SEEDING RATE AND SEED SIZE AS MANAGEMENT TECHNIQUES FOR RYEGRASS (*LOLIUM MULTIFLORUM* LAM) CONTROL IN WINTER WHEAT

A Thesis

by

CASEY LEE COOK

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

May 2005

Major Subject: Agronomy

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Approved as to style and content by:

Harry Cralle (Chair of Committee)	James M. Chandler (Member)
Rodney W. Bovey (Member)	Mark A. Hussey (Head of Department)

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ABSTRACT

Seeding Rate and Seed Size as Management Techniques for Ryegrass (*Lolium multiflorum Lam.)* Control in Winter Wheat. (May 2005)

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Chair of Advisory Committee: Dr. Harry Cralle

Higher seeding rates and larger seed sizes could enhance the competitiveness of wheat with ryegrass. Growth room and field research evaluated the effects of wheat seeding rates and seed size in competition with Italian ryegrass. Winter wheat seeds cultivar "Ogallala" were divided into three seed sizes: small seed passed through a sieve with 2.08mm round holes, large seed which did not pass through a sieve with 3.18mm round holes, and bulk seed directly from a commercial seed bag.

These wheat seed and seed of the Italian ryegrass cultivar "Gulf" were planted in plastic pots containing fritted clay. A replacement series design with 12 plants per pot compared the relative growth in pure culture and competitiveness in mixtures of the two species. The planting proportions of each wheat seed group and ryegrass were 100% and 0%, 50% and 50%, and 0% and 100%, respectively. Wheat seed size did not affect the growth of the wheat plants in pure culture. Wheat seed size did not affect competitiveness with ryegrass. There were no differences related to seed size among the pure or mixed cultures of wheat. The failure of increased wheat seed size to affect competition with ryegrass may be the result of the relative seed size difference between the two species. Even the small wheat seed in this study were almost 9-fold greater in

weight than the ryegrass seed.

Field experiments conducted for two years from fall 2002 through spring 2004 at the Texas A&M University Agronomy Farm measured wheat yields at the same three wheat seed sizes, two wheat densities of 250 plants m^{-2} and 400 plants m^{-2}, and three ryegrass densities of 0, 100 and 200 plants m^{-2}. Small, bulk, and large wheat seed produced similar yields in both years: one season favorable (2003) for growth and the other (2004) unfavorable. Thus, seed size in the field under favorable or unfavorable conditions or in the growth room experiment did not affect the competitiveness of wheat in the presence of ryegrass. Increasing the wheat plant population from 250 to 400 plants m^{-2} in the field also failed to enhance the competitiveness of wheat in either year.

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I want to thank my family: Mark, Lana, and Noland. Their continued support for the past 26 years is the only reason I could complete my degree. My future wife Sarah gave life to the pursuit of my degree.

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CHAPTER I

INTRODUCTION

Over the last half-century, producers have relied on herbicides and tillage to control weeds. Despite great strides in yield, developed complex herbicides, and more efficient means of tillage; each year weeds continue to present a great barrier to agricultural productivity.

The ability of weeds to adapt quickly in response to conventional control measures requires new approaches. Multi-faceted management strategies must be employed with a greater emphasis on preventing weed infestations rather than just reacting to them. Ideally, this approach will lead to cropping systems that minimizing weeds by creating an environment that favors the crop.

Lolium multiflorum Lam, or annual Italian ryegrass, is a premier winter forage. Early vigorous growth in fall-seeded plants and a later maturity than wheat has made annual ryegrass a popular forage crop (Peeper and Wiese, 1990). In the high rainfall areas of central, east, and north Texas, this popular forage is a serious weed in winter wheat (Miller, 1993). When the producers shift from forage production to wheat grain production, Italian ryegrass persists and competes with winter wheat crops. It infests more than 250,000 ha (Peeper and Wiese, 1990) and ranks among the top 5 weeds of winter wheat in Texas (Fay, 1990).

The importance of controlling ryegrass in winter wheat crops has been demonstrated in many studies. Field studies in central Texas (Stone et al., 1999) showed that ryegrass densities of only 40 plants per m^2 can reduce wheat yields by as much as

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This thesis follows the style and format of Weed Science.

50%. In Oregon Appleby et al. (1976) found a decrease in winter wheat yield of 4100 kg/ha when ryegrass densities were increased from 0.7 to 93 plants per m^{-2}. Appleby and Brewster (1992) observed an average wheat yield decrease of 38% when ryegrass densities were increased by only 20 plants per m^{-2}. Another Oregon study found that 9 ryegrass plants in a plot of 100 winter wheat plants per m^{-2} reduced grain yield by 33% (Hashem et al., 1998).

In North Carolina Liebl and Worsham (1987) showed wheat grain yields were decreased by 4% for every 10 Italian ryegrass plants per m^{-2}. In semi-arid Morocco Tanji and Zimdahl (1997) found wheat to be a more competitive plant than ryegrass. Their research showed one wheat plant to be as competitive as 19 ryegrass plants (*Lolium rigidum*). They speculated that this enhanced competitiveness of wheat was the result of earlier emergence and greater leaf area in the seedling plant than ryegrass. They also recommended a wheat population of 120 to 240 plants per m^{-2} to achieve an acceptable grain yield and minimize ryegrass competition.

Research in Australia has indicated the importance of early season competition. At a density of 450 plants per m^{-2}, Smith and Levick (1974) found that ryegrass competition early in the season reduced wheat growth. They speculated that this reduction was caused by competition for light and the consequent reduction in tiller numbers of wheat. This result persisted even when the ryegrass was removed at the two-leaf wheat stage and additional N fertilizer was applied. Riewe and Mondart (1985) found that ryegrass competition within three to six weeks of emergence resulted in a season long decrease in dry matter production.

Stone et al. (1998) found that ryegrass could be very competitive with wheat during early vegetative growth in a greenhouse study that compared the above- and below-ground interference of wheat by Italian ryegrass. Wheat interference with ryegrass did not differ from the pure culture wheat controls when only above ground portions were allowed to interact. But, interference between ryegrass and wheat reduced wheat height, leaf number, tillering, leaf area, percent total nonstructural carbohydrates in the shoot, and dry weight of leaves, stems and roots compared to wheat controls when only the below ground portions were allowed to interact.

Another greenhouse experiment with well watered controls and a treatment of temporary drought found that water stress enhanced the relative competitiveness of ryegrass with wheat (Carson et al., 1999). While control ryegrass 14 wk after planting grew better than control wheat in pure culture, wheat produced greater final leaf area and dry stem weight in control mixtures than ryegrass. Watering following drought shifted the relative performance of the two species in mixtures compared to controls. Drought and its relief increased the relative competitiveness of ryegrass compared to controls in mixtures with wheat. During 4 wk of watering following the drought, ryegrass in mixtures grew vigorously and was similar to wheat in all measures except height and dry stem weight.

A third greenhouse experiment (Cralle et al., 2003) used a replacement series design to compare the vegetative growth six weeks after emergence in pure cultures and mixtures of winter wheat and ryegrass in phosphorus (P) levels recommended by soil testing and low levels of P. In the recommended P treatment in pure culture ryegrass had more tillers, and greater root weight and length than did wheat. Pure culture wheat in the low P treatment exceeded pure culture ryegrass in leaf area; weights of leaves, stems and roots; and root length. Thus, the growth of wheat was inhibited less by P deficiency than that of ryegrass in pure culture. In the 50%-50% mixture of the recommended P treatment, wheat had greater leaf, stem, and root weights than ryegrass. In the 50%-50% mixture of the low P treatment, the two species were very similar in growth, except that ryegrass had about three times more tillers than wheat. While P deficiency limited the growth of wheat less than ryegrass in pure culture, P deficiency did not affect the relative competitiveness of ryegrass as much as wheat in mixed cultures. The ability of ryegrass to compete with wheat when P was limiting may result from a difference in root growth. Ryegrass had a greater fresh root length to fresh root weight ratio than did wheat in the low P treatment in pure culture and in the 50%-50% mixture. The greater surface area of ryegrass roots likely enhanced the competitiveness of ryegrass relative to wheat in P deficit conditions.

Texas and Oklahoma annually produce about 7 million hectares of wheat (Peeper and Wiese, 1990). Herbicides and tillage are the preferred control measures. However, continued losses of wheat yields to ryegrass, herbicide resistant plants, rising input costs, and environmental concerns have led researchers to examine alternative methods of weed control.

Buhler (2002) suggests developing cropping systems that are designed to create the optimal environment for the crop, while creating an environment that is less suitable for weeds. Buhler points out the possible benefits of higher plant populations coupled with selection for vigorous seedling growth characteristics. This combination may produce a light-limiting canopy to reduce weeds.

A study by Xue and Sougaard (2002) examined the effects of spring wheat seed size and seeding rate on wild oat competition. This study showed that spring wheat competitiveness increased as seed size and planting rate increased. The larger seeds produced wheat seedlings that reduced wild oat panicles by 15% and biomass and seed production by 25%. However, Lafond and Baker (1986) found that larger wheat seeds produced wheat with faster growth rates than smaller wheat seeds. The larger wheat seeds produced plants with shoot weights that were 21 to 28% greater than those of small seeds.

A study by Spaner et al. (2000) in Canada, found that a high seeding rate of 450 seeds per m^{-2} achieved optimal yield. However, Justice et al (1994) in Oklahoma showed that applications of diclofop postemergence or chlorsulfuron pre-emergenc for ryegrass control led to increases in net wheat returns greater than increases from seeding rates or reduced row spacing. A study in Kansas (Sudnerman, 1999) emphasized the compensating aspects of wheat yield components. It showed that increased seeding rates resulted in more tillers and spikes per plant, but decreased kernels per head. The yield increases from higher seeding rates were too small to be valuable.

Several studies evaluated the value of high seeding rates and the resulting improvements in crop competitiveness. Carlson and Hill (1985) showed that higher seeding rate increased the competitiveness of spring wheat with wild oat (*Avena fatua*). Higher plant populations increased the competitiveness of barley (*Hordeum vulgare*) with wild oat (Barton et al., 1992 and Evans et al., 1991)

These studies evaluate the potential for management strategies to improve current cropping systems. Higher seeding rates and larger seed sizes could enhance the competitiveness of wheat with ryegrass and other weeds. The purpose of this research was to evaluate the effects of higher wheat seeding rates and greater seed size in a growth room and the field on competition with Italian ryegrass.

CHAPTER II

MATERIALS AND METHODS

Growth room experiment

Winter wheat seed cultivar "Ogallala" were divided into three groups based upon size in accordance with the procedures of Xue and Stougaard (2002) and Lafond and Baker (1986). The small seed group passed through a sieve with 2.08mm round holes. The large seed group did not pass through a sieve with 3.18mm round holes. The third group was the bulk seed directly from the bag. These wheat seed and seed of Italian ryegrass cultivar "Gulf" were planted in 19 liter plastic pots (28 cm in diameter and 30 cm in depth) containing industrially manufactured fritted clay. The clay particles were fused together by heat into larger units of a few millimeters to permit better drainage. Two experimental runs occurred in a growth room under florescent light with photosynthetically active radiation (PAR) of 500 µE m^{-2} s^{-1}, a common value for plant growth chambers. Daily maximum temperature was 25° C and daily minimum temperature was 22° C.

A replacement series design (Harper 1977; Radosevich 1987) was used to compare the relative growth in pure culture and competitiveness in mixtures of the two species. The planting proportions of each wheat seed group and ryegrass were 100% and 0%, 50% and 50%, and 0% and 100%, respectively. There were a total of 12 plants per pot because previous studies (Stone et al., 1998; Carson et al., 1999, Cralle et al., 2003) demonstrated that this population provided for good competition between the two species in 19-l pots. Excess seed were planted by mixing them with the upper 2 cm of the soil in each pot. There were no differences between the two species in percent emergence (above 90%) or time of emergence. Pots were thinned to the final density of 12 plants per pot 21 days after emergence. This final density was equal to about 200 plants m^{-2}, which is very close to the 225 plants m^{-2} commonly found in production fields in central Texas. All pots were fertilized at regular intervals with Peters 20-20-20 water soluble fertilizer (J.R. Peters, Inc., 6656 Grant Way, Allentown, PA 18106) to provide a total of 1.3 g N, 0.54g P, and 1.0g K. Pots were watered daily throughout the experiment with distilled and deionized water.

A destructive harvest occurred 70 days after planting. Measurements were height, leaf area, tiller number, fresh root length, and dry weights of shoots and roots. Plant height was measured from the soil surface to the point on the culm where the uppermost visible leaf emerged. The roots were easily cleaned of the fritted clay using water. Length of fresh roots for the pure culture ryegrass, the pure culture bulk wheat seed, and the mixed culture of bulk wheat seed and its companion ryegrass were assayed with a Comair Root Length Scanner (Commonwealth Aircraft Corp. Ltd., Melbourne, Australia, no longer in business.). The leaf area was measured with a Li-Cor 3000 belt leaf area analyzer (Li-Cor Biosciences, 4421 Superior Street, Lincoln, NE 68504).

The experiment was a randomized complete block design with 5 replications in two runs. The runs were pooled for statistical analysis because the experimental run and treatment interactions were not significant. Means were separated using the least significant difference (LSD) at $\alpha = 0.05$ level. All differences discussed were significant at this level. When one species' mean in the 50-50 proportion was significantly ($\alpha = 0.05$) greater than the other, the greater species was judged to be the more competitive than the lesser species. (Harper 1977).

Field experiment

Experiments were conducted for two years from fall 2002 through spring 2004 at the Texas A&M University Agronomy Farm near College Station, TX. The soil was a Westwood silty clay (thermic, Fluventic Ustochrept**),** that was previously in a cotton-corn rotation. The wheat and Italian ryegrass cultivars were the same as the growth room experiment. Treatments consisted of the same three wheat seed sizes as in the growth room experiment, two wheat densities, and three ryegrass densities. Wheat densities were 250 plants m^{-2} and 400 plants m^{-2}. Ryegrass densities were 0, 100, and 200 plants m^{-2}.

Experimental plots were 1.5 x 3.0 m with eight rows and an 18 cm row width. Based upon recommendations of a soil test, nitrogen fertilizer in the form of urea (46-0-0) was broadcast at the rate of 0.1g m^{-2} before planting in each year. Wheat was drilled into clean cultivated plots in the middle of November with 18 cm rows. The ryegrass was broadcast by a spreader days after planting wheat. Broadleaf weeds, primarily henbit (*Lamium amplexicaule*), were treated in February of both years with dyglycolamine salt:dicamba at a rate of 60 grams per hectare.

Plots were mechanically harvested in the middle of May at 186 and 188 days after planting in 2003 and 2004, respectively. One kilogram sample from each plot was used to measure the percent trash and percent moisture content of grain. Percent trash from the one kilogram sample was determined using a 12/64 inch, round hole, sieve nested on top of a 5/64 inch, round hole, sieve. All material that did not pass through the top sieve or passed through the bottom sieve was considered trash. The wheat grain and separated trash were dried at 130° C for 24 hours and reweighed. Percent moisture, percent trash, and yield of wheat grains were determined from the measured weights of the one kilogram samples.

Accumulated degree-days, precipitation, cloudiness were obtained from the NOAA, National Climatic Data Center at College Station, TX. Accumulated degree days were calculated as the mean of the daily high and low temperature above 4 degrees C. The cumulative rainfall was obtained from the National Climatic Data Center. Plots were irrigated twice with linear overhead irrigation for 1.25 cm in late November and 1.9 cm in early May in 2003 season. There was no irrigation in the 2004 season.

The experiment was a randomized complete block design with four blocks. A regression analysis was performed to assess wheat yield response to ryegrass density in each year.

CHAPTER III

RESULTS AND DISCUSSION

Growth room experiment

Wheat seed size did not affect the growth of the wheat plants. There were no differences related to initial seed size among the pure cultures of wheat (Figures 1, 2, 3 and 4) Wheat seed size did not affect competitiveness with ryegrass. There were no differences related to seed size among the mixed cultures of wheat. Moreover, there were no differences between the pure and mixed cultures of wheat.

However, pure culture ryegrass had a greater height, tiller number, leaf area, and shoot weight than the pure cultures from small, bulk, and large wheat seeds (Figures 1 and 2). There were no differences between the ryegrass and wheat pure cultures in root weight or root length (Figures 3 and 4).

Ryegrass in mixed culture with large, small, and bulk wheat seed grew greater in height, tiller number, leaf area, and weights of shoots and roots than did its companion wheat (Figures 1, 2 and 3). In the only mixed culture measured, ryegrass had a significantly greater root length than its companion bulk wheat seed (Figure 4).

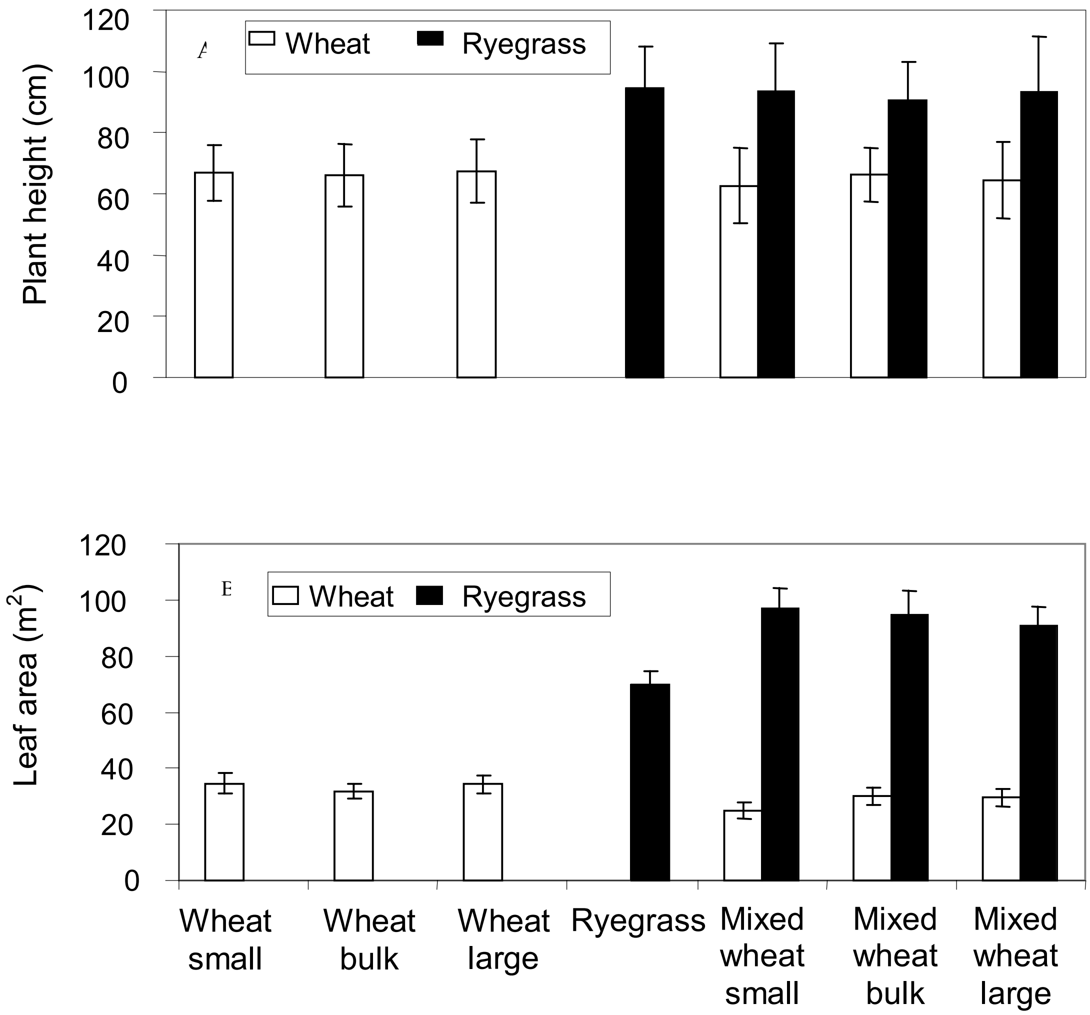

Figure 1. Plant height and leaf area of wheat from small, bulk, and large seeds, and ryegrass in pure and mixed cultures 70 days after planting.

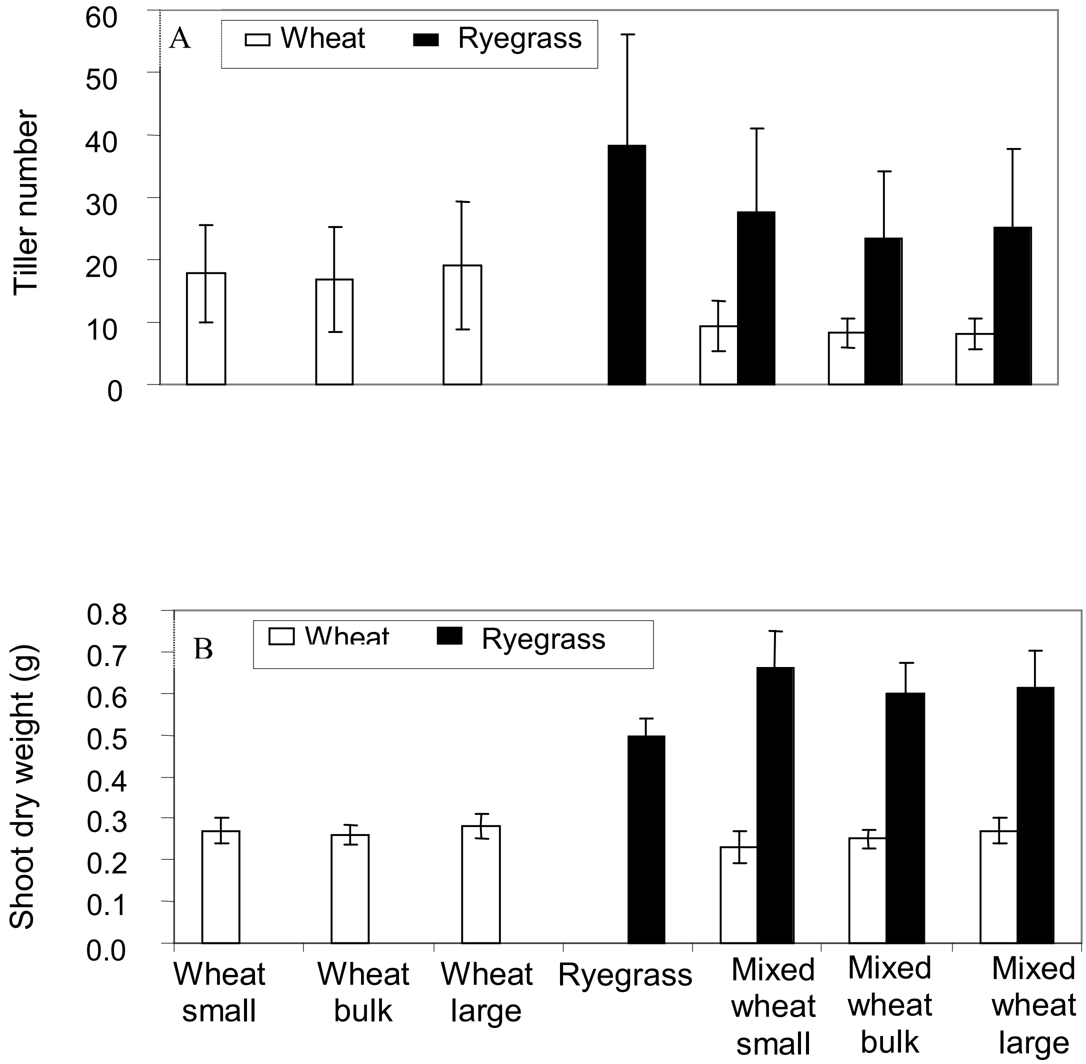

Figure 2. Tiller number and shoot dry weight of wheat from small, bulk, and large seeds, and ryegrass in pure and mixed cultures 70 days after planting.

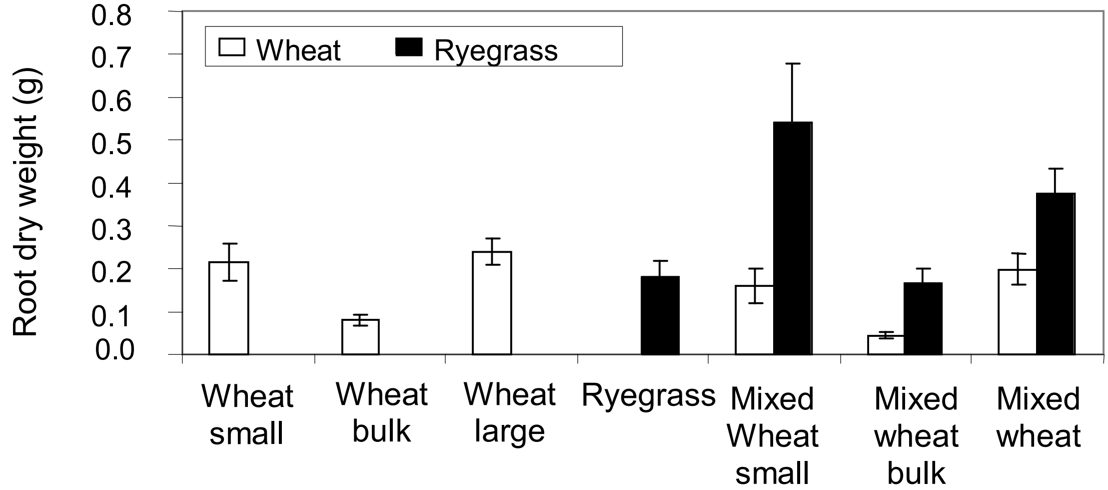

Figure 3. Root dry weight of wheat from small, bulk and large seeds, and ryegrass in pure and mixed cultures 70 days after planting.

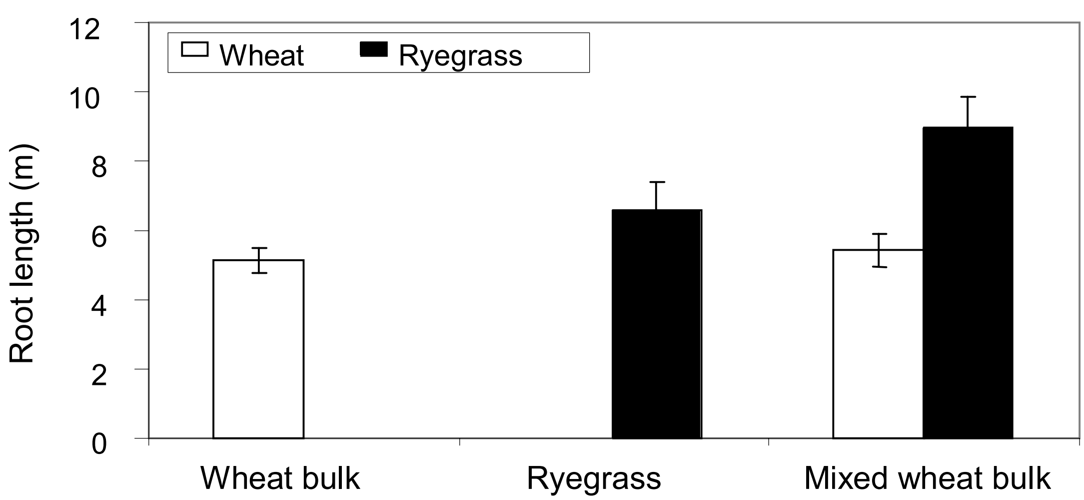

Figure 4. Root length of wheat from bulk seeds and ryegrass in pure and mixed cultures 70 days after planting.

Thus, wheat seed size did not affect its growth in pure culture or its relative competitiveness with ryegrass or the growth of the ryegrass in mixed cultures. This result contrasts with previous studies (Lafond and Baker,1986; Xue and Sougaard, 2002) which showed larger wheat seeds produced larger plants. The latter study also indicated that increased seed size in spring wheat enhanced competitiveness with wild oat plants. These differences in the growth of wheat plants between the studies may be the result of wheat cultivar differences. For example, the "Gulf" ryegrass grew more rapidly compared with the "Ogallala" wheat in pure culture in this study than the "Marshall" ryegrass with the "Mit" wheat in previous studies (Stone et al.,1998; Carson et al., 1999; Cralle et al., 2003) in controlled environments.

The failure of increased wheat seed size to affect competition with ryegrass may also be the result of the relative seed size difference between the two species. While the ryegrass in this study had a mean seed weight of 0.19 g (± 0.04 S.E.); wheat had means of 1.70 g (± 0.04 S.E.) for small seeds, 2.16 g (± 0.03 S.E.) for bulk seed, and 2.75 g (± 0.05 S.E.) for large seeds. This difference in weight between the seed of the two species is similar to the results of other studies (Stone et al., 1998; Carson et al., 1999, Cralle et al., 2003). Thus, even the small wheat seed in this study were almost 9-fold greater in weight than the ryegrass seed.

Field experiment

The greatest difference in the field experiment was between years (Figures 5 and 6). The yield was substantially greater in 2003 than 2004. Cumulative rainfall in October, November, and December was about two-fold greater in 2003 than 2004. There was almost two-fold more cloudy days in January when tillering occurred in 2004 than in 2003. There was also more than two-fold more cloudy days in March and April when seed number was determined in 2004 than 2003. Both tillering and seed number establishment in wheat were key yield components which were sensitive to the supply of photosynthate (Gifford et al.1984).

Since small, bulk, and large wheat seed produced similar yields in both years (Tables 1 and 2); they were pooled to determine the best regression analysis. The absence of the effect of seed size on wheat yield was also observed by Yenish and Young (2004) in Washington. Both wheat plant populations also produced similar yields in the two years. The best models for the 2003 and 2004 data (Figures 5 and 6) at both wheat populations were the following logarithmic equations:

Wheat yield in 2003 at a population of 250 plant m^{-2} = -326 (Ln ryegrass plants m^{-2}) + 2608

Wheat yield in 2003 at a population of 400 plant m^{-2} = -415 (Ln ryegrass plants m^{-2}) + 2654

Wheat yield in 2004 at a population of 250 plant m^{-2} = -93 (Ln ryegrass plants m^{-2}) + 822

Wheat yield in 2004 at a population of 400 plant m^{-2} = -74 (Ln ryegrass plants m^{-2}) + 909

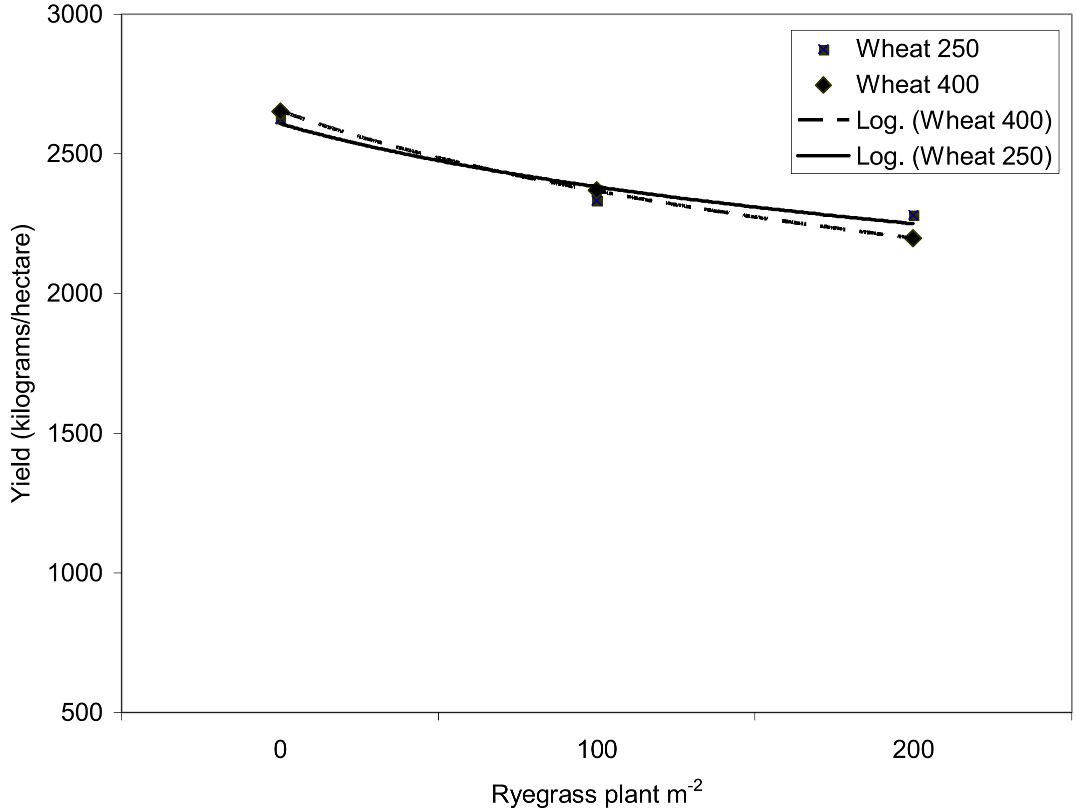

Figure 5. Yield in 2003 of wheat kernels from combined small, bulk and large seeds at 0, 100, and 200 ryegrass plants m^{-2}.

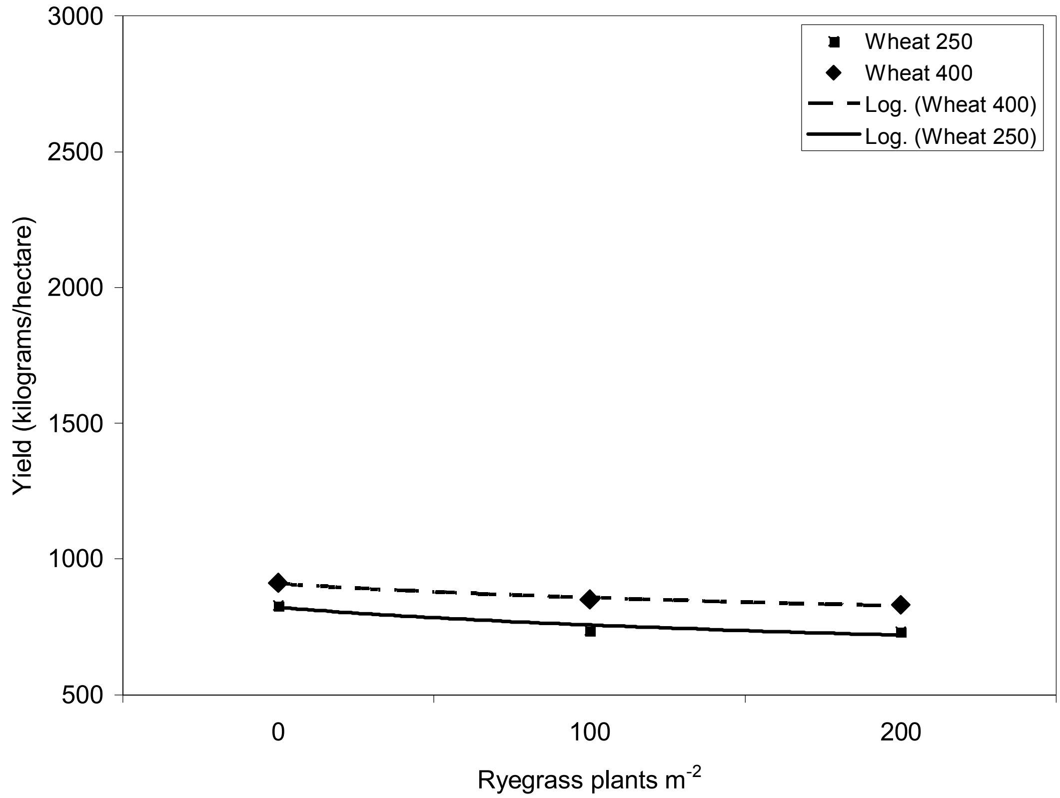

Figure 6. Yield in 2004 of wheat kernels from combined small, bulk and large seeds at 0, 100, and 200 ryegrass plants m^{-2}.

Table 1. Yield of wheat grains in 2003 in kilograms per hectare in plots grown from small, bulk, and large seeds at 0, 100, and 200 ryegrass plants m^{-2}.

Wheat seed size	Wheat plants m^{-2}	0 ryegrass plants m^{-2}	100 ryegrass plants m^{-2}	200 ryegrass plants m^{-2}
Large	250	2.859	2.592	2.175
Bulk	250	2.413	2.222	2.293
Small	250	2.609	2.182	2.376
Large	400	2.732	2.448	2.565
Bulk	400	2.666	2.293	2.197
Small	400	2.360	2.368	1.826

An analysis of variance showed no significance in the F-tests of differences in yield related to seed size, wheat density, or ryegrass density.

Table 2. Yield of wheat grains in 2004 in kilograms per hectare in plots grown from small, bulk, and large seeds at 0, 100, and 200 ryegrass plants m^{-2}.

Wheat seed size	Wheat plants m^{-2}	0 ryegrass plants m^{-2}	100 ryegrass plants m^{-2}	200 ryegrass plants m^{-2}
Large	250	0.838	0.855	0.802
Bulk	250	0.926	0.655	0.711
Small	250	0.723	0.700	0.683
Large	400	0.893	0.890	0.886
Bulk	400	0.974	0.821	0.840
Small	400	0.870	0.842	0.832

An analysis of variance showed no significance in the F-tests of differences in yield related to seed size, wheat density, or ryegrass density.

A previous study (Stone et. al., 1999) using data from Texas, North Carolina, and Oregon found that a 50% reduction of wheat yield could be expected if ryegrass was 40% of the population. In our study we found that a ryegrass proportion of 40% in wheat fields with a population of 250 plant m^{-2} produced only 13% and 12% reductions of wheat yields in 2003 and 2004, respectively. Since the ryegrass appeared to grow as well as the wheat in the field, this unexpectedly low reduction in wheat yields in response to ryegrass in both favorable and unfavorable years for growth may be a result of the enhanced competitiveness of the wheat cultivar used in this experiment. Obviously, the enhanced growth of ryegrass relative to wheat in the growth room study was not reflected in the field experiment. There were, of course, great differences in the environments in terms of light, water, and fertilization, and in the duration of the experiment.

CHAPTER IV

SUMMARY

Higher seeding rates and larger seed sizes could enhance the competitiveness of wheat with ryegrass and other weeds. Growth room and field research evaluated the effects of higher wheat seeding rates and greater seed size in competition with Italian ryegrass. Winter wheat seed cultivar "Ogallala" were divided into three seed sizes: small seed passed through a sieve with 2.08mm round holes; large seed which did not pass through a sieve with 3.18mm round holes; and bulk seed directly from a commercial seed bag.

These wheat seed and seed of Italian ryegrass cultivar "Gulf" were planted in 19 liter volume plastic pots containing industrially manufactured fritted clay. A replacement series design with 12 plants per pot compared the relative growth in pure culture and competitiveness in mixtures of the two species. The planting proportions of each wheat seed group and ryegrass were 100% and 0%, 50% and 50%, and 0% and 100%, respectively. All plants were destructively harvested 70 days after planting. Wheat seed size did not affect the growth of the wheat plants in pure culture. Wheat seed size did not affect competitiveness with ryegrass. There were no differences related to seed size among the pure or mixed cultures of wheat. The failure of increased wheat seed size to affect competition with ryegrass may be the result of the relative seed size difference between the two species. Even the small wheat seeds in this study were almost 9-fold greater in weight than the ryegrass seeds.

Field experiments conducted for two years from Fall 2002 through Spring 2004 at the Texas A&M University Agronomy Farm near College Station, TX measured wheat yields at the same three wheat seed sizes, two wheat densities of 250 plants m^{-2} and 400 plants m^{-2}, and three ryegrass densities of 100 and 200 plants m^{-2}. Small, bulk, and large wheat seed produced similar yields in both years, one season favorable for growth (2003) and the other unfavorable (2004). Thus, seed size in the field in favorable or unfavorable conditions or in the growth room experiment did not affect the competitiveness of wheat in the presence of ryegrass. Increasing the wheat plant population from 250 to 400 plants m^{-2} in the field also failed to enhance the competitiveness of wheat in either year. Therefore, herbicide management systems will likely remain important to the control of ryegrass in wheat fields.

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