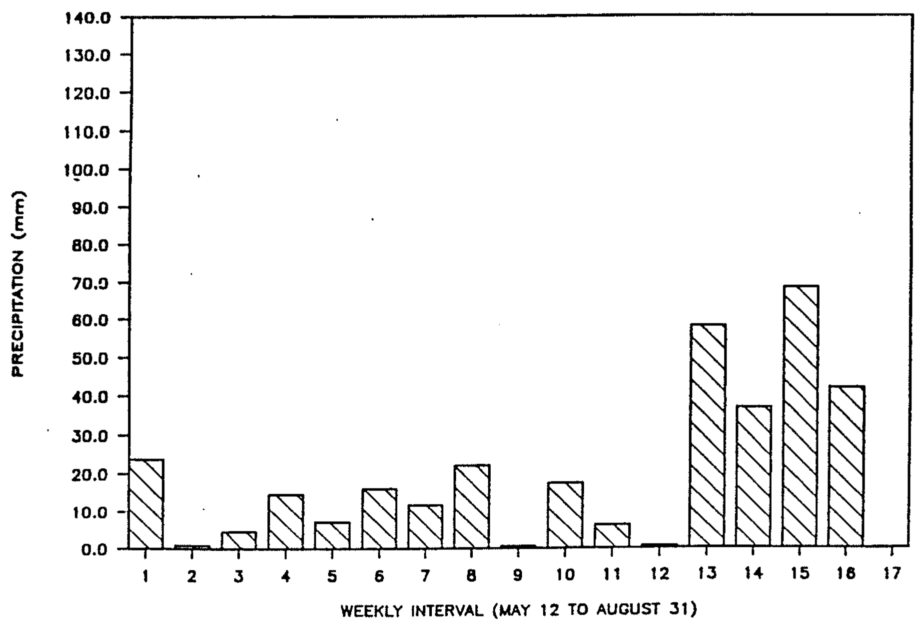


Table 3.4 Weekly precipitation data, Winnipeg, Campus, 1985

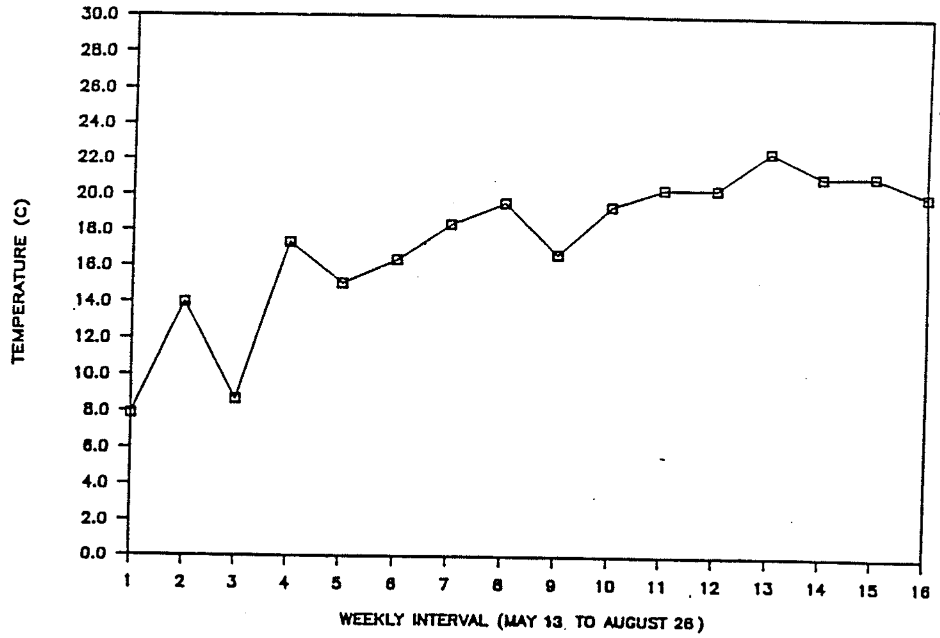


Table 3.5 Weekly temperature data, Teulon, 1984

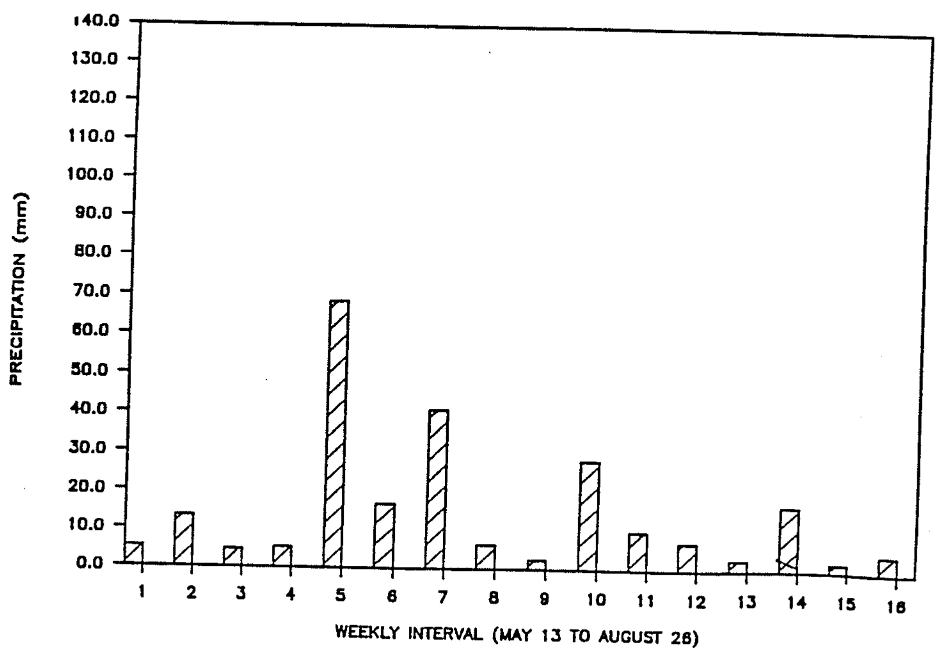


Table 3.6 Weekly precipitation data, Teulon, 1984

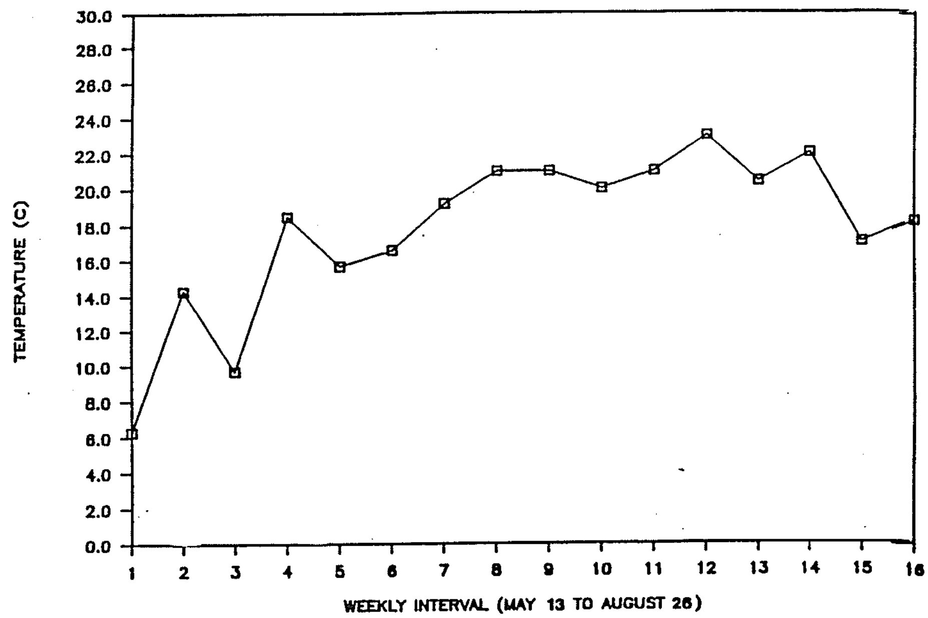


Table 3.7 Weekly temperature data, Portage la Prairie, 1984

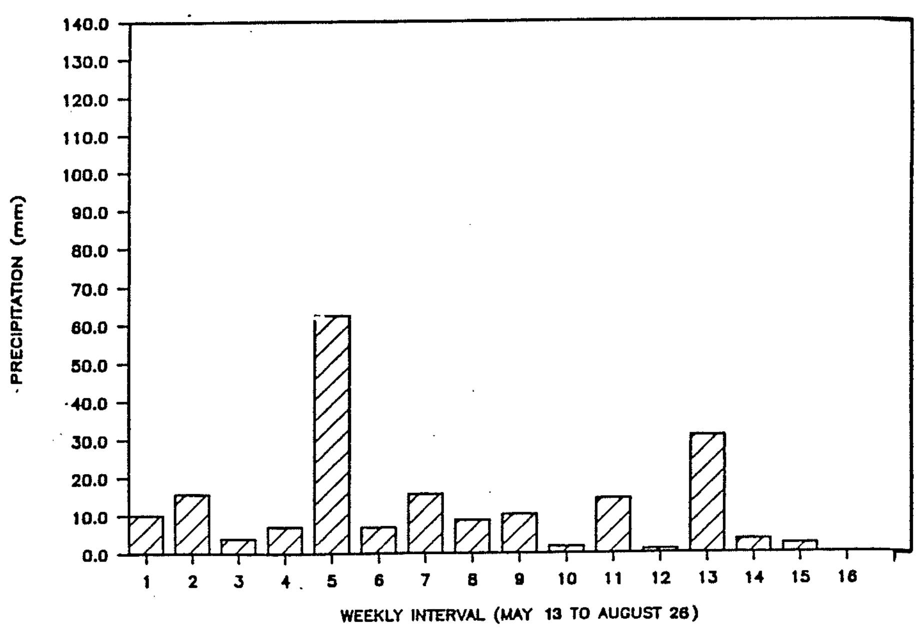


Table 3.8 Weekly precipitation data, Portage la Prairie, 1984

Table 3.9 Field trial establishment parameters, 1984 and 1985.

Experiment	Location	Design	Seeding date	Plot size (cm)	Seeder type	Row spacing (cm)	Seeding density (seeds/m2)	Herbicide application
1	Portage	RCB[1]	May 10/85	3x6	Amazone[5] 300ZT	18.75	300	none none
1	Portage	RCB	June 7/85	3x6	Amazone 300ZT	18.75	300	bromoxynil
2	Winnipeg	SP[2]	May 8/85	6x6	double disc press drill	15.0	300	none
3	Portage	SB[3]	May 22/85	3.2x6	Amazone 300ZT	18.75	300	bromoxynil MCPA
4	Teulon	SSP[4]	May 26/84	3x6	cone-single	30.0	173	
4	Portage	SSP	May 28/84	3x6	cone-single disc openers	30.0	173	dicamba MCPA

1. randomized complete
2. split plot
3. split block
4. split-split plot
5. Product of Amazone Farm Machinery Ltd. Kemnay, Mb.

Table 3.10. Zadoks decimal code for the growth stages of cereals [1].

CODE	
0-09	Germination
10-19	Seedling growth
20-29	Tillering
3	Stem Elongation
30	Pseudo stem erection
31	First node detectable
32	Second node detectable
33	Third node detectable
34	Fourth node detectable
35	Fifth node detectable
36	Sixth node detectable
37	Flag leaf just visible
38	-
39	Flag leaf ligule/collar just visible
4	Booting
40	-
41	Flag leaf sheath extending
42	-
43	Boots just visibly swollen
44	-
45	Boots swollen
46	-
47	Flag leaf sheath opening
48	-
49	First awn visible
5	Inflorescence Emergence
50	First spike of inflorescence just visible
51	-
52	1/4 of inflorescence emerged
53	-
54	1/2 of inflorescence emerged
55	-
56	3/4 of inflorescence emerged
57	-
58	Emergence of inflorescence completed
59	-
60-69	Anthesis
70-79	Milk Development
80-89	Dough Development
90-99	Ripening

1. From Zadoks *et al.*, 1974

Table 3.11 Field trial spray details and growth observations.

Experiment	Plant Growth Regulator	Growth Stage (Zadoks)	Application Date	Water Volume (l/ha)	Internodes Measured	Plant Height	Head Density	Tiller count
1	ethephon mepiquat chloride	39-45	July 9	214	all	+	+	-
1	ethephon mepiquat chloride	39	July 17	214	all	+	+	-
2	ethephon	41-45	July 23	214	all	+	+	+
3	ethephon mepiquat chloride	39-45	July 23	214	none	+	+	-
4	ethephon	45-48	July 11, 16, 16, 19*	250	peduncle	+	+	-
4	ethephon	45-48	July 10, 10, 15, 18*	250	peduncle	+	+	-

* in order of application, Bonanza, Johnston, Norbert and Klages

The basal internode was designated as being internode 1; the following internode being designated internode 2 and so on up to the peduncle (Lasson, 1988). Only plants with six internodes were used in this study. Details on PGR application and crop sampling are presented in Table 3.11.

At harvest the number of heads per meter square were reported in all plots. Grain yield measurements were taken and in 1985 grain samples were dried for 24 hours at 100 C in a forced air drying oven. Thousand kernel weight was determined for all grain samples.

Lodging ratings were taken as required throughout the growing season and at harvest. The Belgian Lodging Scale was used to evaluate the degree of lodging in the plot area. This measurement incorporates both the surface area of the plot lodged and the severity of the lodging (Table 3.12). A total of eleven cultivars of barley were evaluated in this study. Refer to Table 3.13 for a description of the agronomic characteristics of these cultivars.

3.2 Detailed Procedures

3.2.1 Experiment 1 The effect of varying rates of ethephon and ethephon/mepiquat chloride on the height and yield of Bedford barley planted on May 10 and June 7 at Portage la Prairie, 1985.

The planting dates of the two trials were four weeks apart (May 10 and June 7). Prior to seeding, 100 kg/ha. of actual nitrogen, ammonium nitrate, was broadcast over the area where the May 10 seeding site was established. No fertilizer was applied to the area where the June 7 seeding site was established. This experiment was

Table 3.12 The Belgian Lodging Scale

Parameter	Range of Measurement
Surface area	1.0 to 9.0
Intensity of lodging	1.0 to 5.0
Factor	0.2

Formula= Surface area x Intensity x 0.2
= 0.2 to 9.0
0.2= no lodging
9.0=completely lodged

designed to test the effect of ethephon and ethephon/mepiquat chloride on the plant height and internode length of Bedford barley. The experiments were established as a randomized complete block with ten treatments and four replicates. The treatments were: 1) untreated check, 2) 100 g ai/ha ethephon, 3) 200 g ai/ha ethephon, 4) 300 g ai/ha ethephon, 5) 400 g ai/ha ethephon, 5) 500 g ai/ha ethephon, 7) 600 g ai/ha ethephon, 8) 155 g ai/ha ethephon plus 205 g ai/ha mepiquat chloride, 9) 233 g ai/ha ethephon plus 307 g ai/ha mepiquat chloride and 10) 310 g ai/ha ethephon plus 410 g ai/ha mepiquat chloride.

Twenty one days after treatment, and at harvest, 20 plants were randomly selected and plant height, internode length and the number of

Table 3.13 Agronomic characteristices of the barley cultivars tested*

Cultivar	Type	Maturity	Straw Height	Straw Strength	Lodging (0-9)**
Argyle	6-row malting	mid-late	mid-long long	weak	2.2
Bedford	6-row feed	mid season	mid-short	strong	2.2
Bonanza	6-row malting	mid-late	mid-short	strong	2.2
Heartland	6-row feed	mid-late	short	strong	2.2
Herta	2-row feed	mid-late	mid-long	strong	n/a
Johnston	6-row feed	late	medium	weak	3.7
Klages	2-row malting	mid-late	mid-short	strong	3.1
Leduc	6-row feed	mid season	mid-short	medium	3.5
Norbert	2-row feed	mid-late	medium	very strong	1.9
Samson	6-row feed	mid-late	semi-dwarf	very strong	2.0
BT 363	6-row feed	late	mid-long	strong	2.5

* Cultivar characteristics reported in this table are based on data reported in Can. J. Plant Sci., Agriculture Canada Description of Variety and SeedScoop

** 0= no lodging 9.0= completely lodged

mature tillers was determined. Plots seeded on June 7 were harvested using a Hege small plot combine and the harvested area was 7.6 m^2. In plots seeded on May 10, 2 one-square meter quadrants of barley were hand sampled and threshed using a Hege small plot combine.

3.2.2 Experiment 2 The effect of ethephon on the height and yield of Johnston and Bedford barley, at Winnipeg, 1985.

The experiment was designed to test the effect of ethephon, 300 g ai/ha, on two six-row barley cultivars, Bedford and Johnston. No soil tests were taken from the plot area, however, prior to seeding 80 kg/ha of actual nitrogen, ammonium nitrate, was broadcast over the plot area. Seven days after ethephon treatment and at harvest, 20 plants were randomly selected and plant height and internode length measurements of the main culm were determined. At harvest, 2 square meters of barley were hand sampled and threshed using a Hege small plot combine. Protein content was determined from the harvested grain sample (Kjeldahl method).

3.2.3 Experiment 3 The effect of ethephon and ethephon/mepiquat chloride on the growth and yield of nine spring barley cultivars at Portage la Prairie, 1985.

The experiment was conducted to determine the effect of ethephon and ethephon/mepiquat chloride on nine spring barley cultivars. The nine cultivars, Bonanza, Sampson, Herta, Bedford, Norbert, BT363 (unlicensed barley from Agriculture Canada, Brandon, Manitoba), Argyle, Herta, Heartland and Leduc, were seeded in a randomized complete block design with four replicates. Each block was then split with four growth regulator treatments: 1) untreated, 2) 240 g ai/ha ethephon, 3) 400 g ai/ha ethephon and 4) 310 g ai/ha ethephon and 410 g ai/ha mepiquat chloride.

Although no soil test was taken, prior to emergence, the experimental area was fertilized with 100 kg/ha of actual nitrogen (ammonium nitrate).

At harvest, fifteen plants were randomly selected from each plot and plant heights were determined. Plots were harvested using a Hege small plot combine and the harvested area was 7.6 m^2.

3.2.4 Experiment 4 The effect of nitrogen and ethephon on the height and yield of four barley cultivars at Teulon and Portage, 1984.

The experiment was designed to determine the effect of ethephon on two six-row barley cultivars, Bonanza and Johnston and two two-row barley cultivars, Norbert and Klages at three levels of nitrogen. A split-split plot design was used. The main plots were cultivar, the sub plots, the level of nitrogen and the sub-sub plots were the ethephon treatments. Treatments consisted of ethephon at 300 g ai/ha and an untreated check.

From soil tests taken in the spring of 1984 at both locations, it was determined that 40 kg/ha of available nitrogen occurred in the 0 to 60 cm profile at both locations. Additional nitrogen, ammonium nitrate, was applied as a spring broadcast treatment prior to seeding. The levels of additional nitrogen were 20, 50 and 80 kg/ha of actual nitrogen.

At harvest, fifteen plants were randomly selected from each plot and the plant height and peduncle length were measured. Plots were harvested by using a Hege small plot combine and the harvested area was 7.6 m^2.

3.3 Statistical Analysis

Data collected from all experiments was handled in a similar manner. All growth and yield data was subjected to an analysis of variance. Multiple comparisons of the means were made using either the Duncan's Multiple Range Test or by comparing LSD values. Data collected using the Belgian Lodging Scale was not subjected to statistical analysis. Only differences at the 5% level were considered meaningful.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Experiment 1 The effect of varying rates of ethephon and ethephon/mepiquat chloride on the height and yield of Bedford barley planted on May 10 and June 7 at Portage la Prairie, 1985.

4.1.1 May 10 Seeding

4.1.1.1 Plant Height and Internode length

At 21 days after treatment (DAT) and harvest, plant height was reduced by all treatments, except ethephon applied at 100 g ai/ha (Table 4.1 and 4.2). The reduction in plant height was a result of reductions in the length of internodes 4 and 5 and the peduncle. Internodes 1, 2 and 3 were not affected by the PGR treatments. The increase in height of the plants from the 21 DAT sampling time to harvest was a result of an increase in length of internode 5 and the peduncle.

Ethephon applied at 600 g ai/ha resulted in a 17.2 and 22.3 cm reduction in plant height at 21 DAT and harvest respectively. The PGR treatments were most effective in reducing internode 5, at both sampling dates. The addition of mepiquat chloride to ethephon did not have an additive effect in reducing overall plant height at harvest.

4.1.1.2 Lodging

Lodging was reduced or prevented with all PGR treatments

Table 4.1 The effect of ethephon and ethephon/mepiquat chloride on the internode length and plant height of Bedford barley (May 10 seeding, 21 days after treatment)

Treatment	Rate (gai/ha)	Internode length (cm) 1	2	3	4	5	Peduncle length (cm)	Plant height (cm)
check	0	6.2	14.8	17.8	17.3a	15.9a	13.5abc	85.5a
ethephon	100	5.8	14.2	17.5	16.0ab	14.9a	16.2a	84.5a
ethephon	200	5.2	14 2	17.4	14.7ab	13.4b	14.3ab	79.0b
ethephon	300	5.9	14.5	17.5	14.7ab	12.7bc	13.2bc	78.4b
ethephon	400	5.1	14.0	17.4	13.2bc	11.0de	12.3bc	73.0cd
ethephon	500	6.2	14.9	17.6	13.8bc	9.9e	12.1bc	74.4bc
ethephon	600	6.1	15.2	15.4	11.1c	9.8e	10.8c	68.3d
ethephon/ mepiquat chloride	155 205	6.1	14.7	17.1	14.7	12.4bcd	14.2ab	79.2b
ethephon/ mepiquat chloride	233 307	5.9	14.7	17.7	13.2bc	11.4cd	13.3bc	76.4bc
ethephon/ mepiquat chloride	310 410	5.6	14.0	17.5	14.1b	11.1de	12.9bc	75.2bc
LSD (0.05)		ns	ns	ns	2.9	1.4	2.8	7.1

Means within a column followed by the same letter are not significantly different at alpha=0.05

Table 4.2 The effect of ethephon and ethephon/mepiquat chloride on the internode length and plant height of Bedford barley (May 10 seeding, at harvest)

Treatment	Rate (gai/ha)	Internode length (cm) 1	2	3	4	5	Peduncle length (cm)	Plant height (cm)
check	0	6.1	14.7	18.0	17.2a	18.6a	20.3a	100.5a
ethephon	100	5.4	14.0	17.5	16.6ab	15.8b	19.2ab	93.9ab
ethephon	200	5.8	14.2	17.3	14.6abc	13.4c	17.5bc	88.1bc
ethephon	300	6.2	14.4	17.0	15.4ab	13.3c	17.1bcd	88.7bc
ethephon	400	6.0	13.9	16.9	13.7bc	11.9cde	16.3bcd	84.2cd
ethephon	500	5.3	13.3	17.1	13.8bc	10.3de	14.5d	79.5d
ethephon	600	5.6	13.9	16.3	11.2c	10.2e	15.8cd	78.2d
ethephon/ mepiquat chloride	155 205	5.5	14.2	17.7	14.9ab	13.1c	17.4bc	88.0bc
ethephon/ mepiquat chloride	233 307	6.2	14.7	17.5	13.6bc	13.1c	17.7abc	88.4bc
ethephon/ mepiquat chloride	310 410	5.6	14.0	17.3	14.3abc	12.5cd	17.1bcd	86.2c
LSD (0.05)		ns	ns	ns	3.1	2.2	2.8	7.0

Means within a column followed by the same letter are not significantly different at alpha=0.05

(Table 4.3). Lodging was evident on August 9 in most of the plots, but by the August 27 evaluation date all plants had recovered from the lodging, except those treated with the lowest two rates of ethephon. At harvest, lodging was prevented with all treatments, except ethephon applied at 100 and 200 g ai/ha. The addition of mepiquat chloride to ethephon reduced lodging to a greater degree than a similar rate of ethephon applied alone. Lodging was of the bending type.

4.1.1.3 Grain Yield

Final grain yield was not affected by any PGR treatment, however, only ethephon applied at 100 g ai/ha resulted in yields measuring less than the untreated check plot (Table 4.4). Although yield measurements from the PGR treated plots were not significantly different from the check plot, there was an apparent increase in yield with increasing rates of ethephon/mepiquat chloride.

4.1.1.3.1 Yield Components

Final head density was not affected by PGR treatment, however, ethephon applied at 200 g ai/ha resulted in fewer number of heads, when compared to the untreated check (Table 4.4). The application of a PGR did not affect the number of mature tillers/plant.

Kernel weight and seeds per head were not affected by PGR treatment.

4.1.2 June 7 Seeding

Table 4.3 The effect of ethephon and ethephon/mepiquat chloride on the lodging of Bedford barley

Treatment	Rate (gai/ha)	May 10 seeding		June 7 seeding	
		Aug. 09	Aug. 27	Aug. 09	Aug. 27
check	0	3.8	3.2	0.2	4.0
ethephon	100	1.8	3.2	0.2	1.9
ethephon	200	1.2	1.5	0.2	1.1
ethephon	300	0.7	0.2	0.2	0.2
ethephon	400	0.4	0.2	0.2	0.2
ethephon	500	0.2	0.2	0.2	0.2
ethephon	600	0.4	0.2	0.2	0.2
ethephon/ mepiquat chloride	155 205	0.9	0.2	0.2	0.2
ethephon/ mepiquat chloride	233 307	0.8	0.2	0.2	0.2
ethephon/ mepiquat chloride	310 410	1.3	0.2	0.2	0.2

Table 4.4 The effect of ethephon and ethephon/mepiquat chloride on the yield and yield components of Bedford barley (May 10 seeding)

Treatment	Rate (gai/ha)	Yield (g/m2)	Heads/m2	Thousand Kernel wt (g)	Seeds/ head	Tillers/ plant
check	0	398	350	33.2	34.2	1.5
ethephon	100	378	366	32.9	30.7	1.9
ethephon	200	460	336	33.0	41.5	0.9
ethephon	300	426	367	33.0	35.4	0.9
ethephon	400	438	351	33.5	37.4	1.4
ethephon	500	416	366	33.4	34.1	1.4
ethephon	600	422	390	33.1	33.5	1.2
ethephon/ mepiquat chloride	155 205	437	392	32.1	35.0	1.2
ethephon/ mepiquat chloride	233 307	469	399	33.6	36.2	1.4
ethephon/ mepiquat chlorine	310 410	468	396	33.8	34.2	1.3
LSD (0.05)		ns	ns	ns	ns	ns

Means within a column followed by the same letter are not significantly different at alpha=0.05

4.1.2.1 Plant Height and Internode Length

At 21 DAT plant height was reduced by all treatments, however, reductions in height were not significant (Table 4.5). The apparent reduction in plant height was a result of reductions in the length of internodes 4 and 5. Internodes 1, 2, and 3 and the peduncle were not affected by PGR treatment. At harvest, plant height was reduced by the PGR treatments (Table 4.6). Although ethephon applied at 100 and 300 g ai/ha and ethephon/mepiquat chloride applied at 155/205 and 233/307 g ai/ha did not significantly reduce plant height, the plant height was 5.2 to 7.8 cm less than the height of plants in the untreated plots. Reductions in plant height was a result of reductions in the length of internode 4 and the peduncle at harvest. The increase in plant height from 21 DAT to harvest was a result of a 14.1 cm increase in the length of the peduncle. At harvest, the PGR treatments were most effective in reducing the length of the peduncle. The addition of mepiquat chloride to ethephon did not result in a greater decrease in plant height than when ethephon was applied alone.

4.1.2.2 Lodging

Lodging was reduced or prevented with the PGR treatments (Table 4.3). Lodging was not evident on August 9 in any of the plots, but did occur in some plots on August 27. On August 27, lodging was prevented with all treatments, except ethephon applied at the lowest two rates. The addition of mepiquat chloride to ethephon reduced lodging to a greater degree than similar rates of ethephon applied alone. Lodging was of the bending type.

Table 4.5 The effect of ethephon and ethephon/mepiquat chloride on the internode length and plant height of Bedford barley (June 7 seeding, 21 days after treatment)

Treatment	Rate (gai/ha)	Internode length (cm) 1	2	3	4	5	Peduncle length (cm)	Plant height (cm)
check	0	5.4	11.3	13.1	13.4a	14.3a	11.9	69.3
ethephon	100	4.8	10.8	13.3	13.0ab	14.1a	11.2	67.2
ethephon	200	5.6	11.5	13.2	11.8bcde	11.9bc	10.3	64.1
ethephon	300	4.2	10.4	13.2	12.0bcd	11.9bc	11.2	62.7
ethephon	400	5.5	11.5	12.9	10.6de	11.2c	10.2	61.4
ethephon	500	5.5	11.2	13.0	10.5e	10.8c	9.3	60.3
ethephon	600	5.4	11.7	13.3	10.4e	10.7c	10.2	61.5
ethephon/ mepiquat chloride	155 205	4.6	10.4	13.1	12.2abc	13.1ab	12.7	66.0
ethephon/ mepiquat chloride	233 307	5.2	11.5	13.8	11.9bcde	12.0bc	12.3	66.6
ethephon/ mepiquat chloride	310 410	5.3	11.6	13.6	11.4bcde	11.2c	11.1	64.0
LSD (0.05)		ns	ns	ns	1.4	1.7	ns	ns

Means within a column followed by the same letter are not significantly different at alpha=0.05

Table 4.6 The effect of ethephon and ethephon/mepiquat chloride on the internode length and plant height of Bedford (June 7 seeding, at harvest)

Treatment	Rate (gai/ha)	Internode length (cm) 1	2	3	4	5	Peduncle length (cm)	Plant height (cm)
check	0	4.0	9.7	12.4	12.8ab	16.8	26.0a	87.3a
ethephon	100	4.0	10.3	13.1	12.0abc	13.5	21.3b	79.5abc
ethephon	200	4.3	10.3	12.6	11.0cde	13.4	21.7b	79.0bc
ethephon	300	4.5	10.3	12.6	11.3cde	14.7	21.7b	80.6abc
ethephon	400	4.1	9.5	12.2	11.3cde	13.0	20.8b	76.4bc
ethephon	500	3.9	9.3	11.7	10.0e	13.7	20.0b	74.2c
ethephon	600	5.0	11.0	12.9	10.5de	12.2	19.1b	76.0bc
ethephon/ mepiquat chloride	155 205	3.9	10.4	13.3	12.9a	15.3	20.7b	82.1ab
ethephon/ mepiquat chloride	233 307	4.0	10.3	13.1	12.1abc	14.5	22.4ab	81.8ab
ethephon/ mepiquat chloride	310 410	4.1	10.3	12.8	11.4abcd	13.9	21.5b	79.2bc
LSD (0.05)		ns	ns	ns	1.6	ns	3.9	7.7

Means within a column followed by the same letter are not significantly different at alpha=0.05

4.1.2.3 Grain Yield

Final grain yield was not affected by PGR treatment (Table 4.7). Although yield differences are not significant, there is an apparent increase in yield with increasing rates of ethephon/mepiquat chloride.

4.1.2.3.1 Yield Components

Head density was not affected by PGR treatment, except in the plots where ethephon was applied at 100 g ai/ha in which case there were fewer heads when compared to the untreated plots (Table 4.7). The PGR treatments did not, however, affect the number of mature tillers/plant.

Kernel weight and seeds per head were not affected by PGR treatment.

4.1.3 Discussion

The plants seeded on May 10 matured slower than the plants seeded on June 7. The time of seeding and consequent environmental conditions for growth, resulted in differences in plant development of the two trials. The earlier seeded plants were taller than the later seeded plants, at both sampling dates, however, the peduncle accounted for a greater proportion of the plant height in the later seeded plants. The growth of the plant, from 21 DAT to harvest, as measured by increase in height, was solely the elongation of the peduncle with the later seeded plants. The growth of the early seeded plants was a result of the elongation of the fifth internode and the peduncle. This difference

Table 4.7 The effect of ethephon and ethephon/mepiquat chloride on the yield and yield components of Bedford barley (June 7 seeding)

Treatment	Rate (gai/ha)	Yield (g/m2)	Heads/m2	Thousand Kernel wt (g)	Seeds/ head	Tillers/ plant
check	0	508	381ab	34.2	39.2	2.0
ethephon	100	466	334c	35.9	38.9	1.4
ethephon	200	490	420a	34.9	33.2	1.9
ethephon	300	539	386ab	36.6	38.3	1.8
ethephon	400	517	354bc	35.6	41.3	1.5
ethephon	500	524	414a	33.8	37.4	1.6
ethephon	600	469	377abc	33.6	37.1	1.6
ethephon/ mepiquat chloride	155 205	510	362bc	35.8	39.5	1.4
ethephon/ mepiquat chloride	233 307	528	388ab	35.0	39.5	1.3
ethephon/ mepiquat chlorine	310 410	569	409a	36.3	38.4	1.7
LSD (0.05)		ns	46	ns	ns	ns

Means within a column followed by the same letter are not significantly different at alpha=0.05

is also reflected in that the plants seeded early had longer internodes than the later seeded plants. The later seeded plants may have been able to use late season moisture, which could increase peduncle elongation at a time when the early seeded plants were already maturing. A result of the different growth patterns of the two sites is the manner in which the PGR treatments reduced plant height. The plants seeded early showed significant reductions in internode 4 and 5 and the peduncle, whereas shortening of the plants seeded later occurred primarily through shortening of the peduncle.

Wunsche (1973), reported plant height reductions increased as rate of ethephon increased. The data in this experiment concurs with Wunsche's results, however, internodes affected and degree of reduction in plant height varied between the plants in the two trial sites, due to differences in plant development. Stanca (1979), reported ethephon was effective in reducing plant height, however, 200 g ai/ha were required for significant reductions, when compared to the untreated plots. In this study, at least 200 g ai/ha of ethephon is required to reduce plant height, with plants seeded later requiring 400 g ai/ha of ethephon to cause plant height reductions at harvest. With the PGR treatments affecting only the peduncle in the plants seeded later, a higher rate of ethephon is required to cause plant height reductions than plants seeded earlier, where the ethephon caused shortening of internodes 4, 5 and the peduncle.

Jinks and Marshall (1982), suggested the addition of mepiquat chloride to ethephon can enhance the straw shortening effect of the PGR; this did not occur in the experiment.

Although the addition of mepiquat chloride to ethephon did not enhance straw shortening, it caused the plant to be more resistant to lodging. This resistance to lodging may be a result of the straw strengthening affects of the mepiquat chloride as reported by Lasson, 1983, although not quantified in this study.

Yield and yield components were all greater in the plants seeded later, possibly due to differences in environment during development. The sampling method for the yield data varied with the two sites. Two, one-meter quadrants were removed from the earlier seeded trial for yield and yield component data, as mechanical harvesting was not possible because the site was under water. The later seeded site was harvested with a Hege combine, removing a sample size of 7.6 m^2. The difference in sampling methods make yield and yield component comparisons between sites unfair.

Yield and yield component data for each site indicates the PGR treatments having no effect, except with the later seeded plots, where PGR treatments had an effect on head density. This effect was not due to an increase in tillers per plant and can only be explained as random error, possibly due to variation in seeding or plant emergence.

A reduction in lodging as a result of PGR application did not result in a PGR effect on kernel weight as noted by Stanca _et al_, 1978. The lodging that occurred was not that severe, particularly at the later seeding, therefore effects of the PGR on kernel weight may not have been expressed. Had the lodging pressures been more severe treatment differences may have become evident for lodging, yield and yield components. With minimal lodging pressure, plant height was the most influenced parameter.

4.2 Experiment 2. The effect of ethephon on the height and yield of Johnston and Bedford barley at Winnipeg, 1985.

4.2.1 Plant Height and Internode Length

Ethephon caused a reduction in length of internodes 5, the peduncle and overall plant height 7 days after treatment (DAT) (Table 4.8). At harvest, there was a reduction in plant height, due to a reduction in the length of internode 3, 4 and 5 (Table 4.9).

Seven days after treatment the overall height of Bedford was greater than Johnston, due to greater elongation of internodes 2, 3, 5 and the peduncle (Table 4.8). At harvest, internode 5 and the spike of Bedford were longer, however, there are no differences in overall plant height (Table 4.9).

An interaction existed between ethephon and cultivar for internode 4, 7 DAT (Appendix A). Ethephon did not cause a reduction in the fourth internode of Johnston, however, caused a reduction at internode 4 with Bedford. With all other parameters both cultivars were affected in a similar manner. At harvest, the application of ethephon caused the cultivars to react differently at internode 5 (Appendix A).

Ethephon reduced overall plant height at both sampling times.

Plant height of Bedford was greater than the height of Johnston,

Table 4.8 The effect of ethephon and cultivar on plant height and internode length (7 days after treatment)

Treatment	Internode Length (cm)					Peduncle Length (cm)	Plant Height (cm)
	1	2	3	4	5		
PGR							
untreated	7.0	14.3	16.0	18.2	13.9a	6.3a	75.7a
ethephon	6.6	13.5	15.7	17.2	10.9b	4.9b	68.8b
	ns	ns	ns	ns			
VARIETY							
Bedford	7.3	15.1a	16.7a	17.4	15.5a	8.7a	80.7a
Johnston	6.0	12.7b	15.1b	18.0	9.3b	2.6b	63.7b
	ns			ns			

Means within the same column not followed by a letter are not significantly different at alpha=0.05 (LSD).

Table 4.9 The effect of ethephon and cultivar on plant height and internode length (at harvest).

Treatment	Internode Length (cm)					Peduncle Length (cm)	Plant Height (cm)
	1	2	3	4	5		
PGR							
untreated	5.8	13.3	16.6a	19.5a	19.2a	20.8	101.2a
ethephon	7.3	13.8	15.5b	17.3b	17.6b	18.6	96.1b
	ns	ns				ns	
VARIETY							
Bedford	5.4	14.0	16.3	18.0	19.9a	20.9	100.2
Johnston	7.5	13.1	15.9	18.8	16.9b	18.5	97.0
	ns	ns	ns	ns			ns

Means within the same column not followed by a letter are not signsignificantly different at alpha=0.05 (LSD).

7 DAT; however, at maturity there was no difference (Figure 4.1 and 4.2). At 7 DAT it was evident the reduction in length of internode 5 and the peduncle contributed more than internode 1, 2, 3 and 4, in reducing the overall plant with applications of ethephon. At harvest, shortening of internodes 3, 4, 5 and the peduncle all contributed to the reduction in total plant height caused by the ethephon. Figure 4.2 suggests that the cultivar Bedford reacts differently than Johnston to the ethephon application, however, an ethephon by cultivar interaction was determined to occur only for internode 5, 7 DAT.

4.2.2 Lodging

Lodging ratings were taken after each rain storm, three times during the growing season and at harvest. The application of ethephon reduced lodging at all evaluation dates (Table 4.10). Johnston barley was observed to be less resistant to lodging compared to Bedford. At the first evaluation, the untreated plots of both cultivars exhibited some lodging (Table 4.11). Bedford treated with 300 g ai/ha of ethephon was the only plot to remain completely erect throughout the growing season. As the season progressed the ethephon treatments were effective in preventing Bedford from lodging, however, failed with Johnston on the July 28 evaluation. At maturity, August 30, the brittle straw and the poor anchorage in the waterlogged soil caused all plots to

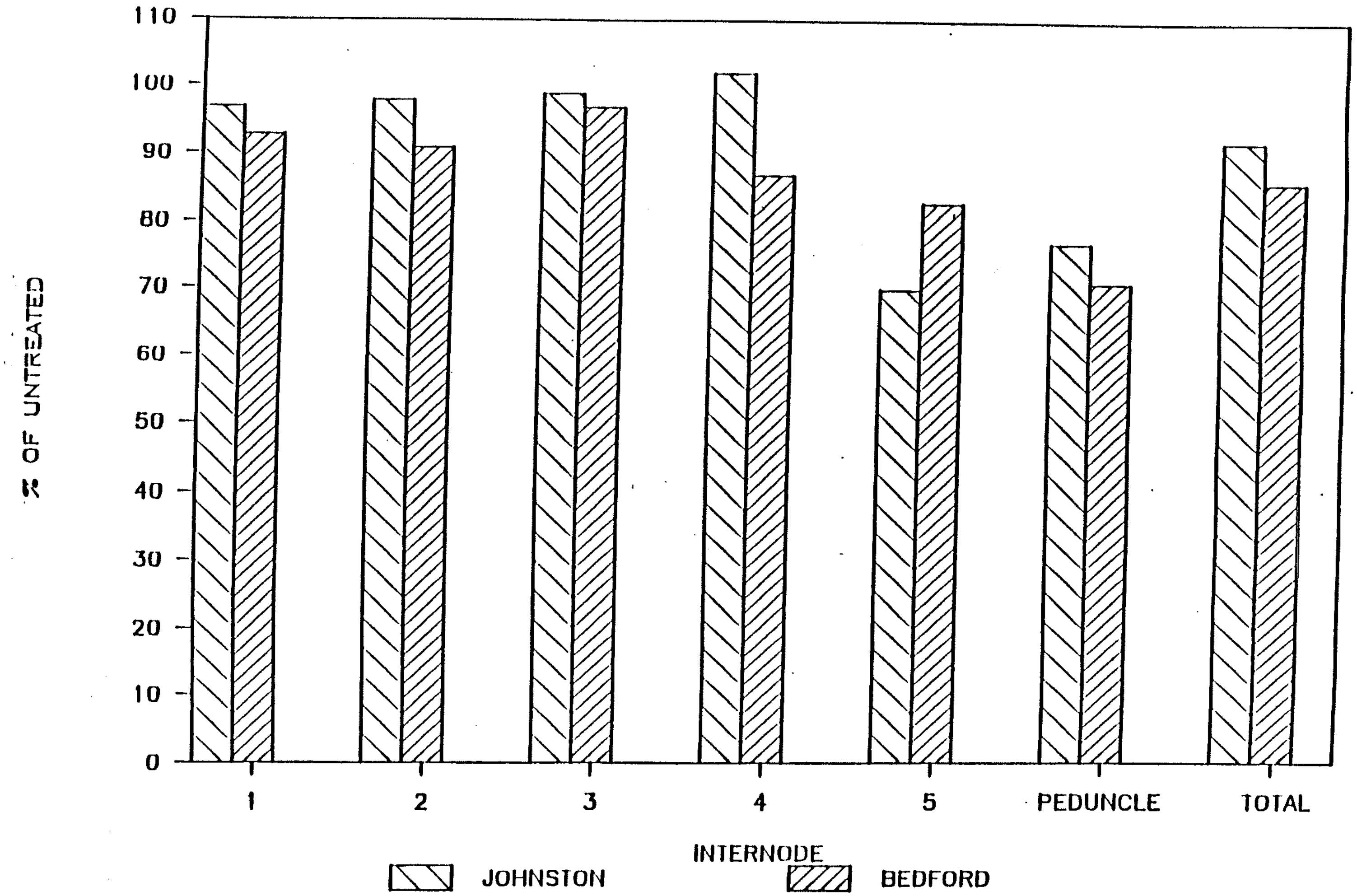


Figure 4.1 The effect of ethephon on the internode length and total plant height of Bedford and Johnston barley, 7 days after treatment

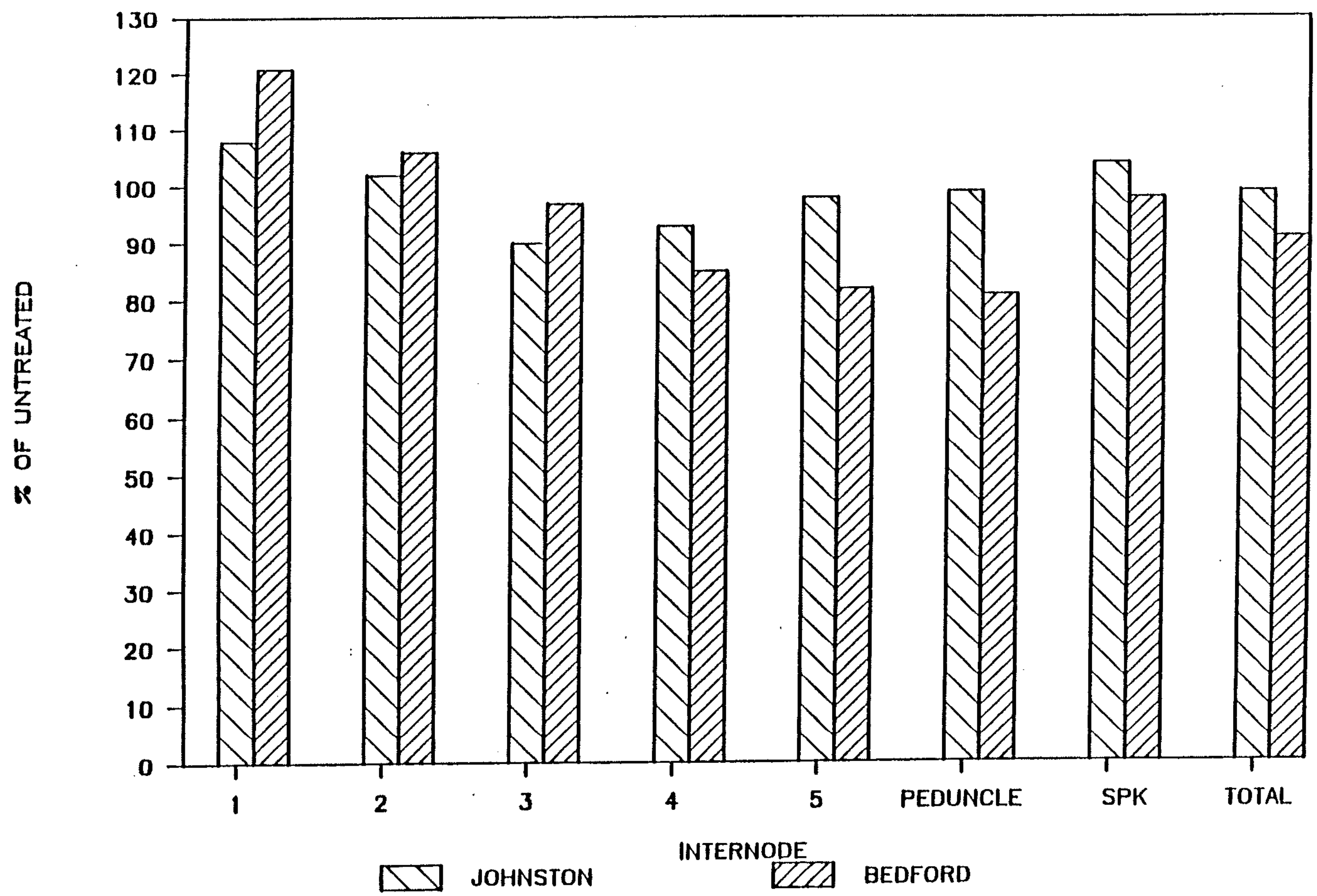


Figure 4.2 The effect of ethephon on the internode length, length of spike and total plant height of Bedford and Johnston barley, at harvest

Table 4.10 The effect of ethephon and cultivar on lodging.

Treatment	Lodging Rating*			
	July1	July 17	July 28	August 30
PGR				
untreated	2.5	2.0	5.7	9.0
ethephon 300g ai/ha	0.3	0.9	3.7	8.5
CULTIVAR				
Bedford	0.9	0.4	2.2	8.5
Johnston	1.8	2.6	7.2	9.0

*based on the Belgian Lodging Scale

Table 4.11 The effect of ethephon on lodging.

Treatment	Lodging Ratings*			
	July 1	July 1	July 2	August 30
Johnston-0 ethephon	4.5	3.5	7.3	9.0
Johnston-300 gai/ha ethephon	0.4	1.7	7.2	9.0
Bedford-0 ethephon	1.6	0.6	4.2	9.0
Bedford-300 gai/ha ethephon	0.2	0.2	0.2	8.1

*based on the Belgian Lodging Scale

Table 4.12 The effect of cultivar and ethephon on yield and yield components and protein measurements

Treatment	Heads/ m2	Seeds/ Head	1000 Kernel Weight (g)	Yield (g)	Protein (%)
PGR					
untreated	286	40.4	35.6	417	15.0
ethephon 300 g/ ha	299	37.9	35.4	405	15.0
VARIETY					
Bedford	301	40.3a	38.9a	506a	14.9
Johnston	283	35.0b	32.1b	317b	15.1

Means within a column not followed by a letter are not significantly different at alpha=0.05 (LSD) lodge severely.

4.2.3 Grain Yield

Ethephon had no effect on yield, yield components or kernel protein. The cultivars differed in final yield, thousand kernel weight and seeds/head, but not in plant density or protein content (Table 4.12). There were no significant cultivar by ethephon interactions for yield or protein measured. The cultivar Johnston, although producing the same number of heads per unit area as Bedford, produced less seeds per head and had a lower kernel weight (Table 4.12).

4.2.4 Discussion

As suggested by Brown and Early (1973), the peduncle alone is not the only internode affected by ethephon applications. Seven DAT, the peduncle and internode 5 were reduced with the application of ethephon, which resulted in overall plant height reductions. At harvest, the third, fourth and fifth internodes of Bedford barley were reduced with the application of ethephon, resulting in overall plant height reductions. The application of ethephon at Zadoks 45 may affect the peduncle more than the other internodes as suggested by Dahnous *et al.* (1982).

Ethephon applied at 300 g ai/ha reduced lodging with both cultivars until late August, with Bedford barley being more lodging resistant than Johnston. The use of lodging resistant cultivars would appear to be an effective method in reducing the lodging in barley rather than the use of ethephon on cultivars with poor lodging resistance.

Johnston and Bedford barley vary in straw strength, plant height and lodging resistance. Although Johnston is a high yielding cultivar as described by Wolfe (1980) the potential yield is not attained when grown under conditions where lodging occurs. The application of 300 g ai/ha of ethephon is not effective in preventing Johnston from lodging and thereby reaching its full yield potential. In comparison, Bedford is better adapted in reaching its yield potential when grown in conditions that cause lodging. When selecting a cultivar to be grown in a particular geography, the overall performance of the cultivar must complement the geography, so that the yield potential of the cultivar can be attained.

In this experiment, the application of ethephon did not affect yield or yield components. Bedford barley had a higher yield than Johnston because of an increase in number of seeds/head and a higher kernel weight. The increase in yield may be due to Bedford being protected from lodging for a longer period in the season, as suggested by Stanca _et al_. (1979).

4.3 _Experiment 3_. The effect of ethephon and ethephon/mepiquat chloride on the growth and yield of nine barley cultivars at at Portage la Prairie, 1985.

4.3.1 _Plant Height_

In all treated plots, plant height was less than in the untreated control plots, when cultivars were grouped (Table 4.13). Ethephon at 400 g ai/ha and ethephon/mepiquat chloride at 310/420 g ai/ha reduced plant height more than ethephon at 240 g ai/ha. All plant growth regulator treatments caused plant height reductions ranging from 9 to 13 percent.

When the data was sorted by cultivars, all plant growth regulator treatments caused a reduction in plant height, with the exception of Leduc barley (Figure 4.3). Generally, plant height reductions increased with rate of ethephon.

4.3.2 Lodging

All PGR treatments reduced lodging at both evaluation dates (Table 4.13). Lodging increased from August 9 to September 16. On August 9, in untreated plots, Samson, Argyle and Heartland scored less than 5.0. At harvest only Leduc scored less than 5.0. On August 9, lodging was less in plots treated with high rates of ethephon. Cultivars rated as having fair to good lodging resistance, lodged greater than cultivars rated as having with excellent lodging resistance. On September 16, lodging was generally reduced where high rates of ethephon were applied; however, this varied somewhat by cultivar (Figure 4.4 and 4.5).

The cultivar Herta exhibited poor lodging resistance at both evaluation dates. Bonanza was completely lodged on September 16 in both treated and untreated plots. Samson and Heartland, both shorter statured cultivars, had similar lodging responses on August 9. On September 16, Samson had lodged more than Heartland. The PGR treatments reduced the lodging of Argyle on August 9, but had little

Table 4.13 The effect of ethephon and ethephon/mepiquat chloride on the plant height and lodging ratings of nine barley cultivars

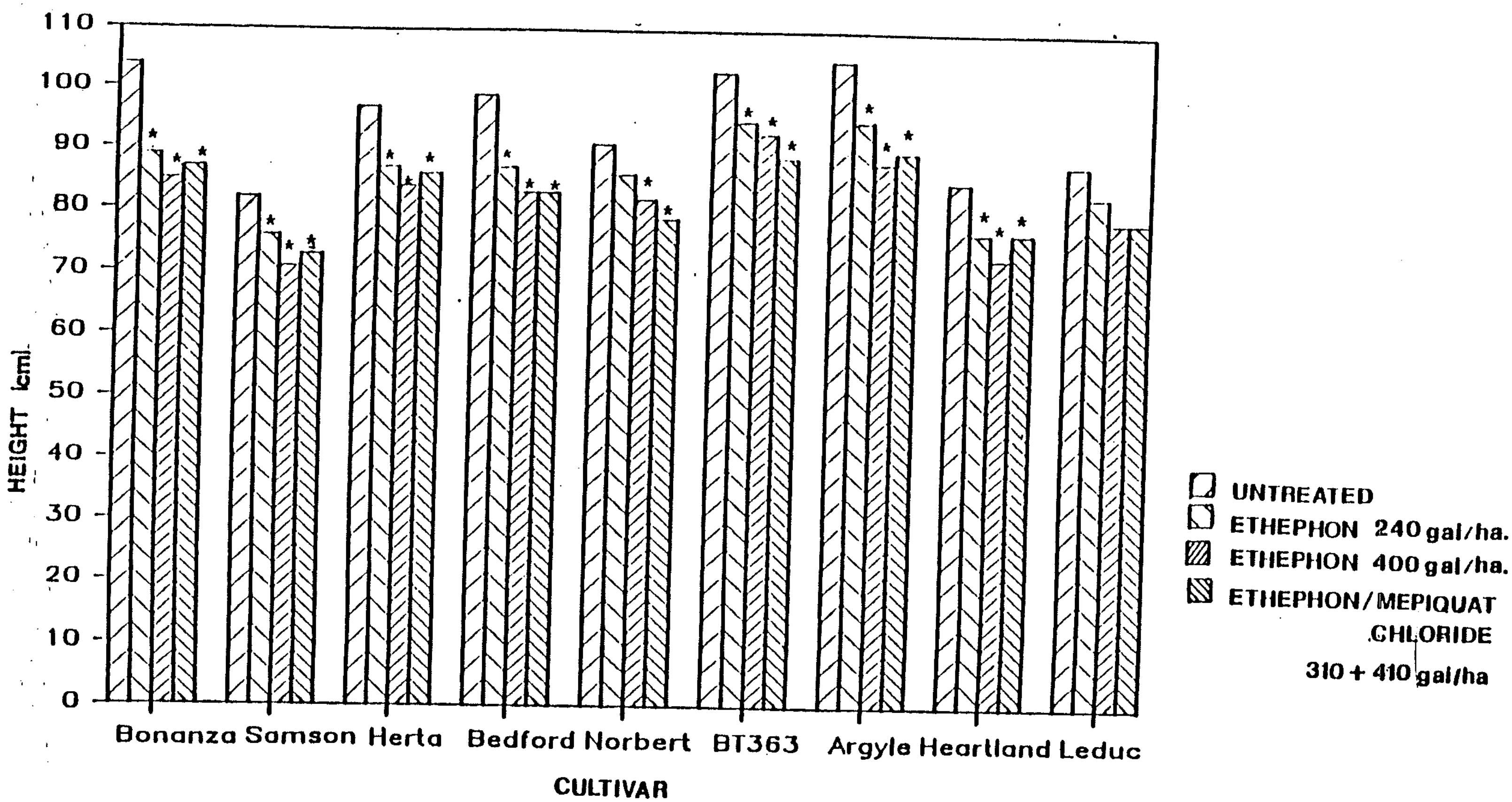
Treatment	Rate (g ai/ha)	Plant Height (cm)	Reduction in Plant Height (%)	Lodging Ratings Aug. 09	Aug. 16
check	0	94.5a	0	5.7	7.1
ethephon	240	85.9b	10	2.6	5.1
ethephon	400	81.9c	13	1.5	3.5
ethephon/ mepiquat chloride	310 420	82.5c	13	1.4	4.3
LSD (0.05)					

Means within a column followed by the same letter are not significantly different at alpha=0.05 (LSD)

Table 4.14 The effect of ethephon and ethephon/mepiquat chloride on the yield and yield components of nine barley cultivars

Treatment	Rate (g ai/ha)	Heads/ m2	Seeds/ head	1000 kernel weight (g)	Yield (g/m2)
check	0	438a	23.9ab	38.1	259b
ethephon	240	453a	26.7c	38.4	297a
ethephon	400	491b	22.0a	38.3	264b
ethephon/ mepiquat	310 410	459a	24.8bc	38.5	274b
LSD (0.05)				ns	

Means within a column followed by the same leter are not significantly different at alpha=0.05 (LSD)



* significantly different from the untreated check at aplha=0.05

Figure 4.3 The effect of ethephon and ethephon/mepiquat chloride on the plant height of nine barley cultivars

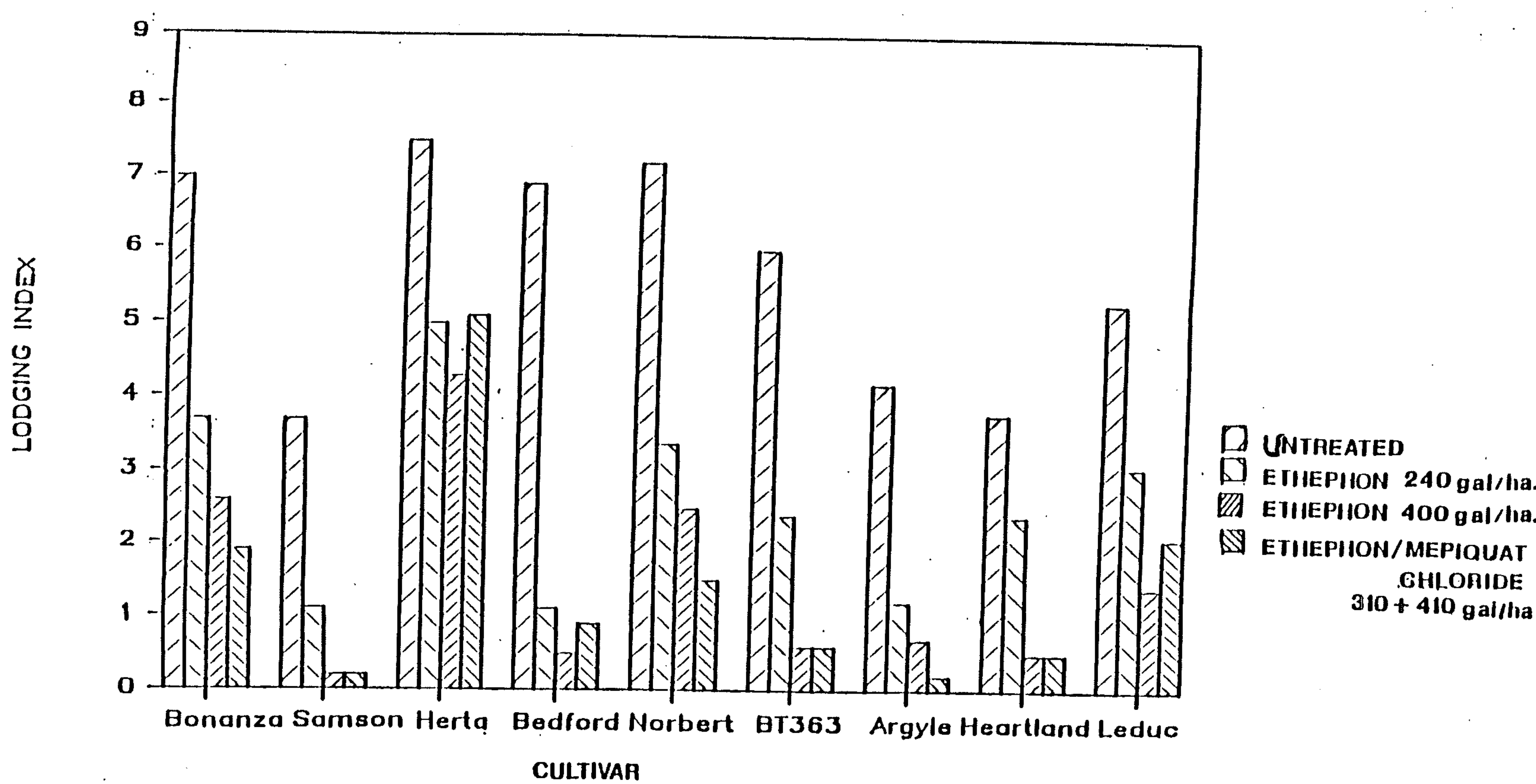


Figure 4.4 The effect of ethephon and ethephon/mepiquat chloride on the August 9 lodging ratings of nine barley cultivars

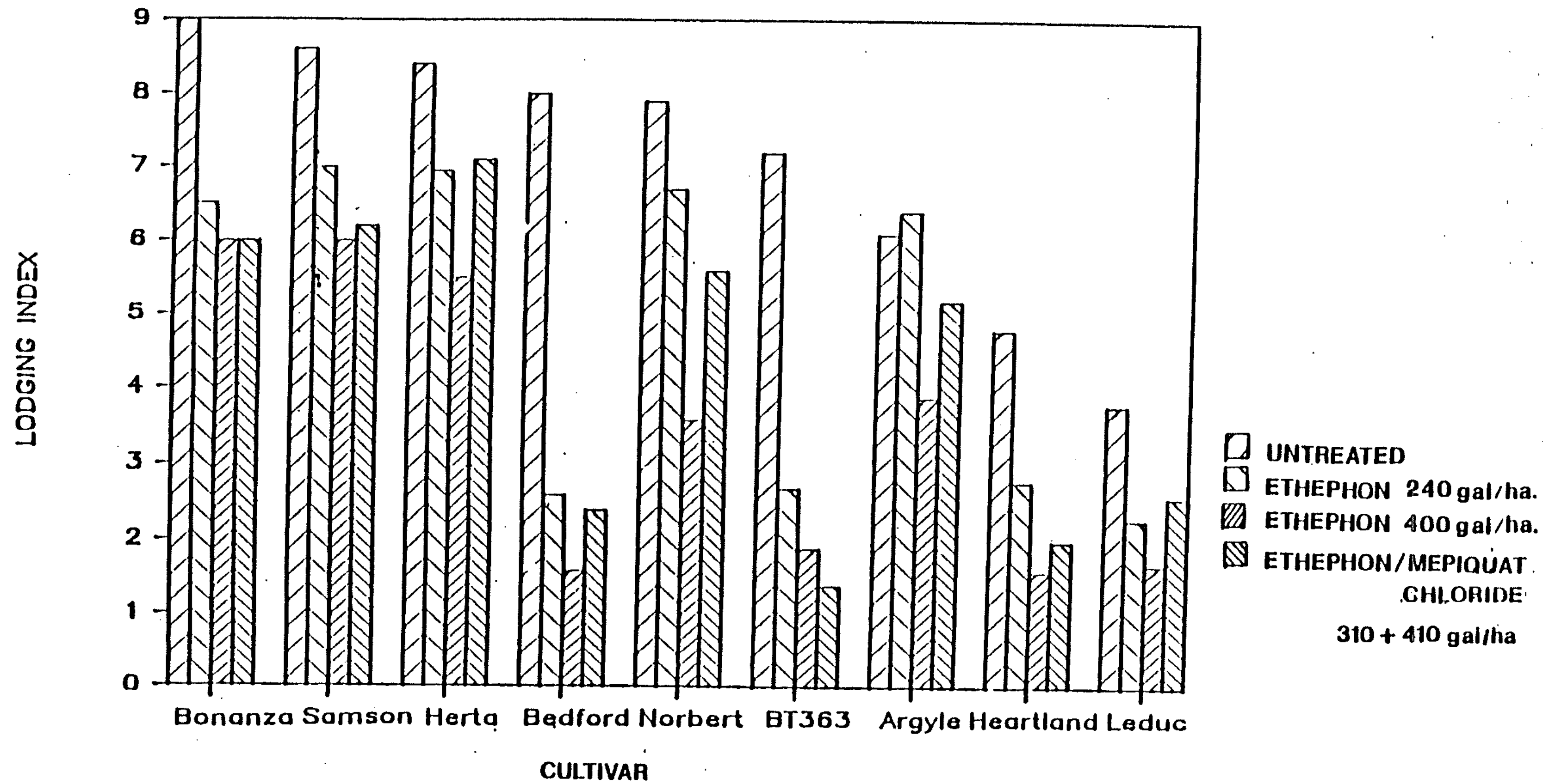


Figure 4.5 The effect of ethephon and ethephon/mepiquat chloride on the September 16 lodging ratings of nine barley cultivars

effect on September 16. Norbert and Bedford were lodged equally at both evaluation dates, however, the PGR treatments were more effective in reducing the lodging of Bedford.

PGR's can reduced lodging with Bedford and BT 363, by up to 5.5 points, whereas, cultivars like Leduc and Heartland are affected by the PGR, but to a lesser extent.

4.3.3 Grain Yield

The increase in yield noticed with applications of 240 g ai/ha of ethephon were apparent with all cultivars tested except Leduc (Table 4.14 and Figure 4.6).

There was an increase in final head density with the application of 400 g ai/ha of ethephon when cultivars were grouped. These increases in head density are apparent with most cultivars tested (Figure 4.7).

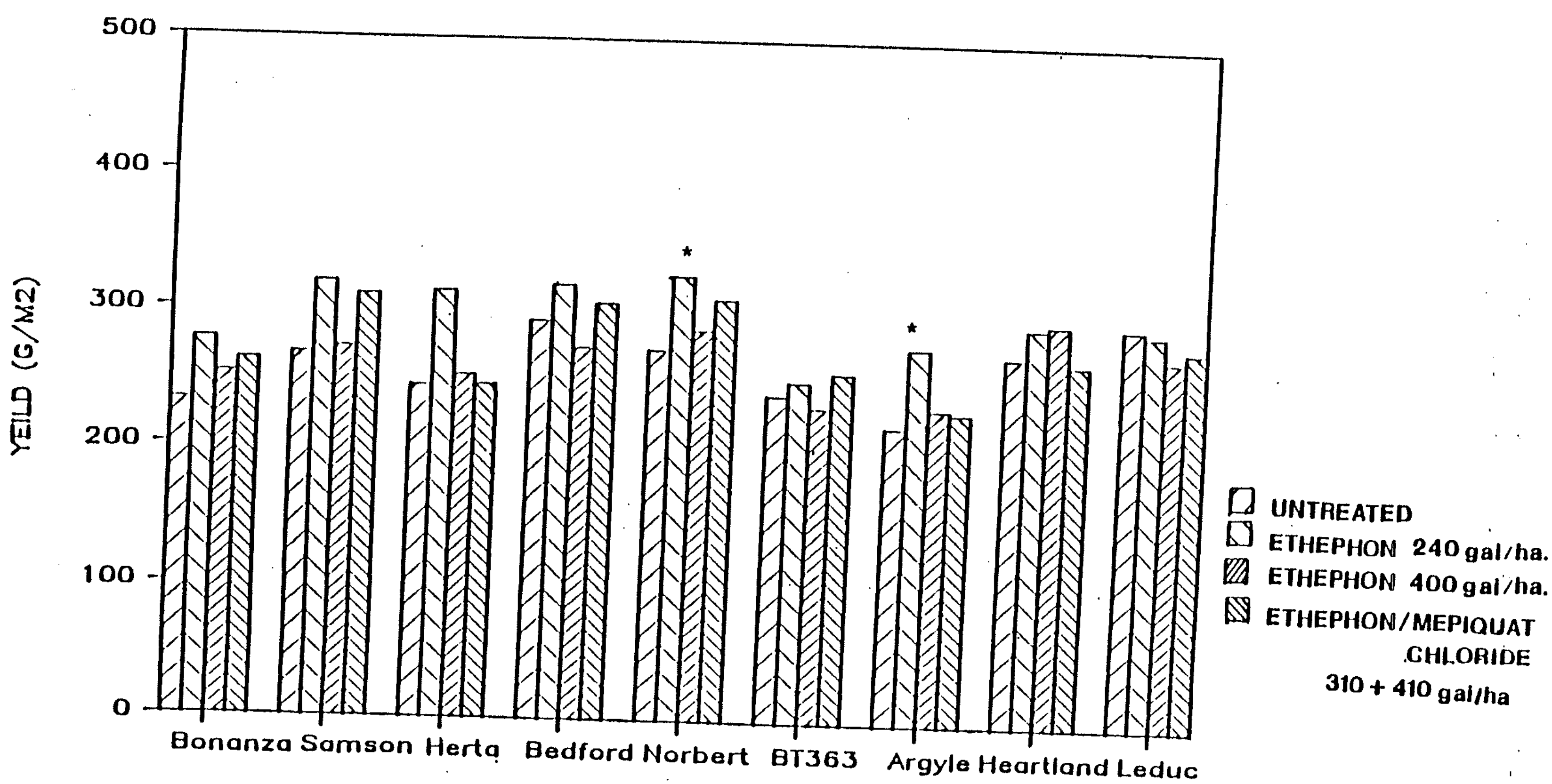
Thousand kernel weight was not affected by the application of any of the PGR treatments (Table 4.14 and Figure 4.8).

There was an increase in seeds per head with the application of 240 g ai/ha of ethephon when cultivar were grouped. These increases in seeds per head were only significantly greater than the untreated check with Heartland (Figure 4.9).

4.3.4 Discussion

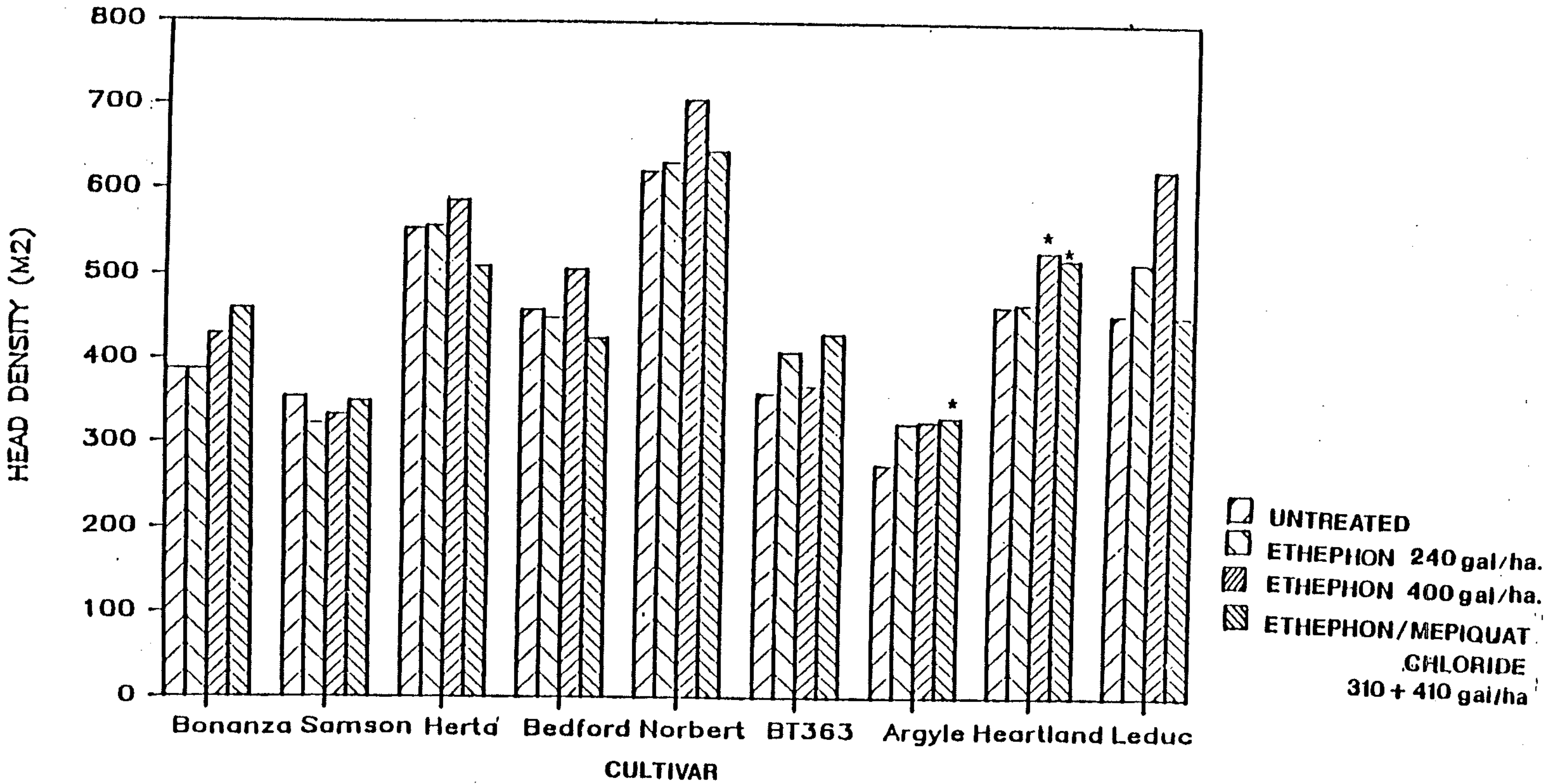
Plant height reductions increase with increasing rate of ethephon. Plant growth regulators reduced plant height to a greater degree with tall statured cultivars, however, the percent plant height reduction did not differ with the cultivars evaluated in this trial.

The height of the cultivar was not correlated to lodging resistance, although Mulder (1954) suggested that tall plants are more



* significantly different from the untreated check at alpha= 0.05

Figure 4.6 The effect of ethephon and ethephon/mepiquat chloride on the yield of nine barley cultivars



* significantly different from the untreated check at alpha=0.05

Figure 4.7 The effect of ethephon and ethephon/mepiquat chloride on the head density of nine barley cultivars

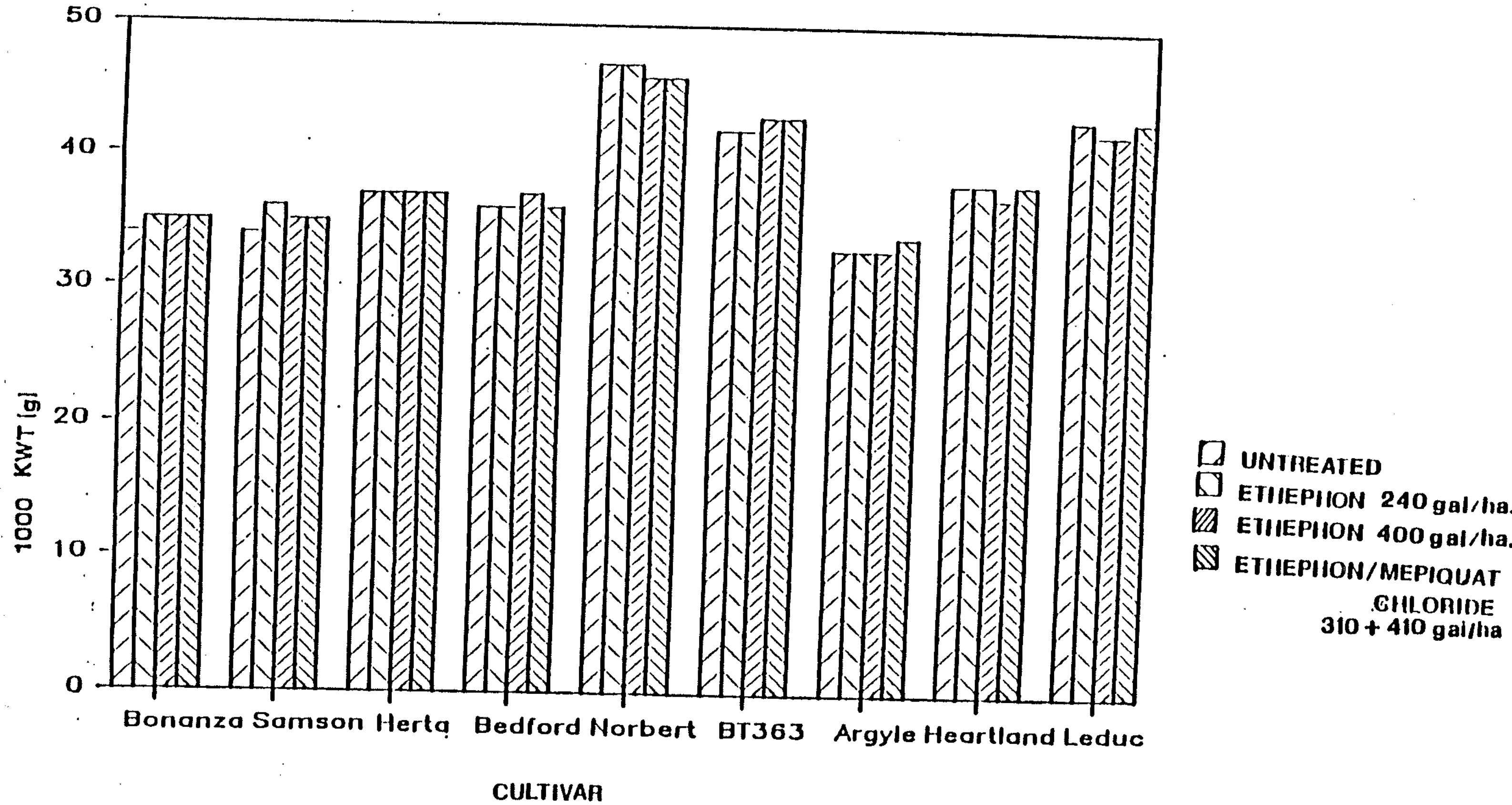
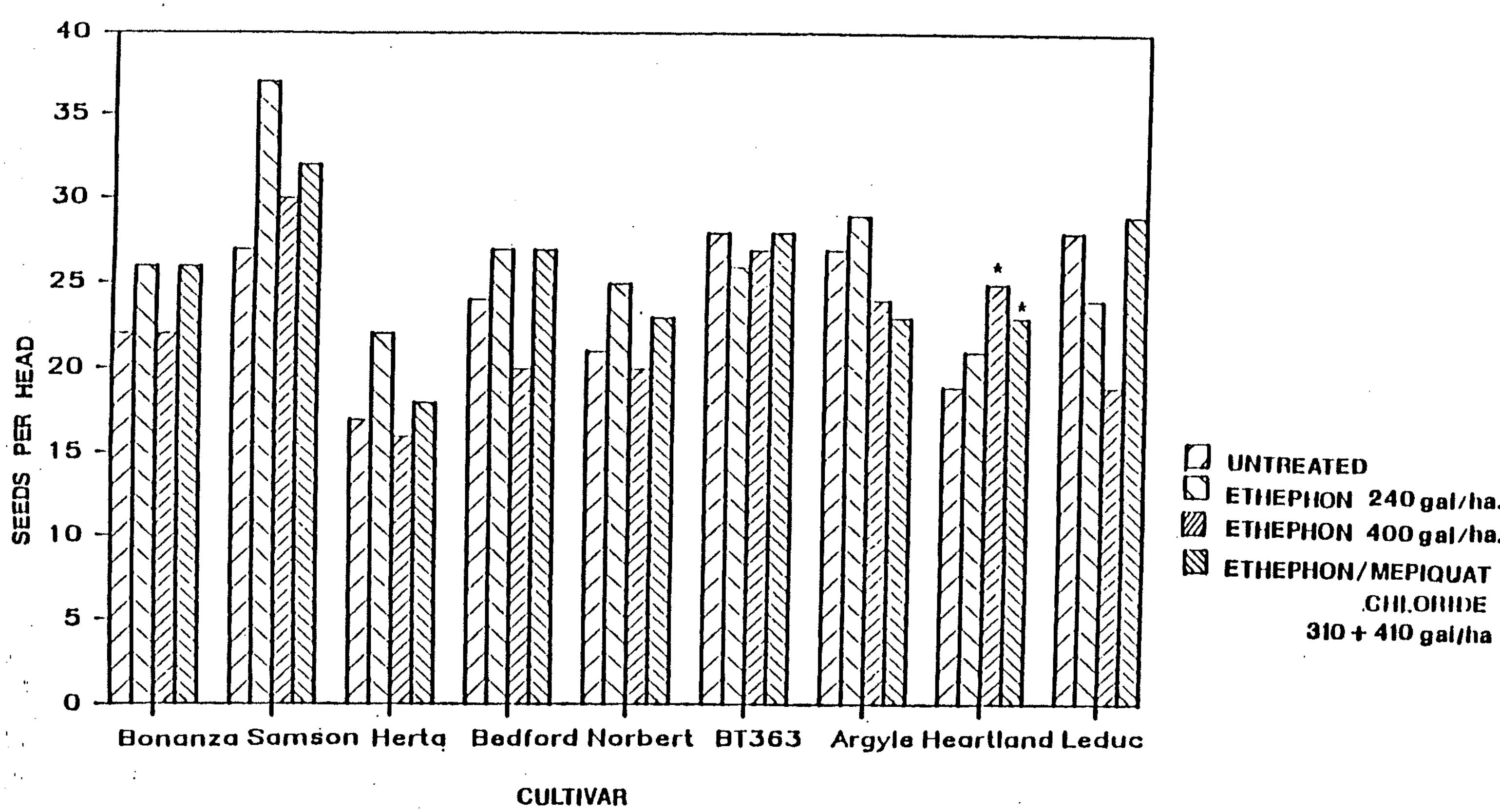


Figure 4.8 The effect of ethephon and ethephon/mepiquat chloride on the thousand kernal weight of nine barley cultivars



* significantly different from the untreated check at alpha=0.05

Figure 4.9 The effect of ethephon and ethephon/mepiquat chloride on the seeds per head of nine barley cultivars likely to lodge than short plants. Bonanza and Samson barley differ in height by 20 cm, yet the degree of lodging was similiar throughout the season. The reduction in plant height caused by the application of a growth regulating substance did result in a reduction of lodging, which concurs with studies reported by Roth et al. (1984).

The ethephon/mepiquat chloride treatment was more effective in reducing lodging than ethephon alone applied at 400 g ai/ha, even though it contained less ethephon. The addition of mepiquat chloride may cause straw strengthening of the culm.

In this experiment the 240 g ai/ha rate of ethephon was sufficient in reducing lodging as it resulted in significant yield increases. The cultivars with excellent lodging resistance all lodged less than cultivars with poor to fair lodging ratings.

PGR's may reduce the plant height and lodging with most cultivars, but there may not be a benefit in terms of yield or yield components, although increases in yield were observed in some cultivars. The trial was conducted with only a few PGR treatments at one location, making conclusions about a specific cultivar difficult. Studies, at several more locations and years, would have to be conducted to determine what cultivars are more responsive to PGR treatment than others. Also, a wide range of PGR rates would be useful in determining the type of response of the cultivars to the PGR. In the present study, all plants were removed at harvest, which may not occur in commercial field operations. In addition, the threshing operation usually results in small kernels being blown out the back of the combine and not collected in the grain hopper. A quantitative examination of the amount of small kernels would have been useful data to estimate the potential yield losses associated with lodging.

Scheffer et al.(1983) mechanically supported cereal plants, to eliminate the effect of lodging in the experiment. This technique enabled the researcher to isolate the effect of the PGR alone.

4.4 Experiment 4. The effect of nitrogen and ethephon on the height and yield of four barley cultivars at Teulon and Portage, 1984.

4.4.1 Plant Height and Peduncle Length

Differences in plant height and peduncle length between cultivars were observed at both locations (Table 4.15). The cultivar Klages was the shortest cultivar at both locations. The peduncle accounted for a greater proportion of overall plant height of Bonanza and Johnston than it did of Norbert and Klages at both locations. The plants at Portage appeared to grow taller than the plants at Teulon.

The height of Norbert barley and the length of the peduncle increased with increasing nitrogen fertility at Teulon (Table 4.16). At Portage, the peduncle length of Bonanza increased with rate of additional nitrogen fertility (Table 4.17). This difference was not reflected in the total plant height.

The application of ethephon to the barley plants at growth stage 45 to 48 reduced plant height of all cultivars, at both locations, with the exception of Johnston at Portage (Table 4.18 and 4.19). The ethephon treatment resulted in a total plant height reduction ranging from 1.4 to 6.4 cm.

The peduncle, although reduced by the ethephon treatment, accounted for less than 50 percent of the total plant height

Table 4.15 The effect of cultivar on plant height characteristics

	Teulon		Portage	
Cultivar	Plant Height (cm)	Peduncle Length (cm)	Plant Height (cm)	Peduncle Length (cm)
Bonanza	89.5a	28.9a	99.8a	35.1a
Johnston	84.7b	22.8b	94.7b	32.0b
Norbert	76.7c	17.0c	87.4c	24.2c
Klages	67.6d	15.5c	84.4d	22.8c

Means within a column followed by the same letter are not significantly different at alpha=0.05 (LSD).

Table 4.16 The effect of nitrogen fertility on the yield, yield components, plant height and lodging of Bonanza, Johnston, Norbert and Klages barley, Portage.

Cultivar	Nitrogen (kg/ha)	Plant Height (cm)	Peduncle Length (cm)	Plant Density (/m2)	1000 Kernel wt.(g)	Yield (g/m2)	Lodging* Aug.20	Aug.26
Bonanza	20	86.6	28.4	189	36.2	308	0.2	-
	50	87.5	27.2	188	32.8	299	0.2	-
	80	85.4	27.1	191	32.3	296	0.3	-
Johnston	20	87.7	21.3a	209	29.6	263	0.5	2.9
	50	83.1	23.2b	206	26.4	265	0.4	2.4
	80	81.6	21.3a	209	28.2	263	0.8	2.6
Norbert	20	71.8a	15.2a	256	46.1	331	0.2	0.2
	50	75.6b	16.7b	275	45.6	327	0.3	0.2
	80	74.6b	17.0b	264	45.2	338	0.2	0.2
Klages	20	65.0	14.8	266b	36.7	230	0.2	0.2
	50	66.6	14.9	288a	36.6	236	0.2	0.2
	80	64.1	13.9	256b	37.8	216	0.2	0.2

* Based on the Belgian Lodging Scale

Table 4.17 The effect of nitrogen fertility on the yield, yield components, plant height and lodging of Bonanza, Johnston, Norbert and Klages barley, Portage.

Cultivar	Nitrogen (kg/ha)	Plant Height (cm)	Peduncle Length (cm)	Plant Density (/m2)	1000 Kernel wt.(g)	Yield (g/m2)	Lodging* Aug. 6	Lodging* Aug. 15	Lodging* Aug.27
Bonanza	20	96.6	32.8a	224	37.1	321	3.2	2.1	-
	50	99.2	33.9ab	233	34.9	314	3.6	1.8	-
	80	98.5	35.6b	218	34.9	326	3.1	1.2	-
Johnston	20	93.8	31.0	201	33.8	242	4.6	2.8	4.4
	50	94.7	32.0	202	32.4	265	5.5	3.6	4.5
	80	93.5	31.6	204	33.6	255	6.5	3.9	4.3
Norbert	20	77.7	22.3	282	45.8	305	1.3	0.5	2.3
	50	81.8	23.5	271	47.3	294	1.9	1.5	1.9
	80	79.1	23.2	273	45.7	294	2.7	1.7	1.7
Klages	20	82.1	22.0	258	40.5	285	1.6	0.6	0.7
	50	81.6	21.9	260	41.1	296	2.5	2.6	2.1
	80	82.2	21.4	302	39.6	279	4.9	3.3	2.6

* Based on the Belgian Lodging Scale

Table 4.18 The effect of ethephon on the height, yield and yield components of Bonanza, Johnston, Norbert and Klages barley Teulon.

	Bonanza		Johnston		Norbert		Klages	
	untreated	ethephon	untreated	ethephon	untreated	ethephon	untreated	ethephon
Plant Height (cm)	89.5a	83.5b	84.7a	79.6b	76.7a	71.3b	67.6a	62.9b
Peduncle Length (cm)	28.9a	26.3b	22.8a	21.1b	17.0a	15.6b	15.5a	13.5b
Total Plant Height Reductions (cm)		2.6		0.7		1.4		2.0
% Plant Height Comprised of Peduncle	32	32	27	27	22	22	23	21
Yield (g/m2)	296a	306a	258a	267a	336a	328a	227a	227a
Plant Density (heads/m2)	191a	188a	207a	210a	261a	269a	261a	279a
1000 kernel weight (g)	33.2a	34.3a	26.5a	29.7b	46.4a	44.9a	37.0	38.4

Means within a row for each cultivar followed by the same letter are not significantly different at alpha=0.05 (LSD)

Table 4.19 The effect of ethephon on the height, yield and yield components of Bonanza, Johnston, Norbert and Klages barley, Portage.

	Bonanza		Johnston		Norbert		Klages	
	untreated	ethephon	untreated	ethephon	untreated	ethephon	untreated	ethephon
Plant Height (cm)	99.8a	96.3b	94.7a	93.3a	87.4a	81.0b	84.4a	79.5b
Peduncle Length (cm)	35.1a	33.1b	32.0a	31.1a	24.2a	21.8b	22.8a	20.7b
Total Plant Height Reductions (cm)		2.0		0.9		0.4		2.1
% Plant Height Comprised of Peduncle	35	34	34	33	28	27	27	26
Yield (g/m2)	300a	340b	237a	271b	294a	300a	302a	271a
Plant Density (heads/m2)	223a	226a	201a	204a	262a	288b	277a	270a
1000 kernel weight (g)	36.8a	34.5a	33.0a	33.5a	46.7a	45.9a	39.7a	41.0a

Means within a row for each cultivar followed by the same letter are not significantly different at alpha=0.05 (LSD) reductions. The length of the lower internodes must have been reduced by the ethephon treatment. The ability of ethephon to reduce the peduncle length varied with the cultivar. At Teulon, the overall plant height and peduncle lengths were less than at Portage.

4.4.2 Lodging

At both locations Johnston lodged to a greater degree than the other cultivars (Table 4.20). At Teulon, Johnston had a lodging score of 4.1 at the time of harvest, whereas the cultivars Bonanza, Norbert and Klages exhibited little or no lodging. The cultivar Johnston exhibited buckling of the peduncle at maturity, also referred to as "necking". Lodging was greater at Portage than at Teulon, possibly due to a greater amount of precipitation. Lodging varied between cultivars, amount of additional fertility, application of ethephon, location and the time of evaluation. Johnston had a lodging score of 5.3 at Portage, with Bonanza, Norbert and Klages all scoring less than 3.0.

When lodging occurred, the addition of nitrogen fertility increased the lodging at Teulon, particularly on the earlier evaluation dates (Table 4.17).

Ethephon reduced lodging at both locations and all rating dates, more noticeably at Portage and at the later evaluations (Table 4.20). Lodging scores were reduced 1.5 to 2.8 points when ethephon was applied. Although ethephon reduced lodging, Johnston still had a lodging rating of 3.5, compared to Norbert and Klages which scored 1.0 and 1.1 respectively.

4.4.3 Grain Yield

Table 4.20 The effect of ethephon on the lodging of Bonanza, Johnston, Norbert and Klages barley*

	Teulon						Portage			
	Aug. 20		Aug. 26		Aug. 6		Aug. 15		Aug. 27	
Cultivar	check	ethephon	check	ethephon	check	ethephon	check	ethephon	check	ethephon
Bonanza	0.3	0.3	0.3	0.2	3.6	2.6	2.5	0.9	harvested	
Johnston	0.8	0.3	4.1	1.2	6.4	4.6	4.8	2.0	5.3	3.5
Norbert	0.3	0.2	0.2	0.2	2.7	1.2	1.8	0.6	2.9	1.0
Klages	0.2	0.2	0.2	0.2	3.9	2.2	3.2	1.0	2.6	1.1

* based on the Belgian Lodging Scale

At both locations there were differences in grain yield between cultivars. At Teulon, Norbert was the highest yielding cultivar, followed by Bonanza, Johnston and Klages. At Portage, Bonanza was the highest yielding cultivar, followed by Norbert, Klages and Johnston (Table 4.21).

Varying the level of fertility did not significantly affect grain yield at either location (Table 4.16 and 4.17).

Head density varied among cultivars at both locations. The two row cultivars, Norbert and Klages, had a greater final head density than the six-row cultivars, Bonanza and Johnston (Table 4.21). Final head density was greater with Bonanza compared with Johnston.

The nitrogen fertilizer treatments did not affect final head density at either location (Table 4.16 and 4.17).

Ethephon had no effect on head density except with the cultivars Norbert at Portage and Klages at Teulon, where a greater number of heads/m^2 was recorded when ethephon was applied (Table 4.18 and 4.19).

Thousand kernel weights differed among cultivars. Norbert had the greatest kernel weight followed by Klages, Bonanza and Johnston. Johnston had the lowest kernel weight and also was the only cultivar to exhibit lodging of greater than 2.0 (Table 4.20).

The thousand kernel weight of barley was not affected by varying the level of nitrogen fertility at Portage (Table 4.17). At Teulon, the 20 kg/ha rate of nitrogen treatment resulted in a greater kernel weight than the 50 or 80 kg/ha of nitrogen treatment. There was no interaction between cultivar and nitrogen fertility levels on kernel weight at either location.

Ethephon applied to Johnston barley, at Teulon, resulted in an

Table 4.21 The effect of cultivar on yield and yield components

	TEULON			PORTAGE		
Cultivar	Yield (g/m2)	1000 kernel weight (g)	Plant Density (heads/m2)	Yield (g/m2)	1000 kernel weight (g)	Plant Density (heads/m2)
Bonanza	301c	33.7b	190a	320c	35.7b	225b
Johnston	263b	28.1a	208b	254a	33.2a	203a
Norbert	332d	45.7d	297c	297b	46.3d	275c
Klages	227a	37.7c	270c	286b	40.4c	273c

Means within the same column followed by the same letter are not significantly different at alpha=0.05 (LSD).

increase in kernel weight (Table 4.18). The kernel weight of other cultivars was not affected by ethephon.

4.4.4 Discussion

The height of all four cultivars were different concurring with cultivar information from Seed Scoop (anonymous c, 1984). The length of the peduncle varied, with the tallest plants having the longest peduncle and a greater proportion of the plant height was composed of the peduncle.

The addition of nitrogen fertilizer did not cause an increase in plant height as noted by Mulder (1954), however, an increase in peduncle length did occur with the addition of nitrogen with some cultivars. The level of additional nitrogen appeared to be too high to cause any noticeable increases in plant height between treatments. A lack of precipitation, especially at Teulon, may have reduced the potential elongation of the plant.

The application of ethephon at 300 g ai/ha consistently caused plant height reductions with most cultivars at both locations, with overall plant height reductions being a result of reductions in the length of the peduncle and the internodes directly below the peduncle. Brown and Early (1973), reported that reductions in plant height from ethephon applications were a result of reductions in the length of the peduncle and second last internode.

The degree of lodging was variable and differed between cultivars, fertility level, location and whether or not ethephon was applied. The degree of lodging between cultivars observed in this experiment was similar to the cultivar descriptions in the Field Crop recommendations for Manitoba, 1986. Lodging was not correlated with plant height as suggested by Pinthus (1973). At Portage, possibly due to greater precipitation than Teulon, lodging increased with rates of additional nitrogen, although plant height was not affected. The ethephon treatment reduced lodging at the Portage location and reduced the incidence of necking with the cultivar Johnston at Teulon. Lodging scores were lower at the later evaluation, because of the positive geotrophic response of the crop, as described in Salisbury and Ross (1978).

The ethephon treatment resulted in increased yield with Bonanza and Johnston barley at Portage when compared to the untreated plots. The Johnston barley in the untreated plots was severely lodged and the ethephon application resulted in a reduction in the level of lodging. Although there was not a significant increase in either final head density or thousand kernel weight, as reported by Roth et al. (1984), the combined effect of these components may have attributed to the yield increases. When an application of ethephon reduced lodging, necking, with Johnston barley, at Teulon, yield was increased.

Ethephon causes the release of tillers in plant (Briggs, 1978), but when endogenously applied at Zadoks 45-48 little effect was noticed with the exception of Norbert barley at Portage. The use of 30 cm row spacing resulted in a low planting density, 176 seeds/m^2, which promoted tillering of the plant. The low planting density may have masked the effect of the ethephon treatment, in terms of influencing final head density. Also, Wunsche (1977) found tillering to be increased by ethephon applications, however, mature ears per plant were not affected, which was the parameter measured in this experiment.

Applying ethephon at Zadoks 45-48 exceeds the tillering period of the plant, but may effect the amount of tillers that abort.

Chapter 5

SUMMARY AND CONCLUSIONS

Four studies were designed and conducted to investigate the use of ethephon and ethephon/mepiquat chloride on spring barley. Eleven cultivars were evaluated throughout these studies to determine their response to the PGR's. Different rates of PGR's were also evaluated. The effectiveness of the PGR's were evaluated by measuring internode length, plant height, lodging, yield and yield components and protein.

The results obtained from the two years of field research were variable, however, several results were consistent throughout the study. Plant height varied between cultivars. Plant height was reduced when ethephon or ethephon/mepiquat chloride was applied at at GS 39-48 with rates containing at least 200 g ai/ha of ethephon. Ethephon applied to Bedford barley at 600 g ai/ha resulted in a 22.3 cm reduction in plant height, when compared to the untreated plants. The reduction in plant height caused by PGR application increased with rate of PGR. This reduction was noticed as early as seven days after treatment with the cultivar Bedford, at Winnipeg, 1985. Reductions in plant height caused by PGR applications, were a result of the reduced elongation of internode 3, 4, 5 and the peduncle. A significant reduction in length of the peduncle and one internode can cause significant plant height reductions. Internodes that were actively elongating at time of application were reduced in length. The degree of overall plant height reduction depended on how much the affected internodes contributed to overall plant height.

The addition of nitrogen fertility can cause an increase in peduncle length of Bonanza and Norbert barley. The fertility trial was conducted in the 1984 season, which was extremely hot and dry. In a year of more typical precipitation, fertility may have affected other cultivars and parameters measured. Lodging of the barley plant can increase with increasing rate of ammonium nitrate applied as a spring broadcast at 20, 50 and 80 kg/ha.

Lodging varied between cultivars, with cultivars noted as having strong straw strength lodging less than cultivars with weak straw, the exception being Herta barley. The height of a cultivar did not determine its resistance to lodging. A cultivar with excellent lodging resistance can lodge less than a cultivar with poor lodging resistance treated with a PGR. The record levels of precipitation received on the plot area at Winnipeg, 1985, showed that cultivars with excellent lodging resistance can lodge under those conditions. The application of a PGR reduced the amount of lodging with all cultivars evaluated.

Although PGR's reduced plant height and lodging with most cultivars, yield or yield components were not affected. Ethephon applied at rates up to 600 g ai/ha did not have a negative affect on the yield of Bedford barley. Ethephon applied to Johnston barley at Teulon, 1984, reduced the bending of the peduncle which resulted in an increase in kernel weight.

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APPENDIX A. Significant effects and interactions in the analysis of variance (Winnipeg, 1985).

7 DAYS AFTER TREATMENT

Source	Internode 1	Internode 2	Internode 3	Internode 4	Internode 5	Peduncle	Plant Height
cultivar (cult)		*	*		*	*	*
ethephon					*	*	*
cult x ethephon				*			

* significant at alpha=0.05

HARVEST

Source	Internode 1	Internode 2	Internode 3	Internode 4	Internode 5	Peduncle	Spike	Plant Height
cultivar (cult)					*		*	
ethephon			*	*	*			*
cult x ethephon					*			

* significant at alpha=0.05

APPENDIX B Agriculture Canada Description of Variety for Samson and Virden barley

Agriculture Canada

FOOD PRODUCTION AND INSPECTION BRANCH	DIRECTION GÉNÉRALE, PRODUCTION ET INSPECTION DES ALIMENTS	DATE March 4, 1986	2525
		SEED DIVISION SECTION	
RE OBJET DESCRIPTION OF VARIETY			

Crop: Six-row spring barley (*Hordeum vulgare*) Licence No.: 2525

Variety: Samson Date Licensed: April 15, 1985

Origin and Breeding:

Samson is a six-row feed barley which was tested as BT521, BT508 and P73108010. It was developed by Alberta Agriculture Crop Research, Field Crops Branch, Lacombe, Alberta. This variety was selected from a cross involving the Minnesota semi-dwarfs of Jotun extraction of pedigree H12-4816 x Rasmusson 72-181. The final cross was made in 1972. A single spike was selected at the F_3 generation and propagated as a head row. A modified bulk pedigree method was followed and 117 lines were bulked at F_{10} to form breeder seed. Selection criteria were plant height, lodging resistance and high yield.

Varietal Characteristics:

Plant Characteristics:

Juvenile growth: intermediate
Coleoptile colour: green
Leaves: dark green; wide; medium length; green sheath; glabrous sheath and blade
Flag leaf: dark green; medium length and width; upright; white auricles; slightly waxy sheath
Stem: grass green with slight waxy bloom; thick with high stem exsertion (10-15 cm); straight neck with V-shaped collar; 5 nodes
Roots: greater rooting capacity
Height: semi dwarf (about 73 cm); about 20 cm shorter than Bonanza
Heading: midseason
Maturity: 3 days earlier than Abee, slightly later than Empress (1 day)
Lodging resistance: very good
Shattering resistance: good
Acid soil tolerance: fair
Drought tolerance: fair
Disease reaction: moderately resistant to common root rot (*Helminthosporium sativum*) and stem rust (*Puccinia graminis*); intermediate reaction to surface-borne smuts (*Ustilago* spp.); susceptibile to loose smut (*Ustilago nuda*), Septoria leaf blotch (*Septoria passerinii*), Net blotch (*Helminthosporium teres*), and scald (*Rhynchosporium secalis*). (Seed should be treated with a recommended fungicide.)

AGR 1202 (80/02)

Chemical reactions: Metribuzin causes some yellowing of the crop
Competitive with weeds: due to its semi-dwarf status it is not as competitive with weeds as taller varieties

Spike Characteristics:

Type: six-row
Shape: strap; lateral kernels overlap 1/4-1/2 of spike; medium density and length
Attitude: semi-nodding
Lemma: long (longer than spike), rough awns with green tip; hairs absent
Glume: half length of lemma; short hairs, completely covered by hairs, rough awns longer than glume length with green glume awn tip; many stigma hairs
Rachis: slightly tapered segments with numerous, medium length hairs; curved first internode; after full heading spike emerged above flag leaf

Kernel Characteristics:

Size: medium length and width
Aleurone colour: yellow
Rachilla: medium length; few abnormal rachillas; long hair length
Lateral lemma veins: few barbs; green
Wrinkling of hulls: wrinkled lemma and palea
Basal marking: horseshoe depression
Protein content: intermediate
Malting quality: poor, feed type

Performance:

Samson is a semi-dwarf feed barley with very good lodging resistance, superior common root rot resistance and is high yielding under high levels of fertility and good management. This variety is adapted to high rainfall areas in Central Alberta and irrigated land in Southern Alberta. It should be grown only where extensive lodging is prevalent due to high moisture.

Maintenance of Breeder Seed: Alberta Agriculture, Crop Research, Field Crops Branch, Lacombe, Alberta

Canadian Distributor: SeCan Association

Recommended by: Alberta Cereal and Oilseeds Advisory Committee

Supported by: Expert Committee on Grain Breeding

4058S

DK/jb

Experimental Data:

Table 1: Agronomic performance of Samson and check varieties, Western Co-operative Six Row Barley Tests, 1983 and 1984. Average of all locations (see Table 2 for list of locations).

Year	Variety	Lodging (1-9)	Height (cm)	Maturity (days)	Yield (kg/ha)	1000 K wt. (g)	Test wt. (kg/hl)
1983	OAC 21	3.7	102.6	88.0	3451	34.7	54.7
	Bonanza	3.1	96.6	89.1	4836	35.8	56.5
	Diamond	2.5	84.0	90.0	5094	39.8	52.7
	Samson	1.4	76.4	94.0	4577	34.5	55.6
1984	OAC 21	3.7	93.0	85.1	2708	37.5	56.6
	Bonanza	4.0	89.7	84.7	3579	37.6	58.2
	Diamond	2.0	76.5	84.8	3980	43.3	55.9
	Samson	2.6	69.0	87.4	3552	36.5	57.1
Mean	OAC 21	3.7	97.8	86.6	3080	36.1	55.7
	Bonanza	3.6	93.2	86.9	4208	36.7	57.4
	Diamond	2.3	80.3	87.4	4537	41.6	54.3
	Samson	2.0	72.7	90.7	4065	35.5	56.4

Table 2: Yield (kg/ha) of Samson and check varieties, Western Co-operative Six Row Barley Tests, 1983 and 1984. Two year means.

Zone 1 - Black Soil

Variety	Bran*	Glen	Indh	Melf	Mord	Nort	Port	Mean
OAC 21	4440	4720	3720	3200	3670	2240	5250	3890
Bonanza	5820	5350	4790	3780	4840	3380	6030	4860
Diamond	5400	5900	4620	4250	4920	2800	6930	4970
Samson	5000	5640	4240	3530	5450	1750	7500	4690

Zone 2 - Brown and Dark Brown Soils

Variety	Leth	Regi	Sask	Scot	Swcr	Watr	Mean
OAC 21	5970	2570	2710	2120	3960	2890	3320
Bonanza	8080	3730	3700	2900	5100	4020	4540
Diamond	9150	4480	4030	3080	6300	4160	5100
Samson	8940	3930	3260	2530	-	1110	4270

Zone 3 - Black and Grey Soil

Variety	Calm	Laco	Troc	Evan	Olds	Verm	Mean
OAC 21	2860	3650	1710	1940	4740	3810	2970
Bonanza	4670	4620	3290	1950	8060	5160	4310
Diamond	4900	4790	3940	2410	8740	6150	4830
Samson	5130	4140	3000	2420	-	6240	4150

Zone 4 - Peace River District

Variety	Beav	Fort	Mean	Overall Mean
OAC 21	2910	1240	2070	3300
Bonanza	4600	1540	3070	4440
Diamond	4970	1550	3260	4800
Samson	4710	2240	3890	4350

*Locations were Brandon, Glenlea, Indian Head, Melfort, Morden, North Battleford, Portage-la-Prairie, Lethbridge, Regina, Saskatoon, Scott, Swift Current, Watrous, Calmar, Lacombe, Trochu, Evansburg, Olds, Vermilion, Beaverlodge and Fort Vermilion

Table 3: Comparison of disease reaction of Samson and Bonanza, Western Co-operative Six-Row Barley Test, 1979, 1983-84

	% Common Root Rot			% Smut			Net Blotch[a]			Scald[a]	Septoria[a]	Rust
	Saskatoon	Scott	Lacombe	*U. nuda*	*U. hordei*	*U. nigra*	102[b]	858[c]	857[d]	837	692	(composite)
1979												
Samson	23	3	27	73	3	12	S	S	S	S	S	10 R-M
Bonanza	16	3	29	17	13	11	S	S	S	S	S	20 R-M
1983												
Samson	74	36	32	70	6	5	S	S	S	S	S	70 MS-S
Bonanza	88	61	76	51	12	14	S	S	MR-MS	MS	S	60 MR-MS
1984												
Samson	73	61	33	67	13	9	10	8	7	S	S	30 MR-MS
Bonanza	70	87	53	59	27	20	9	8	5	S	S	30 R-MR

a reaction categories: 10(VS) - very susceptible; 9(S) - susceptible; 7(MS) - moderately susceptible; 5(MR-MS) - moderately resistant to moderately susceptible; 3(MR) - moderately resistant; 1(R) - resistant

b produces "normal" net blotch sysmptoms

c produces "normal" net blotch symptoms with a different virulence spectrum

d produces "spot-type" net blotch symptoms

Agriculture Canada

FOOD PRODUCTION AND INSPECTION BRANCH	DIRECTION GÉNÉRALE: PRODUCTION ET INSPECTION DES ALIMENTS	DATE December 1, 1987	2834
		SECTION SEED DIVISION	

RE / OBJET: DESCRIPTION OF VARIETY

Crop: Six-row spring barley (Hordeum vulgare)

Registration No.: 2834

Variety: Virden

Registration Date: May 1, 1987

Origin and Breeding:

Virden, tested as BT363, is a six-row feed barley developed at the Agriculture Canada Research Station, Brandon, Manitoba. It is derived from the cross BR.F27-4 x BR.E65-8 made in 1979. The F_1 progeny were grown indoors and individual heads harvested and planted as F_2 head rows in the spring of 1980. The F_3 progeny were multiplied in a California winter nursery and the F_4 grown as spaced plants. BT363 was derived from a single plant selection in the F_4; selection was based on maturity, lodging and yield.

Varietal Characteristics:

Plant Characteristics:

Juvenile growth habit: erect
Coleoptile colour: green
Leaves: medium green; medium width and length; green leaf sheath; glabrous sheath and blade
Flag leaf: medium green; medium width; long; intermediate attitude; white auricles; slightly waxy sheath
Stem: grass green; glossy; medium thick; 5 nodes; closed collar; snaky neck; slight exertion
Plant height: medium tall; shorter than Bonanza; taller than Conquest
Heading: midseason; similar to Johnston, later than Bonanza
Lodging resistance: very good
Shattering resistance: good
Resistance to neck breaking: good
Resistance to straw breaking: good
Disease reaction: susceptible to Septoria leaf blotch (Septoria passerinii), scald (Rhynchosporium secalis) and loose smut (Ustilago nuda); moderately susceptible to the net form of net blotch (Drechslera teres); moderately resistant to the spotted form of net blotch (D. teres), stem rust (Puccinia graminis), common root rot (Cochliobolus sativus), and surface borne smuts (U. hordei and U. nigra)

Spike Characteristics:

Type: six-row
Shape: tapering; medium length; dense; lateral kernels overlap up to 1/2 of spike
Attitude: erect; emerged above flag leaf after full heading
Awns: long; semi-smooth
Lemma: glabrous; long awns with purplish tip
Glumes: short; glabrous; long, smooth awn with green tip
Rachis: margins of segments parallel; glabrous; straight first rachis internode

Kernel Characteristics:

Aleurone: yellow
Rachilla: medium length with long hairs; no abnormal rachillas
Hull: covered; slightly wrinkled lemma
Size: medium length and width
Lemma veins: green; glabrous
Basal marking: horseshoe depression
Malting quality: poor
Protein content: intermediate

Acceptable Variants:

Less than 5% plants with semi-rough lemma awns.

Performance and Adaptation:

Virden is a medium-height, strong strawed six-row barley adapted primarily to Manitoba as well as the Parkland Region of western Canada. It is a high yielding variety with good kernel weight, lodging resistance and shattering resistance but a moderately low test weight and is later maturing than Bonanza. It is anticipated that Virden will replace Bedford in Manitoba as it is of similar agronomic type with a substantial yield advantage.

Maintenance of Breeder Seed: Agriculture Canada Experimental Farm
Indian Head, Saskatchewan

Canadian Distributor: SeCan Association

Recommended by: Western Expert Committees on Grain Breeding and Diseases

MS/jbj
6653S

Table 1: Yield Performance (100's kg/ha) of Virden and Check Varieties, Western Co-operative Six-Row Barley Test, 1984-1986[1].

Variety	Zone 1					Zone 2					Zone 3				Zone 4	Overall
	BR	GL	ME**	IN	Mean	SA	RE	SC	LE	Mean	LA	TR	CA	Mean	BE	Mean
Bonanza	55.47	54.14	51.17	52.31	45.84	48.32	42.70	34.36	55.07	49.32	42.85	30.92	47.04	47.38	39.26	46.43
*Argyle	56.86	40.47	-	47.00	48.10	67.75	66.87	40.56	32.32	51.87	31.06	34.61	65.15	43.60	42.74	47.76
*Heartland	60.72	47.76	-	49.15	52.54	71.06	74.23	46.34	38.02	57.41	31.41	68.37	43.43	47.74	49.57	51.82
*Virden	66.70	42.50	-	61.80	57.00	72.30	80.80	45.10	43.30	60.40	34.00	42.40	70.60	48.70	44.80	54.90
Virden	61.71	63.05	66.52	63.56	54.68	53.33	52.66	34.28	68.62	57.67	49.82	34.14	66.62	58.11	42.57	55.00

* Contains data for one year only - 1986

** Contains data for two years only - 1984 and 1985

[1] Zone 1= Brandon, Glenlea, Melfort and Indian Head
Zone 2= Saskatoon, Regina, Swift Current, Lethbridge
Zone 3= Lacombe, Trochu, Calmar
Zone 4= Beaverlodge

Table 2: Agronomic Performance of Virden and Check Varieties, Western Co-operative Six-Row Barley Test, 1984-1986*

Year	Variety	Height (cm)	Lodging (1-9)**	Maturity (days)	1000 kernel weight (g)	Test weight (kg/hl)
		(9)[1]	(3)	(7)	(6)	(7)
1984	Virden	80.9	2.3	93.1	41.7	56.7
	Bonanza	89.3	2.7	88.0	35.2	58.7
	Winchester	58.8	1.4	90.2	40.9	56.7
	Duke	70.2	1.7	90.8		59.5
		(10)	(2)	(8)	(8)	(8)
1985	Virden	82.1	2.1	98.8	46.5	59.9
	Bonanza	89.1	2.9	94.3	38.7	60.8
	Winchester	64.1	2.0	95.8	43.9	59.6
	Duke	71.9	1.4	96.2	40.1	61.2
		(15)	(5)	(15)	(7)	(7)
1986	Virden	91.6	3.0	96.0	43.0	57.0
	Bonanza	94.7	3.1	92.1	35.4	60.3
	Argyle	96.6	2.9	93.1	35.9	60.1
	Heartland	80.4	2.8	92.6	35.9	60.1
1984-		(47)	(12)	(46)	(35)	(35)
1986	Virden	84.9	2.5	96.0	43.7	57.9
	Bonanza	92.2	2.9	91.5	36.4	59.9

[1] Number in parentheses = number of station-years

*Test locations include: Zone 1 (Black soils): Brandon, Glenlea, Melfort, Indian Head
Zone 2 (Brown and Dark Brown Soils): Saskatoon, Regina, Scott, Lethbridge
Zone 3 (Black and Grey Soils): Lacombe, Trochu, Calmar
Zone 4 (Peace River): Beaverlodge

** Lodging; 1=best resistance

Table 3: Yield Performance (00's kg/ha) for Virden and Check Varieties, Eastern Prairie Barley Test, 1983.

Variety	U.M.	Glen	Mord	Bran	I.HD.	Melf	Sask	Elro	Overall mean
Virden	67.7	55.0	45.1	63.2	47.5	53.1	53.2	46.9	54.0
Argyle	71.9	53.9	45.7	66.5	45.9	33.0	50.0	40.8	51.0
Ellice	56.6	55.3	37.8	59.0	52.4	44.3	47.3	45.3	49.8

Table 4: Agronomic Performance of Virden and Check Varieties at the Brandon Research Station, 1986.

Variety	Height (cm)	Lodging (1-9)*	Net Blotch (1-4)**	Maturity (days)	Yield (00's kg/ha)
Virden	96.5	1.0	2.0	89	91.6
Bedford	85.5	1.5	2.0	87	76.2
Bonanza	94.0	3.0	2.0	85	78.4

* Lodging; 1=best resistance
** From natural infection; 1=slight, 4=severe

Table 5: Yield Performance (00's kg/ha) of Virden and Check Varieties in the six crop zones of Manitoba, 1985-1986*

Zone:	1	2			3					4			5		6	
Variety	Wask	Bran	Mar	Sh Lake	Bag	Dau	Glen	Port	U.M.	Bsr	Teu	Vita	Robl	Sw Riv	The Pas	Overall mean
Virden	41.2	82.6	52.0	63.6	33.4	49.0	18.2	43.9	39.1	46.4	38.8	35.2	51.7	23.9	36.7	43.7
Bedford	28.8	68.7	46.5	48.4	33.8	41.8	18.8	48.8	33.8	41.4	38.3	36.7	44.1	28.3	27.9	39.1
Bonanza	29.8	70.6	47.5	53.0	31.2	41.1	22.6	42.9	29.2	38.1	31.0	30.4	41.2	27.4	25.1	37.4
Heartland	39.7	75.0	46.0	58.0	35.9	46.9	19.4	42.1	35.0	46.7	35.1	29.8	41.7	31.0	34.2	41.1

* Locations: Zone 1: Waskada
Zone 2: Brandon, Margaret, Shoal Lake
Zone 3: Bagot, Dauphin, Glenlea, Portage La Prairie, University of Manitoba
Zone 4: [illegible] Teulon, Vita
Zone 5: [illegible] Swan River
Zone 6: The Pas

Table 6: Disease Ratings* for Virden and Check Varieties in the Western Cooperative Six-Row Barley Test, 1984-1986.

	Smut spp. (%)																	
	nuda			hordei			nigra			Stem rust comp.			Net blotch comp. (1-10)			Root Rot (%)		
Year / Variety	84	85	86	84	85	86	84	85	86	84	85	86	84	85	86	84	85	86
Bonanza	59	57	67	27	13	8	20	12	11	30R-MR	15 MR	30 MR	7.3	7.6	3.9	79	35	15
Argyle	-	-	33	-	-	28	-	-	19	-	-	30 MR	-	-	3.0	-	-	12
Heartland	-	-	43	-	-	8	-	-	1	-	-	30 MR	-	-	4.0	-	-	18
Virden	55	72	46	3	7	5	11	6	0	20 MR	30 MR	30 MR	6.0	6.7	3.5	47	25	4

*(%); infection expressed as a percent of plant infected

Stem rust is a composite of races, and infection is expressed as 0-100% and Leaf involvement as either MR (moderately resistant) or R-MR (resistant to moderately resistant)

Net Blotch infection is from a composite field infection, and is expressed on a scale of 1-10, where 10=very susceptible

APPENDIX C Cultivar description of Herta barley, Annonymous, 1956

BARLEY

HERTA C.A.N. 178

General Information

A two-rowed, rough-awned feed barley from the cross Kenia x Isaria, made at the Plant Breeding Institute, Weibullsholm, Landskrona, Sweden. It was first distributed in Europe in 1949. It was licensed for sale in Canada in 1956. Herta has consistently outyielded other 2-rowed varieties.

Plant Characters

Spike	—Two - rowed; moderately long; lax; definitely nodding at maturity; awns rough, a little longer than the ear; basal rachis internode medium long, curved, pubescent at edges.
Maturity	—Medium late.
Straw	—Medium long; highly resistant to lodging and breaking.
Disease Reaction	—Resistant to mildew and susceptible to loose smut.
Grain Characters	—Kernels moderately large and plump; hull grayish yellow; finely wrinkled; aleurone mixed; rachilla hairs long; basal marking of lemma incomplete horseshoe, barbs on lateral veins of lemma few or absent.