SYSTEMS FOR RETURNING CONSERVATION RESERVE PROGRAM LAND TO WHEAT (*Triticum aestivum*)

By

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SYSTEMS FOR RETURNING CONSERVATION

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WHEAT (*Triticum aestivum*)

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TABLE OF CONTENTS

LIST OF TABLES

Systems for Returning Conservation Reserve Program Land to Wheat (*Triticum aestivum*)

Systems for Returning Conservation Reserve Program Land to Wheat (*Triticum aestivum*)[1]

CASE R. MEDLIN, THOMAS F. PEEPER,
JAMES H. STIEGLER and JOHN B. SOLIE[2]

Abstract. Experiments were established in southwestern Oklahoma near Duke and in the Oklahoma panhandle near Forgan on Conservation Reserve Program (CRP) land seeded to Old World bluestem (OWB) (*Bothriochloa ischaemum*) to evaluate herbicide and tillage systems for returning CRP grassland to wheat production. A split-block design, with a factorial arrangement of subplot treatments and an added check, with four replicates was used at each site. The main factor was primary tillage treatments, i.e. no-till, disk, or moldboard plow. The subplot factor, herbicide treatments, included glyphosate at 280, 560, 840, 1120, and 1680 g ae/ha and glyphosate + 2,4-D at 320 + 530 and 430 + 720 g ae/ha, applied in May and July at Forgan, and June and July at Duke and an untreated check. Primary tillage was conducted 24 h after July herbicide treatments were applied. Herbicides controlled OWB 72% or less in the no-till

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plots. Without herbicides, disking controlled OWB 87% and 96% and moldboard plowing controlled it 99% and 100% at the respective sites. Control in no-till plots was higher when herbicides were applied in July than when applied in May or June. OWB growth in no-till plots decreased soil moisture storage. Compared to disking without herbicide, applying glyphosate at 1680 g/ha in July then disking increased soil moisture storage in most sampling depths. Wheat emergence was greater in tilled than in no-till plots. Compared to the no-till no-herbicide treatment, tillage tripled wheat yields. Pretillage herbicide application increased wheat yield in 3 of 4 tilled systems. **Nomenclature:** 2,4-D, (2,4-dichlorophenoxy)acetic acid; glyphosate, N-(phosphonomethyl)glycine; Old World bluestem, Bothriochloa ischaemum L. #[3] DIHIS; hard red winter wheat, Triticum aestivum L.

Additional index words: Conservation Reserve Program, glyphosate, 2,4-D, Old World bluestem, DIHIS.

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[3] Letters following this symbol are a WSSA approved computer code from Composite List of Weeds, Revised 1989. Available from WSSA, 1508 West University Ave., Champaign, IL 61821-3133.

INTRODUCTION.

The Conservation Title of the 1985 Food Security Act created the Conservation Reserve Program (CRP)[4], a ten year program to convert highly erodible land (HEL)[4] to permanent vegetation and thereby limit soil erosion. Under the program, contracts were established with farmers for keeping HEL in permanent vegetation. In return, the farmer received payments for each acre enrolled. The first contracts were scheduled to expire in October 1995, however, the United States Department of Agriculture extended those contracts for one year to give policy makers more time to decide the fate of the CRP (Hoehn 1995). Thus, in October 1996, CRP contracts signed in 1985 and 1986 (which cover 40% of CRP land) will expire. Estimates indicate that 60% to 70% of producers will put their land back into cultivated crop production (Harris 1991).

CRP land is not spread evenly across the United States, rather it is concentrated in the Northern and Southern Great Plains and the Mountain regions (Young and Osborn 1988). Nationwide, approximately 2400 counties have land in CRP, but only 25% of the 2400 counties contain 80% of the total land area (Dicks and Coombs 1994). This scenario applies to Oklahoma where

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[4] Abbreviations: CRP, Conservation Reserve Program; HEL, highly erodible land, i.e., land whose potential erosion is equal to or greater than eight times the rate at which the soil can maintain continued productivity (U.S.D.A. 1992); OWB, Old World bluestem.

over 480,000 ha are enrolled in CRP and 40% of this land is in the three Oklahoma panhandle counties (Beaver, Cimarron, and Texas) while another 15% is in Oklahoma counties bordering the Texas panhandle (Beckham, Ellis, Harmon, and Roger Mills)[5].

The primary factor governing CRP conversion systems across the Great Plains is control of the cover species. Approximately 90% of the CRP lands in the Corn Belt were planted to cool-season perennial grasses (Dicks and Coombs 1994). Excellent control of cool-season perennial grasses tall fescue (Festuca arundinacea) (Zarnstorff et al. 1990), smooth bromegrass (Bromus inermis), meadow bromegrass (Bromus biebersteinii), intermediate wheatgrass (Agropyron intermedium), tall wheatgrass (Agropyron elongatum), and orchardgrass (Dactylis glomerata) (Vogel et al. 1983) with fall or spring applied glyphosate at 1.7 to 2.3 kg ai/ha has been reported. However, the primary species planted on Oklahoma and western Texas CRP lands was a warm-season perennial grass, Old World bluestem (OWB)[4] (Berg 1993). It was selected for it's relative ease of establishment, high forage production potential, and available seed supply (Berg 1993), however, little is known about the persistence of OWB as a weed in wheat or about the efficacy of glyphosate on OWB.

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[5] Heizer, R. B. Assistant State Conservationist, USDA / NRCS. Oklahoma Bulletin No. OK4-10. April 5, 1994.

In the subhumid/semiarid climate of western Oklahoma, precipitation distribution is highly variable. In this region, seedling emergence, early vegetative growth and seedling development are hampered more by soil water deficiency than by any other input or environmental factor (Dao 1993). Current CRP contracts prohibit killing the sod with tillage and/or herbicides before July 1 and planting before October 1, of the year the contract expires. McGlamery (1995), suggested that glyphosate would control CRP grasses more effectively when applied in the fall rather than in the spring. However, waiting until fall to control the perennial CRP grass could deplete soil moisture, and thus result in a first-year winter wheat crop failure or may force producers to wait until the following fall to plant the first wheat crop.

Although tillage can contribute to soil erosion, it should control CRP grass and thus increase soil moisture storage. Tillage systems available to farmers returning CRP to crops include; 1) conventional tillage, 2) reduced tillage, 3) no-till, and 4) tillage followed by no-till in subsequent years (Anonymous 1995). Each has its advantages and disadvantages. By fracturing and inverting the top 15 to 20 cm of sod, moldboard plowing assists in perennial weed control better than reduced-tillage systems (Buhler et al. 1994). Initial ridges formed by the plow reduce water runoff and enhance water infiltration (Stein et al. 1986).

In a New Mexico CRP conversion research project, higher yields were produced with conventional tillage than with either minimum or no-till systems the first year after CRP (Pigg 1995).

Sweep plowing, used in a stubble mulch tillage system, was the most successful at increasing soil water storage during the fallow season in the Texas Panhandle (Wiese et al. 1994), since it incorporates a minimum amount of surface residue. In a ten year study conducted in north central Oklahoma, wheat yields increased with tillage intensity (Epplin et al. 1994). These authors concluded that wheat yields decrease as wheat plant residue left on the soil surface increases. However, due to the high erodibility of most CRP land, a no-till production system would be ideal for erosion control and therefore should be researched.

The objectives of this research were: 1) to determine which primary tillage system, i.e. moldboard plow, disk, or no-till would be best for killing the sod while producing a high yielding first year wheat crop, 2) to determine the effects of selected herbicides, applied to kill the OWB, on first-year wheat stands and yields, and 3) to determine whether herbicide application timing affects OWB control and soil moisture storage.

MATERIALS AND METHODS.

Experiments were established on private land under 10 year CRP contracts planted to OWB to evaluate tillage and herbicide combinations for returning CRP grassland to wheat. The sites were in southwestern Oklahoma, near Duke, elevation 420 m, on a seven year old stand of OWB, and in the Oklahoma

Panhandle, near Forgan, elevation 760 m, on an eight year old stand of OWB. Table 1 contains soil information and initial nutrient status at each location.

Permission to conduct this research was granted by OK amendment 1 paragraph 139 of the A.S.C.S. handbook (Rev. 2) (U.S.D.A. / A.S.C.S. 1991). However, there was a delay in locating a farmer cooperator in southwest Oklahoma willing to permit the destruction of their CRP grass. Thus, research was started in early May at Forgan and early June at Duke.

A split-block design, with a factorial arrangement of subplot treatments and an added check, with four replications was used for each experiment. The main factor was primary tillage treatments, i.e. moldboard plow, disk, and no-till. These tillages were selected based on maximum, intermediate and minimum residue incorporation. The subplot (herbicide) treatments included glyphosate applied at 280, 560, 840, 1120, and 1680 g ae/ha, and glyphosate + 2,4-D (1:1.58 premix) applied at 320 + 530 and 430 + 720 g ae/ha and a no-herbicide check. Herbicide treatments were broadcast with water carrier in a spray volume of 90 L/ha using a tractor mounted CO_2-pressurized sprayer with a 6 m boom. Ammonium sulfate (2% w/w) was added to each herbicide treatment and 0.5% v/v nonionic surfactant was also added to all glyphosate alone treatments. The herbicide treatments were applied at Forgan on May 17 and July 5 and at Duke on June 17 and July 6. Table 2 contains monthly temperature and rainfall totals for each site. At application, OWB was actively growing and 25 to 35 cm tall at Forgan and 85 to 90 cm tall at Duke. OWB biomass was harvested from a 1.2 m^2 quadrat in each no-till no-herbicide plot prior to tillage.

Foliage plus residue totaled 23,030 (s.d.=7800) kg/ha at Duke and 8070 (s.d.=2460) kg/ha at Forgan. OWB ground cover was 100% at Duke and varied from about 40% to 70% at Forgan where there was no indication of natural seedling establishment to fill in gaps between mechanically seeded plants. Only a few scattered weeds were present at either site. To maintain maximum soil cover in the no-till plots and to aid soil tilth in tilled plots, OWB residue was not removed.

Plots were first tilled 24 h after herbicide treatments were applied in July. Prior to tillage, 340 kg/ha of 34-0-0 fertilizer was broadcast across the experiment to supply nitrogen for grass decomposition. Moldboard plowing was 15 to 20 cm deep with a two bottom mounted plow (Table 3). The plow formed continuous ribbons of sod approximately 35 cm wide and 10 cm thick that were held together by OWB root masses. Soil structure below 10 cm appeared unaffected by OWB root mass. The plow was followed by a single gang cultipacker, to help shatter and compact the distinct 10-cm thick layer of sod. At Duke, the moldboard plow was followed by a 4-m offset disk to help cut the sod, then packed the same day to reduce air pockets in the tilled layer (MacEwan 1983).

The disk system plots at Forgan were tilled with a 9-m tandem disk. However, to penetrate the sod the outside gangs were folded to add weight to the 3-m wide center section. At Duke the disk system plots were tilled with a 4-m offset disk. Although both disks penetrated the soil 6 to 10 cm, initial disking appeared to incorporate little of the OWB residue.

During the next 2 months, the tilled plots at both locations were disked two additional times. To reduce sod clumps in the clay loam at Duke, the plots in the plow system were also packed with a specially constructed 60-cm-diameter rolling packer, 180-cm-long weighing approximately 1100 kg. This packer was not used at Forgan since clumping of the soil was not a major problem.

Prior to planting, one 3.2-cm diameter soil core 120 cm deep was removed from each plot treated with glyphosate at 280 and 1680 g/ha at both herbicide application timings and the no-herbicide checks to determine soil moisture differences among treatments. The cores were divided into 0 to 15, 15 to 30, 30 to 60, 60 to 90, and 90 to 120 cm depth segments. Segments were then oven dried at 100 °C for 48 h to determine soil moisture content at the time of planting (Tan 1996). OWB control was evaluated visually prior to planting and at wheat harvest.

The tilled plots were planted with double disk grain drills with 20-cm row spacing at Duke and 10-cm row spacing at Forgan. A more narrow row spacing was used at Forgan to help control potential wind erosion. Narrow row spacings increase plant distribution uniformity which reduces runoff rates, produces earlier canopy cover and intercepts raindrop energy more effectively (Dabney et al. 1993). The no-till plots at both locations were planted with no-till drills with 25-cm row spacing. Both no-till drills had difficulty planting through the heavy residue cover. Although the coulters adequately penetrated and cut the sod, loose residue on the soil surface became lodged between furrow openers causing the drills to plug with residue and soil. Hard red winter wheat cultivar 'Tomahawk'[6] was seeded at 100 kg/ha. At planting, 170 kg/ha of 18-46-0 fertilizer was applied in accordance with P_2O_5 soil test recommendations taken prior to tillage for a 4030 kg/ha yield goal. Prior to reproductive growth, experiments were fertilized with 340 and 270 kg/ha 34-0-0 fertilizer at Duke and Forgan, based on recommendations of soil tests taken at planting.

Approximately one month after planting, the wheat plants per m of drill row in each subplot were counted to determine effects of tillage and/or herbicide treatments on wheat emergence. At wheat maturity, grain was harvested from two 10 m^2 areas of each plot with a small plot combine. The samples were recleaned to remove chaff and straw. Wheat moisture content, volume weight, and grain yield, adjusted to 13.5% moisture, were determined after cleaning.

Soil moisture data were statistically analyzed using analysis of variance to determine differences due to location, tillage, herbicide, herbicide application time, and/or core depth. OWB control, wheat emergence, and wheat yield data were statistically analyzed using orthogonal contrasts constructed to determine differences due to location, tillage, herbicide treatment and herbicide application time. All means were separated with LSDs at the $P = 0.05$ level.

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[6] AgriPro Seeds Inc., 806 N. 2nd Street, Berthoud, CO 80513

RESULTS AND DISCUSSION

Location was significant in each data analysis. Therefore, all data are presented by location.

Old World bluestem control. A tillage by herbicide treatment interaction and a tillage main effect occurred in OWB control when evaluated prior to fall wheat planting at both sites. No interaction with application date, or herbicide main effect was found thus data were pooled over application date. At Duke and Forgan, OWB control in the no-till plots with glyphosate at 280 g/ha (evaluated prior to planting) was 76% and 34% (Table 4). Increasing the glyphosate rate to 1680 g/ha or adding 2,4-D did not increase control in no-till plots.

Disking without prior herbicide treatment controlled 95% and 75% of the OWB at Duke and Forgan, while plowing without herbicide controlled 100% and 88%. Applying glyphosate or glyphosate + 2,4-D prior to tillage did not improve OWB control over tillage alone.

A tillage by herbicide treatment interaction was also found when OWB control was evaluated at-wheat harvest (Table 4). In no-till plots, OWB control at harvest, (approximately 1 year after treatment), decreased from the at planting ratings. At Duke, 72% of the OWB was controlled with glyphosate at 1680 g/ha without tillage, while at Forgan 53% of the OWB was controlled with this treatment.

Control at Duke in all tilled plots and at Forgan in the plow system plots was 96% to 100% regardless of herbicide application. At Forgan, applying glyphosate at

840 to 1680 g/ha in the disk system plots increased OWB control 9% to 11% over disking without prior herbicide treatment.

A tillage by herbicide application time interaction, averaged over herbicide treatments, was found when OWB control was evaluated at wheat harvest at Forgan (Table 5). Averaged over herbicide treatments, i.e. excluding the no-herbicide plots, control in the no-till system was increased from 9% with May 14 herbicide application to 64% with July 5 application. Increased control may be attributed to more green growth of OWB present at herbicide application in July. Thus, trying to conserve soil moisture by controlling OWB with glyphosate earlier than current CRP contracts permit the grass to be destroyed (July 1) may not be feasible. However, tillage increased control to near 100% regardless of herbicide application time.

At Duke, herbicide application time did not affect OWB control. This was attributed to the one month later application of the first herbicide treatments.

Soil Moisture. A tillage system by glyphosate rate by application time by core depth interaction was found in the soil moisture data at both sites. In the no-till plots with no herbicide applied (undisturbed OWB) at Forgan, soil moisture at planting declined from 6.1% to 3.8% as profile depth increased from 15 to 30 cm to 90 to 120 cm (Table 6). Compared to the no-till no-herbicide treatment, glyphosate at 280 g/ha did not increase soil moisture storage in the top four sampling depths at Forgan, while this treatment at Duke did not increase soil moisture storage below the 0 to 15 cm sampling depth (Table 7). At Forgan, glyphosate at 1680 g/ha applied May 14 in the no-till plots increased soil moisture at 90 to 120 cm, while this treatment applied July 5 increased soil moisture at 0 to 15 cm and 15 to 30 cm. At Duke, glyphosate at 1680 g/ha applied June 14 to the no-till system increased soil moisture at the 60 to 90 cm and 90 to 120 cm depths.

At Forgan, without herbicide, disk tillage increased profile moisture at the 0 to 15, 15 to 30 and 90 to 120 cm depths. Moldboard plow tillage without herbicide further increased soil moisture storage at the 15 to 30 cm depth at this site. Compared to the no-herbicide treatment in the respective tillage-sampling depth combinations, applying glyphosate at 1680 g/ha on May 14 increased soil moisture content in 8 of 15 tillage by sampling depth combinations and applying glyphosate at 1680 g/ha on July 5 increased soil moisture content in 7 of 15 tillage by sampling depth combinations. In the disk tillage system applying glyphosate at 1680 g/ha at either date increased soil moisture storage down to 90 cm.

At Duke in the moldboard plowed system, glyphosate at 1680 g/ha applied July 6 increased soil moisture in only 1 of 5 sampling depths and 2 of 5 sampling depths when applied on June 14. Applying glyphosate at 1680 on June 14 in the disk tillage system increased moisture storage in 3 of 5 sampling depths. However, when glyphosate at 1680 g/ha was applied on July 6 and plots were disked the following day, soil moisture content was increased throughout the 120 cm profile.

Wheat emergence. Herbicide treatment or herbicide application timing did not affect wheat emergence, however, tillage did. At Forgan wheat density was 71 and 62 plants / m^2 in the moldboard and disk systems respectively, and 37 plants / m^2 in the no-till treatment ($P = 0.0004$, $LSD = 10$). At Duke, 53 plants / m^2 emerged in the disk and moldboard systems and 22 plants / m^2 emerged in no-till plots ($P = 0.0001$, $LSD = 8$).

In the no-till plots, heavy surface residue at the time of planting inhibited proper placement and coverage of the wheat seed. In contrast, tillage buried much of the OWB residue, and loosened the soil surface which prepared a better seedbed for planting. For these reasons tillage appears necessary for first year wheat production after CRP.

Wheat yield. Herbicide application time did not affect wheat yield, however, there were tillage main effects and tillage by herbicide treatment interactions in the wheat yield data at Duke and Forgan. There was a quadratic response between glyphosate rate and wheat grain yield in the no-till plots ($y = 1011.82989 + 0.79741x - 0.00029x^2$, $r^2=0.64$ and $y = 698.87783 + 0.64553x, - 0.00024x^2$, $r^2=0.67$ at Duke and Forgan). In the no-herbicide no-till plots wheat yield was 580 kg/ha at Duke and 530 kg/ha at Forgan (Table 8). Glyphosate at 280 g/ha applied to no-till plots at either site, did not increase wheat yield compared to the no-herbicide treatment. However, glyphosate at 560 g/ha or more at Duke and Forgan, or glyphosate plus 2,4-D at either rate at Duke increased wheat yield in no-till plots. The highest yielding no-till treatment produced 1650 kg/ha of grain at Duke and 1140 kg/ha at Forgan. Without herbicide, wheat yield in the disk system at Forgan and plow system at Duke and Forgan was greater than the highest yielding no-till treatments.

At Duke, without prior herbicide treatment, disk system plots averaged 2150 kg/ha of grain while plow system plots averaged 2350 kg/ha. Applying glyphosate at

1680 g/ha prior to disking increased grain yield to 2790 kg/ha and applied prior to plowing increased yield to 3030 kg/ha at this site.

At Forgan, disk system plots without herbicide treatment yielded 1660 kg/ha of wheat, while plow system plots without herbicide yielded 1690 kg/ha. At this site, glyphosate at 1680 g/ha followed by plowing increased wheat yield to 2110 kg/ha.

Compared to the no-herbicide treatment in the respective tillage systems, glyphosate + 2,4-D at either rate did not increase wheat yields at either location. Within either glyphosate + 2,4-D treatment, disking and plowing increased wheat yield compared to the no-till system while plowing more than doubled grain production at both sites.

Glyphosate at all rates applied in May or June (before CRP contracts permit) or at 280 g/ha at either date failed to control OWB enough to prevent continued growth of the grass and soil moisture depletion. Although plowing and disking without herbicide disturbed the roots of the perennial grass, some OWB continued to grow and use soil moisture which decreased wheat yields. However, applying glyphosate at 1680 g/ha in July and disking the following day slowed OWB regrowth, enabled more soil moisture storage, and thus increased wheat grain yields.

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Table 1. Soil information and initial nutrient status at the research sites near Duke and Forgan, Oklahoma.

Soil Information	Duke	Forgan
Series	Tillman (formerly La Casa)	Dalhart
Texture	clay loam	fine sandy loam
Classification	Fine, mixed, thermic, Typic Paleustoll	Fine-loamy, mixed, mesic, Aridic Haplustalfs
Organic matter (g/kg)	23	8
pH	8	8
Nitrogen (mg/kg) 0-10 cm	3.5	6.3
Phosphorus (mg/kg) 0-10 cm	15	10
Potassium (mg/kg) 0-10 cm	500	200

Table 2. Monthly temperature and rainfall records for Duke and Forgan, Oklahoma. Data collected approximately 10 miles from each site by automated weather stations.

		Duke				Forgan			
		Temperature			Total	Temperature			Total
Year	Month	High	Low	Mean	precipitation	High	Low	Mean	precipitation
		°C			cm	°C			cm
1994	April	36	4	17	9.4	36	-8	14	3.8
	May	37	3	22	6.1	39	1	21	2.3
	June	48	18	31	2.5	44	16	28	7.0
	July	41	17	29	4.3	43	11	28	6.1
	August	41	15	28	1.8	42	13	27	3.3
	September	39	6	24	3.4	39	2	22	5.8
	October	36	1	18	4.5	29	-1	16	3.6
	November	30	-2	11	12.3	29	-9	8	3.9
	December	22	-6	6	0.7	24	-8	4	0.0
1995	January	29	-7	5	1.7	25	-12	3	0.0
	Febuary	29	-8	8	0.4	27	-9	6	0.0
	March	34	-9	11	3.1	33	-14	10	4.4
	April	36	-2	15	8.0	34	-6	12	1.5
	May	36	7	19	12.7	32	3	16	12.4
	June	38	13	24	23.4	37	8	22	12.7
	July	44	16	29	11.1	41	13	27	5.0

Table 3. Tillage operations conducted and equipment used at Duke and Forgan.

Location	Date	Tillage system	Equipment used	Tillage operation
Duke	July 7	Moldboard	two bottom plow	plowed 15-20 cm deep
			4 m offset disk	disked 6-10 cm deep
			single gang cultipacker	cultipacked
		Disk	4 m offset disk	disked 6-10 cm deep
	Aug. 22	Moldboard and Disk	4 m offset disk	disked 10-15 cm deep
	Aug. 30	Moldboard	1100 kg packer	packed soil
	Oct. 10	Moldboard and Disk	4 m offset disk and spike-tooth harrow	disked 10-15 cm deep then spike-tooth harrowed
Forgan	July 6	Moldboard	two bottom plow	plowed 15-20 cm deep
			cultipacker	cultipacked after plow
		Disk	9 m tandem disk	disked 6-10 cm deep
	Aug. 24	Moldboard and Disk	9 m tandem disk	disked 10-15 cm deep
	Oct. 12	Moldboard and Disk	9 m tandem disk and spike-tooth harrow	disked 10-15 cm deep then spike-tooth harrowed

Table 4. Visual estimates of Old World bluestem control prior to wheat planting and at wheat harvest at Duke and Forgan.

		Prior to planting						At wheat harvest					
		Duke			Forgan			Duke			Forgan		
		Tillage											
Herbicide(s)	Rate	No-till	Disk	Moldboard	No-till	Disk	Moldboard	No-till	Disk	Moldboard	No-till	Disk	Moldboard
	g ae/ha	%											
Glyphosate	280	76	96	100	34	78	94	21	98	99	24	92	99
Glyphosate	560	86	97	100	31	81	96	49	99	100	30	93	100
Glyphosate	840	86	97	100	38	87	94	59	99	100	45	97	100
Glyphosate	1120	85	97	100	35	86	96	71	99	100	50	96	100
Glyphosate	1680	88	97	100	37	90	95	72	98	100	53	98	100
Glyphosate + 2,4-D	320 + 530	78	97	100	25	86	94	37	99	100	20	93	100
Glyphosate + 2,4-D	430 + 720	80	97	100	30	80	94	30	98	100	32	94	100
None	——	0	95	100	0	75	88	0	96	100	0	87	99
LSD (0.05)		13.0			18.1			16.8			8.4		

Table 5. Tillage method by herbicide time of application interaction in Old World bluestem control at wheat harvest at Duke and Forgan.

Location	Herbicide Application Date	Tillage No-till	Disk	Moldboard
			%	
Forgan	May 14	9	93	99
	July 5	64	96	100
LSD (0.05)			10.6	
Duke	Mean	45	99	100
LSD (0.05)			9.9	

Table 6. Soil moisture content at planting by soil depth at Forgan.

		Glyphosate (g/ha)				
			Application date			
	Tillage		May 14		July 5	
Depth	system	0	280	1680	280	1680
(cm)				%		
0-15	No-till	4.7	4.9	4.8	5.2	9.0
	Disk	8.7	8.6	10.7	10.3	11.0
	Moldboard	9.8	10.1	10.1	9.8	10.7
15-30	No-till	6.1	6.4	6.2	6.4	9.7
	Disk	7.9	9.1	10.6	8.6	11.7
	Moldboard	9.4	9.9	11.9	8.7	10.7
30-60	No-till	5.9	5.6	5.8	5.4	6.1
	Disk	6.5	7.3	9.6	6.8	8.4
	Moldboard	6.5	7.1	9.8	5.9	6.5
60-90	No-till	5.6	3.8	4.4	5.1	5.1
	Disk	5.0	5.3	6.9	4.8	6.5
	Moldboard	5.0	5.0	6.7	4.4	5.3
90-120	No-till	3.8	2.1	6.0	8.3	3.2
	Disk	5.1	4.9	6.0	4.9	5.6
	Moldboard	5.0	4.3	5.3	3.6	4.4
LSD (0.05)				1.15		

Table 7. Soil moisture content at planting by soil depth at Duke.

		Glyphosate (g/ha)				
			Application date			
	Tillage		June 14		July 6	
Depth	system	0	280	1680	280	1680
(cm)		%				
0-15	No-till	10.9	10.8	12.2	12.6	11.8
	Disk	12.8	12.6	14.2	10.8	14.5
	Moldboard	11.0	12.1	12.8	11.0	11.7
15-30	No-till	11.2	11.4	10.4	8.7	12.0
	Disk	12.5	13.6	15.7	10.9	14.3
	Moldboard	13.3	13.8	14.1	12.9	12.9
30-60	No-till	11.2	10.8	11.0	7.9	12.0
	Disk	11.9	13.9	15.2	11.8	14.5
	Moldboard	12.8	14.1	15.0	12.1	12.3
60-90	No-till	9.4	9.9	13.2	8.0	12.7
	Disk	12.9	14.6	15.8	12.1	15.5
	Moldboard	13.2	15.0	14.4	12.4	13.6
90-120	No-till	12.4	12.6	16.1	9.7	13.7
	Disk	14.2	15.3	15.3	13.0	16.7
	Moldboard	13.1	15.6	13.9	12.9	14.8
LSD (0.05)		1.58				

Table 8. Interaction of herbicide treatment and tillage system averaged over date of herbicide application on wheat grain yields at Duke and Forgan.

		Duke			Forgan		
		Tillage system					
Herbicide(s)	Rate	No-till	Disk	Moldboard	No-till	Disk	Moldboard
	g/ha	kg/ha					
Glyphosate	280	1180	2720	2970	870	1860	1920
Glyphosate	560	1330	2660	2950	1060	1820	1870
Glyphosate	840	1500	2810	2760	1020	1970	2120
Glyphosate	1120	1650	2670	2800	1130	2030	2110
Glyphosate	1680	1630	2790	3030	1140	1950	2110
Glyphosate+2,4-D	320 + 530	1340	2680	2920	830	2000	1920
Glyphosate+2,4-D	430 + 720	1380	2480	2870	880	2000	1940
None	——	580	2150	2350	530	1660	1690
LSD (0.05)			614			375	

VITA

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