1985

# Effect of Ethephon on Yield Components and Morphology of Irrigated Spring Wheat

Brian C. Winberg

# EFFECT OF ETHEPHON ON YIELD COMPONENTS AND MORPHOLOGY OF IRRIGATED SPRING WHEAT

by

Brian C. Winberg

A thesis submitted
in partial fulfillment of the requirements for the
degree Master of Science
Major in Agronomy
South Dakota State University
1985

EFFECT OF ETHEPHON ON YIELD COMPONENTS

AND MORPHOLOGY OF IRRIGATED SPRING WHEAT

This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusion of the major department.

W. E. Arnold Date
Thesis Advisor

M. L. Horton Date
Head, Plant Science Department

ACKNOWLEDGEMENTS

The author gratefully acknowledges the guidance and friendship provided by Dr. W. E. Arnold, my major advisor.

Sincere thanks is offered to co-workers and members of the SDSU weed crew who helped in collecting data in the two years of this experiment. Special thanks goes to my wife for encouragement and help while writing this thesis.

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# INTRODUCTION

The number of irrigated acres in South Dakota is approximately 0.5 million acres. Water development plans could increase irrigated acreage four to five times causing an additional demand for electricity. Utilities pay more for electricity used during peak demand and this cost is passed on to consumers. To evenly distribute demand, some utilities are experimenting with irrigation scheduling to avoid peak usage during the day (23) and offering lower electrical rates to participants. Another method to distribute electrical demands could be growing a crop with lower water requirements or one which has requirements earlier in the growing season and matures before the peak electrical demand months of July and August. Wheat (Triticum aestivum L.) and barley (Hordeum vulgare L.) have an earlier water requirement as well as a lower water requirement as compared to corn. However, a problem with irrigating small grains is the possibility of lodging (17,27). The purpose of this research was to study the effect of ethephon applied at different growth stages of irrigated spring wheat varieties on morphological characters associated with lodging, grain quality and yield.

# LITERATURE REVIEW

For spring wheat to be an economic alternative as an irrigated crop, the economic return must be comparable to corn, the primary crop now being irrigated. Wheat yields can be increased by applying increased fertilizer rates and irrigation to a responsive variety. However, increased nitrogen and ample moisture produce an environment conducive to lodging in small grains (14).

Lodging results in reduced yield, poor grain quality, and increased harvest losses. Lodging severity depends on environment and growth stage at which it occurs, with heading and early grain development being crucial stages. Artificially induced lodging at both the soft dough stage and heading reduced grain yield in winter wheat by 20 and 31 percent, respectively (30). Yield reduction due to lodging decreased as the time of occurence neared maturity.

Even temporary lodging can cause significant yield reductions. Plants can recover from early lodging by intercalary growth of nodes (14). In spring barley, temporary artificial lodging at anthesis reduced grain yield by 25 percent and permanent artificial lodging at the same stage reduced yield by 38 percent (21).

The most obvious effect of lodging is interference with carbohydrate production (14). Carbohydrate production is reduced when a large part of the photosynthesizing parts are shaded by overlying plants. Reduced carbohydrate production affects mainly the accumulation of carbohydrate in the grain. However, any process or plant tissue requiring carbohydrates may also be affected, depending on when lodging occurs.

Lodging can reduce test weight by decreasing kernel weight and increasing the number of shriveled kernels (14, 30). Sprouting, mildew damage, and leaf diseases may occur in lodged crops because of the more humid microenvironment within the lodged crop canopy. Lodging also interferes with crop harvest and increases harvest losses. Combine speed is reduced and, often times, not all of the fallen crop can be picked up. Moisture content will be higher. Also, due to the lower cutting height, more straw must pass through the machine making threshing and cleaning less efficient (22).

Lodging is associated with excessive moisture and/or fertilizer in combination with strong winds and/or rains. Mulder stated that nitrogen affects all the morphological and anatomical characters associated with lodging (14). These characters include internode length, number of internodes measurable, internode diameter, and culm wall thickness.The effect of nitrogen on lodging can be related best to its effect on the basal stem internodes. Lodging resulting from increased stem elongation following application of high rates of nitrogen has been found in semidwarf wheats (9,31).

Increased stem elongation can also result from abundant moisture. Furthermore, surplus moisture in the upper soil layer may weaken the anchorage of crown roots allowing a moderate rain and/or wind to cause lodging by uprooting (14,27). Increased nitrogen supply may promote lodging more under wet conditions than under dry conditions and more in dense than in thin plant populations (14). This interaction of lodging-promoting factors is apparently synergistic.

Several methods can be used to control lodging in small grains. Lodge-resistant varieties and semidwarf varieties have contributed greatly to the reduction of lodging, but have not eliminated it. Even semidwarf varieties can lodge when grown with abundant moisture and high fertility (16,31).

Timing of nitrogen fertilization can also help control lodging of small grains growing under high fertility levels. Abundant nitrogen during early growth of cereals promotes conditions conducive to lodging (9,14,31). Later applications of nitrogen after beginning of stem elongation and split applications during early growth and after beginning of stem elongation reduces this effect on the lower internodes and reduces the susceptibility to lodging while maintaining or increasing grain yield in wheat (6,26)

Timing of irrigation also influence lodging susceptibility of irrigated cereals. Withholding water during early vegetative growth of spring wheat reduced susceptibility to lodging following later irrigation (17). The authors suggested that irrigation be withheld until the boot stage unless the crop was experiencing moisture stress so excessive vegetative growth and height would not be promoted. However, another study on irrigating wheat concluded that for maximum yield, even slight plant water deficits should be avoided during jointing and that irrigations should be schelduled to replace water used by evapotranspiration (5).

Plant growth regulators have been used to prevent lodging in cereals. Chlormequat [(2-chloroethyl) trimethyl ammonium chloride] was first reported by Tolbert in 1960 to reduce height and increase stem diameters of young wheat plants (25). He also found that applying gibberellin reversed the action of previous chlormequat application on plant height. Simultaneous application of both resulted in no height reduction, suggesting that chlormequat interferes with gibberellin synthesis. Subsequent researchers reported that chlormequat has similar effects on height of other cereals leading to decreased lodging (7,8,11,24).

Ethephon [(2-chloroethyl) phosphonic acid] is another plant growth regulator that reduces height and lodging of cereals (2,4,8,19). Decomposition of ethephon in plant tissue releases ethylene which inhibits auxin transport in some species causing a reduction in stem elongation (13,29). Ethephon effectively reduces height and lodging in wheat and barley when applied at rates of 0.28 to 0.56 kg ai/ha at boot stage (2, 4). Higher rates (1.12 and 2.24 kg ai/ha) reduced height and lodging but decreased grain yields in winter wheat (2). Rowell and Miller reported that ethephon can cause male sterility when applied at high rates during the boot stages and has been tested as a male gametocide in hybrid wheat programs (18).

Small grains have been shown to differ in magnitude of response to these growth regulators. Ethephon dwarfed oats (Avena sativa L.) more than wheat, barley or rye (Secale cereale L.) (32). In a study by Clark and Fedak, chlormequat reduced the height of wheat more than it did oats and barley (3). Also, in comparing the response of 53 barley varieties, they found reaction to chlormequat ranged from that of height reduction to an increase in height.

Chlormequat is most commonly applied at GS 4-6 on the Feekes Scale (10) of small grains, whereas ethephon is most effective when applied at GS 8-10 (1,2,3,4,8,9,19,24). The later application allows better assessment of lodging potential before treating. Effective rates of chlormequat to reduce lodging are 4.0 to 6.0 kg/ha compared to 0.28 to 0.66 kg/ha for ethephon, so less chemical is used (1,2,4,8,9).

## Materials and Methods

Experiments were conducted at two locations in 1983 and 1984. One near Gettysburg, South Dakota on a Lowry silt loam (Typic Haplustolls-coarse-silty, mixed, mesic) with organic matter of 1.2% and pH of 7.2; the second location was near Redfield, South Dakota, on a Great Bend silt loam (Udic Haploborolls-fine-silty, mixed) with organic matter of 2.8% and pH of 7.4. The experimental design at both locations was a split plot with four replications; varieties as main plots and ethephon applications as subplots.

Both sites were fertilized for a yield goal of 6000 kg/ha according to soil test recommendations. Propachlor at 4.48 kg/ha was applied preemergence to control annual grasses. Bromoxynil+MCPA at 0.42+0.42 kg/ha was applied postemergence to control broadleaf weeds. 'Len', 'Marshall', and 'Butte' varieties of wheat were planted at Redfield on April 23, 1983 and April 24, 1984. Butte and Marshall were planted at Gettysburg on April 20, 1983 and April 10, 1984. Len was also planted at Gettysburg in 1984. Seeding rate for each variety was adjusted for kernel size and germination to obtain a uniform rate of 170 seeds/m$^2$. Sub plots were 1.5 by 4.2 m and 1.5 by 5.7 m at Redfield and Gettysburg, respectively, with seven rows 17.8 cm apart. Plots were sprinkler irrigated when the soil at the 0.3 m depth reached 50-60% of field capacity. Mancozeb at 2.24 kg/ha was used when necessary to control Tan Spot (*Pyrenophora trichostoma*).

Ethephon treatments were: 0.14 kg/ha at GS 4 and GS 6, 0.28 kg/ha at GS 4, 0.28 kg/ha at GS 6, 0.28 kg/ha at GS 8, 0.56 kg/ha at GS 8, and untreated. In 1984 one additional sub treatment of 0.42 kg/ha at GS 8 was included. Growth stages (GS) at application were determined using the Feekes Scale (10, Appendix A). Butte is earlier maturing than Len or Marshall; therefore, Butte was at GS 9 at the last application date. Either a bicycle-wheeled sprayer or backpack sprayer was used to apply ethephon in 187 L/ha of water at 245 kPa. Spraying information is in Appendix B.

Lodging was visually evaluated at GS 11.2 and at harvest. The Belgium lodging index (19) was used which evaluates the severity of lodging as well as amount of lodging as indicated by the formula:

Lodging index=S x I x 0.2

S=surface area lodged (1=no lodging, 9=total lodging)

I=lodging intensity (1=erect, 5=completely flat)

The scale ranges from 0.2 (no lodging) to 9.0 (total area flat). At GS 11.2, plant height was measured from the ground to the base of a spike at three random location in each sub plot. The internodes above the soil surface were measured for ten stems selected randomly from each sub plot. Internode diameter was also measured for each internode and stem in 1984. Plots were harvested on August 8, 1983 and August 10, 1984 at Redfield and August 9, 1983 and August 6, 1984 at Gettysburg with a plot combine to obtain yield, test weight, percent protein, and weight per 1000 seeds. Percent protein was determined using a Technicon Infra Analyzer calibrated for spring wheat.

In 1984 one row 3.0 m long at Redfield and 4.6 m long at Gettysburg was selected at random from each sub plot to be harvested by hand for determining yield components before using the plot combine. The number of spikes were counted from each row sample and ten spikes selected for a subsample. The number of spiklets, kernels, and grain weight per spike were determined from this subsample. The remaining spikes were threshed, weighed, and added to the total plot yield harvested by combine.

Data were evaluated with analysis of variance and correlation analysis for each year. Means were compared with Waller-Duncan K-ratio t-test. Path coefficients were computed from partial regression coefficients and standard deviations of the dependent and independent variables (12). Yield was considered the dependent variable and the components as independent.

## Results and Discussion

Application of ethephon effectively reduced the height of spring wheat (Table 1). Heights were averaged across varieties because there was no significant interaction between varieties and treatments. At Redfield in both years height was reduced significantly as rate increased and by later application at GS 8. In 1983 plants treated with ethephon at either GS 6 or GS 8 were significantly shorter compared to untreated plants at Redfield. All treated plants in 1984 were significantly shorter than untreated ones. This is in agreement with results reported by others on best time of application for winter wheat, barley, oats and triticale (2,4).

At Gettysburg in 1983 (Table 1), applications of ethephon at 0.28 and 0.56 kg/ha were significantly different from the untreated, but not from each other. All treated plants except those treated with 0.28 kg/ha at GS 4 were significantly shorter than the untreated in 1984. Height decreased as rate increased at the GS 8 application date, but different application times of the same rate (0.28 kg/ha) were not significant. Dahnous, et. al., reported height reduction of semidwarf wheats only at 0.55 or 0.85 kg/ha. (4). In this study the heights of both semidwarfs (Len and Marshall) were reduced by 0.28 kg/ha at GS 8. This reduction in height would decrease the forces of wind and

Table 1. Height reduction by ethephon on spring wheat averaged across varieties at Redfield and Gettysburg in 1983 and 1984.

| | | 1983 | | 1984 | |
|---|---|---|---|---|---|
| | | Redfield | Gettysburg | Redfield | Gettysburg |
| Rate (kg/ha) | Growth Stage | Height* (cm) | Height* (cm) | Height* (cm) | Height* (cm) |
| Untreated | -- | 77.6 a | 80.9 a | 83.7 a | 80.2 a |
| 0.14 | GS 4&6 | 74.7 b | 78.8 ab | 80.7 b | 77.3 bcd |
| 0.28 | GS 4 | 77.7 a | 75.8 b | 80.9 b | 78.8 ab |
| 0.28 | GS 6 | 74.9 b | 76.4 b | 79.6 b | 76.0 cd |
| 0.28 | GS 8 | 71.0 c | 75.8 b | 76.9 c | 77.8 bc |
| 0.42 | GS 8 | -- | -- | 74.6 d | 76.1 cd |
| 0.56 | GS 8 | 66.6 d | 75.7 b | 72.8 e | 75.9 d |

*Means within a column followed by the same letter are not significantly different at the 5% level using the Waller-Duncan k-ratio T-test (k=100).

Table 2. Reduction of internode lengths averaged across varieties at Redfield in 1983.

| Rate | Growth | Internode length (mm)* ** | | |
|---|---|---|---|---|
| (kg/ha) | Stage | 1 | 2 | 3 |
| Untreated | -- | 372 a | 180 a | 122 a |
| 0.14 | GS 4&6 | 365 a | 154 bc | 111 b |
| 0.28 | GS 4 | 375 a | 176 a | 120 ab |
| 0.28 | GS 6 | 366 a | 160 b | 111 b |
| 0.28 | GS 8 | 342 b | 149 c | 108 b |
| 0.56 | GS 8 | 333 b | 134 d | 103 c |

*Means within a column followed by the same letter are not significantly different at the 5% level using the Waller-Duncan k-ratio T-test (k=100).

**Internode No. 1 is the uppermost internode, No. 2 is below No. 1 and so on.

grain weight on the lower internodes and roots. Plant height in relation to weight of the upper portions of the plant is a character related to lodging (14).

A lodging character which has been studied extensively is the length of various internodes of the stem, since elongated plants form slender and weak stems (14). Stem diameter is also an important property in resisting bending and breaking.

Length reduction of individual internodes was closely associated with stage and rate of ethephon application (Tables 2,3,4, and 5). Ethephon reduced length of internode No. 1 when applied at GS 8 at Redfield in 1983 (Table 2). Length of internodes No. 2 and 3 were reduced when ethephon was applied at GS 6 and 8. In 1984 at Redfield all applications of ethephon reduced internode length (Table 3). The reduction in length of the top two internodes was increased at later stages of application and higher rates. The greatest length reduction in internode No. 3 occurred when ethephon was applied at 0.28 kg/ha. The third internode was elongating at the time of application.

Gettysburg results are similar to those obtained at Redfield. The top two internodes were not significantly affected by ethephon in either year until application at GS 8 (Tables 4 and 5). Internode No. 3 was significantly reduced by 0.56 kg/ha at GS 6 in 1984. Internodes below No.

Table 3. Reduction of internode lengths averaged across varieties at Redfield in 1984.

| Rate (kg/ha) | Growth Stage | Internode length (mm)* ** 1 | 2 | 3 |
|---|---|---|---|---|
| Untreated | -- | 414 a | 196 a | 120 a |
| 0.14 | GS 4&6 | 394 b | 182 b | 113 b |
| 0.28 | GS 4 | 396 b | 185 b | 112 b |
| 0.28 | GS 6 | 381 c | 173 c | 105 c |
| 0.28 | GS 8 | 361 d | 172 c | 113 b |
| 0.42 | GS 8 | 350 e | 176 c | 112 b |
| 0.56 | GS 8 | 346 e | 160 d | 111 bc |

*Means within a column followed by the same letter are not significantly different at the 5% level using the Waller-Duncan k-ratio T-test (k=100).

**Internode No. 1 is the uppermost internode, No. 2 is below No. 1 and so on.

Table 4. Reduction of internode lengths averaged across varieties at Gettysburg in 1983.

| Rate (kg/ha) | Growth Stage | Internode length (mm)* ** 1 | 2 | 3 |
|---|---|---|---|---|
| Untreated | -- | 336 ab | 189 a | 137 a |
| 0.14 | GS 4&6 | 386 a | 184 ab | 132 ab |
| 0.28 | GS 4 | 375 ab | 184 ab | 130 ab |
| 0.28 | GS 6 | 365 abc | 181 ab | 129 ab |
| 0.28 | GS 8 | 356 bc | 178 bc | 133 ab |
| 0.56 | GS 8 | 341 c | 169 c | 124 b |

*Means within a column followed by the same letter are not significantly different at the 5% level using the Waller-Duncan k-ratio T-test (k=100).

**Internode No. 1 is the uppermost internode, No. 2 is below No. 1 and so on.

3 were not significantly affected (data not presented). Internode diameter was not significantly affected by ethephon application (Table 6) although there was some variation among treatments.

Lodging in Butte was significantly reduced by ethephon application at GS 8 in both years and locations (Table 7,8, and 9). Significant lodging reduction in a semidwarf only occured in Marshall at Gettysburg in 1983 (Table 7) where severe lodging was present. Lodging was reduced by ethephon application at GS 8, but only the high rate was significantly different from the untreated. Lodging of Len and Marshall occurred in 1984 at both locations (Table 9), but was not as severe. No lodging occured in the semidwarf plots when ethephon was applied at GS 8, but it was not significantly different from the untreated. Lodging reduction was positively correlated to decrease in plant height.

Spring wheat yields in 1983 were not negatively affected by ethephon except for the 0.56 kg/ha rate at GS 8 on Marshall and Len (Tables 10 and 11). This is why the 0.42 kg/ha rate was included in 1984. Application of ethephon at GS 4 and 6 on Marshall at Redfield produced a yield increase compared to the untreated even though no lodging occured in 1983 (Table 11). Yield was significantly reduced by all ethephon applications in 1984, compared to the untreated except for 0.28 kg/ha at GS 6 (Table 12).

Table 5. Reduction of internode lengths averaged across varieties at Gettysburg in 1984.

| Rate (kg/ha) | Growth Stage | Internode length (mm)* ** 1 | 2 | 3 |
|---|---|---|---|---|
| Untreated | -- | 396 ab | 172 a | 117 a |
| 0.14 | GS 4&6 | 382 c | 168 ab | 114 ab |
| 0.28 | GS 4 | 403 a | 173 a | 113 abc |
| 0.28 | GS 6 | 389 bc | 166 ab | 109 bc |
| 0.28 | GS 8 | 384 c | 165 b | 113 abc |
| 0.42 | GS 8 | 379 c | 162 b | 109 bc |
| 0.56 | GS 8 | 379 c | 160 b | 107 c |

*Means within a column followed by the same letter are not significantly different at the 5% level using the Waller-Duncan k-ratio T-test (k=100).

**Internode No. 1 is the uppermost internode, No. 2 is below No. 1 and so on.

Table 6. Effect of ethephon on internode diameter averaged across varieties and locations in 1984.

| Rate (kg/ha) | Growth Stage | Internode diameter (mm)* ** 1 | 2 | 3 |
|---|---|---|---|---|
| Untreated | -- | 2.8 a | 3.5 a | 3.4 a |
| 0.14 | GS 4&6 | 2.7 a | 3.3 a | 3.2 a |
| 0.28 | GS 4 | 2.8 a | 3.4 a | 3.2 a |
| 0.28 | GS 6 | 2.8 a | 3.3 a | 3.2 a |
| 0.28 | GS 8 | 2.6 a | 3.3 a | 3.2 a |
| 0.42 | GS 8 | 2.7 a | 3.3 a | 3.3 a |
| 0.56 | GS 8 | 2.7 a | 3.3 a | 3.2 a |

*Means within a column followed by the same letter are not significantly different at the 5% level using the Waller-Duncan k-ratio T-test (k=100).

**Internode No. 1 is the uppermost internode, No. 2 is below No. 1 and so on.

Table 7. Reduction of lodging of spring wheat varieties by ethephon at Gettysburg in 1983.

| | | Marshall* ** | | Butte* ** | |
|---|---|---|---|---|---|
| Rate (kg/ha) | Growth Stage | GS 11.2 Lodging | Harvest Lodging | GS 11.2 Lodging | Harvest Lodging |
| Untreated | -- | 0.2 a | 2.2 ab | 3.9 ab | 6.1 a |
| 0.14 | GS 4&6 | 0.2 a | 1.3 abc | 3.3 b | 5.5 ab |
| 0.28 | GS 4 | 0.2 a | 2.4 a | 5.0 a | 6.2 a |
| 0.28 | GS 6 | 0.2 a | 2.0 abc | 2.6 bc | 5.7 a |
| 0.28 | GS 8 | 0.2 a | 0.4 bc | 1.5 cd | 3.3 bc |
| 0.56 | GS 8 | 0.2 a | 0.2 c | 0.9 d | 2.4 c |

*Means within a column followed by the same letter are not significantly different at the 5% level using the Waller-Duncan k-ratio T-test (k=100).

**The scale ranges from 0.2 (no lodging) to 9.0 (total area flat).

Table 8. Reduction of lodging of spring wheat varieties by ethephon at Redfield in 1983.

| | | Marshall* ** | | Butte* ** | | Len* ** | |
|---|---|---|---|---|---|---|---|
| Rate (kg/ha) | Growth Stage | GS 11.2 Lodging | Harvest Lodging | GS 11.2 Lodging | Harvest Lodging | GS 11.2 Lodging | Harvest Lodging |
| Untreated | -- | 0.2 a | 0.2 a | 0.4 b | 1.5 b | 0.2 a | 0.2 a |
| 0.14 | GS 4&6 | 0.2 a | 0.2 a | 0.2 b | 0.2 c | 0.2 a | 0.2 a |
| 0.28 | GS 4 | 0.2 a | 0.2 a | 1.1 a | 2.6 a | 0.2 a | 0.2 a |
| 0.28 | GS 6 | 0.2 a | 0.2 a | 0.4 b | 0.9 bc | 0.2 a | 0.2 a |
| 0.28 | GS 8 | 0.2 a | 0.2 a | 0.2 b | 0.2 c | 0.2 a | 0.2 a |
| 0.56 | GS 8 | 0.2 a | 0.2 a | 0.2 b | 0.4 c | 0.2 a | 0.2 a |

*Means within a column followed by the same letter are not significantly different at the 5% level using the Waller-Duncan k-ratio T-test (k=100).

**The scale ranges from 0.2 (no lodging) to 9.0 (total area flat).

Table 9. Reduction of lodging of spring wheat varieties by ethephon averaged across locations in 1984.

| Rate (kg/ha) | Growth Stage | Marshall* ** GS 11.2 Lodging | Marshall* ** Harvest Lodging | Butte* ** GS 11.2 Lodging | Butte* ** Harvest Lodging | Len* ** GS 11.2 Lodging | Len* ** Harvest Lodging |
|---|---|---|---|---|---|---|---|
| Untreated | -- | 0.2 a | 0.9 a | 1.6 a | 2.7 a | 0.2 a | 0.4 a |
| 0.14 | GS 4&6 | 0.2 a | 1.0 a | 0.9 b | 1.7 ab | 0.2 a | 0.5 a |
| 0.28 | GS 4 | 0.2 a | 0.8 a | 0.9 b | 1.3 bc | 0.2 a | 0.5 a |
| 0.28 | GS 6 | 0.2 a | 0.6 a | 0.3 c | 0.8 bc | 0.2 a | 0.5 a |
| 0.28 | GS 8 | 0.2 a | 0.2 a | 0.2 c | 0.2 c | 0.2 a | 0.2 a |
| 0.42 | GS 8 | 0.2 a | 0.2 a | 0.2 c | 0.2 c | 0.2 a | 0.2 a |
| 0.56 | GS 8 | 0.2 a | 0.2 a | 0.2 c | 0.2 c | 0.2 a | 0.2 a |

*Means within a column followed by the same letter are not significantly different at the 5% level using the Waller-Duncan k-ratio T-test (k=100).

**The scale ranges from 0.2 (no lodging) to 9.0 (total area flat).

Table 10. Effect of ethephon on plot yield of spring wheat varieties at Gettysburg in 1983.

| Rate (kg/ha) | Growth Stage | Marshall* (kg/ha) | Butte* (kg/ha) |
|---|---|---|---|
| Untreated | -- | 4972 a | 3700 ab |
| 0.14 | GS 4&6 | 4956 a | 3940 a |
| 0.28 | GS 4 | 4703 ab | 3434 b |
| 0.28 | GS 6 | 4925 a | 3678 ab |
| 0.28 | GS 8 | 4755 a | 3791 ab |
| 0.56 | GS 8 | 4381 b | 4030 a |

*Means within a column followed by the same letter are not significantly different at the 5% level using the Waller-Duncan k-ratio T-test (k=100).

Table 11. Effect of ethephon on plot yield of spring wheat varieties at Redfield in 1983.

| Rate (kg/ha) | Growth Stage | Marshall* (kg/ha) | Butte* (kg/ha) | Len* (kg/ha) |
|---|---|---|---|---|
| Untreated | -- | 3654 c | 3576 ab | 3289 a |
| 0.14 | GS 4&6 | 4052 a | 3864 a | 3259 a |
| 0.28 | GS 4 | 3918 ab | 3400 b | 3390 a |
| 0.28 | GS 6 | 4129 a | 3894 a | 3244 a |
| 0.28 | GS 8 | 3726 bc | 3725 ab | 3221 a |
| 0.56 | GS 8 | 3303 d | 3438 b | 2670 b |

*Means within a column followed by the same letter are not significantly different at the 5% level using the Waller-Duncan k-ratio T-test (k=100).

Table 12. Effect of ethephon on plot yield across varieties and locations in 1984.

| Rate (kg/ha) | Growth Stage | Yield* (kg/ha) |
|---|---|---|
| Untreated | -- | 4691 a |
| 0.14 | GS 4&6 | 4506 bc |
| 0.28 | GS 4 | 4516 bc |
| 0.28 | GS 6 | 4538 ab |
| 0.28 | GS 8 | 4370 cd |
| 0.42 | GS 8 | 4300 d |
| 0.56 | GS 8 | 3998 e |

*Means within a column followed by the same letter are not significantly different at the 5% level using the Waller-Duncan k-ratio T-test (k=100).

This yield reduction was greatest at GS 8 applications compared to GS 4 and at higher rates of ethephon at GS 8. Harvest loss due to lodging was not a factor since a small plot combine was used and severe lodging only occured at Gettysburg in 1983.

Protein content of spring wheat was significantly increased by ethephon application at GS 8 except for 0.28 kg/ha in 1983 (Table 13). This is most likely caused by yield reduction rather than the direct result of the treatments. Protein content is usually negatively correlated with yield.

Application of ethephon increased the test weight of Marshall in 1983 (Table 14). The test weights of the other varieties were not significantly different. Test weight of Marshall was increased by application at GS 6 and 8. At Redfield in 1984, test weight of Marshall was increased by ethephon application at GS 4 and 8 (Table 15). The test weight of Len was decreased by ethephon application at all stages. Test weights at Gettysburg were nonsignificant (Table 16).

Since yield was significantly affected by certain applications of ethephon, we wanted to know the effect of ethephon on yield components. Several researchers have previously determined the components important in yield of wheat. The number of kernels per spike was found to be an

Table 13. Ethephon's effect on protein content of spring wheat across varieties and locations in 1983 and 1984.

| Rate (kg/ha) | Growth Stage | 1983 Protein (%) | 1984 Protein (%) |
|---|---|---|---|
| Untreated | -- | 15.7 b | 16.3 c |
| 0.14 | GS 4&6 | 15.8 b | 16.3 c |
| 0.28 | GS 4 | 16.0 ab | 16.3 bc |
| 0.28 | GS 6 | 15.8 b | 16.4 bc |
| 0.28 | GS 8 | 15.9 b | 16.5 ab |
| 0.42 | GS 8 | -- | 16.6 a |
| 0.56 | GS 8 | 16.2 a | 16.5 a |

*Means within a column followed by the same letter are not significantly different at the 5% level using the Waller-Duncan k-ratio T-test (k=100).

Table 14. Effect of ethephon on test weight of spring wheat varieties across locations in 1983.

| Rate (kg/ha) | Growth Stage | Marshall* (lb/bu) | Butte* (lb/bu) | Len* (lb/bu) |
|---|---|---|---|---|
| Untreated | -- | 55.3 c | 56.3 a | 52.4 a |
| 0.14 | GS 4&6 | 56.5 b | 56.1 a | 52.7 a |
| 0.28 | GS 4 | 55.6 c | 54.8 a | 52.8 a |
| 0.28 | GS 6 | 57.1 a | 55.4 a | 51.1 a |
| 0.28 | GS 8 | 56.7 ab | 56.4 a | 52.5 a |
| 0.56 | GS 8 | 56.9 ab | 56.3 a | 53.3 a |

*Means within a column followed by the same letter are not significantly different at the 5% level using the Waller-Duncan k-ratio T-test (k=100).

Table 15. Effect of ethephon on test weight of spring wheat varieties at Redfield in 1984.

| Rate (kg/ha) | Growth Stage | Marshall* (lb/bu) | Butte* (lb/bu) | Len* (lb/bu) |
|---|---|---|---|---|
| Untreated | -- | 57.4 c | 57.6 a | 56.5 a |
| 0.14 | GS 4&6 | 58.2 ab | 57.2 a | 55.3 bc |
| 0.28 | GS 4 | 58.2 ab | 57.8 a | 54.9 c |
| 0.28 | GS 6 | 57.9 bc | 58.0 a | 54.7 c |
| 0.28 | GS 8 | 58.4 ab | 57.9 a | 55.6 b |
| 0.42 | GS 8 | 58.8 a | 57.9 a | 54.9 c |
| 0.56 | GS 8 | 58.3 ab | 57.2 a | 54.8 c |

*Means within a column followed by the same letter are not significantly different at the 5% level using the Waller-Duncan k-ratio T-test (k=100).

Table 16. Effect of ethephon on test weight of spring wheat varieties at Gettysburg in 1984.

| Rate (kg/ha) | Growth Stage | Marshall* (lb/bu) | Butte* (lb/bu) | Len* (lb/bu) |
|---|---|---|---|---|
| Untreated | -- | 59.9 a | 61.4 a | 58.1 a |
| 0.14 | GS 4&6 | 60.1 a | 61.1 a | 57.5 a |
| 0.28 | GS 4 | 60.2 a | 61.2 a | 56.8 a |
| 0.28 | GS 6 | 60.7 a | 61.2 a | 57.4 a |
| 0.28 | GS 8 | 60.7 a | 61.2 a | 57.2 a |
| 0.42 | GS 8 | 60.1 a | 61.5 a | 56.9 a |
| 0.56 | GS 8 | 60.3 a | 61.2 a | 56.4 a |

*Means within a column followed by the same letter are not significantly different at the 5% level using the Waller-Duncan k-ratio T-test (k=100).

important factor in yield of wheat along with the number of fertile spikelets per spike (15,28). A high positive correlation between yield and the number of spikes per unit area was found by Sprague (20). Thousand seed weight has also been positively correlated with yield (20,28).

Number of productive spikes per length of row was not significantly affected by ethephon application when compared to the untreated (Table 17). Ethephon has been reported to increase tillering in barley (32). The effect on tillering may have been reduced because of the high seeding density used.

In 1983, thousand kernel weight was reduced by application of 0.28 kg/ha at GS 4 and GS 6 but was increased by 0.56 kg/ha at GS 8 (Table 18). In 1984, thousand kernel weight of Butte was reduced by application of 0.14 and 0.56 kg/ha at their respective application stage and kernel weight of Len was reduced by all applications of ethephon (Table 19). At Gettysburg the thousand kernel weight of Marshall was increased by 0.28 kg/ha at GS 6 and 0.28 and 0.56 kg/ha at GS 8 (Table 20). The decrease of thousand kernel weight has been noted on barley (32). Also, Brown and Earley reported significant increased in seed weight from application at early and late boot stages in winter wheat (2).

Ethephon's effect on the number of spikelets per spike

Table 17. Effect of ethephon on number of spikes per 3.0 m length of row averaged across spring wheat varieties and locations in 1984.

| Rate (kg/ha) | Growth Stage | Spikes/3.0 m* |
|---|---|---|
| Untreated | -- | 324 ab |
| 0.14 | GS 4&6 | 337 ab |
| 0.28 | GS 4 | 336 ab |
| 0.28 | GS 6 | 355 a |
| 0.28 | GS 8 | 328 ab |
| 0.42 | GS 8 | 328 ab |
| 0.56 | GS 8 | 308 b |

*Means within a column followed by the same letter are not significantly different at the 5% level using the Waller-Duncan k-ratio T-test (k=100).

Table 18. Effect of ethephon on thousand kernel weight of spring wheat averaged across varieties and locations in 1983.

| Rate (kg/ha) | Growth Stage | Weight (g) |
|---|---|---|
| Untreated | -- | 24.67 b |
| 0.14 | GS 4&6 | 24.70 b |
| 0.28 | GS 4 | 24.12 c |
| 0.28 | GS 6 | 24.06 c |
| 0.28 | GS 8 | 24.84 b |
| 0.56 | GS 8 | 25.14 a |

*Means within a column followed by the same letter are not significantly different at the 5% level using the Waller- Duncan k-ratio T-test (k=100).

Table 19. Effect of ethephon on thousand kernel weight of spring wheat varieties at Redfield in 1984.

| Rate (kg/ha) | Growth Stage | Marshall* Weight (g) | Butte* Weight (g) | Len* Weight (g) |
|---|---|---|---|---|
| Untreated | -- | 25.40 ab | 29.83 a | 28.53 a |
| 0.14 | GS 4&6 | 25.25 ab | 27.98 c | 25.63 bc |
| 0.28 | GS 4 | 24.22 b | 28.78 abc | 25.13 cd |
| 0.28 | GS 6 | 25.12 ab | 28.78 abc | 24.66 d |
| 0.28 | GS 8 | 25.75 a | 29.22 ab | 25.75 bc |
| 0.42 | GS 8 | 26.30 a | 28.81 abc | 26.25 b |
| 0.56 | GS 8 | 25.80 a | 27.99 bc | 25.91 b |

*Means within a column followed by the same letter are not significantly different at the 5% level using the Waller-Duncan k-ratio T-test (k=100).

Table 20. Effect of ethephon on thousand kernel weight of spring wheat varieties at Gettysburg in 1984.

| Rate (kg/ha) | Growth Stage | Marshall* Weight (g) | Butte* Weight (g) | Len* Weight (g) |
|---|---|---|---|---|
| Untreated | -- | 27.55 c | 31.97 a | 28.57 a |
| 0.14 | GS 4&6 | 28.48 abc | 31.97 a | 27.45 a |
| 0.28 | GS 4 | 27.66 abc | 31.31 a | 26.88 a |
| 0.28 | GS 6 | 28.93 ab | 31.52 a | 27.09 a |
| 0.28 | GS 8 | 28.93 ab | 31.19 a | 26.83 a |
| 0.42 | GS 8 | 27.57 bc | 31.31 a | 26.92 a |
| 0.56 | GS 8 | 29.02 a | 31.31 a | 26.50 a |

*Means within a column followed by the same letter are not significantly different at the 5% level using the Waller-Duncan k-ratio T-test (k=100).

and the number of seeds per spikelet was nonsignificant (Table 21). The number of seeds per spike of Butte was significantly reduced by the highest rate of ethephon at GS 8 compared to the untreated (Table 22). Spike grain weight of Butte was reduced by ethephon at 0.28 kg/ha at GS 6 and 0.56 kg/ha at GS 8 (Table 23). Spike grain weight of Len was reduced by ethephon applications at GS 6.

Data from the row subsamples were also analyzed using correlation and path coefficients to look at the effect of ethephon on the relationship between yield and yield components. This method measures the direct influence of one variable on another and permits the separation of correlations into components of direct and indirect effects.

All four components were found to be highly correlated to row yield with significance varying among treatments (Tables 24-30) and row yield was highly correlated with total plot yield (data not presented). Thousand seed weight, seeds per spikelet, and spikes per unit area were found to be positively correlated to yield which agrees with results by Waldron and Sprague (20,28). Spikelets per spike was negatively correlated to row yield.

Application of 0.14 and 0.28 at GS 4 reduced the correlation between spikelets per spike and thousand seed weight (Tables 24, 25 and 26). Application of ethephon at GS 4, 6 and 8 increased the correlation between seeds per

Table 21. Effect of ethephon on seeds per spikelet and spikelets per spike of spring wheat averaged across varieties and locations in 1984.

| Rate (kg/ha) | Growth Stage | seeds/ spikelets | spikelet/ spike |
|---|---|---|---|
| Untreated | -- | 2.2 a | 12.8 a |
| 0.14 | GS 4&6 | 2.1 a | 12.7 a |
| 0.28 | GS 4 | 2.2 a | 13.0 a |
| 0.28 | GS 6 | 2.1 a | 12.7 a |
| 0.28 | GS 8 | 2.1 a | 12.6 a |
| 0.42 | GS 8 | 2.1 a | 12.6 a |
| 0.56 | GS 8 | 2.1 a | 12.3 a |

*Means within a column followed by the same letter are not significantly different at the 5% level using the Waller- Duncan k-ratio T-test (k=100).

Table 22. Effect of ethephon on number of seeds per spike of spring wheat varieties averaged across locations in 1984.

| Rated (kg/ha) | Growth Stage | Marshall* seeds/spike | Butte* seeds/spike | Len* seeds/spike |
|---|---|---|---|---|
| Untreated | -- | 29.1 a | 28.8 ab | 25.5 a |
| 0.14 | GS 4&6 | 27.3 a | 28.3 b | 24.7 a |
| 0.28 | GS 4 | 28.3 a | 30.1 a | 26.7 a |
| 0.28 | GS 6 | 28.3 a | 27.4 bc | 26.2 a |
| 0.28 | GS 8 | 27.8 a | 28.5 ab | 26.5 a |
| 0.42 | GS 8 | 27.5 a | 27.8 b | 25.7 a |
| 0.56 | GS 8 | 28.6 a | 26.2 c | 24.8 a |

*Means within a column followed by the same letter are not significantly different at the 5% level using the Waller-Duncan k-ratio T-test (k=100).

Table 23. Effect of ethephon on spike grain weight of spring wheat varieties averaged across locations in 1984.

| | | Marshall* | Butte* | Len* |
|---|---|---|---|---|
| Rate (kg/ha) | Growth Stage | Wt./spike (g) | Wt./spike (g) | Wt./spike (g) |
| Untreated | -- | 0.81 ab | 0.93 a | 0.77 a |
| 0.14 | GS 4&6 | 0.74 b | 0.88 abc | 0.63 c |
| 0.28 | GS 4 | 0.77 ab | 0.92 a | 0.71 ab |
| 0.28 | GS 6 | 0.80 ab | 0.84 bc | 0.68 bc |
| 0.28 | GS 8 | 0.81 ab | 0.90 ab | 0.75 a |
| 0.42 | GS 8 | 0.78 ab | 0.94 ab | 0.74 ab |
| 0.56 | GS 8 | 0.84 a | 0.82 c | 0.72 ab |

*Means within a column followed by the same letter are not significantly different at the 5% level using the Waller-Duncan k-ratio T-test (k=100).

Table 24. Correlation coefficients for yield components combined across varieties and locations for the untreated control.

| | Thousand seed weight | Spikelets per spike | Seeds per spikelet | Spikes per unit area | Row yield |
|---|---|---|---|---|---|
| Thousand seed weight | -- | -.54* | .28 | -.26 | .36 |
| Spikelets per spike | | | -.26 | -.29 | -.53* |
| Seeds per spiklet | | | | .23 | .52* |
| Spikes per unit area | | | | | .47* |

*Significant at the 5% level.

Table 25. Correlation coefficients for yield components combined across varieties and locations for ethephon at 0.14 kg/ha applied at GS 4&6.

| | Thousand seed weight | Spikelets per spike | Seeds per spikelet | Spikes per unit area | Row yield |
|---|---|---|---|---|---|
| Thousand seed weight | -- | -.32 | .49* | .01 | .58* |
| Spikelets per spike | | | .21 | -.34 | -.42* |
| Seeds per spiklet | | | | .09 | .40 |
| Spikes per unit area | | | | | .76* |

*Significant at the 5% level.

Table 26. Correlation coefficients for yield components combined across varieties and locations for ethephon at 0.28 kg/ha applied at GS 4.

| | Thousand seed weight | Spikelets per spike | Seeds per spikelet | Spikes per unit area | Row yield |
|---|---|---|---|---|---|
| Thousand seed weight | -- | -.24 | .56* | -.10 | .55* |
| Spikelets per spike | | | -.36 | -.02 | -.22 |
| Seeds per spiklet | | | | -.01 | .47* |
| Spikes per unit area | | | | | .60* |

*Significant at the 5% level.

Table 27. Correlation coefficients for yield components combined across varieties and locations for ethephon at 0.28 kg/ha applied at GS 6.

| | Thousand seed weight | Spikelets per spike | Seeds per spikelet | Spikes per unit area | Row yield |
|---|---|---|---|---|---|
| Thousand seed weight | -- | -.66* | .58* | .11 | .61* |
| Spikelets per spike | | | -.37 | -.14 | -.48* |
| Seeds per spiklet | | | | .40* | .63* |
| Spikes per unit area | | | | | .76* |

*Significant at the 5% level.

Table 28. Correlation coefficients for yield components combined across varieties and locations for ethephon at 0.28 kg/ha applied at GS 8.

| | Thousand seed weight | Spikelets per spike | Seeds per spikelet | Spikes per unit area | Row yield |
|---|---|---|---|---|---|
| Thousand seed weight | -- | -.56* | .72* | -.07 | .53* |
| Spikelets per spike | | | -.52* | -.51* | -.78* |
| Seeds per spiklet | | | | .07 | .45* |
| Spikes per unit area | | | | | .76* |

*Significant at the 5% level.

Table 29. Correlation coefficients for yield components combined across varieties and locations for ethephon at 0.42 kg/ha applied at GS 8.

| | Thousand seed weight | Spikelets per spike | Seeds per spikelet | Spikes per unit area | Row yield |
|---|---|---|---|---|---|
| Thousand seed weight | -- | -.41* | .66* | .23 | .54* |
| Spikelets per spike | | | -.30 | -.28 | -.48* |
| Seeds per spiklet | | | | .41* | .66* |
| Spikes per unit area | | | | | .81* |

*Significant at the 5% level.

Table 30. Correlation coefficients for yield components combined across varieties and locations for ethephon at 0.56 kg/ha applied at GS 8.

| | Thousand seed weight | Spikelets per spike | Seeds per spikelet | Spikes per unit area | Row yield |
|---|---|---|---|---|---|
| Thousand seed weight | -- | -.45* | .60* | .45* | .61* |
| Spikelets per spike | | | -.12 | -.21 | -.30 |
| Seeds per spiklet | | | | .13 | .36 |
| Spikes per unit area | | | | | .83* |

*Significant at the 5% level.

spikelet and thousand seed weight. The correlation between spikes per unit area and row yield increased in the ethephon treatments and was highest at 0.56 kg/ha applied at GS 8.

Partitioning each correlation into their components gives a better explanation of what was occuring (Table 31). Application of ethephon at GS 4 and 6 increased the direct effect of seed weight on yield. The direct effect was decreased by application of 0.42 and 0.56 kg/ha at GS 8. The indirect effect of seed weight via spikes per unit area went from a negative value to a high positive value for 0.42 and 0.56 kg/ha at GS 8 nullifying the decrease in direct effect. If one were looking only at total correlation, the true direction of association would have been missed because of indirect effects.

Application at of 0.14 and 0.28 kg/haGS 4 and 0.56 kg/ha at GS 8 decreased the direct effect of spikelets per spike on yield and was reflected in total correlation. Direct effect and indirect effect via spikes per unit area in spikelets per spike vs. row yield was highest at 0.28 kg/ha at GS 8, resulting in a high correlation. Ethephon also decreased the direct effect of seeds per spikelet on yield, but was hidden by increased indirect effects. The direct effect of spikes per unit area was increased by applications of ethephon which was also reflected in total correlation.

Table 31. Effect of ethephon on path coefficient analysis of thousand seed weight, spikelets per spike, seeds per spikelet, and number of spikes per unit area on row yield.

| Pathways of association | Rate / Stage | -- / -- | 0.14 / 4&6 | 0.28 / 4 | 0.28 / 6 | 0.28 / 8 | 0.42 / 8 | 0.56 / 8 |
|---|---|---|---|---|---|---|---|---|
| Row yield vs. seed weight | | | | | | | | |
| Direct effect | | .307 | .534 | .499 | .411 | .282 | .181 | .162 |
| Indirect effect via spikelets/spike | | .088 | .006 | .005 | .048 | .171 | .064 | .026 |
| Indirect effect via seeds/spikelet | | .082 | .035 | .107 | .044 | .036 | .154 | .094 |
| Indirect effect via spikes/area | | -.113 | .006 | -.062 | .075 | .040 | .143 | .326 |
| Total correlation | | .364 | .581 | .549 | .578 | .529 | .542 | .608 |
| Row yield vs. spikelets/spike | | | | | | | | |
| Direct effect | | -.163 | -.018 | -.019 | -.073 | -.303 | -.157 | -.058 |
| Indirect effect via seed weight | | -.166 | -.168 | -.118 | -.289 | -.159 | -.073 | -.073 |
| Indirect effect via seeds/spikelet | | -.076 | .015 | -.068 | -.028 | -.027 | -.070 | -.018 |
| Indirect effect via spikes/area | | -.125 | -.250 | -.014 | -.092 | -.296 | -.175 | -.153 |
| Total correlation | | -.530 | -.421 | -.219 | -.482 | -.785 | -.475 | -.302 |
| Row yield vs. seeds/spikelet | | | | | | | | |
| Direct effect | | .290 | .072 | .190 | .076 | .051 | .233 | .156 |
| Indirect effect via seed weight | | .087 | .259 | .282 | .254 | .202 | .120 | .097 |
| Indirect effect via spikelets/spike | | .043 | -.004 | .007 | .027 | .159 | .047 | .007 |
| Indirect effect via spikes/area | | .100 | .067 | -.008 | .269 | .040 | .259 | .096 |
| Total correlation | | .520 | .394 | .471 | .626 | .452 | .659 | .356 |
| Row yield vs. spikes/area | | | | | | | | |
| Direct effect | | .436 | .738 | .651 | .674 | .581 | .634 | .726 |
| Indirect effect via seed weight | | -.080 | .004 | -.047 | .049 | .019 | .041 | .073 |
| Indirect effect via spikelets/spike | | .047 | .006 | .001 | .010 | .154 | .043 | .012 |
| Indirect effect via seeds/spikelet | | .066 | .007 | -.002 | .030 | .004 | .095 | .021 |
| Total correlation | | .469 | .755 | .602 | .763 | .758 | .813 | .832 |

Yield components showing the largest direct effect on row yield in this study were thousand seed weight and spikes per unit area.

The yield reduction caused by 0.56 kg/ha at GS 8 could be due to the nonsignificant reduction in spikes per unit area because of the high direct effect of it vs. row yield (Tables 17 and 31). Treatments at GS 4 and 6 produced lower thousand seed weights which could reduce yield because they produced the highest direct effect vs. row yield. Since yield components are multiplicative, small differences could result in larger differences in the yield, the dependent variable.

## SUMMARY

This experiment was designed to determine the effect of ethephon on morphological characters associated with lodging, grain quality and yield of irrigated spring wheat varieties.

Response of spring wheat to ethephon is dependent on stage of growth. Plant height was shortest when ethephon was applied at GS 8.

Ethephon significantly reduced lodging when applied at GS 8 whenever significant lodging occurred. The reduction in lodging was highly correlated with a reduction of overall height and internode length.

Test weight was variable among varieties, locations and years. Protein content was related more to yield than to the effect of ethephon.

Yield reduction from application of ethephon was variable among years. Lower rates (0.28 and 0.42 kg/ha) at GS 8 were safer because yield reduction was not as severe and lodging was still significantly reduced.

Yield was significantly correlated to yield components with thousand seed weight and spikes per unit area having the greatest direct effect. Some applications of ethephon produced decreases in these two components and could possibly be where yield reduction occurred in this study.

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# APPENDIX A

## Explanation of the Feekes Scale for growth stages in cereals

| Stage | |
|---|---|
| 1. | One shoot |
| 2. | Beginning of tillering |
| 3. | Tillers formed, leaves often twisted spirally. In some varieties of winter wheats, plants may be prostrate |
| 4. | Beginning of the erection of the pseudo-stem, leaf sheaths beginning to lengthen |
| 5. | Pseudo-stem (formed by sheaths of leaves) strongly erected |
| 6. | First node of stem visible at base of shoot |
| 7. | Second node of stem formed, next-to-last leaf just visible |
| 8. | Last leaf visible, but still rolled up, ear beginning to swell |
| 9. | Ligule of last leaf just visible |
| 10. | Sheath of last leaf completely grown out, ear swollen but not visible |
| 10.1 | First ears just visible (awns just showing in barley, ear escaping through split of sheath in wheat or oats) |
| | 10.2 Quarter of heading process completed |
| | 10.3 Half of heading process completed |
| | 10.4 Three-quarters of heading process completed |
| | 10.5 All ears out of sheath |
| | 10.5.1 Beginning of flowering (wheat) |
| | 10.5.2 Flowering complete to top of ear |
| | 10.5.3 Flowering over at base of ear |
| | 10.5.4 Flowering over, kernel watery ripe |
| 11.1 | Milky ripe |
| 11.2 | Mealy ripe, contents of kernel soft but dry |
| 11.3 | Kernel hard (difficult to divide by thumb-nail) |
| 11.4 | Ripe for cutting. Straw dead |

# APPENDIX B

## Spraying Information

| | Redfield | | | Gettysburg | | |
|---|---|---|---|---|---|---|
| GROWTH STAGE | GS 4 | GS 6 | GS 8 | GS 4 | GS 6 | GS 8 |
| **1983 Application** | | | | | | |
| Date | 5-31-83 | 6-10-83 | 6-15-83 | 5-30-83 | 6- 9-83 | 6-15-83 |
| Time | 10:30 p | 1:00 a | 10:00 p | 10:00 p | 10:00 p | 9:30 p |
| Cloud Cover | cloudy | cloudy | clear | cloudy | cloudy | clear |
| Rel. Humidity | 50 % | 50 % | 50 % | 50 % | 40 % | 50 % |
| Air Temperature | 13° C | 18° C | 15° C | 11° C | 21° C | 18° C |
| Wind (kph) | calm | 5-8 | calm | 3-5 | 8 | 5-6 |
| Leaf Moisture | dry | dry | moist | dry | dry | wet |
| **1984 Application** | | | | | | |
| Date | 6- 8-84 | 6-12-84 | 6-18-84 | 5-31-84 | 6- 7-84 | 6-13-84 |
| Time | 10:30 a | 10:30 p | 9:00 p | 3:30 p | 7:30 p | 10:30 a |
| Cloud Cover | cloudy | clear | cloudy | cloudy | cloudy | cloudy |
| Rel. Humidity | 70 % | 85 % | 75 % | 45 % | 50 % | 55 % |
| Air Temperature | 21° C | 17° C | 19° C | 30° C | 19° C | 24° C |
| Wind (kph) | 8 | calm | calm | 6-10 | 8 | 2-3 |
| Leaf Moisture | moist | wet | dry | dry | dry | dry |