GREEN FOXTAIL (*Setaria viridis*) COMPETITION IN SEMIDWARF AND NORMAL HEIGHT SPRING WHEAT

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Allen Richard Wayne Sturko

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ABSTRACT

Sturko, Allen Richard Wayne. M.Sc., The University of Manitoba, May, 1977. Green Foxtail (*Setaria viridis*) Competition in Semidwarf and Normal Height Spring Wheat. Major Professor: E. H. Stobbe.

The effect of green foxtail competition on yield and protein content of semidwarf (c.v. Norquay) and normal height (c.v. Napayo) spring wheat was studied in 1975 and 1976 at Carman, Manitoba

In 1975, 100 green foxtail/m^2 reduced the yield of both wheat varieties when sown on June 18. The yield of Norquay was reduced by 44% and Napayo by 21%. Further increases in green foxtail density resulted in further reduction in wheat yields. In 1976, when sown on June 3, 100 green foxtail/m^2 reduced Norquay wheat yield significantly, however, the density had to reach 800 green foxtail/m^2 for a significant reduction in yield of Napayo wheat.

Dichlofop methyl (methyl-2-[4-(2,4-dichlorophenoxy)-phenoxy] propanoate) at a rate of 1 kg/ha was used to remove the green foxtail at the various stages of growth. In 1975, there was no reduction in wheat yield when the green foxtail plants were removed in the 1-3 leaf stage of growth. If left until the 4-5 leaf stage or later a reduction in yield of both varieties occured. In 1976, no significant differences were noted in Napayo wheat yields for any of the stages of green foxtail removal. However, Norquay wheat yield was reduced by green foxtail competition. When green foxtail plants were left until the 6-7 leaf

stage of growth or later a significant reduction in Norquay wheat yield occurred.

The various seeding dates in 1976 showed that 200 green foxtail/m^2 reduced the yield of Norquay wheat with either May 14 or June 11 seeding dates. Napayo wheat showed reduced yields with 400 green foxtail/m^2 regardless of seeding date. Green foxtail competition in both varieties was less intense for the May 28 seeding date. Adverse weather conditions (overcast and cool temperatures) may account for the reduced competition noted for the May 28 seeding date.

The study indicated that normal height wheat can tolerate higher densities of green foxtail before significant reductions in wheat yields occur. If green foxtail competition is severe early removal (1-3 leaf stage of growth or earlier) will minimize wheat yield losses. Environmental conditions during germination and early growth can have a profound influence on green foxtail competition.

INTRODUCTION

Green foxtail (Setaria viridis) is a summer annual grass which has become a serious weed problem in cereal grains. Green foxtail is not a plant native to North America, but was introduced from Europe and Asia by early settlers with seed grains. Early weed surveys indicate that green foxtail was present in Manitoba as early as 1883, and by 1972 was present in 80% of fields surveyed (Alex et al., 1972). In a 1976 weed survey, green foxtail was the most common weed found in Manitoba grain fields (Donaghy, personal communication).

Although green foxtail has been present in Manitoba grain fields for many years, it has not become a serious weed problem until the last decade. When strong competitors such as wild mustard and wild oats are present in cereal crops they reduce the competitive ability of other weeds. The increased use of herbicides to control wild mustard and wild oats, has enabled green foxtail to flourish and become a serious weed problem.

Green foxtail is well adapted to present agronomic practices. It is capable of producing large quantities of seed, which is easily distributed due to shattering, and, because of late germination, generally escapes spring cultivation intended for weed control. These factors enable a few plants in a field to rapidly infest the entire field with densities high enough to reduce yields.

The purpose of this study was to determine a) the effect of several densities of green foxtail on spring wheat, b) the effect of removal of green foxtail at various stages on spring wheat, and c) the effect of green foxtail on wheat seeded on several dates.

LITERATURE REVIEW

Pavlychenko and Harrington (1935) defined plant competition as a natural phenomenon, in which certain plants of the same or unrelated species growing in close proximity, develope at the expense of their weaker rivals. The species or variety which is able to utilize the environment most efficiently attains competitive supremacy.

Pavlychenko and Harrington (1935) reported on competition between annual weeds and cereal crops. In their studies they found that cereal crops varied in their competitive efficiency. Barley was the most successful competitor, with rye next, then wheat and oats. Flax was the poorest competitor. Their data indicated a correlation between competitive efficiency and development of root systems. Barley had the most extensive root system, the other cereals followed in the order of their competitive ability. Behren *et al*. (1971) and Behren *et al*. (1974), reported that semidwarf cereal varieties were less competitive with weeds than were normal height varieties.

Pavlychenko and Harrington (1934) carried out studies to determine the factors which cause the reduction in yields. They noted that at five days after emergence the root system of the cereal was more extensive than the weeds, however, 21 days after emergence the weeds had a more extensive root system than the cereals. Pavlychenko and Harrington (1935) reported that competition from weeds reduced root development in cereals. They measured root development of wheat, sown at ordinary rates in drill rows free from weeds as compared with wheat sown in drill rows with weeds sown between the rows. In wheat grown with wild oats, the root system was reduced to approximately half that of wheat grown alone.

Pavlychenko and Harrington (1935) indicated that weed seeds require more moisture to germinate than do cereal seeds. Therefore, in a dry spring, cereals have a definite advantage over weeds. They suggested that in the Canadian prairies, where light is generally plentiful and soil fertility is high or can be corrected, moisture is generally the limiting factor.

Blackman and Templeman (1938) in studies on weed crop competition from 1932-1935, found variability in crop yield from year to year. They reported that weeds had a greater depressing effect in a wet spring than in a dry spring. Their experiments indicated that there was competition between weeds and crops for soil nutrients. They concluded other factors such as competition for light and water were also involved, with competition for light depending upon the weed species and density of the infestation.

Blackman and Templeman (1938) reported that the intensity of weed competition with a cereal was directly correlated to the density of the weed infestation. As the density of the weed increased the yield of the cereal decreased. Godel (1935, 1938) found that by increasing the seeding rate it was possible to increase wheat yield. He concluded that the increased seeding rate would give a denser stand of wheat to help smother the weeds.

In a recent review Rice (1974), reported on studies which suggested that the influence plants have upon one another may not be a purely physical process. Research data indicated that there are other mechanisms, such as excretion of toxins by plant species to secure an advantage over rival species. The term allelopathy has been used to refer to the production of chemical compounds to secure an advantage over rival species. Beyer (1960), found flax grown with Camelina alyssum, produced 40% less dry matter than did control plants. They found no toxic root excretions, but the leaves were found to be the source of potent plant inhibitors. Using artificial rain they found the inhibitors were leached from the leaves to the soil. Bell and Koeppe (1972), found that material leached from mature giant foxtail Setaria faberii plants reduced corn growth by 35%.

Several researchers have indicated that weeds reduce the tillering of cereals (Pavlychenko and Harrington, 1934; Godel, 1935; Burrows and Olson, 1955; Bowden and Friesen, 1967). Burrows and Olson (1955) noted, in work with wheat and wild mustard, that as wild mustard density increased there was a reduction in tillering and yield of wheat. Bowden and Friesen (1967), found that as few as ten wild oats per square yard reduce wheat tillering, and that when the density reached 160 to 190 wild oats per square yard, tillering was negligible. Weed species vary in their competitive efficiency, therefore they reduce tillering and yield in cereals by various amounts (Pavlychenko and Harrington, 1934).

Burrows and Olson (1955), reported that as few as ten wild mustard plants per square yard were sufficient to reduce yields of flax, while 50 wild mustard plants per square yard significantly reduced wheat yields. Bowden and Friesen (1967), reported that ten wild oats per square yard reduced the yield of both wheat and flax.

Bowden and Friesen (1967), conducted experiments to determine the effect time of removal has on the competitive effects of wild oats on wheat and flax. In 1964, they found that competition had commenced by the two to three leaf stage of wild oat growth. In 1965, their data indicated that competition had commenced prior to the one to two leaf stage of wild oat growth.

Several researchers (Pavlychenko and Harrington, 1934; Blackman and Templeman, 1938; Friesen et al., 1960; and Welbank, 1963) have shown that species of plants differ in their ability to compete for essential growth elements. Blackman and Templeman (1938), found that the presence of weeds depressed the nitrogen and potassium content of cereals but not the phosphorous content. Additions of nitrogen fertilizer raised the nitrogen and potassium content of the cereal to that of an unfertilized weed-free crop. They noted that the addition of nitrogen to a weedy crop increased the number of tillers as well as shoot and grain yield. They concluded that the response of a weedy crop to nitrogen was dependent upon the relative amounts taken up by the weeds and the crop. They stated the critical period was confined to the early stages of growth, since weeds that developed rapidly in the early part of the season depressed crop yields to a greater extent than did those developing later in the season. It was possible to raise the yield of the weedy crop to that of the weed-free, as long as there was sufficient nitrogen added to supply the maximum required by both the crop and the weed.

Work by Godel (1938) showed ammonium phosphate drilled with the seed reduced losses due to weeds by enhancing crop development in the early spring. Welbank (1963), showed that several weed species could lower the dry weight yield and leaf nitrogen content of wheat. The addition of nitrogen raised the dry weight and leaf nitrogen content of the weed infested crop to the same level as that of the control plants. In some cases the high nitrogen level decreased the dry weight yield of the wheat. He suggested that this may be due to nitrogen increasing the top growth of the weed and consequently shading of the wheat.

Friesen et al. (1960), found that a reduction in yield due to weed competition was generally accompanied by reductions in the protein content of harvested grain. Burrows and Olson (1955), found similar reductions in seed protein content as weed competition increased.

Only limited research has been reported on competitive effects of green foxtail in cereal crops. Friesen and Shebeski (1960) conducted a three year study (1956-1958) of losses due to weed competition in Manitoba grain fields. They found that green foxtail was present in excess of ten plants per square yard in over 47 percent of all fields surveyed. Where green foxtail was the predominant weed, small grain yields were not significantly affected by infestations of less than 350 to 400 plants per square yard. Their data inidcated that barley and oats were more tolerant than wheat to infestations of green foxtail. Similarly Dryden and Whitehead (1963), reported wheat offered little competition to green foxtail plants.

Alex (1967), reported that 1575 green foxtail plants per square meter could reduce the yield of wheat by 35%. He found that under low nitrogen conditions, green foxtail reduced the height of wheat by 5 cm. The rate of seeding did not affect wheat yield or green foxtail dry weight. Friesen (1964) reported that in barley green foxtail densities had to be in excess of 400 plants per square yard before reductions in yield occured. Rahman and Ashford (1972) found that wheat yields were not reduced by green foxtail when sown early, but when sown in late May or early June a reduction in yield occured. They stated that higher than average temperatures in May, or delayed seeding of cereal crops, permit green foxtail to become sufficiently competitive to cause appreciable reductions in crop yields.

Molberg (1970, 1971) found that green foxtail did not emerge until late May or early June. Early seeded crops made substantial growth before the green foxtail emerged.

Vanden Born (1971), showed that green foxtail required high temperatures for germination and emergence. At 15 C it took 17 days longer to reach maximum percent emergence (66%) than at 30 C (90%). He showed that with relatively low temperatures (13-15 C) and low light intensity green foxtail only grew to a height of 14 cm. Plants grown under high light 17,000 lux and 22-10 C day/night temperature regime, grew to a height of 90 cm. He stated that in early spring and summer, temperatures would be more limiting to green foxtail growth than would light intensity.

Rahman and Ashford (1972) reported that early sown wheat suppressed green foxtail growth, but a large amount of viable seed was still produced. They stated that if only 50 to 70 percent of the seed produced by green foxtail in competition with wheat germinated the following year, the infestation would be increased two or three fold. They also stated green foxtail could emerge from depths of 10 cm. Dawson and Bruns (1962) reported green foxtail would emerge from a depth of 10 cm, however emergence was greatest from the 1 to 2.5 cm depth. Although fewer seedlings emerged from 8 to 13 cms than from shallower depths, seeds at the deeper level are a potential source of weed infestation.

MATERIALS AND METHODS

General Procedures. Field experiments were conducted at the Carman Weed Research Station in 1975 and 1976. The soil type was an Almasippi very fine sandy loam: 79% sand, 7% silt, 14% clay and 3.6% organic matter. The climatic data for 1975 and 1976 are presented in Appendix Table 1 and Appendix Table 2 respectively. In 1975 the experiments were conducted on land previously sown to oats, while in 1976 the experiments were sown on land previously sown to triticale. Results from the soil test[1] indicated soil fertility was low. At the time of seeding 225 kg/ha of ammonium nitrate (34-0-0) and 45 kg/ha ammonium phosphate (11-55-0) was applied.

The plot area was fumigated with methyl bromide[2] to inactivate all weeds and weed seeds prior to planting.

The green foxtail seed used in the study was prepared from weed screenings supplied by Peter Friesen, Carman. The percent germination was determined by placing ten 100-seed samples on moist filter paper in petri dishes. The petri dishes were placed in a growth cabinet at constant 22C for 14 days and germination counts were made. Using the percent germination and 100-seed weight, seed samples were then

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1. Analysis of soil samples done by Provincial Soil Testing Laboratory.

2. Methyl bromide application procedures as outlined by Dow Chemical Company Ltd. in Dowfune MC-2 information pamphlet.

weighed, to give predetermined densities for each plot.

Spring wheat (c.v. Norquay, semidwarf and c.v. Napayo, normal height) was sown at 100 kg/ha with a double disc press drill 75 mm deep with a row spacing of 150 mm. Immediately after seeding, the foxtail seed was spread by hand and fertilizer was applied using a Gandy fertilizer spreader. The entire area was harrowed with a spike toothed harrow to incorporate the green foxtail seed and fertilizer.

After emergence, green foxtail plant counts were taken using a 1/16 m^2 area at two randomly selected sites in each plot. Green foxtail emerged at approximately the predetermined densities (± 5%).

Individual plots were 2.0 m by 4.0 m in size. When the crop reached maturity a 1.25 m by 4.0 m swath was harvested from the center of each plot. Green foxtail seed was screened from each harvest sample and its weight recorded. Yield and protein content[3] were then determined for each harvest sample. The data were analyzed statistically and Tukey's honestly significant difference test was used as the test of significance. Only differences at the 5% level of significance were considered meaningful.

Experiment I. Effect of several densities of green foxtail on spring wheat

The experiment was conducted in a latin square design, with separate studies being conducted for Norquay and Napayo wheat. The

3. Protein content was determined by the Kjeldahl Laboratory, University of Manitoba.

plots were sown on June 18, 1975 and June 3, 1976. Green foxtail densities were established at 0, 100, 200, 400, 800, and 1600 plants/m^2. The plots were harvested October 2, 1975 and September 2, 1976.

Experiment II. Removal of green foxtail at various stages and its effect on spring wheat

Separate studies for Norquay and Napayo were conducted, with plots being sown June 18, 1975 and June 3, 1976. Green foxtail densities were established at 0, 200, 400, and 800 plants/m^2. The foxtail was removed using a post emergent herbicide[4] at the 1 to 3 leaf stage, 4 to 5 leaf stage, 6 to 7 leaf stage and heading. A treatment in which the green foxtail was not removed (weedy check) was included at each planting density. The treatments were arranged in a randomized complete block design, replicated six times. The plots were harvested October 2, 1975 and September 2, 1976.

Experiment III. Effect of green foxtail in wheat seeded on several dates

The experiment was established in the field as a split-plot design replicated four times, with dates of seeding as the main plots and foxtail densities as the subplots. Norquay and Napayo wheat were seeded on three dates May 14, May 28 and June 11, with each variety being a separate study. Green foxtail densities of 0, 200, 400, 600 and 800 plants/m^2 were established. The plots were harvested as they

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4. Hoegrass (dichlofop methyl) was applied at 1 kg/ha (active ingredient) in 110 l/ha water with a bicycle sprayer.

matured, August 23, August 30 and September 9 for the three seeding dates respectively.

RESULTS

<u>Experiment I.</u> Effect of several densities of green foxtail on spring wheat

Wheat yields were greater in 1976 than in 1975. The yield of Napayo wheat was higher than Norquay in 1975, with the reverse situation occurring in 1976 (Figure 1). Wheat yield losses due to green foxtail competition were greater in 1975 than in 1976 (Figure 1, Table 1 and Table 2).

In 1975, 100 green foxtail plants/m^2 were sufficient to reduce the yield of Norquay (semidwarf) by 44% and Napayo wheat (normal height) by 21% (Table 1). As the density of green foxtail increased there were further decreases in the yield of both varieties. At 1600 green foxtail/m^2 Norquay wheat yield was reduced by 82% and Napayo wheat yield was reduced by 67%.

In 1976, 100 green foxtail/m^2 reduced the yield of Norquay wheat and Napayo wheat (Table 2). As the density increased the yield of Norquay decreased; 1600 green foxtail/m^2 reduced the yield by 31%. However, the treatments with 200 and 400 green foxtail plants/m^2 did not reduce the grain yield of Napayo wheat. The 800 and 1600 plants/m^2 treatments reduced the grain yield of Napayo wheats with the 1600 green foxtail/m^2 reducing the yield by 14%.

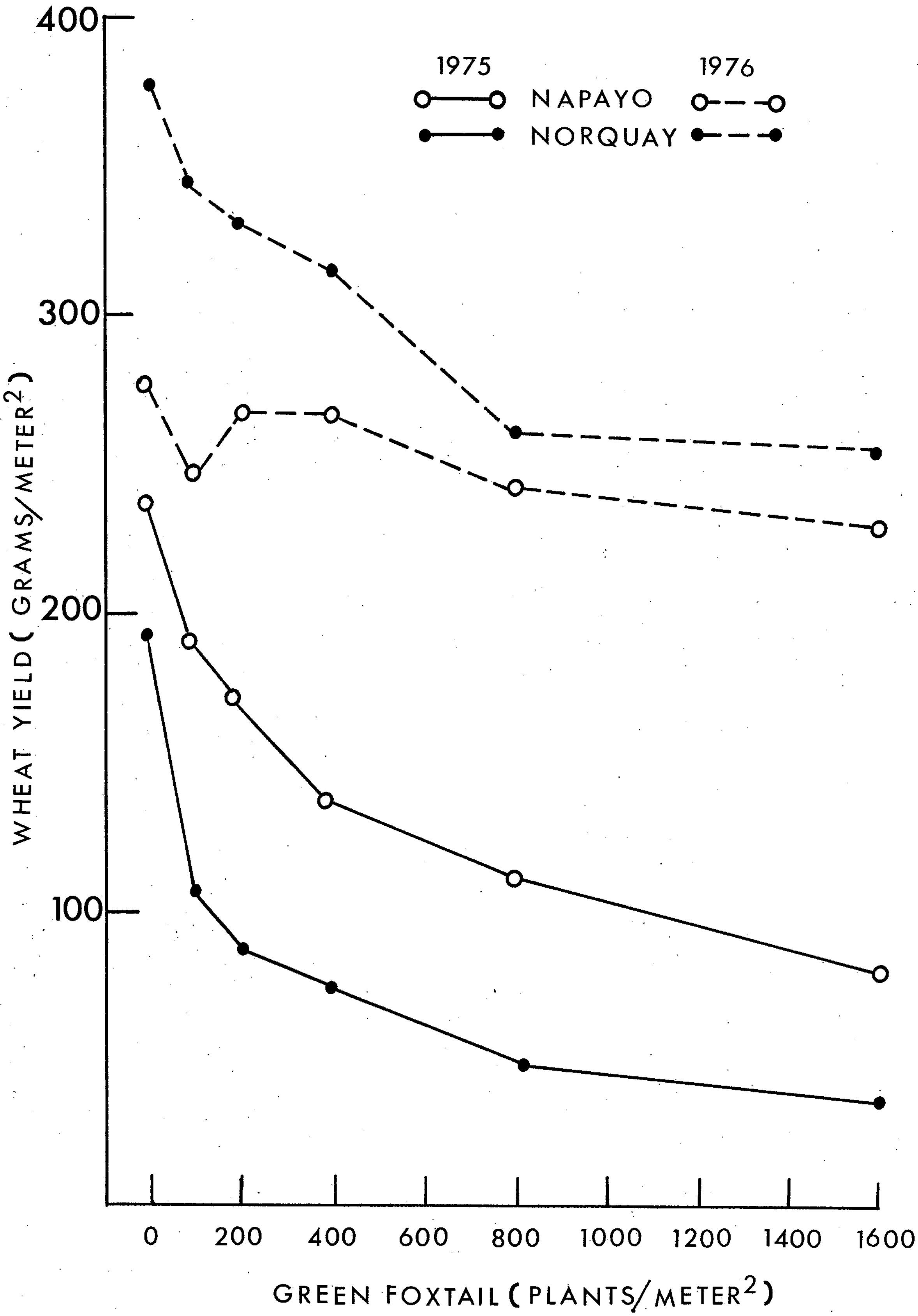

FIGURE 1. The effect of various densities of green foxtail on yield of Norquay and Napayo wheat, 1975, 1976

TABLE 1. Effect of several densities of green foxtail in spring wheat, 1975

Green foxtail plants per square meter	Yield of wheat kg/ha	Protein content of wheat %	Green foxtail seed kg/ha
a) Norquay wheat			
0	1923	16.7	0
100	1075	16.8	224
200	895	17.0	274
400	723	16.8	320
800	469	17.6	329
1600	346	16.7	255
Tukey's H.S.D. (0.05)	161	N.S.	148
b) Napayo wheat			
0	2367	14.9	0
100	1881	15.0	68
200	1713	14.9	89
400	1341	15.0	117
800	1088	14.9	178
1600	773	15.2	226
Tukey's H.S.D. (0.05)	218	N.S.	53

TABLE 2. Effect of several densities of green foxtail on spring wheat, 1976

Green foxtail plants per square meter	Yield of wheat kg/ha	Protein content of wheat %	Green foxtail seed kg/ha
a) Norquay wheat			
0	3763	16.2	0
100	3475	16.2	159
200	3303	16.2	199
400	3154	16.1	261
800	2649	16.1	336
1600	2612	16.1	380
Tukey's H.S.D. (0.05)	219	N.S.	62
b) Napayo wheat			
0	2762	17.3	0
100	2483	17.8	20
200	2672	17.6	23
400	2690	17.4	29
800	2467	17.7	41
1600	2374	17.7	38
Tukey's H.S.D. (0.05)	236	0.4	16

In 1975, grain yield reductions due to green foxtail competition, were greater in Norquay wheat than Napayo wheat at all densities studied.

The amount of green foxtail seed screened from the harvested wheat samples, increased with increasing green foxtail density in both years although not significantly (Table 1 and Table 2). Interspecies competition was severe and at the high densities of green foxtail intraspecies competition may have been important. The combined effect of the two competitions could have reduced the amount of green foxtail seed produced at the higher densities. There was more green foxtail seed screened from Norquay wheat than from Napayo wheat, indicating that green foxtail was more competitive with the semidwarf Norquay than with normal height Napayo.

Green foxtail seed shatters easily from the spike, therefore, the green foxtail seed screened from the harvest samples gives an estimate of the seed produced, and is not an accruate measure of green foxtail seed yield. As much as 20% of the green foxtail seed may have shattered before harvest. Shattering was not uniform over the area and may be the reason for variation within treatments indicated by the large H.S.D. values for green foxtail seed.

In 1976, the protein content of Napayo wheat was higher when green foxtail competed strongly with the crop and reduced the yield compared to the plots with no green foxtail. The protein content of the harvested wheat samples, for the other densities studies (Table 1 and Table 2), were not significantly affected by green foxtail competition. However, protein production per hectare was depressed in parallel with harvest yield.

Experiment II. Removal of green foxtail at various stages and its effect on spring wheat

In 1975, green foxtail competition was severe. When the green foxtail was removed by the 1 to 3 leaf stage of growth, there was no reduction in yield of Norquay wheat (Figure 2) or Napayo wheat (Figure 3). When the foxtail was left until the 4 to 5 leaf stage or later there was a significant reduction in wheat yield (Table 3 and Table 4). The reduction in wheat yield increased with increasing green foxtail density. When the green foxtail was not removed until the 4-5 leaf stage the reduction in Norquay wheat yield was 10% with 200 green foxtail/m^2, 22% with 400 green foxtail/m^2 and 31% with 800 green foxtail/m^2 (Table 3). Napayo wheat yield losses were 12% with 200 green foxtail/m^2, 18% with 400 green foxtail/m^2 and 34% with 800 green foxtail/m^2 when removed at the 4 to 5 leaf stage of growth (Table 4). Removal at the heading stage caused a reduction, although not significant in yield of both wheat varieties. The apparent yield reduction may have been due to the herbicide application. At this late stage, dichlofop methyl caused some chlorosis, and the spraying operation caused some mechanical damage to the wheat.

Green foxtail competition was less severe in 1976, and the green foxtail could be left in the crop until the 4-5 leaf stage of growth with no reduction in Norquay wheat yield (Table 5). When the green foxtail was not removed until the 6-7 leaf stage of growth there was a reduction in the yield of Norquay wheat. There was no reduction in Napayo wheat yield regardless of stage of green foxtail removal (Table 6).

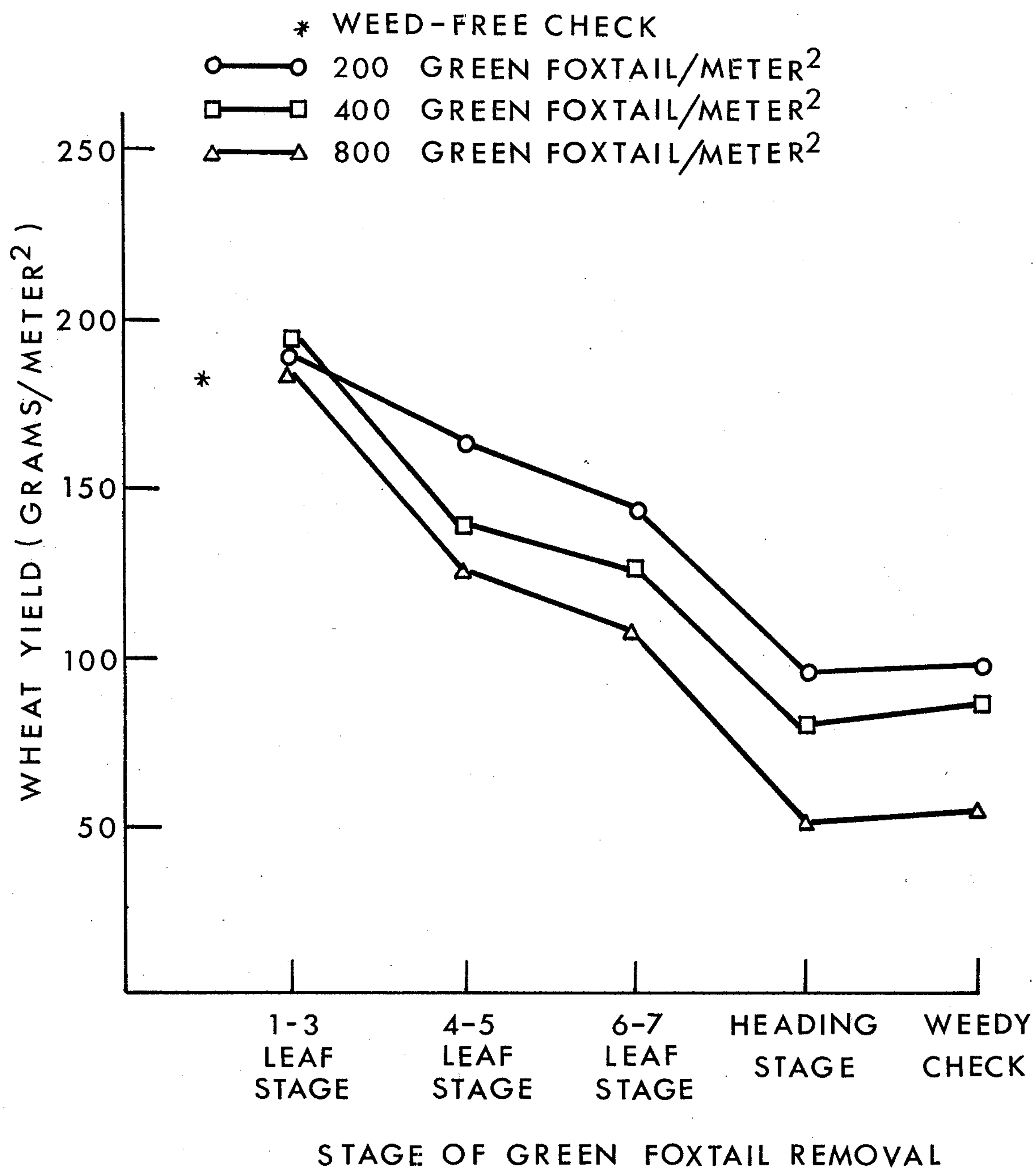

FIGURE 2. The effect of green foxtail growth at time of removal on yield of Norquay wheat, 1975

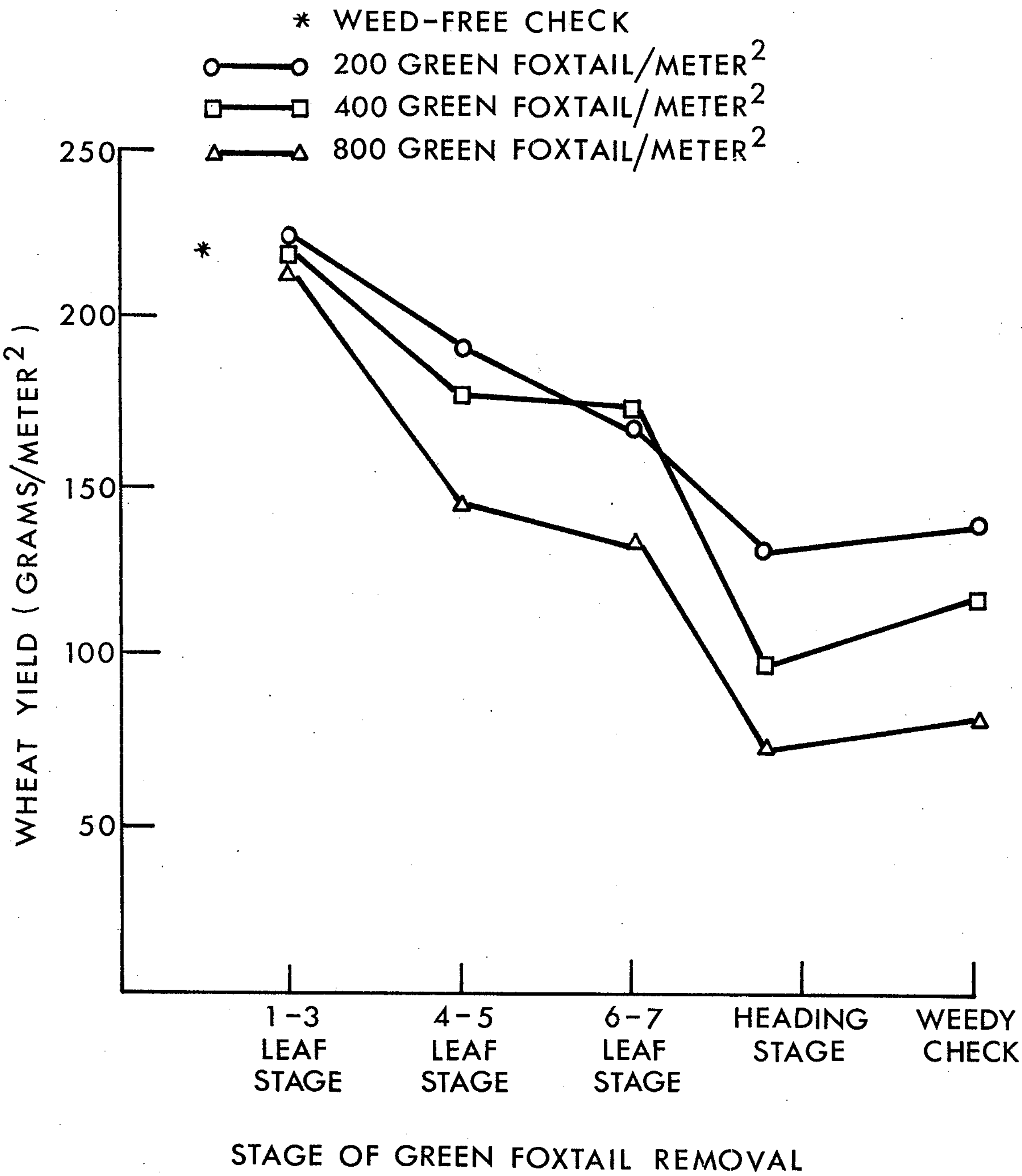

FIGURE 3. The effect of green foxtail growth at time of removal on yield of Napayo wheat, 1976

TABLE 3. Effect of stage of green foxtail growth at time of removal on yield and protein content of Norquay wheat, 1975

Green foxtail density plants per square meter	Stage of green foxtail removal	Protein content of wheat %	Yield of wheat kg/ha
0	weed-free	16.3	1789
200	1-3 leaf	15.9	1868
200	4-5 leaf	16.0	1608
200	6-7 leaf	16.5	1430
200	Heading	16.4	922
200	Weedy check	16.3	965
400	1-3 leaf	15.9	1881
400	4-5 leaf	16.6	1379
400	6-7 leaf	16.5	1221
400	Heading	16.5	764
400	Weedy check	16.6	810
800	1-3 leaf	16.1	1823
800	4-5 leaf	16.4	1233
800	6-7 leaf	16.5	1085
800	Heading	16.3	495
800	Weedy check	16.3	526
Tukey's H.S.D. (0.05)		N.S.	161

TABLE 4. Effect of stage of green foxtail growth at time of removal on yield and protein content of Napayo wheat, 1975

Green foxtail density plants per square meter	Stage of green foxtail removal	Protein content of wheat %	Yield of wheat kg/ha
0	Weed-free	15.0	2176
200	1-3 leaf	15.2	2214
200	4-5 leaf	14.9	1900
200	6-7 leaf	15.3	1670
200	Heading	15.6	1270
200	Weedy check	15.5	1350
400	1-3 leaf	14.9	2182
400	4-5 leaf	15.4	1776
400	6-7 leaf	15.3	1738
400	Heading	15.8	910
400	Weedy check	15.8	1148
800	1-3 leaf	14.8	2144
800	4-5 leaf	15.5	1426
800	6-7 leaf	15.3	1312
800	Heading	15.5	746
800	Weedy check	15.6	796
Tukey's H.S.D. (0.05)		0.2	246

TABLE 5. Effect of stage of green foxtail growth at time of removal on yield and protein content of Norquay wheat, 1976

Green foxtail density plants per square meter	Stage of green foxtail removal	Protein content of wheat %	Yield of wheat kg/ha
0	Weed-free	15.3	3718
200	1-3 leaf	15.5	3737
200	4-5 leaf	15.6	3746
200	6-7 leaf	15.5	3340
200	Heading	15.3	3397
200	Weedy check	14.8	3450
400	1-3 leaf	15.5	3743
400	4-5 leaf	15.4	3648
400	6-7 leaf	15.8	3414
400	Heading	15.3	3134
400	Weedy check	15.4	3319
800	1-3 leaf	15.6	3578
800	4-5 leaf	15.4	3647
800	6-7 leaf	15.5	3252
800	Heading	15.3	2997
800	Weedy check	15.4	3244
Tukey's H.S.D. (0.05)		N.S.	299

TABLE 6. Effect of stage of green foxtail growth at time of removal on yield and protein content of Napayo wheat, 1976

Green foxtail density plants per square meter	Stage of green foxtail removal	Protein content of wheat %	Yield of wheat kg/ha
0	Weed-free	17.1	3135
200	1-3 leaf	17.4	2998
200	4-5 leaf	17.5	3022
200	6-7 leaf	17.1	2986
200	Heading	17.0	2966
200	Weedy check	17.3	2951
400	1-3 leaf	16.9	3139
400	4-5 leaf	17.3	3015
400	6-7 leaf	16.9	3083
400	Heading	17.2	2923
400	Weedy check	17.3	2912
800	1-3 leaf	17.2	2997
800	4-5 leaf	17.5	2820
800	6-7 leaf	17.2	2986
800	Heading	17.7	2745
800	Weedy check	17.1	2845
Tukey's H.S.D. (0.05)		N.S.	N.S.

There appeared to be a decrease in yield, although not significant, in the treatments where the green foxtail was not removed (weedy-checks).

In 1975, there was an increase in the protein content of Napayo wheat when green foxtail removal was delayed beyond 1-3 leaf stage of growth (Table 4). There was no affect on wheat protein content for the other time-of-removal studies regardless of density or stage of green foxtail removal (Table 3, Table 5 and Table 6).

<u>Experiment III.</u> Effect of green foxtail in wheat seeded on several dates

The highest yields for both Norquay wheat 4246 kg/ha and Napayo wheat 3927 kg/ha were obtained from the May 14 seeding date (Figure 4 and Figure 5). Yields decreased as seeding date was delayed and when sown on the final seeding date, June 11, Norquay yielded 2870 kg/ha and Napayo yielded 2788 kg/ha.

Two hundred green foxtail/m^2 reduced Norquay wheat grain yield when sown on May 14 or June 11 (Table 7). Increases in green foxtail density resulted in further decreases in wheat yield. When sown on May 28, Norquay wheat yields were not significantly reduced by any of the densities of green foxtail studied.

The yield of Napayo wheat was reduced by 400 green foxtail/m^2 on all three seeding dates (Table 8). The 400 green foxtail/m^2 reduced the yield by 8% when seeded May 14 or May 28 and by 14% when seeded on June 11, indicating that as seeding date was delayed green foxtail competition was increasing. When seeded June 11, 200 green foxtail/m^2 reduced the yield of Napayo wheat by 7%, though not significant at the 5% level.

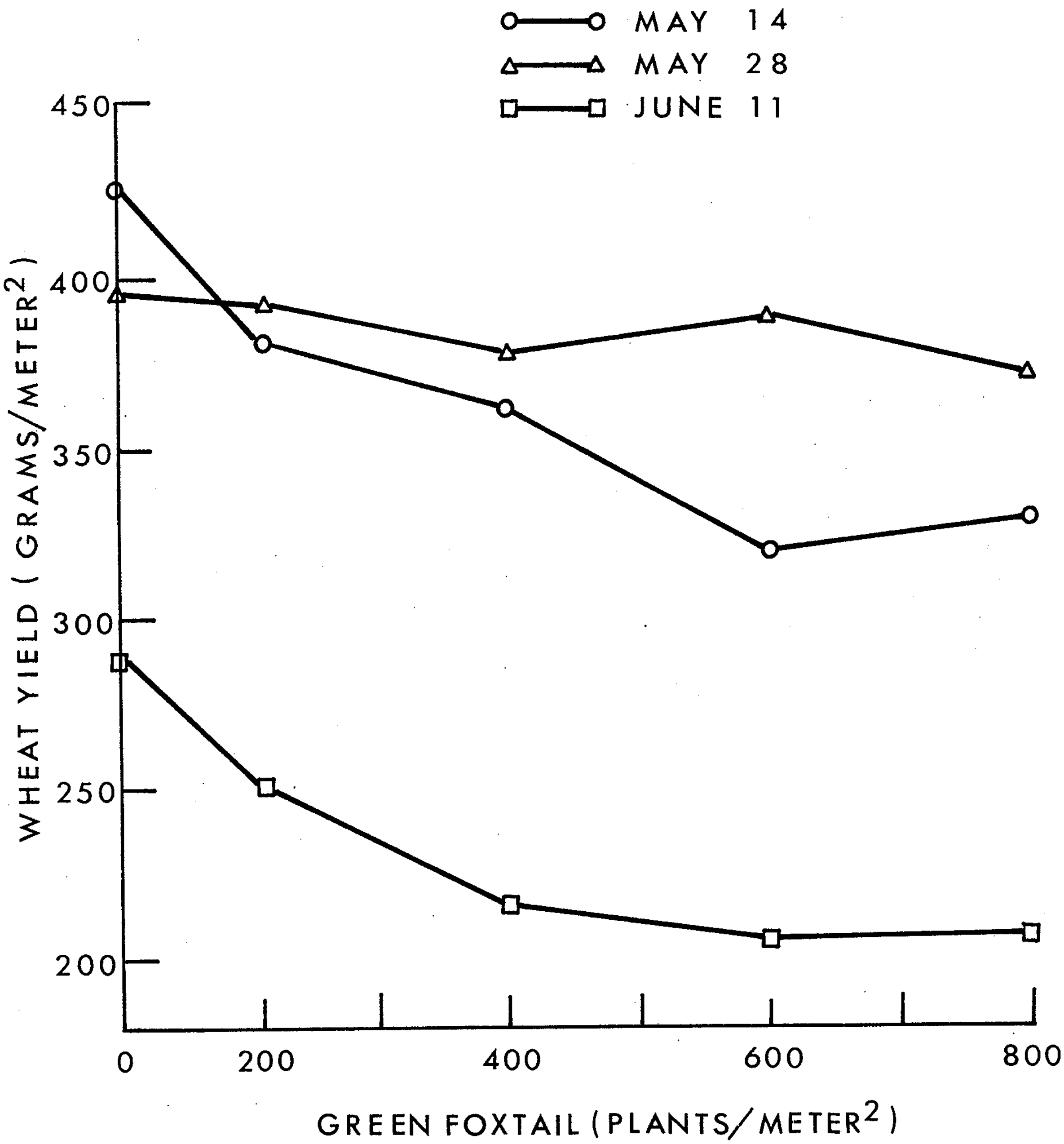

FIGURE 4. The effect of green foxtail competition on the yield of Norauay wheat sown on various dates, 1976

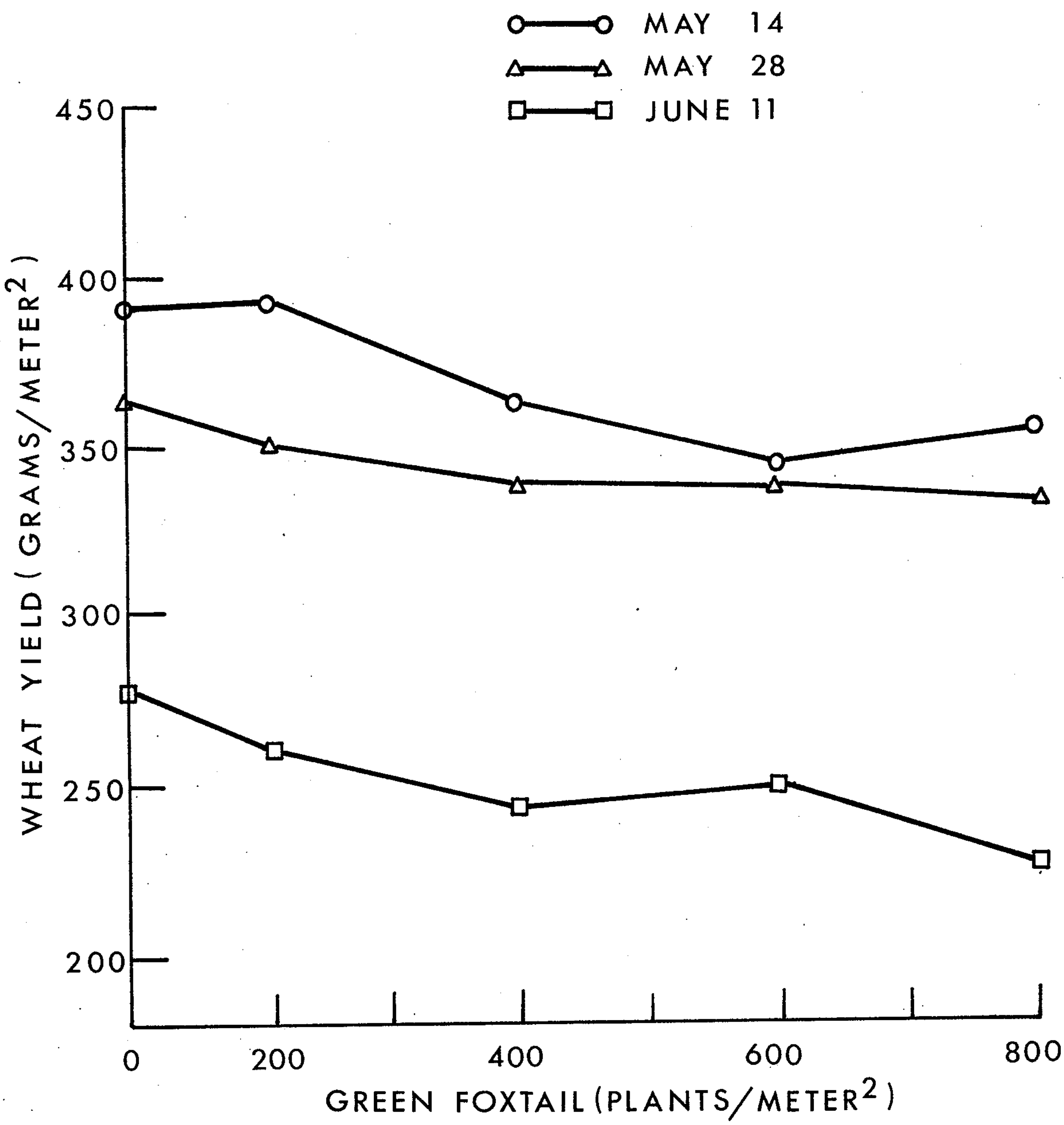

FIGURE 5. The effect of green foxtail competition on the yield of Napayo wheat sown on various dates, 1976

TABLE 7. Effect of seeding date on the ability of green foxtail to compete with Norquay wheat, 1976

Date of seeding	Green foxtail density plants per square meter	Protein content of wheat %	Yield of wheat kg/ha	Green foxtail seed yield kg/ha
May 14	0	15.3	4246	0
	200	14.9	3800	227
	400	15.5	3595	310
	600	15.4	3207	303
	800	15.0	3267	362
May 28	0	15.0	3961	0
	200	15.4	3909	81
	400	15.3	3773	73
	600	15.3	3885	99
	800	15.5	3725	125
June 11	0	15.2	2870	0
	200	15.1	2481	193
	400	15.3	2172	281
	600	14.9	2024	369
	800	15.3	2067	335
L.S.D. (0.05)		N.S.	360	108

TABLE 8. Effect of seeding date on the ability of green foxtail to compete with Napayo wheat, 1976

Date of seeding	Green foxtail density plants per square meter	Protein content of wheat %	Yield of wheat kg/ha	Green foxtail seed yield kg/ha
May 14	0	17.6	3927	0
	200	17.4	3931	111
	400	17.5	3599	121
	600	17.5	3415	144
	800	17.4	3532	168
May 28	0	16.8	3631	0
	200	17.1	3466	37
	400	16.7	3358	34
	600	17.1	3370	36
	800	16.9	3319	33
June 11	0	16.6	2788	0
	200	16.5	2481	88
	400	16.2	2412	154
	600	16.0	2441	165
	800	16.1	2271	194
L.S.D. (0.05)		0.3	230	40

The amount of green foxtail seed in the harvested samples of both varieties was less for the May 28 seeding date than for the May 14 or June 11 seeding dates (Table 7 and Table 8). The lower green foxtail seed production at the May 28 seeding indicates that green foxtail was less competitive at this date of seeding. For all three seeding dates the green foxtail seed screened from the harvest samples increased with increases in green foxtail density.

The protein content of Norquay wheat was not affected by date of seeding or density of green foxtail (Table 7). Napayo wheat showed a decrease in protein content as seeding date was delayed, even under weed-free conditions (Table 8). When sown on May 14 or May 28 green foxtail density had no effect on protein content of Napayo wheat. However, with the June 11 seeding date the protein content of Napayo decreased as the density of green foxtail increased.

DISCUSSION

The results of the field experiments indicated that wheat yields were higher in 1976 than in 1975. In 1975 when sown late (June 18) Napayo wheat outyielded Norquay wheat, while in 1976 when sown earlier (June 3) Norquay outyielded Napayo wheat. The yield variation between years may be partially explained by the date-of-seeding experiment. The yield of both wheat varieties decreased as seeding date was delayed. However, date of seeding appeared to be more important for Norquay wheat, since delay of seeding from May 14 to June 11 depressed the yield of Norquay wheat more than Napayo wheat. Part of the difference in yield between years can be attributed to earlier seeding in 1976. With a late seeding as occured in 1975, Norquay wheat yield could be depressed to a point where Napayo wheat would have a higher yield. These results are in agreement with Schmidt (1960) and Beard (1961) who found that varieties can respond to date of seeding differently. Some varieties show large yield reductions, while others show little or no yield reduction with delayed seeding.

The two varieties showed a difference in their ability to compete with green foxtail. At all densities, green foxtail seed production was lower when in competition with Napayo wheat than with Norquay wheat. Grain yield reductions due to green foxtail competition were lower for Napayo wheat (normal-height) than Norquay wheat (semidwarf). The difference in the ability of the two varieties to compete with green foxtail, may be partly due to their height differential as suggested by Behrens et al. (1971 and 1974). They found that semidwarf varieties of cereals are less competitive with weeds than are normal height varieties.

In the present study it was observed that green foxtail grew taller than the Norquay wheat. At the heading stage, green foxtail spikes were 10-15 cm above the crop. The green foxtail being taller than Norquay wheat could shade the head and flag leaf and reduce their photosynthetic capacity. In contrast, at no time during the growing season did green foxtail become as tall as Napayo wheat. At heading green foxtail spikes were 10-15 cm shorter than Napayo wheat heads. Green foxtail appeared to tiller less and produce less seed when in competition with Napayo wheat than Norquay wheat, which may be due to shading of green foxtail by the taller Napayo wheat. Vanden Born (1971) stated that green foxtail required high light intensity for optimum growth. When grown under low light intensity green foxtail made less vegetative growth and produced less seed than when grown under high light intensity. He stated that green foxtail dry matter production was almost directly proportional to light intensity. This behavior would be consistant with photosynthetic response typical to C_4 plants. Therefore a plant which grows taller and shades green foxtail from direct sunlight, could be a more effective competitor than a plant which grows to the same height or is shorter than green foxtail.

Other researchers have noted that poor seedling emergence due to short coleoptiles was one of the shortcommings of semidwarf wheat varieties (Allan et al., 1961). Allan et al. (1962) indicated that the emergence rate of deep seeded (10-12 cm) winter wheat showed genetic variation and was positively correlated with coleoptile length and plant height. They stated that coleoptile growth and seedling emergence was slower for the semidwarf varieties than for standard-height varieties studied. This differential in coleoptile length, may partially account for the greater competitive ability of Napayo wheat with green foxtail.

The competitive interaction between crops and weeds depends upon when and how fast each starts to grow in relation to the other. The relative speed of germination, establishment and early growth are therefore important in determining the outcome of competition (Williams, 1969). Where early seedling developement is important in a mixed stand, the variety or species which can gain an early competitive advantage will be able to supress the growth of a plant with slower development. Normal height varieties that have a faster rate of emergence are more likely to gain an early competitive advantage over weeds than is a semidwarf variety with a slower emergence rate.

In green foxtail photosynthetic carbon fixation is by the Hatch and Slack or C_4 pathway (Chen et al., 1970), whereas in wheat the Calven cycle or C_3 pathway is used (Moss et al, 1969). In C_4 species photosynthetic rate is maximum between 30 and 40^{o}C and decreases rapidly below 15-20^{o}C (Downton, 1971). For C_3 species the temperature optimum ranges between 10 and 25^{o}C. These plants will grow at temperatures as low as 5-10^{o}C. At temperatures below 16^{o}C, the chlorophyll of C_4

plants is subject to photodecomposition and developing leaves are chlorotic. In addition C_4 plants, at optimum temperatures, typically show increased photosynthetic rate as light intensity increases up to or beyond that of full sunlight ($500w/m^2$) where as C_3 species photosynthesis is light saturated between 150 and $200w/m^2$.

From these considerations, one would predict that green foxtail, a C^4 species, would have competitive advantage at higher temperatures when the more efficient C_4 photosynthesis would take full advantage of high light intensity. More vigorous growth of green foxtail would induce shading of wheat and further limit C_3 photosynthesis which is already limited by temperatures higher than optimum.

At low temperatures, C_3 photosynthesis and growth of wheat would be favored. Photosynthetic rate in C_4 green foxtail would be depressed by low temperatures and photodecomposition of chlorophyll and by shading from the wheat plants.

Weather conditions at the time of seeding appear to have a profound effect on the competitive ability of green foxtail and spring wheat. Competition between green foxtail and wheat varied over the two years studied, with competition being more intense in 1975 than in 1976. In 1975, when the experiments were sown very late (June 18), temperatures during early growth and development were high about 25 to 30C (Appendix Table 1). In 1976, the experiments were sown on June 3 and temperatures during germination were warm 21-31°C. However, there was a period of cool weather June 13-18 where temperatures were low 13-18°C (Appendix Table 2).

Under cool conditions as occured in 1976 during early growth, the green foxtail (C_4 plant) was growing under less than optimum temperatures, where as wheat (C_3 plant) was growing well within the optimum temperature range for photosynthesis and growth. In 1975 both species were growing under near optimum conditions, which would cause competition for growth requirements to be greater. In 1976, wheat could have gained an early competitive advantage over the green foxtail during the cool period, and possibly maintained the advantage through subsequent shading of the green foxtail.

Green foxtail competition was more intense when seeded late (June 11) than when sown early (May 14). Similarly, Rahman and Ashford (1972) found that wheat yield losses due to green foxtail competition were less when wheat was seeded during the first week of May, than when seeded in June. Generally temperatures in late May and early June are higher and closer to the optimum for germination and growth of green foxtail, in early May lower temperatures would be less favorable to green foxtail. Therefore it would be expected that green foxtail would become more competitive as seeding date was delayed. Probably the climatic conditions that prevailed during germination and early growth of the crop and weed were more important than seeding date itself. Delayed seeding did not always increase green foxtail's competitive ability. When seeding was delayed from May 14 to May 28, there was a decrease in the intensity of green foxtail competition. Green foxtail competition was less intense when temperatures were cool during germination and early growth of green foxtail and wheat. The results are in agreement with Vanden Born (1971) who stated that intensity of green foxtail competition would be dependent upon temperatures in early spring.

Therefore, when temperatures are above normal in early May green foxtail competition could be more intense than might be expected. Similarly, when temperatures in late May or early June are below normal, green foxtail competition could be less intense than expected.

When green foxtail competition was severe in 1975, the weed had to be removed by the 1 to 3 leaf stage or earlier in both wheat varieties to minimize losses due to competition. As the density of green foxtail increased it became more important to remove the green foxtail early to avoid severe losses due to green foxtail competition.

Green foxtail competition was less intense in 1976, and it was possible to leave the green foxtail until the 4 to 5 leaf stage in the semidwarf wheat, without a grain yield loss. In the normal height wheat it was not beneficial to remove the green foxtail unless the density was high, over 800 plants/m^2. However, even when wheat yield losses due to green foxtail competition were not large there were still large quantities of green foxtail seed produced. Green foxtail left uncontrolled, could result in high densities of green foxtail in subsequent years, that could reduce wheat yields.

When densities of a weed are high, hand removal can cause a great deal of mechanical damage to the crop. With the use of a herbicide, there is less trampling of the crop, and mechanical damage to the crop's root system is reduced. Hoegrass (dichlofop methyl) was used in this study because of its ability to control green foxtail over a wide range of growth stages. Hoegrass kills green foxtail by contact action, causing severe burning of the plant, therefore there is little or no growth after application of the herbicide (Todd, personal communication). Removal of the green foxtail with dichlofop methyl at the early stage (1 to 3) had no detrimental effect on crop yield; in some cases there was a slight although not significant increase in yield.

Green foxtail competition did not affect the protein content of Norquay wheat in any of the field studies. Napayo wheat showed an increase in protein content as grain yield was reduced due to green foxtail competition in two studies. The increase in protein content of the wheat could be due to there being relatively more nitrogen available to the plant because of less dry matter production. Napayo wheat also showed a decrease in protein content with a decrease in wheat yield for the third seeding date in the seeding date experiment. The reduction in protein content may be due to green foxtail at high densities utilizing a great deal of the available soil nitrogen for vegetative growth early in the season, thus reducing the nitrogen available for the wheat to use at kernel filling.

Protein content of both wheat varieties was high (14.3 to 17%) indicating that there was adequate nitrogen available for plant growth. Competition for soil nitrogen was not the limiting factor, however, the higher rate of nitrogen (76 kg/ha) may have enhanced green foxtail's vegetative growth and caused the green foxtail to become more competitive than at a low level of nitrogen.

After planting a crop, if it received adequate moisture and has sufficient nutrients available, under favorable light and temperature conditions the crop has the potential to maximize its yield. When weed and crop plants grow together in the same area, they will compete with one another for nutrients, water and light. The relative ability of weed and crop plants to compete for these limiting factors seems to be shifted by environmental factors, especially temperature. When environment favors the weed species, crop yields will be reduced.

Green foxtail reduced the yield of both varieties of wheat, therefore green foxtail competition was limiting one or more of the basic growth requirements. In the reported experiments the factor limiting wheat yields did not appear to be soil nitrogen, however, one of the other mineral elements required for growth may have been limiting. At a lower soil nitrogen level, nitrogen may be a limiting factor.

Green foxtail grew taller than the semidwarf Norquay wheat, and may have caused some shading of the crop at kernel filling, thus reducing the photosynthetic potential of the crop. Competition for light was not limiting for Napayo wheat, as green foxtail did not grow taller than Napayo wheat. Although competition for light could explain the difference in the competitive ability of the two wheat varieties, it was probably not the major factor limiting wheat yields.

Competition for available soil moisture was probably the most limiting factor. Plants require large amounts of water to produce a pound of dry matter. As the number of plants per unit area increases there is less water available to each individual plant. The increase in the number of green foxtail plants per unit area would cause the soil moisture to be depleted more rapidly due to the increased transpiration surface. The total dry matter yield may remain the same but the grain yield would be reduced. With high densities of the weed, most of the available moisture would be used to produce vegetative growth in the early stages of the crop cycle and little moisture would be left during the grain filling period.

SUMMARY AND CONCLUSIONS

Competition from green foxtail reduced the yield of Norquay wheat and Napayo wheat. The intensity of green foxtail competition increased when seeding date was delayed from mid May to early June. The climatic conditions at the time of emergence and early growth appeared to be more important than the actual date of seeding. Cool temperatures reduced the intensity of green foxtail competition.

Napayo wheat, the normal height variety, was more competitive than was Norquay wheat, the semidwarf variety. Grain yield losses were lower for Napayo than Norquay wheat at all densities studied. Green foxtail seed production was lower in competition with Napayo wheat than Norquay wheat.

When green foxtail competition was intense the green foxtail had to be removed by the 1 to 3 leaf stage or earlier to minimize yield losses. Early removal was especially important for the semidwarf variety. When green foxtail competition was less intense, green foxtail could be left until the 4 to 5 leaf stage of growth in the semidwarf with no grain yield losses and in the normal height wheat, removal had no effect unless the weed density was higher than 800 plants/m^2.

Seeding should be done early to maximize wheat yields, even in situations where green foxtail is not a problem. Where green foxtail is a problem, seeding early in May when temperatures are lower, will reduce the intensity of green foxtail competition by giving the wheat a competitive advantage. With early seeding, green foxtail removal in normal height wheats would be beneficial only at the higher weed densities. In semidwarf wheat, green foxtail removal would be beneficial at densities as low as 100 plants/m^2. When seeding is delayed until late May or June, and temperatures are warmer, green foxtail should be removed even at low densities in both wheat varieties. If green foxtail is a problem, due to high densities or delayed seeding, removal should be done at the 1 to 3 leaf stage or earlier to minimize grain yield loss.

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APPENDIX TABLE 1. Precipitation and temperature recorded at Carman Research Station, 1975

	May			June			July			August			September		
	Rain	Temperature		Rain	Temperature		Rain	Temperature		Rain	Temperature		Rain	Temperature	
Date	mm	Max (°C)	Min	mm	Max (°C)	Min	mm	Max (°C)	Min	mm	Max (°C)	Min	mm	Max (°C)	Min
1	1.52	6.7	0		22.2	2.8		26.2	12.8		24.4	18.9		20.6	11.1
2	T	10.0	0	9.91	21.1	6.1		27.2	14.4		23.9	13.3	16.51	15.0	2.8
3		13.3	2.8		17.8	6.7		28.3	12.2		24.4	13.3		21.7	7.2
4		13.3	1.1	3.05	16.1	6.7	0.76	28.9	14.4		22.8	10.6		20.6	8.3
5		16.7	0		13.3	7.2		30.6	16.1		22.8	7.8	1.52	20.0	7.8
6		20.6	3.3		17.8	6.1	T	30.0	15.6		27.8	7.8	0.25	20.0	5.6
7		20.6	5.6	1.27	21.7	3.3		28.3	16.1	18.80	27.8	10.6		16.7	9.4
8		22.2	2.2	1.78	18.9	11.7		23.9	8.9		26.1	15.6		18.9	- 0.6
9		24.4	2.2	13.97	14.4	11.1		21.1	11.7		24.4	12.2		22.2	3.9
10		25.0	4.4	1.27	18.9	11.1	T	22.2	5.0	9.14	26.7	10.6		18.3	8.9
11		16.1	3.3		22.2	6.7		20.6	9.4		26.1	14.4		10.6	2.2
12		23.3	0	T	27.8	8.9		29.4	8.3		22.8	14.4		13.9	- 0.6
13	6.35	23.9	9.4	0.76	23.3	11.1		31.7	15.0		25.6	10.6		22.2	- 0.6
14		13.3	2.2		18.9	10.6		32.2	15.6		20.0	12.2		28.3	5.0
15		23.3	- 1.1		21.7	7.8		33.9	17.2	1.52	23.9	5.0		17.2	7.2
16	3.81	28.3	7.2		21.7	6.1		32.2	18.3		21.1	5.6		22.8	0.6
17	4.06	22.2	8.9		22.8	11.1	8.13	28.3	19.4		18.3	6.1	12.70	25.0	5.6
18	3.05	24.4	4.4		26.1	7.2	10.41	27.2	16.7		16.7	2.2	2.03	16.1	12.8
19	1.78	22.2	10.6	1.52	23.9	15.0	3.81	23.9	15.0		17.8	8.9	3.56	10.6	4.4
20	5.59	13.3	6.7	3.30	30.6	15.6	0.76	26.1	13.3	0.76	16.1	6.1		12.2	5.6
21	T	8.9	1.7	7.62	24.4	13.9	1.02	26.1	15.0		18.9	11.7		16.1	- 1.1
22	4.57	16.7	1.7	16.51	18.9	13.9		28.9	14.4	1.78	23.3	12.8		22.2	2.8
23	7.62	21.7	5.0	1.27	26.7	11.1		28.9	11.7		31.7	14.4		16.1	5.0
24	0.76	24.4	9.4		27.2	11.1		28.9	12.8	11.68	26.1	15.0		20.6	2.2
25		17.2	9.4		29.4	11.1		30.0	13.9	4.06	20.6	12.2		25.6	7.2
26		18.9	6.7		27.8	20.6		27.2	18.3		17.8	8.3		25.6	3.9
27		22.2	5.6	34.29	28.9	10.0		31.3	11.1		22.2	3.9		19.4	3.3
28	0.25	22.2	4.4	0.25	27.2	15.6		35.0	17.2		27.8	8.3		14.4	5.6
29		17.8	6.7	3.81	28.3	16.7		34.4	17.8	4.06	20.6	13.9	2.03	17.2	4.4
30	0.76	17.2	3.9		29.4	13.6		35.6	21.7		27.2	11.1		9.4	3.3
31		17.8	5.0				8.38	26.7	19.4		26.7	15.0			
	49.02	18.9	3.9	100.58	22.8	10.6	33.27	28.3	14.4	51.82	23.3	10.6	38.61	18.9	5.0

APPENDIX TABLE 2. Precipitation and temperature recorded at Carman Research Station, 1976

	May			June			July			August			September		
	Rain	Temperature		Rain	Temperature		Rain	Temperature		Rain	Temperature		Rain	Temperature	
Date	mm	Max (°C)	Min	mm	Max (°C)	Min	mm	Max (°C)	Min	mm	Max (°C)	Min	mm	Max (°C)	Min
1		7.2	- 0.6		28.3	11.7		26.7	8.9		25.6	7.8		17.8	6.1
2		6.7	- 2.8	1.3	31.1	13.6		27.2	8.9		27.8	7.8		26.1	3.9
3		13.3	- 5.6		30.6	16.1		26.7	9.4		31.7	8.9		22.8	8.9
4		21.7	1.7		31.1	16.7		28.9	11.1		21.7	16.7		24.4	3.3
5		6.7	- 3.3		25.6	8.9		31.1	13.3		22.2	6.1		35.6	11.1
6		8.9	- 6.1	3.6	29.4	15.6		28.3	16.7		27.2	4.4		37.2	10.0
7		18.3	- 5.6	3.3	21.7	16.1		28.3	11.7		31.1	7.2		23.9	16.1
8		22.8	4.4	0.8	21.7	11.7		27.8	13.3	7.8	24.4	16.1	1.27	16.7	7.8
9		28.3	7.8	4.6	24.4	11.1	5.1	30.6	16.1	1.3	20.6	11.7		21.7	3.3
10		15.6	4.4	0.3	30.0	13.3		23.9	18.3		28.3	13.3		28.9	7.8
11		21.7	- 0.6		31.4	11.7		21.1	11.1		25.0	11.7		31.1	7.2
12	3.6	18.3	3.9	22.1	25.0	15.6		24.4	9.4	4.3	19.4	13.9		27.8	13.3
13		22.2	5.0	2.0	18.3	12.8		25.0	13.9	T	23.9	14.4	3.0	9.4	7.8
14	5.3	19.4	6.7	1.5	16.7	11.7		27.8	13.3		25.0	9.4		13.3	6.1
15		21.7	10.0		16.7	8.9		28.3	11.1		24.4	7.8		26.7	1.1
16		18.9	4.4		18.9	3.3		24.4	9.4		27.2	8.3		26.7	4.4
17		17.8	- 1.7	27.7	13.3	10.6		25.0	8.3	T	28.2	9.4		32.8	12.8
18		27.8	7.2		21.1	4.4		30.0	12.8		31.1	13.3		27.8	13.9
19		24.4	7.2		26.1	10.6	0.3	31.1	18.3	T	31.7	16.7		16.7	7.8
20		22.2	4.4		30.6	12.2	18.8	29.4	11.1	6.9	33.3	17.2		21.1	3.3
21		21.1	5.6	1.3	15.6	14.4		25.6	7.8		28.3	12.2		17.2	- 1.7
22		25.0	1.1		25.6	8.9		26.7	16.1		29.4	8.9		12.2	2.2
23		25.0	1.1		28.9	15.0		27.8	10.6		37.2	12.8		15.6	- 4.4
24		25.0	0.0		22.2	15.6		27.8	7.8		28.9	17.2		12.2	- 1.7
25		27.2	8.9	2.0	22.8	11.7	5.8	28.3	16.7		28.3	17.2		16.7	- 2.8
26	1.0	21.7	18.4	1.0	20.6	11.7	T	27.8	11.7		30.6	15.0		15.6	3.3
27		21.1	3.3		23.3	8.3		30.0	11.1	4.3	18.9	13.3	1.0	24.4	- 3.3
28		25.0	3.9		20.6	7.8	0.5	25.6	6.7		15.6	5.6		25.0	3.9
29		27.2	7.2	11.43	22.8	10.6	T	23.3	13.9		24.4	3.3		26.1	2.2
30		28.9	9.4		25.6	9.4		20.0	11.1		28.9	7.2		31.1	7.2
31	0.5	28.3	10.0					25.0	5.6		19.4	7.2			
	10.4	20.6	3.5	82.93	24.0	11.6	30.5	26.9	11.7	24.6	28.6	10.7	5.27	21.9	6.3