ECONOMICS OF ROTATIONAL CROPPING SYSTEMS TO REDUCE CHEAT (BROMUS SECALINUS) DENSITIES

By

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(BROMUS SECALINUS)

DENSITIES

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ECONOMICS OF ROTATIONAL CROPPING
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ECONOMICS OF ROTATIONAL CROPPING SYSTEMS TO REDUCE CHEAT (*Bromus secalinus*) DENSITIES[1]

JON C. STONE, THOMAS F. PEEPER, EUGENE G. KRENZER, and JAMES R. SHOLAR[2]

Abstract: In the Southern Great Plains producers of winter wheat are seeking methods for controlling winter annual *Bromus* species and improving economic returns. Experiments were conducted at three sites in north central Oklahoma to determine the effect of three crop sequences, each under no-tillage and conventional tillage management, with various weed control strategies in each sequence, on *Bromus* densities and net returns. The cropping sequences, initiated following harvest of wheat, included double-crop soybean followed by soybean; double-crop grain sorghum followed by soybean; and continuous wheat. Compared to continuous wheat-no herbicide, cheat panicle density was reduced by all grain sorghum followed by soybean cheat management programs at all sites and soybean followed by soybean programs at two sites. Rotating out of wheat for one growing season reduced but did not eliminate *Bromus* species.

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Compared to continuous wheat-no herbicide, all cheat management programs with grain sorghum or soybeans increased succedent wheat yield at two sites. Cropping sequences other than continuous wheat reduced dockage and increased succedent wheat grain quality. No cheat management program at any site produced greater net returns than conventional tillage grain sorghum-no herbicide fb soybeans. Cropping sequences containing sorghum and soybeans are economically viable options for controlling *Bromus* species in north central Oklahoma.

Nomenclature: Wheat, *Triticum aestivum* L. '2137'; grain sorghum, *Sorghum bicolor* L. 'Pioneer 8500', 'Dekalb DK28E'; soybean, *Glycine max* L., 'Asgrow 4602RR', 'Dekalb CX367RR', 'Dekalb CX443RRSTS', 'Midland 8433RR'; cheat, *Bromus secalinus* L. #[3] BROSE; downy brome, *Bromus tectorum* L. # BROTE.

Abbreviations: fb, followed by; POST, postemergence; PPI, preplant incorporated; PRE, preemergence.

INTRODUCTION

Winter wheat (*Triticum aestivum* L.) is the major crop in Oklahoma because its yield stability minimizes the risk of crop failure (Peeper and Weise 1990), and because it is a crop that can be used for forage, forage and grain, or

[3] Letters following this symbol are a WSSA-approved computer code from Composite List of Weeds, Revised 1989. Available only on computer disk from WSSA, 810 East 10th Street, Lawrence, KS 66044-8897.

grain only (Krenzer 1994). Wheat is typically produced in the Southern Great Plains using conventional tillage methods.

Continuous wheat production can increase problems with winter annual *Bromus* species including cheat (*Bromus secalinus* L.) and downy brome (*Bromus tectorum* L.) (Wicks 1984). A recent study found cheat in over 80% of the wheat fields in core Oklahoma production areas[4]. In north central Oklahoma, cheat infestations reduced yield of conventional tillage wheat 50% (Driver et al. 1993).

Cheat infestations can delay harvest and increase dockage thus causing marketing difficulties (Ratliff and Peeper 1985). In Kansas and Wyoming, 72 *Bromus* plants/m^2 reduced returns from winter wheat by $75/ha (Stahlman and Miller 1990).

Historically, *Bromus* species control with selective herbicides in winter wheat was difficult (Geier and Stahlman 1996). MON 37500 (1-(2-ethylsulfonylimidazo{1,2-a}pyridin-3-ylsulfonyl)-3-(4,6-dimethyoxypyrimidin-2-yl)urea) applied POST at 34 g/ha controlled cheat 74 to 96% while the experimental herbicide, MKH 6561 (methyl 2-({[(4-methyl-5-oxo-3-propoxy-4,5-dihydro-1H-1,2,4-triazol-1-yl)carbonyl]amino}sulfonyl)benzoate sodium salt) applied POST at 45 g/ha controlled cheat in wheat 95% or more regardless of POST timing in central Kansas and Oklahoma (Kelley and Peeper 2000; Stahlman and Geier 2000b). In central Kansas, timing affected MON 37500

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[4] Barns, M.A. 1999. Personal communication, Oklahoma State University, Department of Plant and Soil Sciences, Stillwater, OK 74078

efficacy. Late spring POST applications of MON 37500 at 34 g/ha controlled downy brome 73% but late fall applications controlled only 50% (Stahlman and Geier 2000a). In a greenhouse, MON 37500 applied PRE or POST at 18 g/ha, reduced cheat growth, but efficacy was reduced by simulated drought or cool temperatures (Geier et al. 1999).

Compared to mono-crop systems, crop rotations provide an inconsistent environment, thus limiting the survival of weed species adapted to mono-crops (Liebman and Dyck 1993). In the past, crop sequences involving spring or summer crops presented the best solution for controlling downy brome in winter wheat in Nebraska (Wicks 1984). A three year no-tillage system that included two years out of winter wheat reduced downy brome densities while systems with only one year out of winter wheat did not (Young et al. 1996).

Except for the drier regions of the panhandle, Oklahoma wheat producers expect to produce wheat each year without a fallow season. To change that crop sequence without introducing a fallow cropping season, a summer crop must be planted immediately following winter wheat harvest. Planting grain sorghum (*Sorghum bicolor* L.) or soybeans (*Glycine max* L.) immediately following wheat harvest is a common practice in eastern Oklahoma and in the southeastern United States (Crabtree et al. 1990) due to higher amounts of rainfall. In eastern Oklahoma, such double-cropping increased total grain production, which suggests more efficient use of climate, land, labor, and equipment resources (Crabtree and Rupp 1980).

Central Oklahoma producers have often expressed interest in shifting from continuous wheat to other cropping sequences to reduce weed problems attributed to continuous wheat. Between 1994 and 2000, the area seeded to wheat in north central Oklahoma decreased from 288,000 to 247,000 hectares. During the same period, soybean area increased from 122,000 to 186,000 hectares and grain sorghum area increased from 130,000 to 182,000 hectares (Anonymous 1994; Anonymous 2000).

Yields and economic returns from crop rotations in central Oklahoma have not been well documented. In eastern Oklahoma, yields of mono-crop conventional tillage wheat were higher than double-cropped conventional tillage wheat following soybeans or grain sorghum (Crabtree et al. 1990). In a 10-year experiment in north central Oklahoma, mean yield of conventional tillage winter wheat was 190 kg/ha greater than no-tillage wheat (Epplin et al. 1991). Similarly, in the coastal plains of North Carolina, wheat yields were generally less with no-tillage than with conventional tillage (Wagger and Denton 1989).

In Oklahoma, production input costs for no-tillage winter wheat production were $300/ha compared to conventional tillage production which cost $230/ha (Epplin et al. 1991). However, at that time, glyphosate was more expensive than it is today. A wheat followed by (fb) double-crop soybean fb wheat sequence was nearly three times as profitable as a wheat fb double-crop grain sorghum fb wheat sequence under either conventional or no-tillage in Mississippi (Sanford et al. 1973). Also, profits from the wheat fb double-crop grain sorghum fb wheat did not differ with tillage.

Rotating soybeans and grain sorghum increased soybean yields 14% compared to mono-cropping soybeans in southeast Georgia (Langdale and Wilson 1987). They also found that average wheat yields were 0.14 Mg/ha lower following grain sorghum than when wheat followed soybeans. Also, over the four years of their research, yields of grain sorghum double-cropped with wheat were similar to yields of mono-cropped grain sorghum (Langdale and Wilson 1987). In Nebraska, grain sorghum yields were less in conventional tillage plots than the no-tillage plots in a wheat, fallow, grain sorghum, fallow rotation (Wicks and Grabouski 1986).

The development of glyphosate resistant soybeans has expanded weed control options. Because glyphosate lacks residual activity and multiple flushes of weed seedlings emerge, a single glyphosate application in resistant soybeans is usually not a complete weed management system (Gonzini et al. 1999, Hart et al. 1994). In Nebraska, glyphosate applied PRE in no-tillage grain sorghum did not provide season long annual grass control (Wicks and Grabouski 1986). In contrast, atrazine applied following conventional tillage seedbed preparation controlled most grasses.

The primary limitation to achieving acceptable soybean yields in Oklahoma is water. Mean precipitation ranges from 76 cm to 86 cm per year in north central Oklahoma[5]. Year to year variations can be extreme. Double-crop soybean success following wheat can be limited by soil moisture required for

[5] Data available through Oklahoma Climatological Survey, University of Oklahoma, 710 Asp Ave., Suite 8, Norman, OK 73019-0501.

both stand establishment and growth (Daniels and Scott 1991). Also, yield potential of double-cropped soybean decreases each day planting is delayed after wheat harvest (Touchton and Johnson 1982).

The objectives of this research were to determine the effect of rotating out of wheat for one growing season on cheat density and wheat yield in the succedent wheat crop and to determine whether cropping sequences other than continuous wheat are economically viable options for *Bromus* species management in north central Oklahoma.

METHODS AND MATERIALS

Field experiments were established in wheat stubble in June, 1999, at three on-farm sites in north central Oklahoma with a history of continuous winter wheat. All sites had been combine harvested with the straw spread back into the field and were reportedly infested with cheat. Wheat stubble and weed residue present after harvest totaled 4700, 6900, and 3300 kg/ha, at Sites 1, 2, and 3 respectively.

Three crop sequences: double-crop soybeans in 1999 followed by (fb) early season soybeans in 2000; double-crop grain sorghum in 1999 fb early season soybeans in 2000; and winter wheat planted in the fall of 1999 (continuous wheat), were established at each site with each crop sequence grown in conventional and no-tillage. The field activities timeline for all crop sequences is in Figure 1 and dates for field activities are in Appendix A.

The experimental design was a randomized complete block with a split plot arrangement with tillage as the main plot and crop sequence as the subplot. Sub-subplots received selective herbicide treatments (weed control strategies) that varied with crop sequence. Soybean and grain sorghum sub-subplots received herbicides to control summer annual weeds. Continuous wheat sub-subplots received *Bromus* control herbicides. Sub-subplot size was 3 by 7.5 m and each treatment was replicated four times (three at site 3). A succedent wheat crop was planted following all crop sequences in the fall of 2000, to determine the impact of the crop sequences, tillage systems, and weed control strategy on the *Bromus* infestation. Cheat was present at all sites. Downy brome was present only at Site 2.

Agronomic data collected from each crop sequence (prior to planting the succedent wheat crop) were analyzed using a randomized complete block experimental design with a split plot arrangement with tillage as the main plot and control strategy as the subplot.

Data for the succedent wheat crop and economic data were analyzed as a split plot with tillage as the main plot and crop sequence-weed control strategy combinations (cheat management programs) considered as subplots. Although this approach requires acceptance of forced randomization due to the split plot arrangement of the crops, it was deemed the best approach to comparing all cheat management programs.

Crop stands and weeds were counted in each plot. Weed density data were analyzed after square root transformation. Original data are reported with means separation in accordance with analysis of transformed data. Grain yields were corrected for moisture content and volume weights were determined for each crop. In the continuous wheat sequence, a simulated wheat-for-forage-only treatment was included.

Net economic returns for the crop sequences and succedent wheat crop were determined for each scenario. Seed and fertilizer costs were based on local prices (Table 1). Equipment costs including fuel, oil, labor, depreciation, and interest were determined by using average custom rates in north central Oklahoma for each practice (Kletke and Doye, 1999). Revenue from federal commodity programs that would have been provided for each crop was included in returns. Returns from the wheat-for-forage-only treatment were determined using \$0.05/kg as the value for oven dried forage (Baker 2000). Although all plots were planted with a no-tillage grain drill or no-tillage row crop planter, the extra cost for that equipment verses conventional seeding equipment was not included in the conventional tillage input costs. Although all sequences containing soybeans were planted with glyphosate resistant varieties, a technology fee was only charged for the treatments containing POST applications of glyphosate.

The soil was a Kirkland-Renfrow silt loam (fine, mixed, thermic Vertic Paleustoll) with pH 4.4 and 1.1% organic matter at Billings (Site 1), a Grant silt loam (fine, silty, mixed, thermic Udic Argiustoll) with pH 6.2 and 0.6% organic matter at Enid (Site 2), and a Kirkland silt loam (fine, mixed, thermic, Abruptic Paleustoll) with pH 5.0 and 1.6% organic matter at Ponca City (Site 3). Soil capability classification was III, I, and III at the respective sites (Swafford, 1967; Culver, 1968). Soil characteristics are in Appendix B.

Monthly rainfall data was collected from the mesonet weather station nearest each site (Appendix C)[6]. Site 1 was 20 km northeast of the Breckenridge mesonet station, Site 2 was 15 km northeast of the Lahoma mesonet station, and Site 3 was 12 km south of the Blackwell mesonet station.

All herbicides were applied using a CO_2-pressurized backpack sprayer equipped with flat fan nozzles spaced 51 cm apart delivering 188 L/ha traveling at 4.8 km/hr. The center two rows of each soybean and grain sorghum plot, and a 140 cm swath from each wheat plot, were harvested using a small plot combine.

Soybean fb soybean sequence. Seven herbicide treatments were applied to both soybean crops (Table 2) at rates recommended for north central Oklahoma (Anonymous 1999). A standard treatment that differed with tillage was also included. The standard treatment was glyphosate POST in no-tillage and trifluralin PPI in conventional tillage. PPI treatments were applied to the double-crop after the wheat stubble was moldboard plowed and field cultivated once. They were then immediately incorporated with one pass of an s-tine field cultivator with double rolling baskets. Soybeans 'Midland 8433RR', 'Asgrow 4602RR', and 'Dekalb CX442RRSTS' at Sites 1, 2, and 3, respectively, were

[6] Data available through Oklahoma Climatological Survey, University of Oklahoma, 710 Asp Ave., Suite 8, Norman, OK 73019-0501.

planted at 340,000 seeds/ha using a no-tillage planter with 76-cm row spacing. PRE herbicides were applied immediately after planting. Conventional tillage plots at Site 3 were rotary hoed to break the soil crust after heavy rain. However, the rotary hoe was not successful and the conventional tillage soybeans were replanted 15 cm to the side of the original rows. No POST herbicides were applied to double-crop soybeans at Site 1 due to lack of weeds.

Winter annual weeds were controlled between soybean crops by discing 10 cm deep in conventional tillage and by applying glyphosate at 1.1 kg/ha in no-tillage in late winter. The final seedbed for the conventional tillage early season soybean crop was prepared by two passes of the s-tine field cultivator with double rolling baskets. The second pass incorporated PPI treatments. Early season soybean variety 'Dekalb CX367CRR' was planted at 361,000 seeds/ha, using the previously described planter. PRE herbicides were applied immediately after planting. Following soybean harvest, the succedent wheat crop was planted.

Sorghum fb soybean sequence. Tillage methods were the same as for conventional tillage double-crop soybean. Double-crop grain sorghum hybrid 'Dekalb 28E' was planted at Site 1 and 'Pioneer 8500' at Sites 2 and 3, at 148,000 seeds/ha, using a no-tillage planter with 76-cm row spacing. Both hybrid seeds were treated with benzene-acetonitrile seed safener. Plots were fertilized to meet a 4000 kg/ha yield goal (Appendix D). Eight herbicide treatments were applied to the grain sorghum (Table 2), at rates recommended for north central Oklahoma (Anonymous 1999). PRE herbicides were applied immediately after planting. No POST herbicides were applied at Site 1 due to a lack of weeds. Due to bird damage of one replicate at Site 2, only three replicates were harvested for yield determination. Winter annual weeds were controlled and early season soybeans were planted in the spring using the same methods as in the soybean fb soybean sequence. In this sequence, glyphosate was the only herbicide applied to the early season soybeans that followed the double-crop grain sorghum.

Continuous wheat sequence. Conventional tillage in 1999 consisted of moldboard plowing fb an s-tine field cultivator with double rolling baskets two to four times depending on soil conditions at each site. The last cultivation was at planting. Glyphosate was applied to no-tillage plots at 1.1 kg/ha twice between harvest in 1999 and planting that fall. Hard red winter wheat '2137', a low pH tolerant cultivar, was planted at 70 kg/ha using a no-tillage grain drill with 18-cm row spacing in both tillage systems. Plots were fertilized to meet a 4000 kg/ha yield goal (Appendix D).

Selective herbicides were applied in the fall when cheat had 2 to 4 tillers and in late winter when cheat had 4 to 5 tillers. Forage production from the wheat-for-forage-only treatment was determined by combining yields of forage clipped on January 6, March 28, and May 15. Both wheat and *Bromus* species were clipped to a height of 5 cm, from a 0.2 m^2 area of each plot. Forage was oven dried at 60° C. *Bromus* panicles were counted on May 15, 2000, before the final forage clipping. The remaining forage in each plot after each clipping was rotary mowed to a height of 5 cm. Glyphosate was applied POST to the wheat-for-forage-only treatment at 1.1 kg/ha on May 25. At Site 1, the no-tillage wheat plots were disced once on July 3, 2000 by the cooperator. The succedent wheat crop was planted the following fall.

Succedent wheat crop. In the fall of 2000, in all crop sequences, all conventional tillage plots were chisel plowed and field cultivated. Hard red winter wheat '2137' was planted at 70 kg/ha with the previously described no-tillage drill. No PREPLANT herbicides were applied immediately prior to planting in no-tillage plots due to a lack of weeds. No POST herbicides were applied to this crop. Plots were fertilized to meet a 4000 kg/ha yield goal (Appendix D). Harvesting methods were as previously described.

RESULTS AND DISCUSSION

Soybean fb soybean sequence. Stand density of the double-crop soybeans averaged 24 and 29 plants/m^2 at Sites 1 and 2 and was unaffected by tillage (P = 0.72 and 0.69) or weed control strategy (P = 0.19 and 0.81). However, at Site 3, stand density in conventional tillage (2 plants/m^2) was less (P = 0.03) than in no-tillage (7 plants/m^2). After rotary hoeing the conventional tillage plots failed to improve emergence through the rain packed crust, they were replanted on July 12, 1999. The resulting stand density in conventional tillage (22 plants/m^2) plots was greater (P = 0.01) than in no-tillage plots (7 plants/m^2) (Table 3).

Mature heights of double-crop soybean at Sites 1, 2, and 3, averaged 37, 54, and 50 cm (Appendix E). Heights were unaffected by tillage (P = 0.31, 0.64, and 0.51) or weed control strategy (P = 0.92, 0.14, and 0.30).

Yield of double-cropped soybeans averaged 500 kg/ha with no effect from tillage (P = 0.63) or weed control strategy (P = 0.10) at Site 1. Weeds were sparse at this site (Appendix F and G) but low yields were attributed to grazing by whitetail deer (*Odocoileus virginianus*).

Double-cropped soybean yield averaged 3000 kg/ha at Site 2 with no effect of tillage (P = 0.29) or weed control strategy (P = 0.38). Similar to Site 1, summer annual weeds were sparse at this site (Appendix F and H). This suggests that in some fields with a history of continuous conventional tillage wheat, too few summer annual weeds emerge after wheat harvest to affect yield of double-cropped soybeans.

Prairie cupgrass [*Eriochloa contracta* Hitch. (#[7] ERBCO)], fall panicum [*Panicum dichotomiflorum* Michx. (# PANDI)] and large crabgrass [*Digitaria sanguinalis* (L.) Scop.(# DIGSA)] limited yields of double-crop soybean at Site 3. A tillage by weed control strategy interaction occurred in prairie cupgrass (P = 0.01) and fall panicum (P = 0.01) density data collected 39 days after the POST treatments were applied (Table 4). Tillage eliminated prairie cupgrass and reduced fall panicum but glyphosate at 1.1 kg/ha applied after wheat was

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[7] Letters following this symbol are a WSSA-approved computer code from Composite List of Weeds, Revised 1989. Available only on computer disk from WSSA, 810 East 10th Street, Lawrence, KS 66044-8897.

harvested when prairie cupgrass was 14 to 17 cm tall did not provide control. This agrees with previous reports in which glyphosate applied at 2.2 kg/ha did not control prairie cupgrass (Cleary, 1979). Large crabgrass was unaffected by tillage (P = 0.07) but was affected by weed control strategy (P = 0.01) (Appendix F and I). Differences in herbicide efficacy were apparent with all species. Summer annual weed control following winter wheat should be determined by weed types and densities.

Yields of double-crop soybean were greater in conventional tillage plots than in no-tillage plots at Site 3 except for plots treated with glyphosate plus chlorimuron (Table 3). Within no-tillage, plots treated with glyphosate plus pendimethalin PRE or glyphosate PRE fb glyphosate plus chlorimuron POST yielded more than the no-tillage check which received only glyphosate PRE (Table 3). In the conventional tillage plots at Site 3, only three of the seven weed control strategies increased yield compared to the no herbicide check. Crop yields may not increase despite controlling weeds.

The cheat stand density in December 1999, following double-cropped soybeans at Site 1 was 37 plants/m^2 in conventional tillage which was less (P = 0.01) than in no-tillage (195 plants/m^2). At Site 2 the downy brome density in conventional tillage (27 plants/m^2) was less (P = 0.01) than in no-tillage (131 plants/m^2). *Bromus* density was not affected (P = 0.55 and 0.31) by the herbicides applied to soybeans at Sites 1 or 2.

A tillage by weed control strategy interaction occurred in cheat density at Site 3. Cheat was less dense in conventional tillage with no herbicide than in five no-tillage treatments (Table 5). Conventional tillage plots treated with metolachlor or pendimethalin in June had less cheat in December than conventional tillage plots that received no herbicide. The consistently lower *Bromus* density in conventional tillage suggests that the no-tillage environment was more favorable for *Bromus* germination. This agrees with previous research wherein conservation tillage increased *Bromus* species (Stahlman and El-hamid 1994; Young et al. 1996).

Stand density of early season soybean following soybean was not affected by tillage (P = 0.26) or site (P = 0.24). Pooled over tillage and site, treatments containing dinitroaniline herbicides reduced (P = 0.01) early season soybean stand density (Table 3). Early season soybeans were planted in early April and were exposed to freezing or below freezing temperatures four days after planting. The potential for crop injury from dinitroaniline herbicides increases when soybeans emerge in cold or wet environments (Bollich et al. 1988).

Mature height of early season soybean following soybean at Sites 1, 2, and 3, averaged 37, 33, and 50 cm. Heights were unaffected by tillage (P = 0.0.31, 0.65 and 0.51) or weed control strategy (P = 0.92, 0.14, and 0.30).

Yields of early season soybeans were not affected by site (P = 0.59) or weed control strategy (P = 0.12). Pooled over site and weed control strategy, mean yield of early season soybeans was greater (P = 0.01) with conventional tillage (2010 kg/ha) than with no-tillage (1570 kg/ha). The lack of impact of summer annual weeds on yield may be attributed to low weed populations or to failure of the summer annual weeds to emerge until after the critical weed free period for soybean had passed (Horn and Burnside, 1985). The yield data also suggest that cooler soil temperatures associated with no-tillage compared to conventional tillage slowed early season root growth and limited yields.

Sorghum fb soybean sequence. Double-crop grain sorghum stand density at Sites 1 and 2 in conventional tillage was 12 and 14 plants/m^2 which was greater ($P = 0.01$ and 0.04) than in no-tillage (9 and 10 plants/m^2). Stand density was unaffected by weed control strategy ($P = 0.38$ to 0.11) thus differences were attributed to soil and seedbed characteristics and rainfall. Wheat residue in no-tillage plots limited seed-soil contact and shaded some seedlings, even though the planter was equipped with rotary row cleaners to remove residue from the furrow. Stand density at Site 3 averaged 9 plants/m^2 and was unaffected by tillage ($P = 0.18$) or weed control strategy ($P = 0.24$). At Site 3, heavy rain after seeding caused soil crusting which reduced grain sorghum emergence. However the impact of the rain on grain sorghum emergence was much lower than the impact on soybean emergence.

Summer annual weeds in double-crop grain sorghum were sparse and varied by site. Weed control data are in Appendixes F, J, K, L and M.

Double-crop grain sorghum mature heights at Sites 1, 2, and 3 in conventional tillage was 77, 65, and 86 cm which was greater ($P = 0.03$, 0.01, and 0.01) than in no-tillage (72, 52, 75). Mature heights at Site 1 was unaffected by weed control strategy ($P = 0.71$). At Site 2 sorghum treated with atrazine + 2,4-D was shorter ($P = 0.01$) than sorghum in all other treatments except alachlor or atrazine + metolachlor (Appendix N). At Site 3, sorghum treated with atrazine + metolachlor was shorter ($P = 0.03$) at maturity than sorghum in all other treatments except atrazine + alachlor.

Mature grain sorghum at Site 1 averaged 9 panicles/m^2 and was unaffected by tillage ($P = 0.69$) or weed control strategy ($P = 0.22$). Sorghum panicle density at Sites 2 and 3 in conventional tillage was 14 and 12 panicles/m^2 which was greater ($P = 0.01$ and 0.01) than in no-tillage (10 and 9) (Appendix N). Panicle density at Sites 2 and 3 was unaffected by weed control strategy ($P =$ 0.30 and 0.38). Grain sorghum panicles at Sites 1, 2, and 3 were positively correlated with stand density ($P = 0.01$,0.01, and 0.01; $r = 0.54$, 0.58, and 0.79).

Mean yield of conventional tillage grain sorghum was 1800 kg/ha at Site 1 which was greater ($P = 0.02$) than mean yield with no-tillage (1180 kg/ha). Yield was unaffected by weed control strategy ($P = 0.92$). The tillage effect on yield may be partially attributable to the tillage effect on grain sorghum stand density.

A tillage by weed control strategy interaction occurred in double-crop grain sorghum yield data at Sites 2 and 3 (Table 6). At these sites, none of the tillage by weed control strategy combinations resulted in higher yields than conventional tillage with no herbicide. This again suggests that fields with a history of continuous wheat may have too few summer annual weeds emerging after wheat harvest to affect yield of double-cropped grain sorghum. Summer annual weed control should be determined by weed types and densities.

Cheat density in December 1999 was much lower in the conventional tillage no herbicide treatment than in the no-tillage no herbicide treatment at Site

1 (Table 5). The tillage effect on cheat density in December was also obvious with each of the weed control strategies applied in June to the sorghum. However, in conventional tillage, metolachlor, atrazine plus alachlor, and atrazine plus metolachlor applied in June reduced the density of cheat present in December. At Site 2, following double-crop sorghum, downy brome density in conventional tillage (18 plants/m^2) was less ($P = 0.04$) than the stand in no-tillage (196 plants/m^2) and was unaffected by weed control strategy ($P = 0.62$). This again suggests that no-tillage provides a favorable environment for *Bromus* germination and survival. Cheat stand density at Site 3 averaged 190 plants/m^2 and was unaffected by tillage ($P = 0.19$) or weed control strategy ($P = 0.35$). Moldboard plowing at this site failed to bury cheat seeds too deep to emerge due to soil conditions at time of planting.

Stand density of early season soybean seeded after grain sorghum was not affected by weed control strategy used in grain sorghum the previous summer ($P = 0.58$) or site ($P = 0.20$). Pooled over sites, stand density in conventional tillage (37 plants/m^2) was greater ($P = 0.01$) than in no-tillage (32 plants/m^2). Following sorghum harvest, all plots within a tillage system received the same weed control strategies and therefore the only differences expected were from tillage.

Early season soybean stand density data did not indicate that density was affected by the previous crop, i.e. soybean or sorghum (Appendix O). Conventional tillage early season soybean stand density following soybeans and sorghum at Site 1 was 35 plants/m^2 which was greater ($P= 0.01$) than with no-tillage (29 plants/m^2). Stand density at Site 2 averaged 33 plants/m^2 and was unaffected by tillage ($P = 0.85$) or cheat management program ($P = 0.12$). At Site 3, none of the weed control strategies within a tillage system had higher early season soybean stand density than sorghum or soybeans treated with no herbicide. As in the soybean fb soybean sequence, dinitroaniline herbicides reduced stand density.

Yield of early season soybean was not affected by weed control strategies applied to grain sorghum the previous year ($P = 0.90$) or site ($P = 0.08$). Mean yield with conventional tillage (1700 kg/ha) was greater ($P = 0.01$) than no-tillage (1310 kg/ha). All early season soybeans following sorghum were treated the same within a tillage system and therefore no weed control strategy differences were expected. Cooler soil temperatures associated with no-tillage may have limited early season soybean root growth and therefore limited yields. Yield data did not indicate that the previous crop, i.e. grain sorghum or soybean, consistently affected yield of the early season soybeans (Appendix O).

Continuous wheat sequence. Wheat stand density in conventional tillage was 90, 180, and 150 plants/m^2 at sites 1, 2, and 3 which was greater ($P = 0.09$, 0.01, and 0.01) than the stand density in no-tillage (70, 130, and 120). Stand differences were attributed to the inability of the press wheels on the drill to close seed furrows in the no-tillage seedbed. Wheat residue in no-tillage plots limited seed-soil contact and shaded some seedlings, even though wheat was planted perpendicular to the harvest direction.

All *Bromus* control herbicides whether applied in December 1999 or February 2000 reduced cheat panicle densities in May 2000 at Sites 1 and 3 (Table 7). Cheat density was too low at Site 2 to evaluate control. Reductions in cheat panicle densities with MON 37500 and MKH 6561 were similar to previous reports (Kelley and Peeper 2000; Stahlman and Geier 2000a; Stahlman and Geier 2000b). The no-tillage check with no *Bromus* control herbicides at Site 1 had four times as many cheat panicles as the conventional tillage check (Table 7). Cheat panicle density at Site 2 averaged 1 panicle/m^2 and was unaffected by tillage (P = 0.43) or weed control strategies (P = 0.20). Pooled over weed control strategies, cheat panicle density in conventional tillage (22 panicles/m^2) was less (P = 0.03) than in no-tillage (34 panicles/m^2) at Site 3. Cheat panicle density was greater in the wheat-for-forage-only treatment than in the no-tillage check at Site 3, suggesting that grazing can favor cheat over wheat. In previous research in central Oklahoma utilizing cheat infested wheat-for-forage increased cheat biomass (Koscelny and Peeper 1990).

At Site 2, downy brome was the predominate weed. *Bromus* control strategies reduced downy brome panicle density except for MKH 6561 applied in winter in no-tillage and metribuzin or MKH 6561 applied in the fall in conventional tillage (Table 7). At Site 2, utilizing wheat-for-forage-only did not reduce downy brome panicle density compared to no herbicide.

At Sites 1 and 2, yields of continuous wheat averaged 1280 and 2600 kg/ha, and were unaffected by tillage (P = 0.31 and 0.99) or weed control strategy (P = 0.35 and 0.14). Yield was also unaffected by weed control strategy

(P = 0.26) at Site 3. Averaged across weed control strategies, yield of conventional tillage wheat at Site 3 was 3260 kg/ha which was greater (P = 0.01) than yield with no-tillage (2780 kg/ha). Despite differences in *Bromus* densities immediately prior to wheat harvest, and relatively low coefficients of variation (CV = 20, 24, and 14%), yields were not different. *Bromus* may have limited tillering prior to control, and thus limited yields. This would agree with previous research where low densities (54 plants/m^2) of downy brome that emerged with wheat reduced wheat yields 28% whereas higher downy brome densities (215 plants/m^2) that emerged later in the season reduced yield only 20% (Rydrych and Muzik 1968).

Tillage and weed control strategy affected dockage at Site 1 where all weed control strategies reduced dockage compared to no herbicide in no-tillage (Appendix P). The relatively high dockage at Site 1 was attributed to unidentified root disease which reduced grain fill and caused severe lodging prior to harvest. At Sites 2 and 3, dockage was 2.5% and 3.6% and was unaffected by tillage (P = 0.97 and 0.34) or weed control strategy (P = 0.74 and 0.40). Downy brome seeds are light weight and therefore a higher quantity is needed to increase dockage compared to other weed seeds.

Succedent wheat crop. In the succedent wheat crop, no site, tillage, or weed control strategy interaction was found in wheat stand density (Table 8). Cheat management programs containing soybeans or sorghum had higher succedent wheat stand than the continuous wheat-no herbicide treatment. This agrees with previous research where wheat mulch and soil extracts inhibited wheat germination and seedling growth (Lodhi et al. 1987). Thus, rotating out of wheat for one production cycle can increase succedent wheat stand.

Pooled over tillage (P = 0.06) and sites (P = 0.10), stand density in the continuous wheat-no herbicide treatment was 117 wheat plants/m^2 while density in plots which were utilized as wheat-for-foraged-only the previous year was 135 plants/m^2 (Table 8). Of the *Bromus* herbicides applied to the previous wheat crop, only MON 37500 applied in the winter increased succedent wheat stand density.

Cheat management program had a major impact on cheat density in the succedent wheat crop at Site 1. Cheat was more dense in no-tillage continuous wheat-no herbicide than in any other cheat management program (Appendix Q). In both tillage systems at this site, utilizing wheat-for-forage-only the previous year reduced cheat in the succedent wheat crop. All *Bromus* control herbicides (except metribuzin) applied to continuous wheat reduced cheat density in the succedent wheat crop. Within a tillage system, all cheat management programs that included sorghum or soybeans reduced cheat density compared to continuous wheat-no herbicide except conventional tillage sorghum treated with atrazine fb 2,4-D fb soybean.

At Site 2, downy brome was more dense in no-tillage continuous wheat-no herbicide than in any other cheat management program that included sorghum, soybean, or conventional tillage continuous wheat (Appendix Q). However, none of the downy brome management programs were more effective at reducing downy brome than conventional tillage wheat with no herbicide. Utilizing wheat for-forage-only or applying *Bromus* control herbicides to the previous wheat crop did not reduce downy brome density within a tillage system. Despite some reductions in *Bromus* densities the previous year, enough viable seeds were present in the soil to establish downy brome in the succedent wheat crop.

Cheat stand density at Site 3 was affected by cheat management program (P = 0.01) but not tillage (P = 0.10) (Appendix Q). Utilizing wheat-for-forage-only or applying *Bromus* control herbicides to the previous wheat crop did not reduce cheat density as was the case at Site 1. All cheat management programs that included sorghum fb soybeans and all but three cheat management programs that included soybean fb soybean reduced cheat stand density compared to continuous wheat-no herbicide.

Cheat panicle densities in the succedent wheat crop varied with site (Table 9). Panicle density at Sites 1 and 3 was greatly affected by cheat management program (P = 0.01 and 0.01) but not by tillage (P = 0.55 and 0.70). At Site 2, a tillage by cheat management program interaction was found but cheat levels were so low that cheat was only found in a few treatments.

Utilizing wheat-for-forage-only the previous winter reduced cheat panicle density at Site 1 and in no-tillage continuous wheat at Site 2 (Table 9). There was no cheat in conventional tillage plots at Site 2.

All *Bromus* control herbicides except metribuzin applied to the previous wheat crop reduced cheat panicle densities at Site 1 (Table 9). All of these herbicides reduced cheat panicle density in no-tillage at Site 2. Only MON 37500 + 2,4-D reduced cheat panicle density at Site 3.

Compared to continuous wheat-no herbicide, cheat panicle density was reduced by all sorghum fb soybean cheat management programs at Sites 1 and 3, all soybean fb soybean programs at Site 1, and two soybean fb soybean programs at Site 3 (Table 9). At Site 2, all cheat management programs containing soybeans or sorghum reduced cheat in no-tillage. This agrees with previous reports where crop rotations provided effective methods for controlling winter annual weeds (Liebman and Dick 1993; Lyon and Baltensperger 1995; Wicks 1984). Thus cheat management programs which include one year out of wheat production reduced cheat panicle densities in the succedent wheat crop.

Downy brome was the predominate weed at Site 2, where panicle density was less in conventional tillage continuous wheat-no herbicide than in no-tillage continuous wheat-no herbicide (Table 9). Utilizing wheat-for-forage-only did not reduce downy brome panicle density in the succedent wheat crop. Only metribuzin reduced panicle density in the no-tillage succedent wheat crop. In contrast, in conventional tillage, only MKH 6561 or MON 37500 applied in winter to the previous wheat crop reduced downy brome panicle density in the succedent wheat crop. With no-tillage soil management, cheat management programs containing sorghum or soybeans reduced downy brome panicles in the succedent wheat crop more than programs with *Bromus* control herbicides in continuous wheat. Cheat management programs with conventional tillage and soybean fb soybean did not reduce downy brome panicle density compared to continuous wheat-no herbicide.

All cheat management programs except metribuzin applied in the fall increased wheat head density over the no herbicide continuous wheat option at Site 1 (Appendix R). None of the weed control strategies in continuous wheat increased wheat head density over wheat-for-forage-only. Five soybean fb soybean and five sorghum fb soybean sequences increased succedent wheat head density over continuous wheat-for-forage-only. At Site 2 nothing increased the wheat head density over the conventional tillage wheat-for-forage-only. Within no-tillage, none of the weed control strategies in continuous wheat increased succedent wheat head density over the no herbicide. All no-tillage soybean fb soybean and sorghum fb soybean sequences had higher wheat head density than no-tillage continuous wheat-no herbicide. At Site 3 only one soybean fb soybean sequence and four sorghum fb soybean sequences increased wheat head density compared to continuous wheat-no herbicide.

Succedent wheat yields at Sites 1 and 3 were affected by cheat management program ($P = 0.01$ and 0.01) but not tillage ($P = 0.18$ and 0.85) while tillage and cheat management program interacted to affect yields at Site 2 (Table 8). At Sites 1 and 3 but not at Site 2, utilizing wheat-for-forage-only increased yield of succedent wheat. None of the *Bromus* control herbicides applied to the previous crop consistently increased yield of the succedent wheat crop at all sites. At Sites 1 and 3, compared to continuous wheat-no herbicides, all cheat management programs with sorghum or soybeans increased yield of succedent wheat. This contradicts previous reports where double-crop wheat following soybeans yielded less than mono-crop wheat (Crabtree et al. 1987). This suggests that rotating to sorghum or soybeans for one production cycle can increase yields in the succedent wheat crop. At Site 2, with no-tillage soil management, cheat management programs with sorghum or soybean increased yield of succedent wheat compared to continuous wheat. Cheat management programs with conventional tillage sorghum increased yield of succedent wheat at Site 2 while those with soybeans did not.

A tillage by cheat management program interaction affected dockage at Sites 1 and 2, while at Site 3 cheat management program affected dockage ($P = 0.01$) but tillage did not ($P = 0.19$) (Appendix S). At Sites 1 and 2, dockage was lower in conventional tillage than in no-tillage continuous wheat-no herbicide. Harvesting the previous wheat crop as wheat-for-forage-only decreased dockage in the succedent wheat crop at only one of three sites. At Site 1, MKH 6561 or MON 37500 in the previous wheat crop reduced dockage in no-tillage continuous wheat. Also, fall applied MKH 6561 and MON 37500, and winter applied MON 37500 reduced dockage in conventional tillage. None of the *Bromus* control herbicides reduced dockage in either tillage system at Sites 2 or 3.

At Sites 1 and 2, with no-tillage soil management, all cheat management programs with sorghum or soybean reduced dockage compared to continuous wheat-no herbicide (Appendix S). With conventional tillage, all cheat management programs that included sorghum at Site 1 and 3, and one cheat management program with sorghum at Site 2 reduced dockage. At Site 3, all but four of the cheat management programs that included sorghum or soybeans reduced dockage compared to continuous wheat-no herbicide. In the succedent wheat crop, where *Bromus* species were reduced, dockage was reduced and thus wheat grain quality improved.

Net returns varied greatly with site, cheat management program, and at Site 1, with tillage (Table 8). Harvesting wheat-for-forage-only for one year increased net returns from continuous wheat at one of three sites. The use of *Bromus* control herbicides for one year in continuous wheat seldom improved net returns. Almost all of the cheat management programs with a sorghum fb soybean crop sequence produced higher net returns than continuous wheat-no herbicide or continuous wheat with a *Bromus* control herbicide. Net returns from cheat management programs that included soybean fb soybean were consistently higher than programs with continuous wheat only at Site 2. No cheat management program at any site produced greater net returns than conventional tillage sorghum with no herbicide fb soybeans.

Rotating out of wheat for one growing season reduced but did not eliminate *Bromus* species. Further research is needed to determine if more than one year out of wheat production can eliminate *Bromus* species. Succedent wheat yield was increased by rotating out of wheat for one growing season. By utilizing cropping sequences other than continuous wheat, dockage can be reduced and therefore increase succedent wheat grain quality. Cropping sequences containing sorghum and soybeans are economically viable options for controlling *Bromus* species in north central Oklahoma.

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Table 1. Value of crop inputs and returns.

Input/Output	Source or task	Unit	Price	Quantity	Value[a] NT	Value[a] CT
			$/unit	units/ha	—$/ha—	
Crop receipts	Double-crop soybeans	kg	0.086	Varied	-	-
	Double-crop sorghum	kg	0.054	Varied	-	-
	Continuous wheat	kg	0.045	Varied	-	-
	Early season soybeans	kg	0.084	Varied	-	-
	Succedent wheat	kg	0.048	Varied	-	-
Operation	Moldboard plow	ha	-	-	-	23.99
	Chisel plow	ha	-	-	-	18.51
	Disc	ha	-	-	-	14.90
	Field cultivate	ha	-	-	-	14.01
	Rotary hoe	ha	-	-	-	10.08
	Dry fertilizer application	ha	-	-	6.13	6.13
	Liquid fertilizer application	ha	-	-	6.67	6.67
	Herbicide application	ha	-	-	7.34	7.34
	Sorghum planting	ha	-	-	19.92	25.33
	Sorghum harvesting	ha	-	-	38.82	38.82
	Sorghum hauling	kg	0.003	Varied	-	-
	Soybeans planting	ha	-	-	25.95	20.53
	Soybeans harvesting	ha	-	-	35.83	35.83
	Soybeans hauling	kg	0.003	Varied	-	-

Wheat planting	ha	-	-	14.33	14.33
Wheat harvesting	ha	-	-	35.83	35.83
Wheat hauling	kg	0.003	Varied	-	-
Midland 8433RR soybean seed	kg	1.05	56.07	58.87	58.87
Asgrow 4602RR soybean seed	kg	1.17	56.07	65.60	65.60
Dekalb CX442RRSTS soybean seed	kg	1.26	56.07	70.65	70.65
Dekalb CX367RR soybean seed	kg	1.17	59.53	69.65	69.65
Dekalb DK28E sorghum seed	kg	2.56	3.94	10.09	10.09
Pioneer 8500 sorghum seed	kg	2.43	3.94	9.57	9.57
2137 hard red winter wheat seed	kg	0.17	69.44	11.80	11.80
28-0-0 fertilizer	kg	0.15	Varied	-	-
18-46-0 fertilizer	kg	0.23	Varied	-	-
46-0-0 fertilizer	kg	0.26	Varied	-	-

[a] NT = no-tillage, CT = conventional tillage.

Table 2. Herbicide application rates and cost by crop sequence and time of application.

			Timing							
				First crop in sequence				Second crop in sequence		
Crop sequence	Herbicide	Rate	Fallow[a]	PPI	PRE	POST	Fallow[a]	PPI	PRE	POST
		g/ha	$/ha							
Soybean fb soybean	Alachlor	2240	-	-	29	-	-	-	29	-
	Glyphosate	1120	-	-	29	29	29	-	29	29
	Glyphosate + chlorimuron	1120+9	-	-	-	42	-	-	-	42
	Metolachlor	1140	-	-	42	-	-	-	42	-
	Metolachlor + flumetsulam	2110+56	-	-	57	-	-	-	57	-
	Pendimethalin	1160	-	17	17	-	-	17	17	-
	Pendimethalin + imazethapyr	1160+100	-	-	48	-	-	-	48	-
	Trifluralin	1120	-	17	-	-	-	17	-	-
Sorghum fb soybean	Alachlor	2240	-	-	29	-	-	-	-	-

	Atrazine	1270	-	-	7	-	-	-	-	-
	Atrazine + 2,4-D	840+800	-	-	-	10	-	-	-	-
	Atrazine + alachlor	1270+2100	-	-	46	-	-	-	-	-
	Atrazine + metolachlor	950+1160	-	-	29	-	-	-	-	-
	Aatrazine + prosulfuron	840+20	-	-	-	21	-	-	-	-
	Glyphosate	1120	-	-	29	-	29	-	29	29
	Metolachlor	1160	-	-	29	-	-	-	-	-
Wheat fb wheat	2,4-D	28	2	-	-	2	-	-	-	-
	Glyphosate	1120	29	-	29	-	29	-	-	-
	Glyphosate + 2,4-D	580+900	25	-	-	-	-	-	-	-
	Metribuzin	310	-	-	-	25	-	-	-	-
	MKH-6561[b]	45	-	-	-	24	-	-	-	-
	MON 37500	35	-	-	-	24	-	-	-	-
	Triasulfuron	20	6	-	-	-	6	-	-	-

[a] Fallow treatment applied only to no-tillage treatments.

[b] Estimated cost based on competitive product cost.

Table 3. Tillage by weed control strategy interaction on stand density of double-crop soybeans on July 12, 1999, double-crop soybean yield at Site 3, and early season soybean stand density pooled over sites and tillage.

	Double-cropped soybean				Early season soybean
	Stand density		Yield		Stand density
	Tillage[a]				
Weed control strategy[b]	NT	CT[c]	NT	CT	Mean
	no./m^2		kg/ha		no./m^2
No herbicide	10	20	830	1420	35
Alachlor, PRE	6	19	610	1530	40
Glyphosate + chlorimuron, POST	9	18	1440	1520	35
Metolachlor, PRE	4	24	890	1870	34
Metolachlor + flumetsulam, PRE	9	23	1080	1860	34
Pendimethalin, PRE/PPI[d]	9	25	1120	1540	25
Pendimethalin fb imazethapyr, PRE fb POST	7	21	1130	1650	27
Standard treatment, PPI/POST[e]	4	25	1050	1870	27

LSD (0.05)	——— 4 ———	——— 280 ———	6

[a] NT = no-tillage, CT = conventional tillage, Mean = pooled over tillage.

[b] In addition to the herbicides listed, glyphosate at 1.1 kg/ha was applied PRE to all NT treatments.

[c] Stand density after CT plots were replanted.

[d] Pendimethalin was applied PRE in NT and PPI in CT.

[e] Standard treatment differed with tillage and consisted of glyphosate applied POST in NT and trifluralin applied PPI in CT.

Table 4 . Control of fall panicum and prairie cupgrass with weed control strategies used in the soybean fb soybean sequence at Site 3[a].

	Fall panicum				Prairie cupgrass			
	8-27-99[b]		7-5-00[c]		8-27-99[b]		7-5-00[c]	
	Tillage[d]							
Weed control strategy[e]	NT	CT	NT	CT	NT	CT	NT	CT
	%							
No herbicide	45 b	90 a	0 c	0 c	45 bc	100 a	0 e	50 bcd
Alachlor, PRE	30 b	100 a	25 c	85 a	75 ab	100 a	0 e	95 a
Glyphosate + chlorimuron, POST	100 a	100 a	100 a	100 a	100 a	100 a	100 a	100 a
Metolachlor, PRE	40 b	100 a	30 bc	100 a	40 c	100 a	50 bc	100 a
Metolachlor + flumetsulam, PRE	80 a	95 a	70 a	65 ab	50 bc	100 a	30 cde	100 a
Pendimethalin, PRE/PPI[f]	65 a	100 a	90 a	100 a	45 c	100 a	75 ab	100 a
Pendimethalin fb imazethapyr, PRE fb POST	85 a	100 a	95 a	100 a	100 a	100 a	100 a	100 a
Standard treatment, PPI/POST[g]	100 a	100 a	100 a	100 a	100 a	100 a	100 a	100 a

[a] Means within a species and date followed by the same letter do not differ at P = 0.05. Identical means may be followed by different letters because of the square root transformation conducted prior to data analysis.

[b] 39 days after POST treatments were applied.

[c] 42 days after POST treatments were applied.

[d] NT = no-tillage, CT = conventional tillage.

[e] In addition to the herbicides listed, glyphosate at 1.1 kg/ha was applied PRE to all NT treatments.

[f] Pendimethalin was applied PRE in NT and PPI in CT.

[g] Standard treatment varied with tillage and consisted of glyphosate applied POST in NT and trifluralin applied PPI in CT.

Table 5. Tillage by weed control strategy on cheat plant density in December 1999 following double-crop soybeans at Site 3 and following double-crop grain sorghum at Site 1[a].

Crop sequence	Weed control strategy	Tillage[b] NT	Tillage[b] CT
		no./m^2	
Soybean fb soybean	No herbicide	330 a-d	170 e-g
	Alachlor	190 def	190 efg
	Glyphosate + chlorimuron	350 abc	210 c-f
	Metolachlor	460 a	80 h
	Metolachlor + flumetsulam	270 b-e	70 h
	Pendimethalin	440 ab	80 h
	Pendimethalin fb imazethapyr	250 b-e	100 h
	Standard treatment[c]	370 abc	100 fgh
Sorghum fb soybean	No herbicide	120 d	60 e
	Alachlor	150 a-d	30 efg
	Atrazine	140 a-d	40 ef
	Metolachlor	180 ab	30 fg
	Atrazine fb 2,4-D	130 cd	40 ef
	Atrazine + alachlor	140 bcd	20 fg
	Atrazine + metolachlor	200 a	20 g
	Atrazine fb prosulfuron	160 abc	40 ef

[a] Means within a crop followed by the same letter do not differ at $P = 0.05$. Identical means may be followed by different letters because of the square root transformation conducted prior to data analysis.

[b] NT = no-tillage, CT = conventional tillage.

[c] Standard treatment differed with tillage and consisted of glyphosate applied POST in NT and trifluralin applied PPI in CT.

Table 6. Tillage by weed control strategy interactions in double-crop grain sorghum yield at Sites 2 and 3.

	Site 2		Site 3	
	Tillage[a]			
Weed control strategy[b]	NT	CT	NT	CT
	kg/ha			
No herbicide	2720	4640	2640	3400
Alachlor, PRE	2920	4200	1600	3650
Atrazine, PRE	3090	3710	1810	3690
Metolachlor, PRE	2840	3230	2400	3610
Atrazine fb 2,4-D, PRE fb POST	2910	3920	2570	3240
Atrazine + alachlor, PRE	2930	4120	1110	3630
Atrazine + metolachlor, PRE	3440	4470	1860	2890
Atrazine fb prosulfuron, PRE fb POST	3150	4950	2070	3310
LSD (0.05)	700		850	

[a] NT = no-tillage, CT = conventional tillage.

[b] In addition to the herbicides listed, glyphosate at 1.1 kg/ha was applied PRE to all NT treatments.

Table 7. Tillage by weed control strategy interaction on cheat panicle density at Site 1, weed control strategy effects pooled over tillage on cheat density at Sites 2 and 3, and tillage by weed control strategy interaction on downy brome density at Site 2 in May, 2000 in the continuous wheat sequence[a].

	Cheat				Downy brome	
	Site 1		Site 2	Site 3	Site 2	
	Tillage[b]					
Weed control strategy	NT	CT	Mean	Mean	NT	CT
	no./m^2					
No herbicide	142 ab	32 d	3 a	75 b	209 a	132 ab
Forage-only[c]	176 a	34 d	2 a	96 a	216 a	45 bcd
Metribuzin, Fall	76 c	13 e	0 a	15 c	32 cde	85 bc
MKH 6561, Fall	1 ef	0 f	0 a	0 e	85 bc	72 bcd
MKH 6561, Winter	2 ef	0 f	1 a	0 e	170 ab	2 e
MON 37500, Fall	7 ef	2 ef	0 a	20 c	64 bcd	67 cd
MON 37500, Winter	6 ef	1 ef	0 a	12 d	75 bc	40 cd
MON 37500 + 2,4-D, Winter	5 ef	0 f	0 a	0 e	148 bc	17 d

[a] Means within a site followed by the same letter do not differ at P = 0.05 at Sites 1 and 3 and P = 0.10 at Site 2. Identical means may be followed by different letters because of the square root transformation conducted prior to data analysis.

[b] NT = no-tillage, CT = conventional tillage, Mean = pooled over tillage.

[c] Plots mowed to 5 cm in January and March.

Table 8. Wheat stand density pooled over tillage and sites, cheat management program effect on yield of the succedent wheat crop and total net returns from each cheat management program.

Cheat management program		Wheat density	Yield				Net returns[a]			
			Site 1	Site 2		Site 3	Site 1		Site 2	Site 3
		Tillage[b]								
Sequence	Weed control strategy	Mean	Mean	NT	CT	Mean	NT	CT	Mean	Mean
		no./m^2	kg/ha				$/ha			
Soybean fb soybean	No herbicide	146	2840	3810	2370	3580	193	284	658	128
	Alachlor	146	2770	3820	2280	3850	178	215	537	181
	Metolachlor	154	2690	3830	2450	3790	133	140	906	232
	Pendimethalin	150	2620	3510	2810	3600	109	156	673	253
	Glyphosate + chlorimuron	155	2790	3920	2400	4010	147	186	514	252
	Metolachlor + flumetsulam	160	2750	3670	2520	3910	198	234	618	314
	Pendimethalin fb imazethapyr	147	2730	3740	2910	3240	66	114	443	125
	Standard treatment[c]	158	2730	4020	2320	3930	224	145	725	312

Sorghum fb	No herbicide	164	2960	4150	3530	4000	178	347	601	513
soybean	Alachlor	149	2640	4220	3270	3870	135	296	582	455
	Atrazine	149	2910	3970	3720	3940	213	334	622	486
	Metolachlor	155	2870	3900	3870	3840	188	353	502	458
	Atrazine + 2,4-D	158	2620	4200	3790	3970	223	412	626	483
	Atrazine + alachlor	160	2780	4150	3610	3930	148	338	582	429
	Atrazine + metolachlor	154	2780	4000	2960	3850	132	415	564	384
	Atrazine + prosulfuron	147	2840	4140	3560	3980	213	368	635	471
Continuous	No herbicide	117	1550	1210	2270	2310	(44)	7	109	170
wheat	Forage-only	135	2440	1800	2710	2790	239	166	311	290
	Metribuzin, fall	114	1600	1870	2610	2240	(46)	(56)	167	150
	MKH 6561, fall	121	2190	1700	2460	2360	78	(21)	140	179
	MKH 6561, winter	126	2130	1760	3010	2450	83	(34)	131	207
	MON 37500, fall	129	2100	1790	2750	2330	(10)	(8)	165	164
	MON 37500, winter	154	2290	2000	3110	2430	65	4	183	188

MON 37500 + 2,4-D, winter	122	2180	2160	2670	2330	37	(2)	162	205
LSD (0.05)	28	320	—650—		300	—94—		236	123

[a] Negative numbers are in ( ).

[b] NT = no-tillage, CT = conventional tillage, Mean = pooled over tillage.

[c] Standard treatment differed with tillage and consisted of glyphosate applied POST in NT and trifluralin applied PPI in CT.

Table 9. Cheat management program effect on cheat panicle density at all sites and tillage by cheat management program interaction on downy brome panicle density at Site 2[a].

Cheat management program		Cheat density				Downy brome density	
		Site 1	Site 2		Site 3	Site 2	
		Tillage[b]					
Sequence	Weed control strategy	Mean	NT	CT	Mean	NT	CT
		no./m^2					
Soybean fb soybean	No herbicide	15 c-g	0 b	0 b	18 ab	14 kl	352 a-d
	Alachlor	7 efg	0 b	0 b	15 ab	8 kl	282 a-d
	Glyphosate + chlorimuron	16 c-g	0 b	0 b	2 cde	8 kl	277 b-e
	Metolachlor	5 fg	0 b	0 b	14 ab	15 kl	190 d-h
	Pendimethalin	13 c-g	0 b	0 b	16 ab	12 kl	183 c-h
	Metolachlor + flumetsulam	9 d-g	0 b	0 b	7 b-e	17 kl	172 d-i
	Pendimethalin fb imazethapyr	10 d-g	0 b	0 b	0 e	5 l	85 f-l
	Standard treatment[c]	8 efg	0 b	0 b	19 ab	8 kl	534 ab

Sorghum fb	No herbicide	10 d-g	0 b	0 b	2 cde	10 kl	48 i-l
soybean	Alachlor	41 c-f	0 b	0 b	0 e	29 i-l	70 f-l
	Atrazine	53 cde	0 b	0 b	1 de	28 i-l	65 f-l
	Metolachlor	52 c-f	0 b	0 b	2 cde	16 jkl	53 h-l
	Atrazine + 2,4-D	2 g	0 b	0 b	0 e	22 jkl	72 h-l
	Atrazine + alachlor	69 cd	0 b	0 b	1 cde	25 i-l	36 jkl
	Atrazine + metolachlor	48 c-g	0 b	0 b	1 cde	15 kl	120 e-l
	Atrazine fb prosulfuron	9 d-g	0 b	0 b	1 de	13 kl	26 jkl
Continuous	No herbicide	110 ab	4 a	0 b	19 ab	489 ab	176 c-g
wheat	Forage-only	35 cde	2 b	0 b	8 a-d	579 a	52 g-l
	Metribuzin, fall	200 a	1 b	0 b	14 ab	199 c-f	99 e-k
	MKH 6561, fall	17 c-g	0 b	0 b	7 a-e	265 a-d	97 f-l
	MKH 6561, winter	12 c-g	0 b	0 b	6 b-e	500 abc	27 jkl
	MON 37500, fall	47 cd	0 b	0 b	18 a	343 a-d	146 d-j
	MON 37500, winter	49 cd	0 b	0 b	9 abc	321 bcd	33 i-l

MON 37500 + 2,4-D, winter	40 c-f	0 b	0 b	3 cde	326 b-e	45 h-l

[a] Means within a site followed by the same letter do not differ at $P = 0.05$. Identical means may be followed by different letters because of the square root transformation conducted prior to data analysis.

[b] NT = no-tillage, CT = conventional tillage, Mean = pooled over tillage.

[c] Standard treatment differed with tillage and consisted of glyphosate applied POST in NT and trifluralin applied PPI in CT.

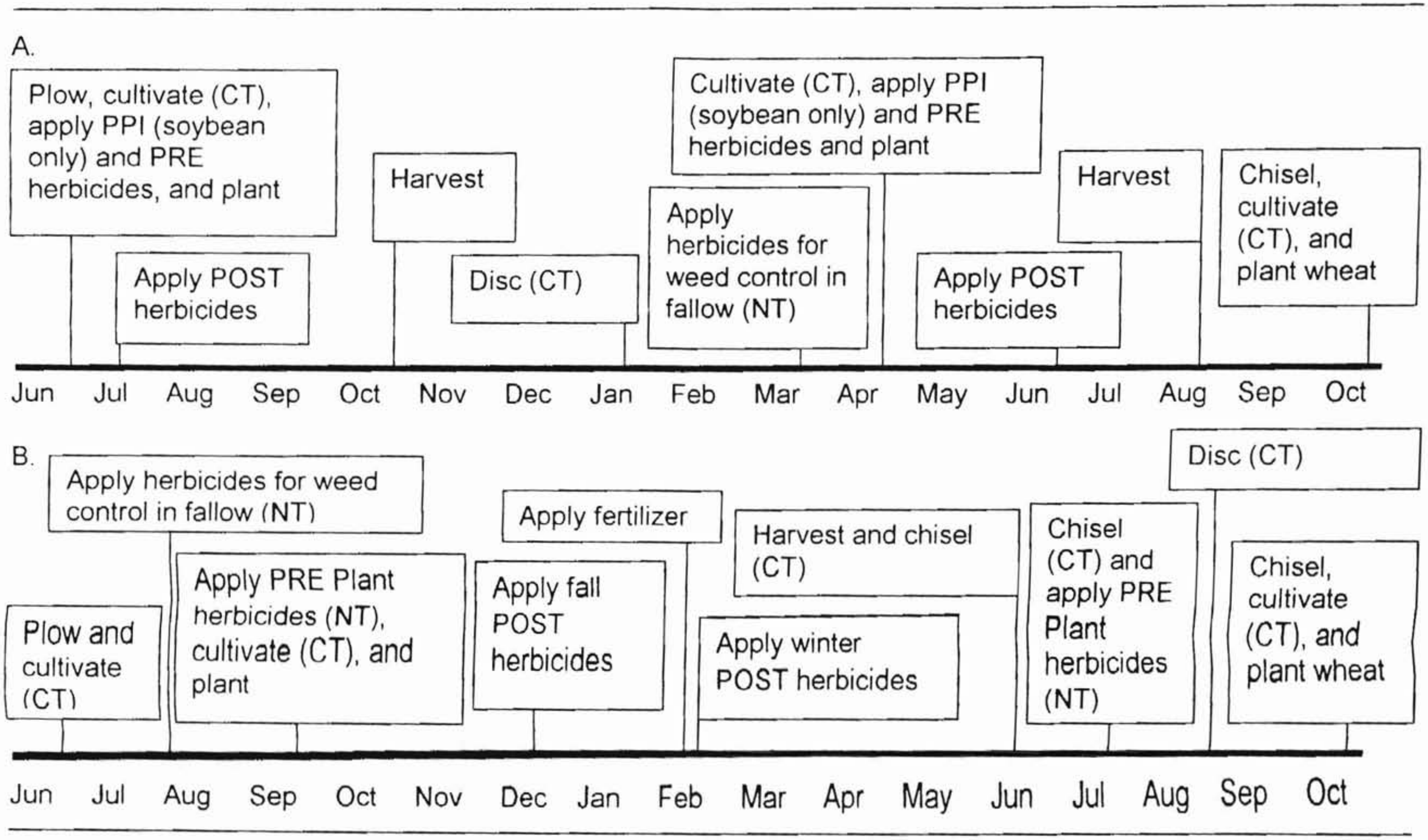

Figure 1. Timeline of field activities from June 1999 to October 2000, in (A), sorghum fb soybean and soybean fb soybean sequences and (B), the continuous wheat sequence. NT = only no-tillage, CT = only conventional tillage, and fb = followed by.

Appendix A. Dates of field operations by tillage and site.

Crop sequence	Field operation	Tillage[a] NT	CT	Site 1	Site 2	Site 3
				date		
Soybean fb soybean	Moldboard plow	-	CT	7/6/99	6/7/99	6/29/99
	Field cultivate	-	CT	7/6/99	6/7/99	6/29/99
	Apply PRE and PPI herbicides	NT	CT	7/6/99	6/7/99	6/29/99
	Plant double-crop	NT	CT	7/6/99	6/7/99	6/29/99
	Rotary hoe	-	CT	-	-	7/7/99
	Re-plant	-	CT	-	-	7/12/99
	Apply POST herbicide	NT	CT	-	7/8/99	7/19/99
	Harvest	NT	CT	10/28/99	10/13/99	10/25/99
	Disc stubble	-	CT	1/11/00	1/11/00	1/11/00
	Field cultivate	-	CT	4/6/00	4/5/00	4/7/00
	Apply fallow herbicide	NT		2/29/00	2/29/00	2/29/00
	Apply PRE and PPI herbicides	NT	CT	4/6/00	4/6/00	4/7/00
	Plant early season crop	NT	CT	4/6/00	4/6/00	4/7/00
	Apply POST herbicide	-	CT	7/3/00	5/24/00	5/24/00
	Harvest	NT[d]	CT[e]	10/5/00	8/30/00	9/1/00
Sorghum fb soybean	Moldboard plow	-	CT	7/6/99	6/7/99	6/29/99
	Field cultivate	-	CT	7/6/99	6/7/99	6/29/99

	Apply PRE herbicide	NT	CT	7/6/99	6/7/99	6/29/99
	Plant double-crop	NT	CT	7/6/99	6/7/99	6/29/99
	Apply POST herbicide	NT	CT	-	7/8/99	7/8/99
	Harvest	NT[b]	CT[c]	11/11/99	10/3/99	10/5/99
Continuous	Moldboard plow	-	CT	7/6/99	6/7/99	6/29/99
wheat	Apply fallow herbicide	NT	-	7/8/99	7/8/99	7/8/99
	Field cultivate	-	CT	7/20/99	7/20/99	7/20/99
	Apply PRE herbicide	NT	-	9/30/99	9/30/99	9/30/99
	Field cultivate	-	CT	10/1/99	10/1/99	10/1/99
	Plant	NT	CT	10/1/99	10/1/99	10/1/99
	Apply POST herbicide	NT	CT	12/2/99	12/2/99	12/2/99
	Topdress	NT	CT	2/6/00	2/6/00	2/6/00
	Apply POST herbicide	NT	CT	2/15/00	2/15/00	2/15/00
	Harvest	-	CT	6/8/00	6/6/00	6/8/00
	Chisel plow	-	CT	6/8/00	6/9/00	6/8/00
	Disc stubble	-	CT	8/11/00	8/11/00	8/11/00
	Chisel plow	-	CT	10/18/00	10/20/00	10/18/00
	Field cultivate	-	CT	10/18/00	10/20/00	10/18/00
	Plant	NT	CT	10/18/00	10/20/00	10/18/00
	Topdress	NT	CT	2/7/01	2/7/01	2/7/01
	Harvest	NT	CT	6/8/01	6/6/01	6/8/01

[a] NT = no-tillage, CT = conventional tillage.

[b] Plots treated the same as no-tillage soybeans through the remainder of the experiment

[c] Plots treated the same as conventional tillage soybeans through the remainder of the experiment

[d] Plots treated the same as no-tillage continuous wheat through the remainder of the experiment

[e] Plots treated the same as conventional tillage continuous wheat through the remainder of the experiment

Appendix B. Soil characteristics by site.

Characteristic	Site 1	Site 2	Site 3
Texture	Silt loam	Silt loam	Silt loam
pH	4.4	6.2	5.0
% Organic Matter	1.1	0.6	1.6
% Clay	22	13	25
% Sand	29	49	27
% Silt	49	38	48
CEC	15	8	19
Capability classification	III	I	III

Appendix C. Monthly rainfall totals from the mesonet weather station nearest each research site[a] and 30 year monthly mean rainfall for north central Oklahoma.

Date	Site 1	Site 2	Site 3	30 year mean
	cm			
April 1999	17.1	17.4	8.7	7.11
May 1999	7.9	11.8	7.6	11.4
June 1999	27.9	18.4	16.4	9.4
July 1999	5.7	6.0	3.1	7.1
August 1999	5.5	12.0	2.3	7.8
September 1999	20.0	8.6	5.9	8.0
October 1999	5.7	7.2	2.1	5.7
November 1999	1.1	3.4	0.5	4.8
December 1999	10.1	9.6	3.0	2.9
January 2000	0.5	0.6	0.5	2.1
February 2000	4.7	6.2	2.0	3.0
March 2000	10.1	14.8	5.7	5.9
April 2000	5.0	6.3	2.1	7.1
May 2000	10.2	5.9	4.3	11.4
June 2000	10.8	9.1	5.9	9.4
July 2000	10.4	6.1	3.4	7.1
August 2000	0.0	0.0	0.0	7.8
September 2000	0.1	0.0	0.1	8.0

October 2000	6.8	16.1	3.1[b]	5.7
November 2000	NA[c]	7.6	2.5	4.8
December 2000	1.6	1.5	0.6	2.9
January 2001	5.2	6.1	2.4	2.1
February 2001	8.5	5.8	3.1	3.0
March 2001	2.4	2.8	0.8	5.9
April 2001	2.0	0.8	0.9	7.1
May 2001	17.7	18.7	5.5	11.4
June 2001	2.2	2.4	1.5	9.4

[a] Data available through Oklahoma Climatological Survey, University of Oklahoma, 710 Asp Ave., Suite 8, Norman, OK 73019-0501.

[b] Rainfall data was not available for one day in the month.

[c] Rainfall data was not available for 1 week in the month.

Appendix D. Source and rate of nitrogen fertilizer applied by crop sequence at each site.

		Site 1				Site 2				Site 3			
		First crop in sequence		Second crop in sequence		First crop in sequence		Second crop in sequence		First crop in sequence		Second crop in sequence	
Crop sequence	N source	Plant	POST	Plant	POST	Plant	POST	Plant	POST	Plant	POST	Plant	POST
		N kg/ha											
Soybean fb soybean	-	-	-	-	-	-	-	-	-	-	-	-	-
Sorghum fb soybean	46-0-0[a]	55	-	-	-	55	-	-	-	55	-	-	-
Continuous wheat	28-0-0[b]	-	90	-	-	-	100	-	-	-	80	-	-
	46-0-0[c]	-	-	30	85	-	-	30	85	-	-	-	85
	18-46-0[c]	12	-	-	-	-	-	-	-	12	-	22	-

[a] Banded on soil surface at planting.

[b] Broadcast with field sprayer.

[c] Drilled at planting in the furrow or broadcast POST with cone spreader.

Appendix E. Tillage and weed control strategy interaction on height of mature double-crop soybeans.

	Site 1		Site 2		Site 3	
	Tillage[a]					
Weed control strategy[b]	NT	CT	NT	CT	NT	CT
	cm					
No herbicide	37	38	54	54	45	52
Alachlor, PRE	37	37	55	51	43	50
Glyphosate + chlorimuron, POST	37	36	56	50	51	49
Metolachlor, PRE	37	36	53	52	50	52
Metolachlor + flumetsulam, PRE	37	37	51	52	49	51
Pendimethalin, PRE/PPI[c]	34	37	58	53	49	54
Pendimethalin fb imazethapyr, PRE fb POST	35	37	53	54	51	51
Standard treatment, PPI/POST[d]	36	38	56	54	52	52
LSD (0.05)	ND		ND		ND	

[a] NT = no-tillage, CT = conventional tillage.

[b] In addition to the herbicides listed, glyphosate at 1.1 kg/ha was applied PRE to all NT treatments.

[c] Pendimethalin was applied PRE in NT and PPI in CT.

[d] Standard treatment varied with tillage and consisted of glyphosate applied POST in NT and trifluralin applied PPI in CT.

Appendix F. Weed density on various dates in plots which received glyphosate PRE (NT) or no herbicide (CT) by site.

			Site 1		Site 2		Site 3	
Cheat management program			Tillage					
Crop sequence	Weed species	Date	NT	CT	NT	CT	NT	CT
			no./m^2					
Soybean fb soybean	Horseweed[a]	8-12-99	0.25	0.25	-	-	-	-
		8-5-00	0.5	0.5	-	-	-	-
	Cutleaf eveningprimrose[b]	8-12-99	8	12	-	-	-	-
	Tumble pigweed[c]	7-16-99	-	-	5	5	-	-
		6-22-00	-	-	4	4	-	-
	Carpetweed[d]	7-16-99	-	-	2	2	-	-
	Fall panicum[e]	8-27-99	-	-	-	-	4	1
		7-5-00	-	-	-	-	4	2
	Prairie cupgrass[f]	8-27-99	-	-	-	-	4	1
		7-5-00	-	-	-	-	5	2
	Crabgrass[g]	8-27-/99	-	-	-	-	14	20
		6-22-00	-	-	6	6	-	-
		7-5-00	-	-	-	-	26	26
Sorghum fb soybean	Horseweed	8-12-99	0.25	0.25	-	-	-	-
		8-5-00	0.5	0.5	-	-	-	-
	Tumble pigweed	7-16-99	-	-	5	5	-	-

	6-20-00	-	-	2	7	-	-
Carpetweed	7-16-99	-	-	1	2	-	-
Fall panicum	8-27-99	-	-	-	-	3	1
	7-5-00	-	-	-	-	3	1
Prairie cupgrass	8-27-99	-	-	-	-	3	1
	7-5-00	-	-	-	-	1	1
Crabgrass	8-27-99	-	-	-	-	14	20
	6-22-00	-	-	1	2	-	-
	7-5-00	-	-	-	-	40	40

[a] Horseweed, *Conyza canadensis* (L.) Cronq.

[b] Cutleaf eveningprimrose, *Oenothera laciniata* Hill.

[c] Tumble pigweed, *Amaranthus albus* L.

[d] Carpetweed, *Mollugo verticillata* L.

[e] Fall panicum, *Panicum dichotomiflorum* Michx.

[f] Prairie cupgrass, *Eriochloa contracta* Hitch.

[g] Crabgrass, *Digitaria sanguinalis* (L.) Scop.

Appendix G. Horseweed and cutleaf eveningprimrose control in the soybean fb soybean sequence at Site 1[a].

	Horseweed				Cutleaf eveningprimrose	
	8-12-99[b]		8-5-00[c]		8-12-99[b]	
	Tillage[d]					
Weed control strategy[e]	NT	CT	NT	CT	NT	CT
	%					
No herbicide	60 b	100 a	25 bcd	0 d	90 a	100 a
Alachlor, PRE	45 bc	100 a	60 ab	25 cd	75 a	100 a
Glyphosate + chlorimuron, POST	95 a	100 a	95 a	100 a	100 a	100 a
Metolachlor, PRE	100 a	100 a	95 a	50 bc	100 a	100 a
Metolachlor + flumetsulam, PRE	100 a	100 a	100 bc	75 ab	100 a	100 a
Pendimethalin, PRE/PPI[f]	45 c	100 a	40 bc	60 abc	100 a	100 a
Pendimethalin fb imazethapyr, PRE fb POST	95 a	100 a	95 a	90 a	95 a	100 a
Standard treatment, PPI/POST[g]	100 a	100 a	100 a	0 d	100 a	100 a

[a] Means within a species and date followed by the same letter do not differ at P = 0.05. Identical means may be followed by different letters because of the square root transformation conducted prior to data analysis.

[b] 35 days after PRE treatments were applied.

[c] 32 days after POST treatments were applied.

[d] NT = no-tillage, CT = conventional tillage.

[e] In addition to the herbicides listed, glyphosate at 1.1 kg/ha was applied PRE to all NT treatments.

[f] Pendimethalin was applied PRE in NT and PPI in CT.

[g] Standard treatment varied with tillage and consisted of glyphosate applied POST in NT and trifluralin applied PPI in CT.

Appendix H. Tumble pigweed and carpetweed control in the soybean fb soybean sequence at Site 2[a].

	Tumble pigweed			Carpetweed
	7-16-99[b]	6-22-00[c]		7-16-99[b]
	Tillage[d]			
Weed control strategy[e]	Mean	NT	CT	Mean
	%			
No herbicide	50 b	25 c	0 c	50 b
Alachlor, PRE	100 a	60 b	95 a	80 a
Glyphosate + chlorimuron, POST	100 a	100 a	100 a	100 a
Metolachlor, PRE	100 a	80 ab	100 a	90 a
Metolachlor + flumetsulam, PRE	100 a	95 a	100 a	100 a
Pendimethalin, PRE/PPI[f]	85 a	80 ab	90 ab	80 a
Pendimethalin fb imazethapyr, PRE fb POST	85 a	100 a	100 a	90 a
Standard treatment, PPI/POST[g]	100 a	70 ab	80 ab	100 a

[a] Means within a species and date followed by the same letter do not differ at P = 0.05. Identical means may be followed by different letters because of the square root transformation conducted prior to analysis.

[b] 39 days after POST treatments were applied.

[c] 30 days after POST treatments were applied.

[d] NT = no-tillage, CT = conventional tillage, Mean = pooled over tillage.

[e] In addition to the herbicides listed, glyphosate at 1.1 kg/ha was applied PRE to all NT treatments.

[f] Pendimethalin was applied PRE in NT and PPI in CT.

[g] Standard treatment varied with tillage and consisted of glyphosate applied POST in NT and trifluralin applied PPI in CT.

Appendix I. Large crabgrass control in the soybean fb soybean sequence at two sites.

	Site 2	Site 3	
	6-22-00[b]	8-27-99[c]	7-5-00[d]
	Tillage[e]		
Weed control strategy[f]	Mean	Mean	Mean
	no./m^2		
No herbicide	50 b	60 b	10 b
Alachlor, PRE	85 a	70 b	70 a
Glyphosate + chlorimuron, POST	100 a	100 a	100 a
Metolachlor, PRE	100 a	90 a	70 a
Metolachlor + flumetsulam, PRE	85 a	90 a	65 a
Pendimethalin, PRE/PPI[g]	100 a	85 a	80 a
Pendimethalin fb imazethapyr, PRE fb POST	100 a	95 a	100 a
Standard treatment, PPI/POST[h]	85 a	100 a	100 a

[a] Means within a site and date followed by the same letter do not differ at P = 0.05. Identical means may be followed by different letters because of the square root transformation conducted prior to data analysis.

[b] 29 days after POST treatments were applied.

[c] 39 days after POST treatments were applied.

[d] 41 days after POST treatments were applied.

[e] NT = no-tillage, CT = conventional tillage, Mean = pooled over tillage.

[f] In addition to the herbicides listed, glyphosate at 1.1 kg/ha was applied PRE to all NT treatments.

[g] Pendimethalin was applied PRE in NT and PPI in CT.

[h] Standard treatment varied with tillage and consisted of glyphosate applied POST in NT and trifluralin applied PPI in CT.

Appendix J. Horseweed control in the sorghum fb soybean sequence at Site 1[a].

	8-12-99[b]		8-5-00[c]	
	Tillage[d]			
Weed control strategy[e]	NT	CT	NT	CT
	%			
No herbicide	100 a	100 a	90 a	100 a
Alachlor, PRE	100 a	100 a	100 a	100 a
Atrazine, PRE	70 a	100 a	95 a	100 a
Metolachlor, PRE	70 a	100 a	95 a	100 a
Atrazine fb 2,4-D, PRE fb POST	100 a	100 a	100 a	100 a
Atrazine + alachlor, PRE	100 a	100 a	100 a	100 a
Atrazine + metolachlor, PRE	75 a	100 a	95 a	100 a
Atrazine fb prosulfuron, PRE fb POST	100 a	100 a	95 a	100 a

[a] Means within a date followed by the same letter do not differ at $P = 0.05$.

[b] 35 days after PRE treatments were applied.

[c] 32 days after POST treatments were applied.

[d] NT = no-tillage, CT = conventional tillage.

[e] In addition to the herbicides listed, glyphosate at 1.1 kg/ha was applied PRE to all NT treatments.

Appendix K. Tumble pigweed and carpetweed control in the sorghum fb soybean sequence at Site 2[a].

	Tumble pigweed		Carpetweed	
	7-16-99[b]	6-20-00[c]	7-16-99[b]	
	Tillage[d]			
Weed control strategy[e]	Mean	Mean	NT	CT
	%			
No herbicide	95 a	40 b	100 a	85 b
Alachlor, PRE	100 a	100 a	100 a	90 ab
Atrazine, PRE	100 a	100 a	100 a	100 a
Metolachlor, PRE	95 a	100 a	100 a	100 a
Atrazine fb 2,4-D, PRE fb POST	100 a	100 a	100 a	100 a
Atrazine + alachlor, PRE	100 a	100 a	100 a	100 a
Atrazine + metolachlor, PRE	100 a	100 a	100 a	100 a
Atrazine fb prosulfuron, PRE fb POST	100 a	95 a	100 a	100 a

[a] Means within a species and date followed by the same letter do not differ at P = 0.05.

[b] 39 days after POST treatments were applied.

[c] 30 days after POST treatments were applied.

[d] NT = no-tillage, CT = conventional tillage, Mean = pooled over tillage.

[e] In addition to the herbicides listed, glyphosate at 1.1 kg/ha was applied PRE to all NT treatments.

Appendix L. Fall panicum and prairie cupgrass control in the sorghum fb soybean sequence at Site 3[a].

	Fall Panicum				Pairie cupgrass			
	8-27-99[b]		7-5-00[c]		8-27-99[b]		7-5-00[c]	
	Tillage							
Weed control strategy[b]	NT	CT	NT	CT	NT	CT	NT	CT
	%							
No herbicide	75 abc	100 a	100 a	100 a	70 a	100 a	100 a	85 a
Alachlor, PRE	60 c	100 a	100 a	100 a	70 a	100 a	95 a	90 a
Atrazine, PRE	75 abc	95 a	100 a	100 a	70 a	100 a	80 a	100 a
Metolachlor, PRE	90 abc	100 a	95 a	100 a	70 a	100 a	95 a	100 a
Atrazine fb 2,4-D, PRE fb POST	65 bc	100 a	100 a	100 a	90 a	100 a	95 a	100 a
Atrazine + alachlor, PRE	35 d	100 a	100 a	100 a	70 a	100 a	95 a	100 a
Atrazine + metolachlor, PRE	95 a	100 a	100 a	100 a	70 a	100 a	100 a	100 a
Atrazine fb prosulfuron, PRE fb POST	40 d	100 a	100 a	100 a	85 a	95 a	85 a	100 a

[a] Means within a species and date followed by the same letter do not differ at $P = 0.05$.

[b] 39 days after POST treatments were applied.

[c] 42 days after POST treatments were applied.

[d] NT = no-tillage, CT = conventional tillage.

[e] In addition to the herbicides listed, glyphosate at 1.1 kg/ha was applied PRE to all NT treatments.

Appendix M. Large crabgrass control in the sorghum fb soybean sequence at Sites 2 and 3[a].

	Site 2		Site 3			
	6-22-00[b]		8-27-99[c]		7-5-00[d]	
	Tillage[e]					
Weed control strategy[f]	NT	CT	NT	CT	NT	CT
	%					
No herbicide	100 a	90 a	95 a	20 d	95 a	95 a
Alachlor, PRE	100 a	100 a	80 abc	80 abc	95 a	95 a
Atrazine, PRE	100 a	100 a	90 ab	80 abc	100 a	100 a
Metolachlor, PRE	80 a	100 a	100 a	100 a	95 a	100 a
Atrazine fb 2,4-D, PRE fb POST	100 a	100 a	90 ab	40 cd	95 a	100 a
Atrazine + alachlor, PRE	100 a	100 a	85 abc	95 ab	100 a	100 a
Atrazine + metolachlor , PRE	100 a	100 a	100 a	65 bcd	100 a	95 a
Atrazine fb prosulfuron, PRE fb POST	100 a	100 a	90 ab	55 abc	100 a	100 a

[a] Means within a site and date followed by the same letter do not differ at P = 0.05. Identical means may be followed by different letters because of the square root transformation conducted prior to data analysis.

[b] 30 days after POST treatments were applied.

[c] 39 days after POST treatments were applied.

[d] 42 days after POST treatments were applied.

[e] NT = no-tillage, CT = conventional tillage.

[f] In addition to the herbicides listed, glyphosate at 1.1 kg/ha was applied PRE to all NT treatments.

Appendix N. Effect of weed control strategy, pooled across tillage on height and panicle density of mature double-cropped grain sorghum.

	Height			Panicle density					
	Site 1	Site 2	Site 3	Site 1		Site 2		Site 3	
	Tillage[a]								
Weed control strategy	Mean	Mean	Mean	NT	CT	NT	CT	NT	CT
	cm			no./m^2					
No herbicide	75	62	82	10	9	11	14	8	12
Alachlor, PRE	76	57	83	9	10	10	14	8	12
Atrazine, PRE	73	59	82	8	9	11	15	8	13
Metolachlor, PRE	76	59	82	9	10	10	14	9	11
Atrazine + 2,4-D, PRE fb POST	74	55	83	9	8	10	14	10	12
Atrazine + alachlor, PRE	75	59	78	9	10	11	14	7	11
Atrazine + metolachlor, PRE	75	58	73	8	9	10	14	9	12
Atrazine + prosulfuron, PRE fb POST	76	59	81	9	10	11	14	9	11

LSD (0.05)	ND	3	6	—ND—	—ND—	—ND—

[a] NT = no-tillage, CT = conventional tillage, Mean = pooled over tillage.

Appendix O. Early season soybean stand density, mature height, and yield in the cheat management programs with soybean fb soybeans and sorghum fb soybeans crop sequences.

		Density				Height						Yield					
		Site 1	Site 2	Site 3		Site 1		Site 2		Site 3		Site 1		Site 2		Site 3	
Cheat management program		Tillage[a]															
Sequence	Weed control strategy	Mean	Mean	NT	CT	NT	CT	NT	CT	NT	CT	NT	CT	NT	CT	NT	CT
		no./m²				cm						kg/ha					
Soybean fb soybean	No herbicide	33	31	32	34	63	69	64	62	48	45	1130	1710	1490	1200	590	430
	Alachlor	31	32	31	32	64	68	66	65	45	63	1400	1670	1580	1330	510	1670
	Glyphosate + chlorimuron	33	33	32	33	65	68	64	57	53	61	1200	1620	1410	1020	1150	1500
	Metolachlor	31	30	29	31	64	68	63	63	46	62	1190	1580	1140	1290	640	1720
	Metolachlor + flumetsulam	32	32	31	32	64	72	63	64	53	59	1310	1760	1080	1370	1010	1553
	Pendimethalin[c]	27	29	26	21	62	66	64	69	49	60	1080	1310	1130	1420	850	1580

	Pendimethalin fb imazethapyr	28	30	29	21	62	65	66	58	53	57	1040	1210	1330	950	960	1470
	Standard treatment[d]	28	31	29	20	63	66	63	58	54	60	1210	1150	1390	1050	1310	1530
Sorghum fb soybean	No herbicide	29	32	32	33	53	62	65	65	59	61	750	1320	1190	1410	1520	1630
	Alachlor	32	32	31	33	52	62	62	67	59	65	960	1160	1530	1350	1470	1750
	Atrazine	29	32	32	34	56	63	62	67	58	65	1050	1190	1160	1410	1370	1910
	Metolachlor	32	30	31	34	53	57	62	64	57	64	1040	1440	1330	1370	1430	1770
	Atrazine fb 2,4-D	32	31	32	34	55	67	61	66	58	62	1030	1870	1340	1580	1480	1630
	Atrazine + alachlor	31	33	33	33	57	64	64	67	60	64	940	1390	1530	1520	1460	1800
	Atrazine + metolachlor	30	32	31	32	51	65	62	65	61	64	810	1670	1270	1510	1530	1740
	Atrazine fb prosulfuron	30	29	32	33	47	65	56	67	60	62	990	1530	1180	1410	1590	1670
	LSD (0.05)	ND	ND	—3—		—5—		—5—		—5—		—340—		—300—		—320—	

[a] NT = no-tillage, CT = conventional tillage, Mean = pooled over tillage.

[b] Standard treatment differed with tillage and consisted of glyphosate applied POST in NT and trifluralin applied PPI in CT.

[c] Pendimethalin was applied PRE in NT and PPI in CT.

[d] Standard treatment differed with tillage and consisted of glyphosate applied POST in NT and trifluralin applied PPI in CT.

Appendix P. Tillage by weed control strategy interaction on dockage in the continuous wheat sequence in June, 2000 at Site 1.

	Tillage[a]	
Weed control strategy	NT	CT
	%	
No herbicide	17.9	8.9
Forage-only	-	-
Metribuzin, fall	9.9	8.6
MKH 6561, fall	6.2	8.6
MKH 6561, winter	6.8	7.5
MON 37500, fall	8.7	7.5
MON 37500, winter	6.1	6.5
MON 37500 + 2,4-D, winter	6.6	8.4
LSD (0.05)	3.3	

[a] NT = no-tillage, CT = conventional tillage

Appendix Q. Tillage by cheat management program interaction on cheat stand density at Site 1, downy brome stand density at Site 2, and cheat management program effect on cheat density at Site 3, in December, 2000[a].

Cheat management program		Site 1		Site 2		Site 3
		Tillage[b]				
Crop sequence	Weed control strategy	NT	CT	NT	CT	Mean
		no./m²				
Soybean fb soybean	No herbicide	28 efg	17 efg	15 jkl	95 d-j	9 f-h
	Alachlor	22 efg	24 efg	31 i-l	186 b-g	17 b-h
	Glyphosate + chlorimuron	24 efg	23 efg	11 jkl	155 c-h	12 d-h
	Metolachlor	19 efg	15 g	26 i-l	93 e-k	17 b-h
	Metolachlor + flumetsulam	27 d-g	26 efg	11 kl	94 f-k	15 c-h
	Pendimethalin	28 def	22 efg	16 jkl	112 c-i	27 b-g
	Pendimethalin fb imazethapyr	29 d-g	19 efg	8 kl	71 f-k	11 d-h
	Standard treatment [c]	18 def	20 efg	35 h-l	180 b-g	13 c-h
Sorghum fb soybean	No herbicide	26 efg	20 efg	14 jkl	22 jkl	8 gh

	Alachlor	24 efg	18 efg	11 jkl	38 h-l	7 h
	Atrazine	25 efg	27 efg	29 h-l	18 jkl	9 f-h
	Metolachlor	23 efg	28 efg	19 i-l	22 jkl	11 d-h
	Atrazine fb 2,4-D	34 d-g	61 cd	8 l	62 g-l	9 f-h
	Atrazine + alachlor	28 efg	21 efg	23 i-l	39 h-l	13 d-h
	Atrazine + metolachlor	22 efg	18 fg	39 h-l	155 f-l	11 d-h
	Atrazine fb prosulfuron	24 efg	23 efg	10 jkl	21 jkl	10 e-h
Continuous wheat	No herbicide	198 a	54 cd	465 a	47 g-l	35 b
	No herbicide, foraged	35 def	21 efg	290 ab	49 h-l	19 b-h
	Metribuzin, fall	114 b	30 d-g	240 bc	23 i-l	71 a
	MKH 6561, fall	33 def	19 efg	221 a-f	66 f-l	25 b-e
	MKH 6561, winter	40 de	22 efg	315 abc	23 i-l	22 b-f
	MON 37500, fall	85 bc	23 efg	260 a-e	40 h-l	27 bc
	MON 37500, winter	35 def	25 efg	283 a-e	28 i-l	27 b-d
	MON 37500 + 2,4-D, winter	35 def	23 efg	275 a-d	14 jkl	24 b-e

[a] Means within a site followed by the same letter do not differ at P = 0.05. Identical means may be followed by different letters because of the square root transformation conducted prior to data analysis.

[b] NT = no-tillage, CT = conventional tillage, Mean = pooled over tillage.

[c] Standard treatment differed with tillage and consisted of glyphosate applied POST in NT and trifluralin applied PPI in CT.

Appendix R. Tillage and cheat management program interaction on wheat head density in the succedent wheat crop.

		Site 1	Site 2		Site 3
Cheat management program		Tillage[a]			
Crop sequence	Weed control strategy	Mean	NT	CT	Mean
		no./m^2			
Soybean fb soybean	No herbicide	310	350	255	355
	Alachlor	300	350	240	345
	Metolachlor	290	380	295	395
	Pendimethalin	310	345	355	345
	Glyphosate + chlorimuron	310	355	240	355
	Metolachlor + flumetsulam	290	400	260	350
	Pendimethalin fb imazethapyr	310	320	360	345
	Standard treatment[b]	320	375	205	345
Sorghum fb soybean	No herbicide	315	355	345	370
	Alachlor	320	430	305	395
	Atrazine	290	335	340	365
	Metolachlor	300	380	360	390
	Atrazine + 2,4-D	315	415	315	395
	Atrazine + alachlor	295	400	370	370
	Atrazine + metolachlor	325	405	285	395
	Atrazine + prosulfuron	315	365	330	370
Continuous	No herbicide	195	195	275	330

wheat	Forage-only	255	255	345	335
	Metribuzin, fall	220	265	255	305
	MKH 6561, fall	260	230	295	300
	MKH 6561, winter	260	255	355	335
	MON 37500, fall	255	225	290	315
	MON 37500, winter	255	235	315	310
	MON 37500 + 2,4-D, winter	250	260	290	315
	LSD (0.05)	50	—— 95 ——		45

[a] NT =no-tillage, CT = conventional tillage, Mean = pooled over tillage.

[b] Standard treatment differed with tillage and consisted of glyphosate applied POST in NT and trifluralin applied PPI in CT.

Appendix S. Tillage and cheat management program interaction on dockage in the succedent wheat crop.

Cheat management program[b]		Site 1		Site 2		Site 3
		Tillage[a]				
Crop sequence	Weed control strategy[c]	NT	CT	NT	CT	Mean
		%				
Soybean fb soybean	No herbicide	3	4	7	10	6
	Alachlor	4	3	5	7	5
	Glyphosate + chlorimuron	4	4	5	13	2
	Metolachlor	4	5	5	6	5
	Metolachlor + flumetsulam	5	5	5	9	4
	Pendimethalin	6	4	10	8	5
	Pendimethalin + imazethapyr	4	4	5	11	2
	Standard treatment[c]	4	5	5	8	3
Sorghum fb soybean	No herbicide	4	4	4	5	2
	Alachlor	5	5	5	5	2
	Atrazine	4	5	4	5	2
	Metolachlor	5	6	7	6	3
	Atrazine + 2,4-D	3	9	1	6	2
	Atrazine + alachlor	8	4	5	2	3
	Atrazine + metolachlor	13	4	9	9	3
	Atrazine + prosulfuron	4	5	5	5	2
Continuous wheat	No herbicide	40	18	16	10	14

Forage-only	12	5	14	7	10
Metribuzin, fall	33	22	13	10	9
MKH 6561, fall	8	6	14	8	6
MKH 6561, winter	8	16	18	6	6
MON 37500, fall	20	5	17	8	9
MON 37500, winter	9	7	19	7	8
MON 37500 + 2,4-D, winter	12	6	17	7	13
LSD (0.05)	—8—		—5—		9

[a] NT = no-tillage, CT = conventional tillage, Mean = pooled over tillage.

[b] In addition to the herbicides listed, glyphosate at 1.1 kg/ha was applied PRE to all NT treatments.

[c] Standard treatment differed with tillage and consisted of glyphosate applied POST in NT and trifluralin applied PPI in CT.

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VITA

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