EFFECT OF WHEAT (*Triticum aestivum)* ROW SPACING, SEEDING RATE, AND CULTIVAR ON INTERFERENCE FROM RYE (*Secale cereale*), AND VARIATION IN MORPHOLOGICAL AND PHENOLOGICAL CHARACTERISTICS AND GERMINATION OF FERAL RYE

By

JOHN RICHARD ROBERTS, JR.

Bachelor of Science

Oklahoma State University

Stillwater, Oklahoma

1997

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
May, 2000

EFFECT OF WHEAT (*Triticum aestivum)* ROW SPACING, SEEDING RATE, AND CULTIVAR ON INTERFERENCE FROM RYE (*Secale cereale*), AND VARIATION IN MORPHOLOGICAL AND PHENOLOGICAL CHARACTERISTICS AND GERMINATION OF FERAL RYE

Thesis Approved:

Thomas F. Peeper
Thesis Adviser

Eugene G. Krenzer, Jr.

John B. Solie

Wayne B. Powell
Dean of the Graduate College

ACKNOWLEDGEMENTS

I would like to extend my sincere appreciation to my major advisor, Dr. Tom Peeper, Professor of Agronomy, for his time, guidance, and constructive criticism throughout the course of my research. Appreciation is also extended to Dr. John Solie and Dr. Eugene Krenzer for their assistance and suggestions as members of my graduate committee. A special thanks to Dr. Carla Goad of the Department of Statistics for her time and effort, and Dr. Edwards, Val Oyster, and the OCIA for use of their lab and equipment.

I would like to thank my wife Jenice for her love, patience, understanding, encouragement, and support throughout the course of my graduate work. A special thanks to my son Cole for keeping me entertained and light hearted. I would also like to thank my parents, John and Carol Roberts for their support.

Appreciation is extended to the Department of Plant and Soil Sciences at Oklahoma State University for providing all the necessary facilities and equipment needed for this research. A special thanks to Mark Wood for his help and advice. Finally, I am indebted to the Small Grains Weed Science crew, Jason Kelley, Todd Heap, Michelle Armstrong, Matt Barnes, Chad Trusler, Andy Hollon, Caleb and Amanda Stone, Joey Collins, Kerry O'Neill, Kylie Vincent, Jason Walker, Kendall Truett, Sandy Stanton, Amber Cargill, Travis Purcell, and Kevin White whose hard work and dedication made this research possible.

TABLE OF CONTENTS

LIST OF TABLES

Table | Page

CHAPTER I

LIST OF TABLES

Table | Page

CHAPTER II

LIST OF FIGURES

INTRODUCTION

Chapters I and II of this thesis are manuscripts to be submitted for publication in Weed Technology, a Weed Science Society of America publication.

CHAPTER I

Effect of Wheat *(Triticum aestivum)* Row Spacing, Seeding Rate, and Cultivar on Interference from Rye *(Secale cereale)*

Effect of Wheat *(Triticum aestivum)* Row Spacing, Seeding Rate, and Cultivar on Interference from Rye *(Secale cereale)*[1]

JOHN R. ROBERTS, JR., THOMAS F. PEEPER, and JOHN B. SOLIE[2]

Abstract: Two field experiments were conducted in Oklahoma to evaluate the effects of wheat row spacing and seeding rate on interference from rye. Wheat row spacing did not affect rye seed production. Averaged over row spacing, increasing wheat seeding rate from 67 to 134 kg/ha reduced rye seed production 21% and 25% in two experiments. At one site, yield of rye-infested wheat was increased 27 and 23% by doubling the wheat seeding rate of wheat in 10- and 20-cm rows. Doubling the seeding rate of rye infested wheat in 30-cm rows did not increase wheat yield. At a second site, pooled across row spacing, increasing the wheat seeding rate from 67 to 101 kg/ha increased yield of rye-infested wheat 21%, but yield was still 36% less than rye-free wheat. In two additional experiments, rye seed in harvested wheat was reduced 36% by increasing the wheat seeding rate from 60 to 162 kg/ha, while yield of rye-infested wheat was increased 82%. Nine cultivars were compared for

---

[1] Received for publication ____________ and in revised form_____________. Approved for publication by the Director, Oklahoma Agricultural Experiment Station, Oklahoma State University, Stillwater, OK 74078.

[2] Graduate Research Assistant and Professor, Department of Plant and Soil Sciences, and Professor, Department of Biosystems and Agricultural Engineering, Oklahoma State University, Stillwater, OK 74078.

competitive ability against rye in four experiments. Of 32 possible cultivar location situations, the rye-induced yield loss of 'Jagger' wheat was less than 16 other cultivar location situations, while the yield loss of 'Triumph 64' wheat was less than 10 other cultivar location situations. Mature wheat height, wheat yield, and wheat maturity classification were each negatively correlated to rye yield in infested wheat at two of four sites. Wheat plant density, head density, sunlight interception, and fall cover capability classification were each negatively correlated to rye yield at one of four sites.

Nomenclature: Rye, *Secale cereale* L., wheat, *Triticum aestivum* L., '2163', '2180', 'Agseco 7853', Jagger, 'Karl 92', 'Longhorn', 'TAM 107', 'TAM 202', Triumph 64.

Additional index words: Winter wheat, competitive ability.

Abbreviations: PAR, photosynthetically active radiation.

INTRODUCTION

Feral rye has been a serious problem weed in winter wheat throughout the Great Plains and Western United States for decades. In the 1930's and 1940's, one of the main goals of the Oklahoma Farm Wheat Improvement Program was to reduce rye in Oklahoma wheat (Oswalt 1946). A 1989 survey in Colorado found 115,000 ha of cropland infested with feral rye (Stump and Westra 1993). Over 5% of Kansas wheat (243,000 hectares) was infested with feral rye in 1994 (Stahlman and Peterson 1995). Infestations were concentrated in Central and Southeast Kansas. One fourth of the Kansas survey respondents who reported feral rye infestations had also been penalized for dockage in their wheat due to weed contamination.

In Kansas, wheat yield was reduced 1715 kg/ha by 24 feral rye plants/m^2 (Schneweis et al. 1993). In later research, wheat yield was reduced 67% by 50 feral rye plants/m^2 in 1994, and 45% by 21 feral rye plants/m^2 in 1995 (Stahlman and Northam 1995). In Oregon, 194 feral rye plants/m^2 reduced winter wheat yields 33% when rye was removed in February and 69% when feral rye remained until harvest (Rydrych 1987).

Glyphosate, applied in a rope wick applicator, is the only herbicide treatment registered for rye control in winter wheat (Lyon and Klein 1994). Since a selective herbicide that will effectively control feral rye in winter wheat has not been found, producers depend on crop rotation and uncontaminated seed sources (Schneweis et al. 1993). Thus, current research has focused on developing cultural control measures.

The effects of wheat row spacing and seeding rate on weed interference from other grass weeds have been examined with variable results. Increasing wheat seeding rate from 34 to 134 kg/ha decreased jointed goatgrass (*Aegilops cylindrica* Host) spikelet yield from 668 to 335, 363 to 136, and 136 to 54 kg/ha in three experiments in Oklahoma when averaged over row spacings (Kelley 1998). Narrowing wheat row spacing from 30 to 10 cm reduced jointed goatgrass spikelet yield from 513 to 391 and 240 to 207 kg/ha at two sites, but no reduction was found at a third site (Kelley 1998). Decreasing row spacing from 23 to 8 cm increased the yield of wheat infested with cheat (*Bromus secalinus* L.) in six of ten experiments in Oklahoma, and increasing wheat seeding rates from 265 to 530 seeds/m^2 increased wheat yield (Koscelny et al. 1990). Cheat seed yield was reduced in wheat by narrowing wheat row spacing from 23 cm to 7.5 cm (Justice et al. 1993).

Winter wheat tiller number, canopy diameter, and plant height were negatively correlated with downy brome (*Bromus tectorum* L.) yield, but changes in these growth parameters did not always translate into a grain yield advantage in downy brome-infested plots (Challaiah et al. 1986). Of these three growth characteristics, wheat plant height was better correlated with yield of infested wheat than crop canopy diameter or number of tillers. Snaydon (1984) suggested that a cultivar's competitive ability may be negatively associated with wheat yield. Less competitive cultivars should yield more because resource allocation in weaker plants is directed at seed production. 'Turkey' was the most competitive cultivar in terms of restricting downy brome growth, but it has poor grain yielding potential (Challaiah et al. 1986). Turkey was also the tallest cultivar while 'Vona' and 'NE 78798' were the shortest, but the latter two had greater grain yields than Turkey when grown with and without downy brome.

In a dry year, the rate of wheat height increase was the most important trait in enhancing the competitiveness of a wheat cultivar against jointed goatgrass, i.e. maintaining wheat yields and reducing jointed goatgrass yields (Ogg and Seefeldt 1999). In a wet year, rate of wheat height increase, number of wheat heads per plant, rate of water use, and weight gain were important traits associated with the competitiveness of a wheat cultivar against jointed goatgrass.

These traits were positively correlated to smaller wheat yield decrease due to weed interference, while no cultivar traits were identified that were critical in enhancing a reduction in jointed goatgrass yields in a wet year.

The effect of wheat plant height on competition against jointed goatgrass was determined in Washington using four near isolines with different heights (Seefeldt et al. 1999). The shortest isoline allowed the greatest amount of jointed goatgrass seed production, but did not have the lowest wheat yield. The tallest isoline reduced jointed goatgrass seed production the most, and had the least percent wheat yield reduction. The tallest isoline did not always have the highest wheat yield, and the shortest isoline did not always have the lowest wheat yield. In 1995, the yield reduction due to jointed goatgrass interference was 29% with the tallest isoline, compared with 46 to 48% in the shorter isolines. In 1996, the yields of the taller isolines were reduced 6 to 13%, while the yield of the shortest isoline was reduced 28%. The shortest isolines were most negatively affected by jointed goatgrass in wet years due to shading during the growing season and especially when grain was filling.

These results suggest that increasing wheat height is an important factor in increasing competition against jointed goatgrass, but the degree of winter wheat competitiveness appeared to be an interaction between the rate of height increase and available moisture (Seefeldt et al. 1999).

In Oklahoma, cheat seed production was affected by cultivar at five locations, but no cultivar consistently suppressed cheat production more than any other

(Koscelny et al. 1990). Juvenile growth habit was unrelated to wheat competitiveness.

Jointed goatgrass reduced the yield of popular wheat cultivars from 0 to 24%, 10 to 32%, 4 to 29%, and 10 to 28% at four locations in Oklahoma (Kelley et al. 1997). Juvenile wheat growth habit and wheat cultivar forage production potential did not affect jointed goatgrass spikelet production. Wheat height and yield were negatively correlated with percent jointed goatgrass spikelet content in harvested grain at all locations, and wheat heads per square meter were negatively correlated with percent jointed goatgrass spikelet content in harvested grain at three of four locations.

The first objective of this research was to compare the influence of wheat row spacing and seeding rate on interference from rye. The second objective was to compare the effect of wheat cultivar on interference from rye.

MATERIALS AND METHODS

Row Spacing and Seeding Rate. Field experiments were conducted near Chickasha and Perkins, Oklahoma during the 1997-1998 winter wheat growing season to evaluate the effect of hard red winter wheat row spacing and seeding rate on interference from rye. The experimental design for each location was a randomized complete block with a factorial arrangement of treatments with six replications. Plot size was 3 by 7.6 m. Factors included wheat row spacing (10, 20, and 30 cm), wheat seeding rate (67, 101, and 134 kg/ha), and rye presence (present or absent).

The soil was a Dale loam (fine-silty, mixed, thermic Pachic Haplustoll) with pH 5.7 and 1.1% organic matter at Chickasha, and a Teller sandy loam (fine-loamy, mixed, thermic Udic Argiustoll) with pH 5.4 and 0.8% organic matter at Perkins. Precipitation from planting until harvest was 553 mm at Chickasha, and 559 mm at Perkins.

At each site, 'Oklon' rye was broadcast by hand onto appropriate plots at 17 kg/ha and incorporated with one pass of an S-tine field cultivator. Hard red winter wheat cultivar 2163 was seeded into a conventionally tilled seedbed using a double disk drill with press wheels and 10-cm row spacing. To seed 20- and 30-cm rows, seed metering units for unplanted rows were covered, and wheat seeding rate of the active metering units were adjusted to compensate for the change in row spacing. The experiments were seeded October 21 and 30, 1997 at Perkins and Chickasha. Experiments were fertilized according to soil test recommendations for a 4,000 kg/ha wheat yield goal (Johnson et al. 1998). Plots were harvested in June using a small plot combine. After harvested samples were scalped using a small commercial seed cleaner to remove straw and chaff, rye was hand separated from 10 g grain samples to determine wheat and rye yield for each plot. Wheat yields were adjusted to 13.5 percent moisture.

Data was subjected to analysis of variance. Means were separated using protected least significant differences at P = 0.05.

Additional field experiments were conducted at Perkins and Orlando, Oklahoma during the 1998-1999 winter wheat growing season to evaluate the effect of a wider range of wheat seeding rates on interference from rye. The experimental design for each location was a randomized complete block with a factorial arrangement of treatments with six replications. Factors included wheat seeding rate (60, 82, 102, 122, 142, or 162 kg/ha) and rye presence (present or absent). A treatment of rye with no wheat seeded was included. Plot size was 1.2 by 6.1 m.

The soil was a Teller sandy loam (fine-loamy, mixed, thermic Udic Argiustoll) with pH 6.9 and 0.9% organic matter at Perkins, and a Port loam (fine-silty, mixed, thermic Cumulic Haplustoll) with pH 6.3 and 1.7% organic matter at Orlando. Precipitation from planting until harvest was 629 mm at Perkins, and 733 mm at Orlando.

The hard red winter wheat cultivar Jagger was seeded October 23, 1998 into a conventionally tilled seedbed using a cone seeder with double disk openers, press wheels, and 15-cm row spacing. Rye was included in the appropriate plots at 34 kg/ha. Plots were seeded, fertilized, harvested, and grain processed as previously described.

Data were subjected to analysis of variance and regression analysis. Means were separated using protected least significant differences at P = 0.05. Data were pooled across locations except when precluded by interactions.

Cultivar Competitive Ability. Replicated field experiments were conducted near Chickasha and Perkins, Oklahoma during the 1997-1998 winter wheat growing season, and near Orlando and Perkins, Oklahoma during the 1998-1999 winter wheat growing season to evaluate the effect of wheat cultivar on interference from rye. The soils were the same as described above at Chickasha and Perkins in 1997. In 1998, the soil at Orlando was a Pulaski loam (coarse-loamy, mixed, nonacid, thermic Typic Ustifluvents) with 5.4 pH and 0.9% organic matter, and at Perkins was as mentioned previously, but with 6.3 pH and 0.5% organic matter.

The experimental design for each location was a randomized complete block with a factorial arrangement of treatments with six replications. Factors include hard red winter wheat cultivar (Agseco 7853, Triumph 64, 2163, Karl 92, TAM 107, 2180, Jagger, Longhorn, and TAM 202) and rye presence (present or absent). A treatment of rye with no wheat was added. Plot size was 1.2 by 7.6 m.

Each wheat cultivar was seeded at 67 kg/ha using the cone seeder previously described. Plots containing rye had 'Elbon' rye mixed with the wheat seed at 34 kg/ha. The experiments were seeded October 19 ± 4 days. Experiments were fertilized as previously described.

Stand density was determined by counting wheat plants in two meters of row in the center of each weed free plot. Photosynthetically active radiation (PAR) interception by the wheat and rye canopy was determined on April 22 and May 13 at Perkins and Chickasha in 1998, and on April 1 at Orlando and Perkins in 1999. PAR was determined above the crop canopy and approximately 5 cm above the soil surface by inserting a ceptometer[3] between two rows in the center of each plot. Sunlight interception was calculated as: [(PAR above canopy – PAR below canopy) / PAR above canopy) x 100]. Wheat heads in two meters of

[3]Decagon Devices, Inc. Pullman, WA. Sunfleck Ceptometer.

row were counted in the center of each plot. Mature plant heights were measured in each plot. Heads per plant were calculated from plant density and head density counts. Plots were harvested with a small plot combine, and harvested samples were processed as previously described.

Data were subjected to analysis of variance, and means were separated using protected least significant differences at P = 0.05. Correlations between cultivar characteristics and rye yield were determined.

RESULTS AND DISCUSSION

Row Spacing and Seeding Rate. Data were not pooled across locations because of the appearance of an interaction with location (P = 0.1). Wheat plants outnumbered rye 3 to 1 or 4 to 1 with the lowest wheat seeding rate, and proportionally greater with higher seeding rates (Table 1).

At Perkins, compared to the standard practice of seeding 67 kg/ha in 20-cm rows, where rye was not seeded, wheat yields were not increased by decreasing row spacing or increasing the seeding rate (Table 2). Increasing the row spacing to 30 cm decreased yield regardless of seeding rate. Compared to the standard practice, with rye present, wheat yield was increased by doubling the wheat seeding rate with or without reducing row spacing to 10 cm. With rye present, increasing the wheat seeding rate from 67 to 101 kg/ha increased the wheat yield at 10-cm row spacing, but failed to do so at 20-cm row spacing. The benefit from increased wheat seeding rate was not apparent when row spacing was 30 cm.

At Chickasha there were no interactions with row spacing in the wheat yield data. Pooled over seeding rate and rye presence, mean yield of wheat in 30-cm rows (3170 kg/ha) was less than yield in 20- or 10-cm rows (3500 and 3580 kg/ha) (LSD 0.05 = 150). Pooled across row spacing, with rye absent, seeding rate did not affect wheat yield (Table 2). Pooled across row spacing, with rye present, increasing the seeding rate from 67 to 101 kg/ha increased wheat yield.

Row spacing did not affect rye yield at either site ($P > 0.5$). Averaged over row spacing, increasing the wheat seeding rate from 67 to 134 kg/ha reduced ($P = 0.05$) rye yield 21% at Perkins and 25% at Chickasha.

In the experiments with a wider seeding rate range, pooled across locations, a quadratic relationship was found between wheat seeding rate and rye yield ($y = 3320 - 18.6x + 0.05x^2$, $R^2 = .95$) (Figure 1). Rye seed in harvested wheat was reduced 36% by increasing the wheat seeding rate from 60 kg/ha to 162 kg/ha. There also was a quadratic relationship between wheat seeding rate and yield of rye-infested wheat ($y = 45 + 26.7x - 0.09x^2 +$, $R^2 = .77$). The yield of the rye-infested wheat increased from 1110 kg/ha to 2020 kg/ha as the wheat seeding rate increased from 60 kg/ha to 162 kg/ha. Rye seed in harvested wheat was reduced 36% by increasing wheat seeding rate from 60 to 162 kg/ha, while wheat yield was increased 82%.

Grain yield of wheat growing without rye was approximately 3500 kg/ha regardless of seeding rate (Figure 1.). When rye was present, increasing the wheat seeding rate increased wheat yield and decreased rye yield. When rye was growing with wheat, total yield of rye plus wheat grain was similar to wheat grain yield when wheat was grown alone. Thus, rye grain yield replaced wheat grain yield in approximately a 1:1 ratio, over the range of seeding rates.

These data indicate that wheat row spacing and seeding rate can have an impact on wheat yield in rye-infested wheat, and wheat seeding rate can also impact rye seed production. Narrowing wheat row spacing to at least 20 cm and increasing wheat seeding rate are practices that producers could use to reduce the impact of rye in winter wheat.

Cultivar Competitive Ability. In 1998, the rye-induced yield loss of Jagger was less than the yield loss of five other cultivars at both locations (Table 3). The yield loss of Triumph 64 was less than the yield loss of one other cultivar at Chickasha, and two other cultivars at Perkins.

In 1999, the rye-induced yield loss of Jagger was less than only one other cultivar at Chickasha, but less than five of six other cultivars at Perkins. At Orlando, where mean wheat yields were lowest, the old standard cultivar Triumph 64 had less rye-induced yield loss than any other cultivar except Jagger. At Perkins, Triumph 64 suffered less rye-induced yield loss than three of the other cultivars. The cultivar TAM 202 was variable in yield loss. This cultivar is known for its lack of predictable yield consistency (Table 4).

All cultivars of wheat except for Longhorn at Perkins in 1999 reduced rye yield at all sites. Jagger reduced rye yield more than five other cultivars at Chickasha, and more than any other cultivar at Perkins. The second year, Jagger reduced rye yield more than four other cultivars at Orlando, and five other cultivars at

Perkins. Triumph 64 reduced rye yield more than one to six other cultivars in the four experiments.

In sunlight interception data, no wheat cultivar by rye presence interaction (P = 0.3 to 0.9) was found at any site. At Perkins (1997-98), averaged over cultivars, light interception in rye-free plots (76%) was less (P = 0.02) than light interception in rye-infested plots (77%). Results were similar (P = 0.01) in 1998-99 when light interception was 72 and 87% in rye-free plots and rye-infested plots at Perkins, and 80 and 86% in respective plots at Orlando.

When wheat, growing alone, was intercepting more sunlight than rye growing alone, as at Chickasha, (Table 5), mature wheat height and sunlight interception by the wheat canopy were important competitive characteristics. Each was negatively correlated with rye yield (Table 6). Where rye growing alone was intercepting as much sunlight as wheat growing alone (Perkins 1997-98), yield of non-infested wheat and fall cover capability classification were negatively correlated with rye yield. When rye growing alone intercepted as much or more sunlight than wheat growing alone (1998-99), the time of wheat maturity was important i.e. earlier maturity was negatively correlated with rye yield at both sites.

At Perkins in 1998-99, where rye growing alone was intercepting as much sunlight as wheat growing alone, wheat plant density, head density, mature height and non-infested wheat yield were negatively correlated with rye yield. Thus, no single wheat plant characteristic was identified that was correlated with rye yield at more than two of four sites.

Challaiah et al. (1986) found wheat height to be negatively correlated to downy brome yield, while our results indicate wheat height to have a negative correlation with rye yield at two of four sites. Our results seem in agreement with Seefeldt et al. (1999), who suggested that, an interaction between rate of wheat height increase and environmental conditions may be more important than mature wheat height alone.

Lemerle et al. (1996) indicated that extensive leaf display and shading ability were characteristic of competitive cultivars, but in our results sunlight interception was negatively correlated with rye yield at only one of four sites. At both sites in 1998-99, earlier wheat maturity was negatively correlated to rye yield, which could agree with the suggestion by Lemerle et al. (1996) that early vigor and high early biomass accumulation could be used to select indirectly for competitive ability, but no correlation was evident in 1997-98 data. Our results agree with Lemerle et al. (1996) who found that a wheat cultivar's competitive ability could not be explained by a single characteristic.

ACKNOWLEDGMENTS

Technical assistance provided by Dr. Eugene Krenzer, Richard Austin, and Charles Luper, Oklahoma State University Department of Plant and Soil Sciences, is gratefully acknowledged. Statistical assistance provided by Dr. Carla Goad, Oklahoma State University Department of Statistics, is also gratefully appreciated.

LITERATURE CITED

Challaiah, O. C. Burnside, G. A. Wicks, and V. A. Johnson. 1986. Competition between winter wheat (*Triticum aestivum*) cultivars and downy brome (*Bromus tectorum*). Weed Sci. 34;689-693.

Johnson, G., N. Basta, J. Hattey, B. Raun, and H. Zhang. 1998. OSU Soil Test Interpretations. OSU Ext. Facts No. 2225. Coop. Ext. Serv., Okla State Univ., Stillwater. 8pp.

Justice, G. G., T. F. Peeper, J. B. Solie, and F. M. Epplin. 1993. Net returns from cheat (*Bromus secalinus*) control in winter wheat (*Triticum aestivum*). Weed Technol. 7:459-464.

Kelley, J. P. 1998. Impact of cultural practices on jointed goatgrass (*Aegilops cylindrica*) in wheat (*Triticum aestivum*). MS Thesis. Oklahoma State University, Stillwater, 35pp.

Kelley, J. P., E. G. Krenzer, and T. F. Peeper. 1997. Effect of wheat cultivar on interference from jointed goatgrass (*Aegilops cylindrica*). Proc. South. Weed Sci. Soc. 50:45.

Koscelny, J. A., T. F. Peeper, J. B. Solie, and S. G. Solomon, Jr. 1990. Effect of Wheat (*Triticum aestivum*) Row Spacing, Seeding Rate, and Cultivar on Yield Loss from Cheat (*Bromus secalinus*). Weed Technology. 4:487-492.

Lemerle, D., B. Verbeek, R. D. Cousens, and N. E. Coombes. 1996. The potential for selecting wheat varieties strongly competitive against weeds. Weed Res. 36:505-513.

Lyon, D. J. and R. N. Klein. 1994. Controlling Volunteer Rye In Winter Wheat. NebGuide G94-1225-A. Coop. Ext., Univ. of Nebraska, Lincoln. 4pp.

Ogg, A. G., and S. S. Seefeldt. 1999. Characterizing traits that enhance the competitiveness of winter wheat (*Triticum aestivum*) against jointed goatgrass (*Aegilops cylindrica*). Weed Sci. 47:74-80.

Oswalt, R. M. 1946. The Oklahoma Farm Wheat Improvement Program: Progress Report, 1938-1945. Oklahoma Agricultural Experiment Station, Stillwater, OK 74078. Misc. Pub. No. MP-9. 18pp.

Rydrych, D. J. 1987. Cereal Rye Competition in Winter Wheat in Eastern Oregon. Res. Prog. Rep. West. Soc. Weed Sci. p. 335.

Schneweis, D. A., F. E. Northam, and P. W. Stahlman. 1993. Volunteer Rye (*Secale cereale*) Interference in Winter Wheat. Proc. North Cent. Weed Sci. Soc. 48:6.

Seefeldt, S. S., A. G. Ogg, and H. Yuesheng. 1999. Near-isogenic lines for *Triticum aestivum* height and crop competitiveness. Weed Sci. 47:316-320.

Snaydon, R. W. 1984. Plant demography in an agricultural context. Pages 389-407 *in* R. Dirzo and J. Sarukhan, eds. Perspectives on plant population Ecology. Sunderland, MA: Sinauer.

Stahlman, P. W. and F. E. Northam. 1995. Weedy rye interference in winter wheat. Proc. North Cent. Weed Sci. Soc. 50:64.

Stahlman, P. W. and D. E. Peterson. 1995. Winter Annual Grass Survey in Kansas. Proc. North Cent. Weed Sci. Soc. 50:64-65.

Stump, W. L. and P. Westra. 1993. The Effects of Tillage on Volunteer Rye Emergence and Seed Bank Dynamics. 1993 Res. Prog. Rep. West Soc. Weed Sci. p. 180.

Watson, S. 1999. Wheat Varieties for Kansas and the Great Plains. Topeka, KS: Lone Star Publishing Co. 119pp.

Table 1. Mean and standard deviation of seedling rye density and seedling wheat density for each wheat seeding rate at two locations.

		Wheat seeding rate (kg/ha)		
Location	Rye	67	101	134
	Plants / m^2			
Chickasha	66 ± 8	264 ± 39	331 ± 40	444 ± 59
Perkins	59 ± 16	186 ± 38	267 ± 57	366 ± 64

Table 2. Interaction of wheat seeding rate, rye presence, and row spacing on wheat yield at Perkins and interaction of wheat seeding rate and rye presence on wheat yield at Chickasha.

		Rye absent			Rye present		
		Wheat seeding rate (kg/ha)					
Site	Row width	67	101	134	67	101	134
	cm	kg/ha					
Perkins	10	3600	3410	3810	1570	1920	2000
	20	3620	3650	3450	1680	1730	2080
	30	3290	3210	3260	1510	1540	1600
LSD (0.05)		260					
Chickasha	mean	4270	4380	4260	2280	2570	2740
LSD (0.05)		210					

Table 3. Effect of wheat cultivar on weed-free wheat yield, percent wheat yield loss due to rye infestation, and yield of rye seeded with each wheat cultivar in four experiments.

	Weed-free wheat yield				Wheat yield loss due to rye				Rye yield			
Cultivar	Chick.[a]	Perk.1[a]	Orl.[b]	Perk.2[b]	Chick.	Perk.1	Orl.	Perk.2	Chick.	Perk.1	Orl.	Perk.2
	kg/ha				%				kg/ha			
2163	5300	3100	4040	3170	47	57	58	78	1230	1460	1630	3660
2180	5270	2940	—[c]	—	45	58	—	—	1340	1450	—	—
Agseco 7853	5690	3620	4340	3780	40	56	53	73	1350	1360	1710	3220
Jagger	6710	3600	4720	3800	28	45	42	50	920	850	1120	2590
Karl 92	5360	3360	—	—	40	55	—	—	1160	1510	—	—
Longhorn	4900	2800	3300	2690	36	49	52	81	1110	1440	1990	3820
TAM 107	4870	2900	3800	2860	48	59	49	54	1600	2020	1490	2990
TAM 202	6360	2700	3840	3100	52	33	53	78	1270	1470	1840	3750
Triumph 64	5300	3350	2680	3270	38	49	33	68	860	1360	1330	2650
Elbon rye[d]	2680	2800	2760	4150	—	—	—	—	—	—	—	—

Table 3. Continued.

LSD (0.05)	520	420	530	470	11	9	14	8	260	360	470	370

[a]1997-1998 wheat growing season at Chickasha (Chick.) and Perkins (Perk.1), OK.

[b]1998-1999 wheat growing season at Orlando (Orl.) and Perkins (Perk.2), OK.

[c]2180 and Karl 92 were not included in 1998-1999 experiments.

[d]Plot seeded with rye only. Data not included in analysis of variance for wheat yields.

Table 4. Wheat cultivar characteristics[a] and height of mature wheat.

	Yield	Grazing		Fall cover	Height of mature wheat			
Cultivar	consistency[b]	potential[c]	Maturity	capability	Chick.[d]	Perk.1[d]	Orl.[e]	Perk.2[e]
					cm			
2163	2	3	Medium early	Not quick	88	70	94	81
2180	4	2	Early	Average	76	62	—[f]	—
Agseco 7853	3	4	Medium	Not quick	100	75	102	90
Jagger	3	1	Early	Quick	96	75	91	84
Karl 92	2	3	Early	Not quick	88	74	—	—
Longhorn	4	1	Medium late	Quick	97	75	98	86
TAM 107	3	3	Early	Not quick	91	70	95	81
TAM 202	5	2	Medium	Quick	86	69	87	78
Triumph 64	1	4	Early	Not quick	104	83	111	91
LSD (0.05)					7	3	4	3

[a]Information from Watson 1999.

[b]1 = predictable, 5 = unpredictable.

Table 4. Continued.

[c]1 = good grazing potential i.e. abundant foliage , 4 = below average foliage growth.

[d]1997-1998 wheat growing season at Chickasha (Chick.) and Perkins (Perk.1), OK.

[e]1998-1999 wheat growing season at Orlando (Orl.) and Perkins (Perk.2), OK.

[f]2180 and Karl 92 were not included in 1998-1999 experiments.

Table 5. Effect of wheat cultivar on sunlight interception by the crop canopy pooled over rye-free and rye-infested wheat, and sunlight interception of monoculture rye in four experiments in Oklahoma.

	Mean sunlight interception			
Cultivar	Chickasha[a]	Perkins - 1[a]	Orlando[b]	Perkins - 2[b]
	%			
2163	91.4	76.6	84.2	76.8
2180	92.1	76.6	—[c]	—
Agseco 7853	93.5	75.6	74.1	78.5
Jagger	96.3	76.1	84.2	84.8
Karl 92	93.0	81.2	—	—
Longhorn	92.5	79.2	83.0	76.5
TAM 107	92.9	74.9	84.6	79.5
TAM 202	93.6	78.0	85.3	81.0
Triumph 64	93.5	75.5	80.0	79.1
Elbon Rye[d]	87.5	76.5	89.9	87.1

Table 5. Continued.

LSD (0.05)	—— 2.2 ——	—— NS ——	—— 7.1 ——	—— NS ——

[a]1997-1998 wheat growing season.

[b]1998-1999 wheat growing season.

[c]2180 and Karl 92 were not included in 1998-1999 experiments.

[d]Plot seeded with rye only.

Table 6. Correlations coefficients (r) and probabilities (p) of a greater absolute r value between wheat growth characteristics and rye yield in harvested grain at four locations.

	Rye yield			
Characteristic	Chickasha[a]	Perkins - 1[a]	Orlando[b]	Perkins - 2[b]
	r (p)			
Wheat plants /m^2	0.06 (0.68)	0.03 (0.84)	-0.12 (0.49)	-0.61 (0.01)
Wheat mature height	-0.33 (0.02)	-0.11 (0.41)	-0.04 (0.82)	-0.30 (0.06)
Wheat heads /m^2	-0.21 (0.13)	-0.13 (0.36)	0.15 (0.42)	-0.46 (0.01)
Wheat heads / plant	-0.19 (0.18)	-0.06 (0.65)	0.21 (0.25)	0.39 (0.01)
Sunlight interception	-0.25 (0.08)	0.09 (0.54)	-0.27 (0.13)	-0.20 (0.21)
Wheat yield	-0.24 (0.09)	-0.38 (0.01)	0.01 (0.97)	-0.40 (0.01)
Wheat time of maturity[c]	0.06 (0.67)	-0.01 (0.96)	0.45 (0.01)	0.70 (0.01)
Wheat fall cover capability[c]	0.22 (0.12)	0.33 (0.02)	0.05 (0.76)	-0.22 (0.15)

[a]1997-1998 wheat growing season.

[b]1998-1999 wheat growing season.

[c]Maturity and fall cover capability classifications used from Watson 1999.

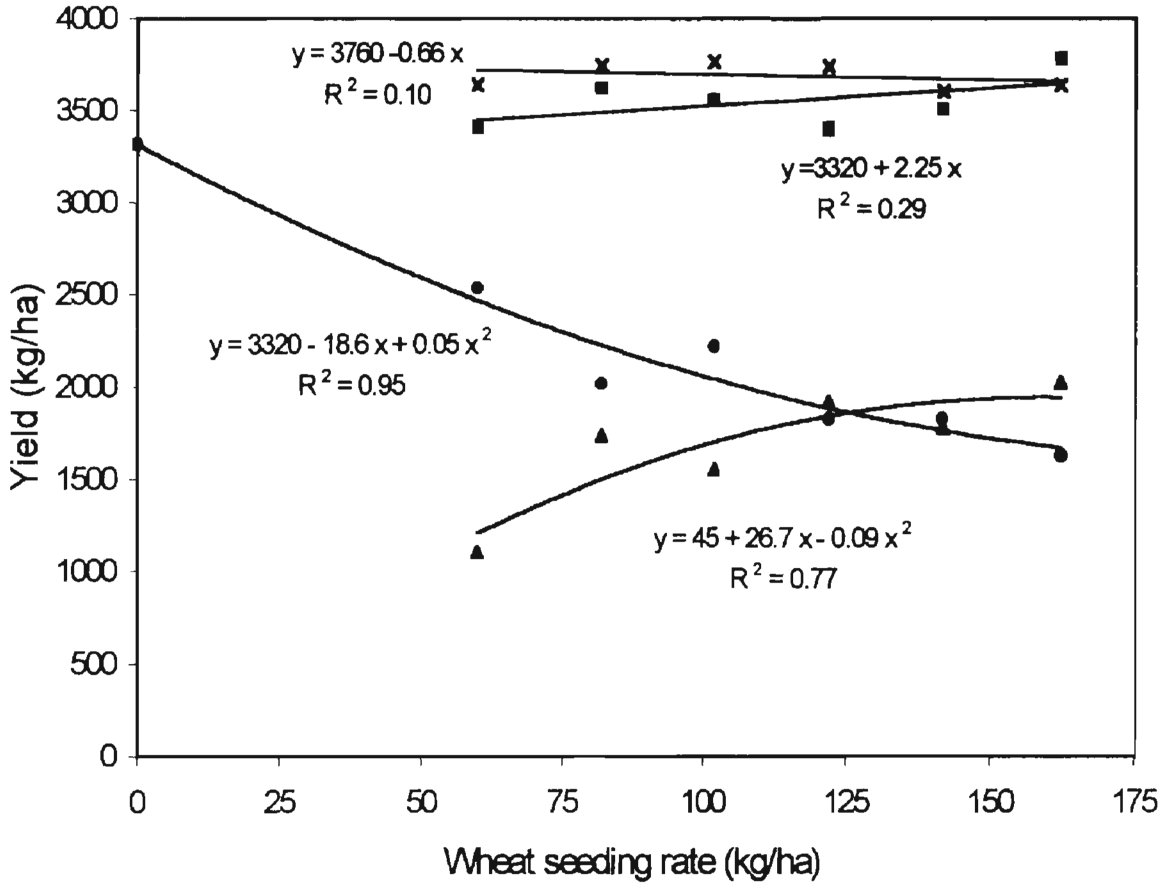

Figure 1. Effect of wheat seeding rate on yield of wheat grown without rye (■), wheat (▲) and rye (●) grain yields in rye-infested wheat, and combined rye and wheat grain yield in rye-infested wheat (x) at Perkins and Orlando, Oklahoma.

CHAPTER II

Variation in Morphological and Phenological Characteristics and Germination of Feral Rye (*Secale cereale*)

Variation in Morphological and Phenological Characteristics and Germination of Feral Rye *(Secale cereale)*[1]

JOHN R. ROBERTS, JR., THOMAS F. PEEPER, and CARLA L. GOAD[2]

Abstract: In June 1998, mature feral rye spikes were collected from 24 wheat (*Triticum aestivum*) fields in North Central Oklahoma. Ten mature spikes from each site were hand threshed, and one seed from each spike was planted into a peat pellet in a greenhouse. Seedlings were transplanted into a field to evaluate variability in plant characteristics. The rye population varied within source fields in number of tillers produced and tallest spike height at maturity. Visually estimated maturity varied within source fields, indicating that the rye within source fields does not exhibit uniform maturity. Within-fields, rye varied in number of lodged spikes per plant, late spike emergence, seed kernel color, and weight of 1,000 seeds. Among source fields, the rye populations varied in plant height measured on February 25 and April 9, spike emergence on April 30 and May 5, weight of 1,000 seeds, and seed kernel color.

Nomenclature: Feral rye, *Secale cereale L.*; wheat, *Triticum aestivum* L.

---

[1]Received for publication ____________ and in revised form____________. Approved for publication by the Director, Oklahoma Agricultural Experiment Station, Oklahoma State University, Stillwater, OK 74078.

[2]Graduate Research Assistant and Professor, Department of Plant and Soil Sciences, and Associate Professor, Department of Statistics, Oklahoma State University, Stillwater, OK 74078.

Additional index words: Winter wheat, rye, volunteer rye.

Abbreviations: REML, Restricted Maximum Likelihood.

INTRODUCTION

Feral rye has been a serious problem weed in winter wheat throughout the Great Plains and Western United States for decades. In the 1930's and 1940's, one of the main goals of the Oklahoma Farm Wheat Improvement Program was to reduce rye in Oklahoma wheat (Oswalt 1946). Feral rye infests an estimated 115,000 ha of Colorado cropland (Stump and Westra 1993), and 243,000 ha of Kansas wheat (Stahlman and Peterson 1995).

Cultivated rye, *Secale cereale* may be derived from *Secale montanum*, a wild perennial found in southern Europe and central Asia (Wilson 1948), although the relationship has not been confirmed (Bushuk 1976). Rye was grown in today's United States by colonists as early as 1625 (Hutcheson et al. 1936). Rye differs from other small grains in that it is cross-pollinated, and wild and cultivated forms of rye may be easily crossed which indicates a close relationship (Hayes and Garber 1927). Cross-pollination also makes it extremely difficult to keep rye cultivars pure (Bushuk 1976). There are great differences in yield potential and growth habit among rye cultivars (Hutcheson et al. 1936).

Rye is the most widely adapted of all cereals, and is also the most drought-resistant due to its extensive root system and inherent ability to adjust its maturity to moisture conditions (Evans and Scoles 1976). Rye has been classified as a poor soil crop and is often seeded on less fertile, more weedy fields, and when sown on a well prepared seedbed it curtails weed growth (Wilson 1948). Fall seeded rye is usually better able to compete for use of the land than other grains. Feral rye is not always a tall, robust plant (Lyon and Klein 1994). Under stressful conditions it can still grow and produce seed despite attaining heights of less than 15 cm.

Rye seed is normally grayish yellow in color although a number of color forms are known (Simmonds and Campbell 1976). Rye seed color has been described as yellow, gray, green or grayish-brown (Hutcheson et al. 1936), and colorless or white to greens and dark purples (Wilson 1948).

In 1998, rye was planted on 121,500 ha in Oklahoma of which 28,350 ha were harvested for grain. Rye is planted as a winter cover crop in cotton fields in Oklahoma to reduce wind erosion on sandy soils (Tomlinson 1965). Rye is used as a mulch and cover crop in conservation tillage systems to reduce early season weeds in corn and soybean (Liebl et al. 1992, Zasada et al. 1997). It is also utilized extensively as a cool season forage (Dunavin 1987).

'Elbon', 'Maton', and 'Oklon' are common cultivars grown in Oklahoma. Elbon, released in 1958, has more erect plant growth, produces more forage, and matures earlier than rye cultivars grown in Oklahoma before its release (Oklahoma Crop Improvement Association 1958). Maton, released in 1976, produces more early forage and grain and has improved disease tolerance compared to earlier cultivars (Bates 1979). Oklon, a selection from Maton released in 1993, produces more fall, early winter, and total forage than Maton (Bates and Baker 1994). Seed production was less than Maton, but more than

Elbon. The vegetative and seed characteristics are very similar to Maton with no consistent differences in lodging, plant height, or disease and insect resistance reported. Oklon and Maton can probably not be visually distinguished.

Economic threshold levels for feral rye in winter wheat vary from four rye reproductive tillers per square meter in Nebraska and Wyoming, to 70 rye reproductive tillers per square meter in Kansas (Pester et al. 1998). In Wyoming, feral rye was harvested with winter wheat and did not contribute to the soil seed bank (Neider and Miller 1993).

Defining phenological differences can provide information useful in estimating the potential for emergence of herbicide resistance (Putwain et al. 1982). Differential response of plants to herbicides has generally been attributed to differences in morphological and physiological factors between and within species (Anderson 1996). The objective of this research was to evaluate the variation in morphological and phenological characteristics of feral rye populations from infested wheat fields in Oklahoma.

MATERIALS AND METHODS

In June 1998, ten mature spikes from feral rye plants were randomly collected from 24 randomly selected wheat fields in North Central Oklahoma. One seed from each spike was planted in a peat pellet and incubated in a greenhouse on December 10, 1998. Seedlings were transplanted into a field at the Agronomy Research Station near Perkins, Oklahoma on January 13, 1999, to compare rye characteristics when grown under the same environmental conditions. A completely randomized design was used. Variation within this population of source fields was tested as a random effect. Plot size was one plant. Plants were seeded 0.6-m apart.

The soil was a Teller sandy loam (fine-loamy, mixed, thermic Udic Argiustoll) with pH 5.4 and 0.8% organic matter. Precipitation from transplanting until harvest was 461 mm.

Tillers per plant were counted and plant height measured on February 25, 1999. Plant height was measured again on April 9, 1999. Spikes completely emerged from the flag leaf were counted on April 23, 27, and 30, and May 5, 13, 20, and 27, 1999. Earlier heading rye could mature earlier, and shatter prior to wheat harvest and therefore be more likely to reinfest the field. No spikes emerged after May 27. Shortest and tallest spike heights were measured on May 27 to determine whether differences existed that could influence the likelihood of being collected by a combine header during harvest. Maturity was visually estimated as the percent of the plant exhibiting green color on June 14. Lodged spikes were counted on June 18. Combine harvesting could have a tendency to select for phenotypes that lodge easily.

Spikes from each plant were hand clipped on June 18 and threshed using a belt thresher. Chaff was removed using a laboratory seed cleaner. Seeds from each plant were counted and weighed, and thousand seed weights calculated. Percentage of dark colored seeds was visually estimated for each plant.

Three 100 seed subsamples from each plant harvested in 1999 were germinated using standard rye germination procedures (Anonymous 1993) at the

Oklahoma Crop Improvement Association laboratory. Germinated seeds were manually counted after seven days, and seed remaining dormant were counted. A seed was considered dormant if it remained firm and did not imbibe water, germinate, or deteriorate.

The mixed procedure of SAS[3] with the Restricted Maximum Likelihood (REML) method was used to estimate and test variance components within and among source fields. Results were tested as random effects since samples were randomly collected and could not be repeated. Thus, means and standard deviations for characteristics are for information only and should not be compared.

RESULTS AND DISCUSSION

Within Source Fields. For tillers per plant counted on February 25, within-field variances were different (P = 0.03) (Table 1). Variance estimates ranged from 4 to 27 (data not shown). For plant heights on February 25 and April 9, within-field variances were homogeneous (P = 0.4 and 0.9). Within-field variances were also homogeneous for shortest spike height per plant at maturity (P = 0.7), indicating that current harvesting procedures have not caused selection for short spikes. For the tallest spike height per plant at maturity, within-field variances were different (P = 0.01). Variance estimates for the tallest spike height per plant ranged from 3 to 35. Within-field variances for the visual estimate of the plant's green color percentage were different (P = 0.01), indicating diversity in maturity.

[3] SAS is the registered trademark of SAS Institute, Cary, NC 27513.

Variance estimates ranged from 5 to 252. Within-field variances were different for the number of lodged spikes per plant (P = 0.01), suggesting that within a field, selection for tendency to lodge may be occurring. Variances estimated ranged from 1 to 19.

Most spikes were not fully emerged until May 5; therefore, within-field variance estimates were not analyzed prior to this date. For spike emergence on May 5, within-field variances were homogeneous (P = 0.09) (Table 2). Within-field variances were different for spike emergence on May 13, 20, and 27 (P = 0.01, 0.02, and 0.03, respectively). Variance estimates ranged from 27 to 342, 44 to 500, and 22 to 362, respectively.

Within-field variances were homogeneous for seeds produced per plant (P = 0.09). Within-field variances were also homogeneous for total seed weight produced per plant (P = 0.8)., Within-field variances were different for weight of 1,000 seeds (P = 0.04), suggesting that within a field, selection for smaller seed size could be occurring. Variance estimates for weight of 1,000 seeds ranged from 4 to 34. Within-field variances were different for the visual estimate of dark colored seed kernels (P = 0.01). Variance estimates ranged from 11 to 1230. REML estimates could not be computed for seed germination and dormancy data. Therefore, it could not be determined if differences in variances occurred within fields.

Among Source Fields. No variability was found among source fields for tillers per plant counted on February 25 (P = 1.0) (Table 1). Plant heights measured on February 25 and April 9 did vary among source fields (P = 0.04 and 0.01).

Variance estimates for plant height were 0.5 and 23. No variability among source fields was found for the shortest and tallest spike height at maturity (P = 0.6 and 0.07). There was also no variability (P = 1.0) among source fields in the visual estimate of the plant's green color percentage as plants approached maturity. The number of lodged spikes per plant had no variability among source fields (P = 0.4).

No variability was found among source fields in early spike emergence on April 23 and 27 (P = 0.6 and 0.2) (Table 2). Spike emergence on April 30 and May 5 did vary among source fields (P = 0.01 and 0.02). Variance estimates for these were 8 and 22. No variability was found among source fields in late spike emergence on May 13, 20, and 27 (P = 0.3, 0.7, and 0.9, respectively).

No variability was found among source fields in seed number and weight per plant (P = 0.3 and 0.09). The weight of 1,000 seeds did vary among source fields (P = 0.01), with a variance estimate of 4. The visual estimate of dark colored seed kernel percentage also varied among source fields (P = 0.01). The variance estimate was 223. No variability among source fields occurred in seed germination percentage or seed dormancy (P = 1 and 0.2) (Table 3).

These data indicate that the rye populations varied in many characteristics both within and among source fields. This variability could impact both cultural and chemical control practices developed to combat this weed.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the assistance of Val Oyster, Coordinator of Lab Resources, and Dr Lewis Edwards, Oklahoma Crop Improvement Association, for their technical assistance and use of their laboratory.

LITERATURE CITED

Anderson, W. P. 1996. Weed science : principles and applications. West Publishing Co. St. Paul, MN. 388 pp.

Anonymous. 1993. Rules for testing seeds. Association of Official Seed Analysts. Journal of Seed Technol. 16:60.

Bates, R. P. 1979. Registration of "Maton" rye. Crop Sci. 19:746.

Bates, R. P. and J. L. Baker. 1994. Registration of "Oklon" rye. Crop Sci. 34:541.

Bloyd, B. L. and G. L. Shepler. 1999. Oklahoma agricultural statistics 1998. Oklahoma Agricultural Statistics Service, P. O. Box 528804, Oklahoma City, OK 73152. 145 p.

Bushuk, W. 1976. Rye: Production, Chemistry, and Technology – history, world distribution, production, and marketing. American Association of Cereal Chemists, Inc. St. Paul, MN. 181pp.

Dunavin, L. S., Jr. 1987. Comparison of Turnip-Chinese cabbage hybrid , rape, and rye, alone and in combination with annual ryegrass and crimson clover. Agron. J. 79:591-594.

Evans, Scoles. 1976. Rye: Production, Chemistry, and Technology – cytogenetics, plant breeding, and agronomy. American Association of Cereal Chemists, Inc. St. Paul, MN. 181pp.

Hutcheson, T. B., T. K. Wolfe, and M. S. Kipps. 1936. The production of field crops. New York: McGraw-Hill Book Company. 445pp.

Hayes, H. K. and R. J. Garber. 1927. Breeding crop plants. New York: McGraw-Hill Book Company. 438pp.

Liebl, R., F. W. Simmons, L. M. Wax, and E. W. Stoller. 1992. Effect of rye (*Secale cereale*) mulch on weed control and soil moisture in soybean (*Glycine max*). Weed Technol. 6:838-846.

Lyon, D. J. and R. N. Klein. 1994. Controlling volunteer rye in winter wheat. NebGuide G94-1225-A. Coop. Ext., University of Nebraska, Lincoln. 4pp.

Neider, T. L. and S. D. Miller. 1993. Effects of winter annual grass weeds in winter wheat. Proc. North Cent. Weed Sci. Soc. 48:33.

Oklahoma Crop Improvement Association. 1958. Oklahoma Certified Seed Directory, Fall Planting Seed Directory. Stillwater, OK 74074.

Oswalt, R. M. 1946. The Oklahoma farm wheat improvement program: progress report, 1938-1945. Oklahoma Agricultural Experiment Station, Stillwater, OK 74078. Misc. Pub. No. MP-9. 18pp.

Pester, T. A., P. Westra, T. J. D'Amato, K. A. Howatt, R. L. Anderson, P. W. Stahlman, G. A Wicks, D. J. Lyon, and S. D. Miller 1998. Analysis of volunteer rye economic thresholds in winter wheat. Proc. West. Soc. Weed Sci. 51:110.

Putwain, P. D., K. R. Scott, and R. J. Holliday. 1982. Herbicide resistance in plants – the nature of resistance to triazine herbicides: case histories of phenology and population studies. New York: John Wiley and Sons, Inc.. 410pp.

Rydrych, D. J. 1987. Cereal rye competition in winter wheat in eastern Oregon. Res. Prog. Rep. West Soc. Weed Sci. p.335.

Schneweis, D. A., F. E. Northam, and P. W. Stahlman. 1993. Volunteer rye (*Secale cereale*) interference in winter wheat. Proc. North Cent. Weed Sci. Soc. 48:6.

Simmonds, D. H. and W. P. Campbell. 1976. Rye: Production, Chemistry, and Technology – morphology and chemistry of the rye grain. American Association of Cereal Chemists, Inc. St. Paul, MN. 181pp.

Stahlman, P. W. and D. E. Peterson. 1995. Winter Annual Grass Survey in Kansas. Proc. North Cent. Weed Sci. Soc. 50:64-65.

Stump, W. L. and P. Westra. 1993. The Effects of Tillage on Volunteer Rye Emergence and Seed Bank Dynamics. 1993 Res. Prog. Rep. West Soc. Weed Sci. p. 180.

Tomlinson, J. F. 1965. An economic evaluation of cropping systems on sandy soils in southwestern Oklahoma. Oklahoma Agricultural Experiment Station, Stillwater, OK 74078. Bulletin B-634. 31pp.

Wilson, H. K. 1948. Grain crops. New York: McGraw-Hill Book Company. 384pp.

Zasada, I. A., H. M. Linker, and H. D. Coble. 1997. Initial weed densities affect no-tillage weed management with a rye (*Secale cereale*) cover crop. Weed Technol. 11:473-477.

Table 1. Mean and standard deviation of tillers per plant on February 25, plant heights on February 25 and April 9, spike heights on May 27, visual estimate of maturity (green tissue) on June 14, lodged spikes per plant on June 18, seeds per plant, seed weight per plant, 1000 seed weight, and percentage of dark colored seed kernels observed from plants grown at the same location with seed from 24 source fields.[a]

		Plant height		Shortest	Tallest		Lodged			Seed	Dark
Source[b]	Tillers	2/25	4/9	spike ht	spike ht	Maturity	spikes	Seed	Seed	weight	kernels
	no./plant	cm				%	number/plant		g/plant	g/1000	%
Elbon	12 ± 3	8 ± 6	38 ± 26	57 ± 26	124 ± 9	6 ± 8	3 ± 2	2040 ± 1020	36 ± 12	19 ± 5	5 ± 9
Oklon	12 ± 2	6 ± 6	32 ± 28	53 ± 19	121 ± 12	10 ± 9	1 ± 2	1880 ± 430	37 ± 13	19 ± 4	12 ± 16
Maton	12 ± 5	6 ± 6	28 ± 30	59 ± 22	125 ± 10	3 ± 4	3 ± 2	1670 ± 870	30 ± 17	16 ± 6	9 ± 12
G1	12 ± 2	5 ± 4	30 ± 23	57 ± 18	122 ± 9	8 ± 8	4 ± 4	1690 ± 770	35 ± 18	20 ± 4	2 ± 3
G2	10 ± 3	5 ± 5	18 ± 26	54 ± 12	124 ± 12	3 ± 2	3 ± 2	1670 ± 490	25 ± 13	15 ± 3	16 ± 29
G3	10 ± 5	4 ± 5	19 ± 22	59 ± 17	122 ± 5	9 ± 13	4 ± 4	1350 ± 360	18 ± 7	13 ± 3	9 ± 14
G4	12 ± 3	4 ± 3	27 ± 25	52 ± 15	118 ± 10	7 ± 11	2 ± 2	1450 ± 680	23 ± 14	15 ± 4	19 ± 22
G5	11 ± 4	4 ± 4	27 ± 30	64 ± 17	124 ± 11	5 ± 7	2 ± 2	2200 ± 810	34 ± 15	15 ± 3	41 ± 33

Table 1. Continued.

G6	11 ± 2	6 ± 6	30 ± 19	67 ± 23	129 ± 9	5 ± 7	2 ± 3	1870 ± 620	36 ± 13	19 ± 2	41 ± 34
G7	10 ± 4	4 ± 5	19 ± 24	57 ± 16	123 ± 7	9 ± 13	4 ± 3	1200 ± 480	19 ± 11	15 ± 5	10 ± 17
G8	11 ± 5	4 ± 3	15 ± 21	55 ± 15	112 ± 13	9 ± 14	2 ± 2	1460 ± 940	20 ± 14	12 ± 4	43 ± 35
G9	10 ± 4	5 ± 3	16 ± 21	53 ± 21	113 ± 15	15 ± 8	1 ± 1	1710 ± 460	22 ± 12	12 ± 4	26 ± 30
G10	12 ± 2	5 ± 3	26 ± 21	50 ± 17	113 ± 12	7 ± 8	3 ± 3	1950 ± 880	32 ± 17	15 ± 4	37 ± 33
G11	13 ± 3	5 ± 6	30 ± 14	52 ± 20	118 ± 5	3 ± 3	2 ± 1	1630 ± 610	32 ± 14	19 ± 4	30 ± 33
G12	10 ± 5	5 ± 5	21 ± 21	56 ± 15	124 ± 12	8 ± 10	1 ± 1	1930 ± 810	30 ± 14	15 ± 3	63 ± 25
G13	11 ± 3	5 ± 5	27 ± 26	49 ± 18	124 ± 4	8 ± 9	4 ± 4	1720 ± 1000	27 ± 17	15 ± 2	18 ± 23
G14	10 ± 5	4 ± 3	19 ± 18	52 ± 12	118 ± 6	10 ± 16	2 ± 1	1510 ± 750	22 ± 16	13 ± 4	16 ± 24
G15	11 ± 2	5 ± 5	29 ± 14	70 ± 13	122 ± 10	6 ± 7	2 ± 2	1880 ± 400	30 ± 8	16 ± 2	22 ± 24
K1	11 ± 3	5 ± 4	26 ± 25	65 ± 18	119 ± 4	10 ± 8	2 ± 2	1680 ± 640	27 ± 13	16 ± 3	31 ± 25
K2	11 ± 2	5 ± 4	29 ± 29	68 ± 21	124 ± 10	8 ± 7	1 ± 1	2090 ± 890	37 ± 19	17 ± 4	58 ± 26
L1	11 ± 3	3 ± 4	23 ± 26	59 ± 12	128 ± 8	8 ± 3	2 ± 2	2410 ± 520	40 ± 11	17 ± 2	40 ± 30
L2	14 ± 2	5 ± 4	30 ± 22	65 ± 12	118 ± 8	7 ± 9	2 ± 1	1840 ± 640	31 ± 13	16 ± 2	18 ± 23

Table 1. Continued.

N1	11 ± 4	4 ± 6	28 ± 20	60 ± 18	118 ± 9	6 ± 6	2 ± 2	1280 ± 710	19 ± 11	15 ± 2	9 ± 14
N2	10 ± 3	4 ± 4	24 ± 23	52 ± 13	115 ± 11	9 ± 13	2 ± 2	1650 ± 690	24 ± 12	14 ± 4	20 ± 27
P value[c]	1.0	0.04	0.01	0.6	0.07	1.0	0.4	0.3	0.09	0.01	0.01
P value[d]	0.03	0.4	0.9	0.7	0.01	0.01	0.01	0.09	0.8	0.04	0.01

[a]Means and standard deviations are rounded to the nearest whole number.

[b]Elbon, Maton, and Oklon seed were collected from a variety demonstration at the Oklahoma State University Agronomy Research Station, Stillwater, OK. Sources G1 - G15, K1 - K2, L1 - L2, and N1 - N2 were wheat fields in Garfield, Kingfisher, Logan, and Noble counties of Oklahoma, respectively.

[c]Probability of a zero variance component among source fields for the characteristics.

[d]Probability of equal within-field variances.

Table 2. Mean and standard deviation of the number of rye spikes completely emerged from the flag leaf at seven dates in 1999.[a]

Source[b]	April 23	April 27	April 30	May 5	May 13	May 20	May 27
	no. / plant						
Elbon	1 ± 1.7	4 ± 5.1	14 ± 8	23 ± 8	32 ± 6	41 ± 10	41 ± 11
Oklon	0 ± 1.0	1 ± 2.2	8 ± 9	14 ± 12	34 ± 12	44 ± 8	50 ± 12
Maton	0 ± 0.3	1 ± 1.6	5 ± 7	13 ± 11	27 ± 12	41 ± 14	44 ± 15
G1	0 ± 0.9	1 ± 3.2	6 ± 5	18 ± 8	29 ± 7	42 ± 16	45 ± 18
G2	0 ± 0.3	1 ± 2.8	4 ± 6	9 ± 12	29 ± 12	46 ± 9	51 ± 10
G3	0 ± 0.3	0 ± 0.3	2 ± 6	5 ± 5	29 ± 8	41 ± 9	41 ± 7
G4	0 ± 0.7	1 ± 2.5	7 ± 7	15 ± 10	29 ± 10	41 ± 10	44 ± 11
G5	0 ± 0.3	1 ± 1.3	6 ± 5	21 ± 12	34 ± 14	50 ± 17	51 ± 18
G6	0 ± 0	0 ± 0	4 ± 5	17 ± 10	34 ± 5	40 ± 7	43 ± 9
G7	0 ± 0	0 ± 0	2 ± 4	7 ± 10	29 ± 9	40 ± 12	42 ± 12
G8	0 ± 0	0 ± 0	0 ± 1	5 ± 5	29 ± 19	45 ± 22	47 ± 19

Table 2. Continued.

G9	0 ± 0	0 ± 0	0 ± 0	3 ± 4	26 ± 15	46 ± 9	49 ± 11
G10	0 ± 0.7	2 ± 4.0	6 ± 6	19 ± 8	38 ± 12	56 ± 18	58 ± 19
G11	1 ± 1.9	2 ± 3.5	11 ± 7	20 ± 10	37 ± 7	47 ± 13	47 ± 12
G12	0 ± 0	0 ± 0	1 ± 3	10 ± 7	31 ± 16	42 ± 17	45 ± 17
G13	0 ± 0	0 ± 0	1 ± 3	10 ± 10	34 ± 13	44 ± 13	46 ± 11
G14	0 ± 0	0 ± 0	1 ± 1	7 ± 8	27 ± 13	43 ± 10	50 ± 11
G15	0 ± 1.3	1 ± 1.6	5 ± 5	17 ± 9	36 ± 5	46 ± 9	47 ± 9
K1	0 ± 0.3	0 ± 1.3	3 ± 4	13 ± 10	31 ± 10	42 ± 15	46 ± 17
K2	0 ± 1.0	1 ± 2.2	6 ± 7	14 ± 11	36 ± 10	48 ± 14	49 ± 14
L1	0 ± 0	0 ± 0.0	2 ± 5	11 ± 13	38 ± 8	50 ± 12	51 ± 12
L2	0 ± 0.6	2 ± 4.4	7 ± 7	23 ± 12	42 ± 5	52 ± 8	53 ± 10
N1	0 ± 0	0 ± 0.3	2 ± 3	10 ± 4	27 ± 6	42 ± 13	45 ± 12
N2	0 ± 0.3	1 ± 1.6	5 ± 4	16 ± 10	31 ± 11	42 ± 12	44 ± 14

Table 2. Continued.

P value[c]	0.6	0.2	0.01	0.02	0.3	0.7	0.9
P value[d]	—[e]	—	—	0.09	0.01	0.02	0.03

[a]Means and standard deviations are rounded.

[b]Elbon, Maton, and Oklon seed were collected from a variety demonstration at the Oklahoma State University Agronomy Research Station, Stillwater, OK. Sources G1 - G15, K1 - K2, L1 - L2, and N1 - N2 were wheat fields in Garfield, Kingfisher, Logan, and Noble counties of Oklahoma, respectively.

[c]Probability of a zero variance component among source fields in spike emergence.

[d]Probability of equal within-field variances.

[e]Within-field variances were not estimated prior to May 5.

Table 3. Percent germination of seed harvested from plants grown at same location from each source site, and percent of seed that remained dormant[a] after germination period.

Source[b]	Germination	Dormant seeds
	%	
Elbon	89.5	0.7
Oklon	92.9	0.4
Maton	92.7	0.7
G1	91.2	0.9
G2	94.6	1.3
G3	91.6	1.3
G4	89.3	0.6
G5	94.7	0.3
G6	95.3	0.8
G7	92.3	0.6
G8	94.4	0.6
G9	90.7	3.9
G10	89.2	1.9
G11	90.8	0.9
G12	94.4	1.1
G13	91.2	1.1
G14	92.7	1.0
G15	95.1	0.4

Table 3. Continued.

K1	94.9	0.6
K2	94.2	0.7
L1	93.7	1.2
L2	91.1	2.0
N1	93.1	0.6
N2	95.2	0.8
P value[c]	1.0	0.23

[a]Dormant seeds were determined to be any seed that did not imbibe water, germinate, or mold.

[b]Elbon, Maton, and Oklon seed were collected from a variety demonstration at the Oklahoma State University Agronomy Research Station, Stillwater, OK. Sources G1 - G15, K1 - K2, L1 - L2, and N1 - N2 were wheat fields in Garfield, Kingfisher, Logan, and Noble counties of Oklahoma, respectively.

[c]Probability of a zero variance component among source fields for the characteristics.

2

VITA

John Richard Roberts, Jr.

Candidate for the Degree of

Master of Science

Thesis: EFFECT OF WHEAT (*Triticum aestivum*) ROW SPACING, SEEDING RATE, AND CULTIVAR ON INTERFERENCE FROM RYE (*Secale cereale*), AND VARIATION IN MORPHOLOGICAL AND PHENOLOGICAL CHARACTERISTICS AND GERMINATION OF FERAL RYE

Major Field: Plant and Soil Sciences

Biographical:

Personal Data: Born in Clovis, New Mexico, on January 28, 1975, the son of John and Carol Roberts. Married to Jenice Burford on June 8, 1996. A son, Cole J. Roberts, was born on December 21, 1998.

Education: Graduated from Washington High School, Washington, Oklahoma in May 1993; received Bachelor of Science degree in Agronomy from Oklahoma State University, Stillwater, Oklahoma in December 1997. Completed the requirements for the Master of Science degree with a major in Plant and Soil Sciences at Oklahoma State University in May 2000.

Experience: Raised on family farm near Cole, Oklahoma; Crop scout intern, Collingwood Grain, May 1995 to August 1995; Technical service intern, American Cyanamid, May 1997 to August 1997; Undergraduate research assistant, Oklahoma State University, Department of Agronomy, May 1996 to December 1997; Teaching assistant, Oklahoma State University, Department of Plant and Soil Sciences, August 1998 to December 1998; Graduate research assistant, Oklahoma State University, Department of Plant and Soil Sciences, January 1998 to present.

Professional Memberships:
Southern Weed Science Society
Western Society of Weed Science