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Integrated Management of Cheat *(Bromus secalinus* L.*)* and Downy Brome (*Bromus tectorum* L.) in Oklahoma Grain Only Winter Wheat

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Nomenclature: pyroxsulam; sulfosulfuron; cheat, *Bromus secalinus* L. BROSE; downy brome, *Bromus tectorum* L. BROTE; winter wheat, *Triticum aestivum* L. TRZAX;

ABSTRACT

In Oklahoma, downy brome and cheat are difficult-to-control winter annual grasses. In the past, cheat infested most of the winter wheat hectares harvested in Oklahoma. Biotypes cross-resistant to acetolactate-synthase-inhibiting herbicides have left growers with minimal management options in conventional and herbicide-tolerant systems. Field trials at Lahoma, Oklahoma in 2019-20 and 2020-21 evaluated integrated management of cheat and downy brome using three strategies: planting date (optimal, mid-, and late), cultivar selection (high- and low-competitiveness), and herbicide choice (no herbicide, sulfosulfuron at 35.2 g ai ha^{-1} and pyroxsulam at 18.4 g ai ha^{-1}). Visual control, weed species (spp.) present, wheat biomass at heading, and grain yield data were collected. In 2019-20, eight to nine weeks after treatment, visual control increased 15% with mid-planting compared to optimal planting date and 14% with late planting compared to mid-planting. In 2020-21, similar control (~99%) was recorded for mid- and late plantings with 23% greater control than the optimal timing. Due to a lack of weed coverage, weed biomass in 2019-20 had no response to planting date, cultivar, or herbicide treatment. Downy brome biomass during 2020-21 was ~90% lower with mid to late planting than optimal. In the same year, downy brome and cheat biomass were low ($\leq$ 0.4 and 0.2 g m^{-2}) and 98% less after an herbicide application than nontreated. Wheat grain yield at the optimal planting date was greatest compared to mid- and late planting date for 2019-20. A delay in planting from the optimal date to mid- or late timings decreased wheat yield 14 and 21%, respectively. In 2020-21, late planting reduced wheat yield 57% compared to optimal planting. Delaying planting date and the use of a common herbicide can suppress cheat and downy brome., but a decline in wheat yield may occur.

Keywords: Planting date, cultivar, herbicide, weed control

Introduction

From 2020 to 2022, Oklahoma was ranked second or third in the nation for winter wheat production; winter wheat was the number one cash crop produced on 991 thousand ha harvested in Oklahoma during 2022 (USDA 2022). Oklahoma winter wheat is unique because producers utilize the system for forage and/or grain purposes, increasing the diversity of products and income for the year. When utilizing the land for forage and grain, producers will place cattle out to graze wheat through mid-fall and winter, remove cattle before wheat jointing, and harvest grain in summer, known as a dual-purpose system. Because of the flexibility winter wheat systems provide, Oklahoma producers can either sow wheat for dual purpose from August to mid-October or seed for grain only from mid-October to November (Lollato 2017). Due to the diverse benefits dual-purpose winter wheat provides, many producers grow wheat season-to-season within the same field in a monoculture.

Additionally, in these continuous winter annual grass crop systems, winter annual grass weeds, such as downy brome (*Bromus tectorum* L.), form monospecific stands that adapt and thrive (Menalled et al. 2008). Persistence of winter annual grass weeds becomes common as continuous monoculture systems fail to break up pest cycles through lack of herbicide availability, cultural efforts, and use of crop rotation to hinder weed growth cycles.

Considering the unique and economically important resource of Oklahoma winter wheat in the state and region, the consistency of *Bromus* spp. infestations contribute to significant direct and indirect losses. Ratliff and Peeper (1987) observed dockage in harvested grain exceeding 40% in cheat-infested (*Bromus secalinus* L.) wheat fields. Other economically critical *Bromus* spp. found in Oklahoma winter wheat includes not only cheat but also Japanese brome (*Bromus japonicus* Thunb..), rescuegrass (*Bromus catharticus* Vahl.), and occasionally, downy brome. At one time, cheat infested approximately 1.4 million ha of harvested winter wheat in Oklahoma (Ratliff and Pepper 1987) and reduced grain yield up to 19% at a density of 89 plant m^{-2} (Fast et al. 2009). Downy brome densities can exceed 400 plants m^{-2} and may cause crop failure (Reddy et al. 2013).

Despite many regionally adapted wheat cultivars available to producers in Oklahoma and the region, cheat can still compete with wheat, causing grain and forage yield loss, delayed harvest operations, additional seed cleaning, and grain quality discounts for dockage, foreign material, or both. Immediate control and removal of *Bromus* spp., like cheat, can be correlated to

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reduced competition and higher crop yield response (Ratliff 1985) and quality. Cheat and downy brome have unique qualities that contribute to their weediness and persistence, such as an ability to germinate over a wide range of environmental conditions (Haferkamp et al. 1994). Downy brome grows rapidly in the spring, which reduces resources for wheat during heading, reducing yields by up to 20% (Menalled et al. 2008; Stahlman and Miller 1990)

Many *Bromus* spp. have evolved resistance to herbicides. As early as 2009, Oklahoma documented cheat cross-resistant to all acetolactate-synthase-inhibiting (ALS; WSSA Group 2) herbicides, including imazamox, propoxycarbazone-sodium, pyroxsulam, and sulfosulfuron (Heap 2021a). Quizalofop-resistant (CoAXium®) and imazamox-resistant (Clearfield®) winter wheat systems provide control of many winter annual grass species, including *Bromus* spp.; however, they are not a tool for sustainable management of WSSA Group 1 and Group 2 resistant species, such as downy brome; resistant to ALS and acetolactate-synthase-inhibitors in the Pacific Northwest (Heap 2024).

With recent documentation of ALS cross-resistant cheat in Oklahoma, imazamox is now ineffective in many regions, leaving wheat growers with only one option – to spray quizalofop in quizalofop-resistant wheat. However, without proper stewardship (crop and herbicide rotations) of the technology, continued development of WSSA Group 1 herbicide-resistant grass weed biotypes will occur. Some wheat fields still have susceptible cheat populations, where our study was located, allowing reliance on some herbicide. Herbicide-only management practices that fail to integrate other practices will result in the further selection of herbicide-resistant spp., likely not being detected until their populations reach 30% of total weed populations (Mahmood et al. 2014). Although, it is still critical that winter wheat systems utilize integrated weed management rather than relying on herbicides alone.

The lack of consistent, effective management strategies of cheat and downy brome. is a serious production problem facing many southern Great Plains winter wheat producers. To improve management of cheat and downy brome in the region, a study was conducted at Lahoma, Oklahoma over two growing seasons to evaluate the impact of wheat cultivar selection, planting date, and herbicide treatment on ALS-susceptible cheat and downy brome populations.

Materials and Methods

Field experiments were located at Lahoma (36°23'08.6"N 98°06'46.4"W; elevation of 380m), Oklahoma during the 2019-2020 and 2020-2021 winter wheat growing seasons. Soil type at Lahoma primarily consisted of a Grant silt loam (Fine-silty, mixed, superactive, thermic Udic Argiustolls) with an average pH of 5.9 and OM of 1.5%. Field trial growing seasons are referred to as the year grain harvest occurred. Winter wheat was sown from early October to mid-November (Table 1). In-season rainfall and average monthly temperature are listed in Table 2.

The experimental design was a three-way factorial treatment structure (3 planting dates x 2 cultivars x 3 herbicides), arranged as a split-plot design with 18 treatments with four replications. Main plots consisted of three planting dates, subplots represented one of two wheat cultivars, and sub-sub-plots included two herbicide treatments plus a nontreated control. Individual sub-sub plots were 2.2 m wide by 10 m in length. Nitrogen (N), phosphorus (P), and potassium (K) fertilizer was applied as indicated by soil test results. Fungicide was applied at wheat flag leaf emergence. Soil samples were collected from an acre of each field location prior to planting each year by obtaining 20 to 30 soil cores from 0 to 15 cm in depth. Samples were thoroughly mixed and analyzed at Oklahoma State University Soil, Water and Forage Analytical Laboratory (SWFAL; 136 Agricultural Hall, Oklahoma State University, Stillwater, OK) for pH, OM, and N-P-K analysis. Based on SWAFL results, N-P-K needs were applied either prior to planting or split into two applications: prior to planting and prior to green-up in the late winter/early spring.

Three planting dates were used to represent optimal, mid-, and late plantings (Table 1) for grain-only winter wheat production in Oklahoma. The optimal planting date occurred from October to mid-November (Lollato 2017), representing the optimal time to sow grain-only wheat for north central Oklahoma. The mid-planting date was approximately a two-to-three-week delay from the optimal, and the late planting date was approximately a five- to six-week delay from the optimal planting. Two high-yielding winter wheat cultivars were selected: one ('Showdown') with early canopy coverage and low forage-yielding characteristics during spring and 'Green Hammer' with low-competitive early canopy coverage and high forage-yielding characteristics during spring (OGI 2021). Fields were prepped with a disk and field cultivator; undercutting 10 cm below the soil surface and churning the topsoil with multiple shanks and teeth to smooth out the field. Wheat was seeded at a soil depth of 1.9 cm and a rate of 67 kg ha^{-1} using a grain drill

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with 19-cm row spacing. Immediately after each sowing for each planting date, a burndown application of glyphosate at 0.86 kg ae ha^{-1} with ammonium sulfate (AMS) at 2.85 kg ha^{-1} was sprayed to ensure a weed-free field before wheat emergence.

Herbicide treatments included two common ALS-inhibiting herbicides and a nontreated control (Table 2). Each herbicide treatment included a non-ionic surfactant at 0.25% v/v plus liquid urea-ammonium nitrate at 30% v/v. Treatments consisted of pyroxsulam (PowerFlex® HL, 18.4 g ai ha^{-1}, Corteva, 974 Centre Road Wilmington, DE 19805 USA) or sulfosulfuron (Outrider®, 35.2 g ai ha^{-1}, Valent U.S.A. LLC, 2600 Norris Canyon Road, San Ramon, CA 94583) applied at the 2- to 3-leaf stage of cheat and downy brome at each site and planting date. Herbicides were sprayed at the recommended labeled rate using water as the carrier with a CO_2-pressurized backpack sprayer calibrated to deliver 140 L ha^{-1} at 1.6 kph, using Turbo TeeJet® 11002 nozzles. As previously mentioned, cross-resistant ALS cheat has been confirmed in the state; however, a susceptible biotype was present at this site for both cheat and downy brome. Downy brome has recorded ALS resistance in Oregon and Montana but not Oklahoma.

Visual control estimates of cheat and downy brome (Table 3) were evaluated approximately eight to nine weeks after treatment using a scale of 0 to 100 percent, where 0 equaled no weed control and 100 equaled complete control. At the heading of wheat, downy brome, cheat, wheat biomass was collected from one m2 quadrat between the second and third row of the crop from the west side of each plot. Biomass samples were separated by species in the field. Samples were dried in ovens at 60 C for five days, weighed, and recorded. Wheat was harvested in June or July of each year (Table 2) with a small-plot combine (Model Classic Plus, Wintersteiger Inc, Salt Lake City, UT).

Due to significant site year-by-treatment interactions, all site years were analyzed independently. Fixed effects included planting date, winter wheat cultivar, and herbicide treatment, with replication considered a random effect. Observations of fixed-effect interactions were also included. A univariate analysis was performed on all responses to test for stable variance (Version 9.4, SAS Institute Inc., SAS Campus Drive, NC). No data sets were transformed, as transformation did not increase stabilization. Data sets were analyzed using PROC GLIMMIX and treatments were separated by Fisher's Protected LSD at an α level of 0.05.

Results and Discussions

There were no significant effects of wheat cultivar on visual control of cheat or downy brome, the biomass of cheat, downy brome, and wheat, or wheat grain yield. There were also no significant interactions between wheat cultivar and planting date, wheat cultivar and herbicide, or wheat cultivar, planting date, and herbicide. Consequently, data were averaged across cultivars within planting dates and herbicide treatments. Data for cultivar selection will not be discussed in the following results. It is critical to note that only two cultivars were assessed.

Cheat and Downy Brome

Visual Control

Weed species data are presented by year to account for differences observed across total species and population variations. In 2020, planting date affected cheat and downy brome visual control eight to nine weeks after treatment (Table 3). A delay in planting allowed for a longer window to apply glyphosate as a burndown treatment to control emerged *Bromus* spp. before sowing wheat, ultimately reducing the amount of cheat and downy brome vegetation observed. Visual cheat and downy brome control increased 9% at the mid-planting compared to the optimal and increased 13% at the late planting compared to the mid-planting. In 2021, similar visual control (~99%) was recorded for mid- and late plantings and was 23% greater than visual control following the optimal planting.

The effects of planting date on cheat and downy brome are similar to those reported by Koscelny et al. (1991). Wheat plots planted in September, October, and November at Lahoma, Oklahoma, averaged 84, 71, and 11 plants m^{-2}, respectively. Massee (1976) observed similar trends in Idaho when downy brome was purposely planted with winter wheat across three planting dates (September 20, October 3, and October 19), with downy brome germination declining as planting date was delayed. Delaying planting not only reduces weeds present but creates fewer instances of weed-crop competition due to reduced competitive ability of weeds with a later planted crop (Melander 1995).

Biomass

For both years, cheat and downy brome biomass collected at heading averaged 2.6 and 2.75% of total biomass, respectively. Cheat and downy brome biomass during the 2020 growing season was unaffected by any management strategy (Table 4). This may result from inadequate rainfall before the optimal planting date, delaying overall cheat and downy brome emergence (Table 1). Additionally, weed biomass was highly variable from plot to plot in 2020, with some plots having no biomass (data not shown). In 2021, planting date also did not create significant differences in cheat biomass but did for downy brome. Mid- and late planting dates reduced downy brome biomass by 87 and 91%, respectively, compared with the optimal planting (Table 4). Sufficient rainfall around the optimal planting encouraged downy brome emergence and control with preplant burndown glyphosate prior to the mid- and late planting dates (Table 1). Koscelny et al. (1991) conducted an experiment at Lahoma, Oklahoma and documented similar cheat biomass values as well as a similar trend of cheat biomass peaking that averaged 390, 499, and 54 kg ha^{-1} at wheat planting dates of September 21st, October 11th, and November 2nd, respectively.

In 2021, there was an herbicide effect for both cheat and downy brome biomass, where pyroxsulam or sulfosulfuron reduced biomass by 98 and 97%, respectively, compared to the nontreated controls (Table 4). Cheat and downy brome biomass in 2020 were not affected by herbicide application. Herbicide efficacy may be limited by cheat and downy brome’s delayed asynchronous emergence, allowing late-emerging individuals to escape the timing of herbicide applications. Although herbicide application successfully controlled susceptible cheat and downy brome populations at the research location in 2021, *Bromus* spp. populations can still create problems of herbicide control with a cross-resistant cheat to ALS herbicides imazamox, propoxycarbazone-sodium, pyroxsulam, and sulfosulfuron (Heap 2021a).

Winter Wheat

Biomass

Wheat biomass is presented by year to account for differences observed across temperature and environmental variations. Delaying planting did affect wheat biomass in 2020 and 2021 (Table 4). Optimal planting in 2020 resulted in up to 26% greater wheat biomass compared to mid- and late plantings. Biomass for optimal and mid-plantings were similar with 33% greater than late planted wheat biomass in 2021. Similar findings by Wajid et al. (2004)

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revealed that wheat biomass following a recommended sowing timing significantly increased final biomass of wheat, compared to a late planting date. Planting within a recommended planting window allows producers to sow wheat during optimal soil temperatures of 12 to 25°C (Edwards 2008). As planting date is delayed, soil temperatures fall below the optimal range, resulting in less wheat emergence.

Grain Yield

Even though optimal planting dates improved wheat biomass for both years, end of season grain yield was variable. In 2020, grain yield was reduced with a delay in planting from optimal to mid- or late planting deceasing grain yield up to 21% (Table 5). In 2021, increased wheat biomass was observed for optimal and mid- plantings compared to late planted wheat, only the optimal timing yielded more grain than the late timing with 57% more grain harvested from the optimal planting. It is important to note that during the 2021 growing season, a severe freeze occurred in early February, prolonging crop stress. A severe freeze during the winter and/or multiple freezes in the spring can result in severe wheat injury depending on the wheat growth stage at time of the event or events (Barret 1978, Miller 1992). Additionally, significant stripe rust (*Puccinia striiformis* f. sp. *tritici*) followed by leaf rust (*Puccinia triticina [P. recondite* Roberge ex Desmaz. f. sp. *tritici*.]) infection during wheat recovery from the freeze-reduced growth for late-planted wheat.

The use of ALS-inhibiting herbicides pyroxsulam and sulfosulfuron can provide effective control of cheat and downy brome but may affect crop growth. Environmental conditions, such as air temperature (Olson et al. 2000), soil organic matter, pH (Moyer and Hamman 2001), and precipitation (Shinn et al. 1998) can alter the efficacy of sulfonylurea herbicides (sulfosulfuron). A wide range of weather conditions occurred throughout the two site years evaluated in our study. This likely explains the varying herbicide effects.

Winter wheat cultivar selection, herbicide treatment, and wheat planting time can be important strategies for cheat and downy brome management in winter wheat. Producers in Oklahoma and the southern Great Plains have the option to integrate these tools with their existing weed management plans, either individually, together, or in a sequential manner. Treatments of pyroxsulam and sulfosulfuron can control or suppress cheat and downy brome growth when proper stewardship and favorable conditions occur. In our studies, herbicides did not negatively impact wheat biomass or yield, but weed control was inconsistent. Producers

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utilizing ALS-inhibiting herbicides to control cheat or downy brome also need to be aware that continued use of this chemistry without incorporating other management strategies will continue to increase selection pressure for ALS-resistant cheat and downy brome biotypes. Finally, delaying planting by two to six weeks after the optimal time provided control of cheat and downy brome but also decreased wheat biomass and grain yield. If choosing to incorporate a delay in planting as a cheat and downy brome. management strategy, producers will need to evaluate their weed. infestations and decide if they can afford possible short-term yield decreases to make a long-term investment in *Bromus* spp. seed bank management.

Practical Implications

Weed management is critical for winter wheat producers in the southern Great Plains. Timing of wheat planting is a key weed management tool for downy brome and cheat. Downy brome and cheat are early emerging winter annual grasses primarily germinating from mid-September to mid-October. This coincides with the optimal sowing window of dual-purpose and grain-only production in Oklahoma. This overlap creates management problems for wheat producers, as delaying wheat planting allows the producer to control early-emerging downy brome and cheat, resulting in yield loss. We recommend a planting date of early- to mid-November, two to six weeks after the beginning of the optimal sowing window used by grain-only producers with high infestations of cheat and downy brome in Oklahoma. Weather conditions may further allow producers to delay the sowing of winter wheat while mitigating the yield loss from downy brome. In addition to planting date, producers can use common ALS-inhibiting herbicides such as pyroxsulam or sulfosulfuron to suppress downy brome and cheat.

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References

Barrett SW (1978) Response of Five Winter Wheat Cultivars to Three Seeding Rates and Six Planting Dates. M.S. Thesis. Stillwater, OK: Oklahoma State University. 61 p

Beres BL, Clayton GW, Harker KN, Stevenson FC, Blackshaw RE, Graf RJ (2010) A sustainable management package to improve winter wheat production and competition with weeds. Agron. J. 102:649-657

Edwards JT (2008) Factors affecting wheat germination and stand establishment in hot soils. Stillwater, OK: Oklahoma Cooperative Extension Service PSS-2256. 2 p

Epplin FM, Fofana NF, Peeper TF, Solie JB (1996) Optimal wheat seeding rates for conventional and narrow rows for cheat-free and cheat-infested fields. J Prod Agric 9:265-270

Fast BJ, Medlin CR, Murray DS (2009) Five cool-season annual grass weeds reduce hard red winter wheat grain yield and price. Weed Technol 23:206-213

Haferkemp MR, Karl MG, Macneil MD (1994) Influence of storage, temperature, and light on germination of Japanese brome seed. J Range Manage. 47:140-144

Heap (2021) Herbicide Resistant Weeds in Oklahoma, United States. http://www.weedscience.org/Pages/USState.aspx?StateAbbr=OK. Accessed: March 8, 2023

Heap (2024) Herbicide Resistant Downy Brome Globally. https://www.weedscience.org/Pages/Species.aspx. Accessed: February 12, 2024

Koscelny JA, Peeper TF, Solie JB, Solomon SG Jr (1991) Seeding date, seeding rate, and row spacing affect wheat (*Triticum aestivum*) and cheat (*Bromus secalinus*). Weed Technol 5:707-712

Kumar V, Liu R, Manuchehri MR, Westra EP, Gaines TA, Shelton CW (2020) Feral rye control in quizalofop-resistant wheat in central Great Plains. Agron. J. 2020: 1-12

Lollato RP, Patrignani A, Ochsner T, Rocateli A, Edwards J (2017) Dual purpose wheat: improving grazing management using a smartphone app. Stillwater, OK: Oklahoma State University PSS-2170 4 p

Mahmood Q, Bilal M, Jan S (2014) Chapter 17 – Herbicides, pesticide, and plant tolerance: an overview. Biol Tech 1:423-448

Manuchehri MR, Lindell HC, Newlin LS (2022) True Cheat Control in Oklahoma Winter Wheat. Stillwater, OK: Oklahoma Cooperative Extension Service PSS-2774. 7 p

Massee TW (1976) Downy brome control in dryland winter wheat with stubble-mulch fallow and seeding management. J Agron 6:952-955

Melander B (1995) Impact of drilling date on *Apera spica-venti* and *Alopecurus myosuriodes* Huds in winter cereals. Weed Res 35:157-166

Menalled F, Mangold J, Davis E(2008) Cheatgrass: Identification, Biology and Integrated Management. Bozeman, Montana: Montana State University Extension 6 p

Miller TD (1992) Growth Stages of Wheat: Identification and Understanding Improve Crop Management. College Station, TX: Texas A&M University. 4 p

Moyer JR, Hamman WM (2001) Factors affecting the toxicity of MON 37500 residues to following crops. Weed Technol 15:42-47

[OGI] Oklahoma Genetics, Inc. (2021) Hard Red Winter. https://okgenetics.com/hard-red-winter. Accessed: February 12, 2024

Olson BLS, Al-Khatib K, Stahlman P, Isakson PJ (2000) Efficacy and metabolism of MON 37500 in *Triticum aestivum* and weedy grass species as affected by temperature and soil moisture. Weed Sci 48:541–548

Peeper TF (1984) Chemical and biological control of downy brome (*Bromus tectorum*) in wheat and alfalfa in north America. Weed Sci 32:18-25

Ratliff RL, Peeper TF (1987) *Bromus* control in winter wheat (*Triticum aestivum*) with the ethylthio analog of metribuzin. Weed Technol 1:235-241

Ratliff RL (1985) Investigation of BAY SSH 0860 for cheat control in wheat. Master's thesis. Stillwater, OK: Oklahoma State University. 76 p

Reddy SS, Stahlman PW, Geier PW (2013) Downy brome (*Bromus tectorum* L.) and broadleaf weed control in winter wheat with acetolactate synthase-inhibiting herbicides. J Agron 3:340-348

Shinn SL, Thill DC, Price WJ, Ball DA (1998) Response of downy brome (*Bromus tectorum*) and rotational crops to MON 37500. Weed Technol 12:690–698

Stahlman PW, Miller SD (1990) Downy brome (*Bromus tectorum*) interference and economic thresholds in winter wheat (*Triticum aestivum*). Weed Sci 38:224-228

https://doi.org/10.1017/wet.2024.26 Published online by Cambridge University Press

[USDA] United State Department of Agriculture (2022) Small Grains 2022 Summary. https://downloads.usda.library.cornell.edu/usda-esmis/files/5t34sj573/h128pr261/5138kq83p/smgr0922.pdf. Accessed: March 8, 2023

Wajid A, Hussain A, Ahmad A, Goheer AR. Ibrahim M, Mussaddique M (2004) Effect of sowing date and plant population on biomass, grain yield and yield components of wheat. Int. J. Agri. Biol. 6:1003-1005

Williams MR (2006) Planting date influences critical period of weed control in sweet corn. Weed Sci 54:928-933

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Table 1. Agronomic practices at Lahoma, OK during the 2019-20 and 2020-21 winter wheat growing seasons.

Growing season	Plant timing	Planting date	Herbicide application date	Biomass collection	Harvest date
2019-20	Optimal[a]	Oct 17	Dec 20[b]	May 12[c]	Jun 8[d]
	Mid-	Nov 5	Jan 14	May 14	Jun 8
	Late	Nov 18	Feb 7	May 19	Jun 18
2020-21	Optimal	Oct 9	Dec 1	May 7	Jul 7
	Mid-	Nov 11	Feb 2	May 15	Jul 7
	Late	Nov 30	Mar 31	May 20	Jul 7

[a] The optimal planting date represents the optimal window for sowing grain only wheat to maximize grain yield and quality. The mid- timing occurred two to three weeks after the optimal while the late occurred two to three weeks after the mid-.

[b] Application timing of pyroxsulam sprayed at a rate of 18.4 g ai ha^{-1} and sulfosulfuron at 35.2 g ai ha^{-1} at 2- to 3-leaf stage of winter wheat and cheat for each planting date. All herbicide treatments were applied using water as the carrier and included a non-ionic surfactant at 0.25% volume/volume and a urea-ammonium nitrate at 30% volume/volume.

[c] Biomass collection of wheat and cheat at heading.

[d] Harvest date of wheat grain when kernel moisture was between 9 and 12%.

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Table 2. Monthly average weather data at Lahoma, OK, during the 2019-20 and 2020-21 winter wheat growing season.

Month	2019 - 2020			2020 - 2021		
	Temperature			Temperature		
	Min	Max	Rainfall	Min	Max	Rainfall
	----------------------C---------------------		mm	----------------------C---------------------		mm
October	-7[a]	28	20[b]	-3[a]	34	55[b]
November	-11	24	30	-6	27	41
December	-6	22	38	-12	20	46
January	-7	20	38	-7	18	38
February	-10	24	30	-25	21	5
March	-3	27	76	-4	27	117
April	-3	30	25	-3	27	56
May	2	34	48	5	30	107
June	11	39	0	12	39	114
July	---	---	---	17	33	8
Average	-4	28	34	-3	28	59
Total			305			587

[a] All Oklahoma max and min temperature data collected from the Oklahoma Mesonet (mesonet.org).
[b] Rainfall was determined from planting date to harvest date.

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Table 3. Visual control of cheat and downy brome eight to nine weeks after herbicide treatment at Lahoma, OK during the 2019-20 and 2020-21 winter wheat growing seasons.

	2020	2021
	———————————————————— % Visual control[a] ————————————————————	
Planting date[b]		
Optimal	74 c[c]	76 b
Mid-	83 b	98 a
Late	96 a	99 a
Herbicide[d]		
Pyroxsulam	84	90
Sulfosulfuron	82	91

[a] Visual rating of cheat control on a scale of 0 to 100% as compared to nontreated plots. 0 represents no control, 100 represents complete control.
[b] The optimal planting date represents the optimal window for sowing grain only wheat to maximize grain yield and quality. The mid- timing occurred two to three weeks after the optimal while the late occurred two to three weeks after the mid-.
[c] Means within a column for each site year followed by a common letter were similar according to Fisher's protected LSD at $P < 0.05$.
[d] Pyroxsulam sprayed at a rate of 18.4 g ai ha^{-1} and sulfosulfuron at 35.2 g ai ha^{-1}. All herbicide treatments were applied using water as the carrier and included a non-ionic surfactant at 0.25% volume/volume and a urea-ammonium nitrate solution at 30% volume/volume.

Table 4. Wheat, downy brome, and cheat biomass collected at heading (g 0.25 m^{-2}) at Lahoma, OK during the 2019-20 and 2020-21 winter wheat growing seasons.

	2019 - 2020			2020 - 2021		
	Wheat	Downy brome	Cheat	Wheat	Downy brome	Cheat
	——— g m^{-2} ———					
Planting date[a]						
Optimal	935 a[b]	17.6	11.2	830 a	43.2 a	13.6
Mid-	686 b	11.2	28.8	793 a	5.6 b	11.6
Late	750 b	22.8	17.6	608 b	4.0 b	30.8
Herbicide[c]						
nontreated	838	21.6	21.2	698	50.0 a	54.0 a
Pyroxsulam	783	3.6	8.4	757	1.6 b	0.8 b
Sulfosulfuron	750	26.8	28.8	776	1.6b	0.8 b

[a] The optimal planting date represents the optimal window for sowing grain only wheat to maximize yield and quality. The mid- timing occurred two to three weeks after the optimal while the late occurred two to three weeks after the mid-.

[b] Means within a column for each site year followed by a common letter were similar according to Fisher's protected LSD at $P < 0.05$.

[c] Pyroxsulam sprayed at a rate of 18.4 g ai ha^{-1}, sulfosulfuron at 35.2 g ai ha^{-1}, and nontreated. All herbicide treatments were applied using water as the carrier and included a non-ionic surfactant at 0.25% v/v and a urea-ammonium nitrate solution at 30% v/v.

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Table 5. Grain yield (kg ha^{-1}) at Lahoma, OK during the 2019-20 and 2020-21 winter wheat growing seasons.

	2019 - 2020	2020 - 2021
	——— kg ha^{-1} ———	
Planting date[a]		
Optimal	3,980 a[b]	4,870 a
Mid-	3,410 b	4,400 ab
Late	3,160 b	2,080 b

[a] The optimal planting date represents the optimal window for sowing only wheat to maximize grain yield and quality. The mid-timing occurred two to three weeks after the optimal, while the late-timing occurred two to three weeks after the mid.

[b] Means within a column for each site year followed by a common letter were similar according to Fisher's protected LSD at a < 0.05.

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