ELSEVIER

Agricultural Systems 63 (2000) 161–173

AGRICULTURAL SYSTEMS

www.elsevier.com/locate/agsy

Winter wheat fall–winter forage yield and grain yield response to planting date in a dual-purpose system

F.M. Epplin[a,*], I. Hossain[a], E.G. Krenzer Jr.[b]

[a]*Department of Agricultural Economics, Oklahoma State University, Stillwater, OK 74078-6026, USA*
[b]*Department of Plant and Soil Sciences, Oklahoma State University, Stillwater, OK 74078, USA*

Received 19 July 1999; received in revised form 14 January 2000; accepted 20 January 2000

Abstract

Previous published research suggests that if fall–winter grazing of winter wheat is properly managed, it will not reduce grain yield. However, highly aggregated state average data suggest that fall–winter grazing is associated with lower grain yields. This study was undertaken to determine the trade-off, or substitution in production, between winter wheat fall–winter forage yield and grain yield across planting dates. Data from experiment station trials were used to estimate response functions and to determine optimal planting dates. The estimated response functions suggest relatively large differences in expected fall–winter forage yield and expected grain yield across planting date. Optimal planting date is sensitive to the value of fall–winter forage relative to the value of wheat grain. Producers will optimally plant wheat intended for dual-purpose use earlier than wheat intended for grain-only. The expected yield from the earlier planted dual-purpose wheat is lower than the expected yield of the later planted grain-only wheat as a result of the earlier planting date. © 2000 Elsevier Science Ltd. All rights reserved.

Keywords: Dual-purpose; Grazing; Joint products; Planting date; Winter wheat

---

1. Introduction

Grazing winter wheat during its vegetative stage is a common practice in the US Southern Plains. Pinchak et al. (1996) estimate that 30–80% of the eight million hectares seeded annually to wheat in the region are grazed. Wheat may be seeded in

---

* Corresponding author. Tel.: +1-405-744-7126; fax: +1-405-744-8210.
E-mail address: epplin@okstate.edu (F.M. Epplin).

PII: S0308-521X(00)00004-4

the late summer and grazed throughout the fall and winter. If livestock are removed in late winter, prior to the development of the first hollow stem, the wheat will mature and produce a grain crop. The use of winter wheat as a dual-purpose forage and grain crop is important to the agricultural economies of southwestern Kansas, eastern New Mexico, western Oklahoma, southeastern Colorado, and the Texas Panhandle (Shroyer et al., 1993; Redmon et al., 1995; Pinchak et al., 1996; Ralphs et al., 1997). Wheat grazing is also practiced in Argentina, Australia, Morocco, Pakistan, Syria, and Uruguay (Rodriguez et al., 1990).

Many lightweight calves are shipped to the Southern Plains in the fall from the Southeast, Midwest, and West to graze on lush winter wheat pastures (Brorsen et al., 1994). After wintering on wheat pasture these calves are fed to slaughter weight in feedlots also located in the Southern Plains. Hence, wheat pasture constitutes a unique and important niche for Southern Plains agriculture (Washko, 1947; Christiansen, et al., 1989; Redmon et al., 1995).

Production of wheat for dual-purpose use (forage and grain) is a complicated process involving the interaction of livestock production with wheat grain production. Relatively few studies to determine the consequences of grazing on wheat grain yield have been conducted (Holliday, 1956; Christiansen et al., 1989; Redmon et al., 1996). Holliday (1956) summarized several studies and found that some reported that grazing reduced grain yield while others reported that grain yield was greater on plots that had been mechanically clipped or grazed. Christiansen et al. (1989) concluded that when wheat growth potential is such that removal of forage will prevent lodging, grazing could increase grain yield. Redmon et al. (1995) contend that grazing will have minimal effect on grain yield if soil moisture is adequate throughout the growing season. Redmon et al. (1995) also reported that under some circumstances fall–winter grazing could increase the grain yield of tall varieties. A careful evaluation of these research findings would lead one to conclude that if grazing is properly managed, fall–winter grazing will not reduce grain yield. Proper management implies sufficient fertility, grazing initiation delayed until after the root system is well developed, low to moderate stocking density, and grazing termination prior to the development of the first hollow stem. Highly aggregated data show a negative correlation between Oklahoma state average grain yield and the proportion of wheat hectares harvested for grain that were winter grazed (Epplin, 1997). Contrary to the findings from designed field trials, these state average data suggest that fall–winter grazing is associated with lower grain yields. Aggregate data also show a negative correlation between Oklahoma state average wheat yield and the proportion planted prior to 1 October. The conclusions that fall–winter grazing has minimal to no effect on grain yield were derived from designed research trials in which planting date was not a treatment variable. Hence, a more appropriate conclusion might have been that for a given planting date, properly managed fall–winter grazing will not reduce grain yield. Farmers may plant wheat intended for dual-purpose use earlier than wheat intended for grain-only. The expected grain yield of dual-purpose wheat may be lower than the expected yield of grain-only wheat not because of the effects of fall–winter grazing but as a result of the difference in planting date.

Selection of wheat planting date is one of the most important management decisions for dual-purpose production. Historically, public wheat breeding and development programs conducted in the US Southern Plains have selected varieties based upon grain yield and grain quality from planting in mid-October (Winter and Thompson, 1990; Carver et al., 1991). However, in most growing seasons, fall–winter forage production from wheat that is not seeded until mid-October will be insufficient to support fall–winter grazing. Thus, farmers who plan to produce both forage and grain may plant in an environment different from that used in the wheat breeding programs.

Early planting increases the total length of time that the wheat crop is in the field and exposed to the environment. Early planting is associated with increased incidences of several diseases including wheat streak mosaic, High Plains mosaic, barley yellow dwarf, sharp eyespot, common root rot, and take-all root rot (Bowden, 1997). Early planting is also associated with an increase in weed pressure. In a monoculture system, early planting also increases the risk of volunteer wheat that may facilitate the build-up and transfer of pests and diseases from one wheat crop to the next. Thus, early planting increases the probability of unfavorable consequences relative to grain yield. Here-to-fore the tradeoff, or substitution in production, between fall–winter forage yield and grain yield across planting dates has not been evaluated.

The objective of the research reported in this paper is to determine wheat forage and grain yield response to alternative planting dates and to determine the optimal planting date for dual-purpose winter wheat. Data from an experiment station trial are used to estimate forage yield and grain yield response functions. The estimated functions are used to determine optimal planting dates for dual-purpose winter wheat for several sets of grain and forage prices.

Several research studies have been conducted to determine the influence of planting date on wheat grain yield (Epplin et al., 1993; Heer and Krenzer, 1978; Knapp and Knapp, 1978; Winter and Musick, 1993). However, no prior planting date studies have considered the joint products of wheat produced for both fall–winter forage and grain.

2. Data

Data were generated in experiment station trials conducted at the north central research station near Lahoma, OK. A series of field experiments were conducted over six growing seasons beginning in 1991–92. Treatments varied some from season to season. However, planting date treatments were included in each of the six seasons. Four planting date treatments, ranging from late August to early October, were included during the first five seasons. The 1996–97 trial included five planting date treatments ranging from late August to late October. Each treatment was replicated four times in a randomized complete block design. In all, there were a total of 608 observations available to estimate grain yield response to planting date. Since fall–winter forage production is negligible for wheat seeded in the region after the first of October, only observations from 360 pre-October planting dates were used to estimate forage yield response to planting date.

For the first three seasons, seeding rate treatments were included in the study. All plots were seeded with the variety Karl. After the third season a seeding rate of 134 kg ha^{-1} was used for all plots and variety treatments were added. To simulate grazing, the plots were mechanically clipped and the forage removed once in the fall and once in the spring prior to development of the first hollow stem. Forage yield was based upon the combined dry matter yield of the two clippings. All plots were fertilized to ensure that soil fertility would not be the first yield-limiting factor.

3. Response functions

The full fall–winter forage production model is:

$$F = \beta_0 + \beta_1\mathrm{PD} + \beta_2\mathrm{PD}^2 + \beta_3\mathrm{SR} + \beta_4\mathrm{SR}^2 + \beta_5\mathrm{PDXR} + \beta_6 Y92 + \beta_7 Y93 + \beta_8 Y94 + \beta_9 Y95 + \beta_{10} Y96 + \beta_{11}\mathrm{V1} + \beta_{12}\mathrm{V2} + \beta_{13}\mathrm{V3} + \mathrm{e} \quad (1)$$

where F = fall–winter forage production (kg dry matter per hectare); β_i = regression coefficients to be estimated; PD = planting date (Julian day); SR = seeding rate (kilograms per hectare); PDXSR = planting date by seeding rate interaction; $Y9x = 1$ if observation from grain harvest year 9x, otherwise $Y9x = 0$; $V1 = 1$ if variety Karl92, 0 otherwise; $V2 = 1$ if variety 2180, 0 otherwise; $V3 = 1$ if variety Jagger, 0 otherwise; and e = statistical error term.

Forage yield is expected to be lower with later planting dates. The quadratic term for planting date is included in the full model to allow for a nonlinear response. The seeding rate terms are included to determine the manner in which seeding rate is related to fall–winter forage yield. The dummy variables are included to account for differences across seasons and varieties.

The full wheat grain production model is:

$$G = \beta_0 + \beta_1 F + \beta_2\mathrm{PD} + \beta_3\mathrm{PD}^2 + \beta_4\mathrm{SR} + \beta_5\mathrm{SR}^2 + \beta_6\mathrm{PDXR} + \beta_7 Y92 + \beta_8 Y93 + \beta_9 Y94 + \beta_{10} Y95 + \beta_{11} Y96 + \beta_{12}\mathrm{V1} + \beta_{13}\mathrm{V2} + \beta_{14}\mathrm{V3} + \mathrm{e} \quad (2)$$

where G = wheat grain production (kilograms per hectare); and other symbols are as previously defined.

The fall–winter forage production (F) term is included as an independent variable in the wheat grain response function to determine if forage clipping and removal influences grain yield. As noted, results from prior studies are ambiguous. Grain yield is expected to be greater with later planting dates. The quadratic term for

Table 1
Estimates of wheat forage yield response to planting date and seeding rate[a]

Variable	Symbol	Model
Intercept		56759* (5.52)
Planting date (Julian day)	PD	−403.78* (−5.08)
	PD^2	0.71598* (4.64)
Seeding rate (kg ha^{-1})	SR	87.128* (6.05)
	SR^2	−0.0375* (−2.93)
Interaction	PDXSR	−0.2950* (−5.54)
1991–92	Y92	1147.4 (11.23)
1992–93	Y93	−20.297 (−0.21)
1993–94	Y94	−803.63* (−6.42)
1994–95	Y95	−19.623 (−0.22)
1995–96	Y96	−68.499 (−0.61)
Variety — Karl 92	V1	20.182 (0.27)
Variety — 2180	V2	88.435 (1.26)
Variety — Jagger	V3	484.71 (5.14)
Number of observations		360
Log likelihood function		−2631.04

[a] An asterisk indicates significance at the 0.05 level. Values in parentheses are *t*-statistics for the null hypothesis that the parameter equals zero. The dependent variable is wheat forage yield (kg ha^{-1}). The 1996–97 growing season and Karl variety are included in the intercept.

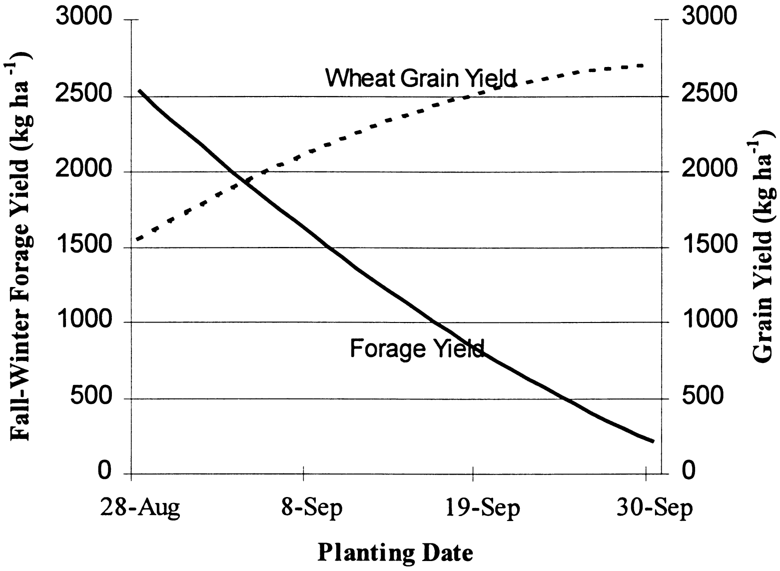

Fig. 1. Predicted dual-purpose winter wheat fall–winter forage yield and grain yield by planting date, from data generated in field trails conducted at Lahoma, OK, USA from 1991–92 through 1996–97.

Table 2
Estimates of wheat grain yield response to planting date and seeding rate[a]

Variable	Symbol	Model				
		A	B	C	D	E
Intercept		−54731* (−12.17)	−54933* (−12.27)	−57058* (−15.91)	−53245* (−11.91)	−57081* (−15.87)
Fall–winter forage (kg ha^{-1})	*F*	−0.03060 (−0.77)	−0.02820 (−0.72)		−0.04979 (−1.30)	
Planting date (Julian day)	PD	428.9* (13.10)	428.0* (13.23)	442.3* (16.49)	416.2* (12.91)	441.9* (16.43)
	PD^2	−0.7794* (−12.93)	−0.7693* (−13.18)	−0.7928* (−15.88)	−0.7498* (−12.88)	−0.7928* (−15.83)
Seeding rate (kg ha^{-1})	SR	−6.0985 (−0.76)	−0.60873 (−1.26)	−0.70986 (−1.51)		
	SR^2	−0.0050 (−0.53)				
	PDXSR	0.0256 (0.90)				
1991–92	*Y*92	−941.9* (−11.46)	−964.4* (−12.78)	−983.9* (−13.93)	−927.6* (−12.89)	−957.7* (−13.85)
1992–93	*Y*93	−2255.8* (−27.71)	−2267.7* (−30.21)	−2266.4* (−29.88)	−2251.8* (−31.17)	−2244.5* (−30.47)
1993–94	*Y*94	−2647.9* (−26.35)	−2656.6* (−27.75)	−2638.0* (−29.20)	−2640.0* (−27.37)	−2611.3* (−29.29)
1994–95	*Y*95	−2015.4* (−18.85)	−2022.6* (−19.14)	−2013.0* (−18.95)	−2030.1* (−19.35)	−2016.0* (−19.03)
1995–96	*Y*96	−2430.7* (−19.39)	−2426.2* (−19.53)	−2423.6* (−19.44)	−2425.5* (−19.63)	−2423.1*(−19.47)
Variety — Karl 92	*V*1	−214.9* (−1.93)	−215.2* (−1.95)	−217.1* (−1.97)	−214.3* (−1.95)	−217.0* (−1.97)
Variety — 2180	*V2*	−416.2* (−3.85)	−412.0* (−3.85)	−416.3* (−3.89)	−407.8* (−3.83)	−415.6* (−3.89)
Variety — Jagger	*V3*	−806.8* (−10.81)	−803.5* (−10.75)	−816.7* (−11.06)	−792.8* (−10.70)	−815.2* (−11.03)
Observations		608	608	608	608	608
Log likelihood function		−2025.67	−2026.39	−2026.55	−2027.15	−2027.69

[a] An asterisk indicates significance at the 0.05 level. Values in parentheses are *t*-statistics for the null hypothesis that the parameter equals zero. The dependent variable is wheat grain yield (kg/ha^{-1}). The 1996–97 growing season and Karl variety are included in the intercept.

planting date is included in the full model to allow for a nonlinear response. Seeding rate terms and dummy variables are included to complete the model.

Model specification tests were conducted. The Jarque–Bera test failed to reject normality. The Glesjer test revealed the presence of heteroskedasticity. Ordinary least squares estimates would not be efficient (Judge et al., 1988). Thus, maximum likelihood estimation (MLE) procedures with the option to correct for heteroskedasticity with the standard deviation as a linear function of exogenous variables in the Shazam software package were used to fit the model (het procedure with stdlin option) (White, 1993).

The MLE estimates for the fall–winter forage response function are reported in Table 1. All estimated coefficients in the full model are significantly different from zero at the 0.05 level of probability except for five of the intercept shifting dummy variables. The fall–winter forage response to planting date function is graphed in Fig. 1 with forage yield on the left vertical axis and planting date on the horizontal axis. The graph illustrates the critical influence of planting date on forage yield. Based upon the estimated function, early September plantings yield twice as much fall–winter forage as mid-September plantings. The forage yield from late September plantings is negligible.

Statistical estimates for the wheat grain yield response function are reported in Table 2. In the full model (model A) forage yield, seeding rate, seeding rate squared, and the planting date by seeding rate interaction term are not significant. While it was determined that seeding rate is a significant factor for determining fall–winter forage yield, no significant differences were detected in grain yield across the seeding rates used in the study. Even at a relatively low seeding rate of 34 kg ha^{-1}, the varieties used in the trial generated sufficient tillers to produce as much grain as plots seeded at a rate of 202 kg ha^{-1}.

The estimates indicate that fall–winter forage yield is not significant in explaining differences in subsequent grain yield over and above the planting date effect. For a given planting date, removal of fall–winter forage does not alter subsequent grain yield. However, the estimates show that planting date is highly significant. The wheat grain yield response to planting date, as estimated in model E, is graphed in Fig. 1 with grain yield on the right vertical axis and planting date on the horizontal axis.

The fall–winter forage yield response and the grain yield response to planting date as depicted in Fig. 1 illustrate the trade-off between forage production and grain production encountered by a dual-purpose wheat producer. A 3-week delay in planting from 1 to 21 September is associated with an expected 44% increase in grain yield (from 1750 to 2550 kg ha^{-1}). However, the same 3-week delay will result in a fall–winter forage yield of only 32% as much as 1 September planting (2170 kg ha^{-1} on 1 September to 690 kg ha^{-1} on 21 September).

4. Economic model

The objective function is formulated as a conventional joint products model. Since the available data contained seeding rate as well as planting date information, forage and grain yield response to both planting date and seeding rate can be determined. Thus, the objective is to determine the optimal planting date and seeding rate for a dual-purpose production system. The objective function is formulated with planting date and seeding rate as choice variables.

$$\begin{aligned}\pi(\mathrm{PD},\mathrm{SR}) = {} & P_{\mathrm{f}}F(\mathrm{PD},\mathrm{SR}) + P_{\mathrm{g}}G(\mathrm{PD}) - P_sSR - P_nN \\ & (F(\mathrm{PD},\mathrm{SR}),G(\mathrm{PD})) - \mathrm{FC}\end{aligned} \tag{3}$$

where π = return (\$ ha^{-1}); $P_{\mathrm{f}=}$ value of standing fall–winter wheat forage (\$ kg^{-1} dry matter); P_{g} = price of wheat grain (\$ kg^{-1}); P_{s} = price of wheat seed (\$ kg^{-1}); P_{n} = price of nitrogen (\$ kg^{-1}); N = nitrogen (kg); FC = fixed costs. It is assumed that all costs other than the cost of seed and nitrogen are constant across planting dates. Fall–winter forage yield is assumed to be independent of grain production. Based upon the response function estimates, for a given planting date, grain yield is not influenced by fall–winter forage removal. Grain yield was the same across the seeding rates used in the field trials. Hence, for the economic model, planting date is the only choice variable that influences grain yield.

In the field experiment, fertilizer was applied to all plots to eliminate any nutrient deficiencies. This is a standard procedure for agronomic trials with treatment variables other than fertilizer. The fertility level in each plot was sufficient so that from the perspective of fertility the yield is at a plateau (Paris, 1992). However, differences in nitrogen removal can be postulated as a function of forage dry matter and grain removed. Krenzer (1994) reports that a kilogram of wheat grain removes 0.0333 kg of nitrogen and that a kilogram of wheat forage removes 0.03 kg of nitrogen. Requirements for phosphorus and potassium fertilizer are assumed to be constant across the range of forage and grain yields in the study (Krenzer, 1994; Warmann, 1997).

Table 3
Optimal planting dates for wheat for forage and grain for alternative wheat grain prices and alternative values of fall–winter wheat standing forage[a]

Forage value (\$ kg^{-1})	Seed price (\$ kg^{-1})	Grain price (\$ kg^{-1})		
		0.11	0.13	0.15
0.0550	0.18	27 September	30 September	1 October
0.0605	0.18	17 September	27 September	30 September
0.0660	0.18	24 August[b]	20 September	27 September
0.0550	0.26	29 September	30 September	1 October
0.0605	0.26	27 September	29 September	1 October
0.0660	0.26	7 September	27 September	30 September

[a] Nitrogen removal was estimated at 0.0333 kg kg^{-1} of wheat grain and 0.03 kg kg^{-1} of wheat forage. A nitrogen price of \$0.33 kg^{-1} was used.

[b] Predicted optimal planting date is earlier than the earliest date used in the field trials, 24 August.

Table 4
Optimal seeding rates for wheat for forage and grain for alternative wheat grain prices and alternative values of fall–winter wheat standing forage (kg ha^{-1})[a]

Forage value ($ kg^{-1})	Seed price ($ kg^{-1})	Grain price ($ kg^{-1})		
		0.11	0.13	0.15
0.0550	0.18	47	34[b]	34[b]
0.0605	0.18	92	52	40
0.0660	0.18	202[b]	83	57
0.0550	0.26	34[b]	34[b]	34[b]
0.0605	0.26	34[b]	34[b]	34[b]
0.0660	0.26	119	38	34[b]

[a] Nitrogen removal was estimated at 0.0333 kg kg^{-1} of wheat grain and 0.03 kg kg^{-1} of wheat forage. A nitrogen price of $0.33 kg^{-1} was used.

[b] Predicted optimal seeding rate is outside the range of seeding rates used in the trial, 34–202 kg ha^{-1}.

The optimal seeding rate and planting date can be derived by setting the first derivatives of the profit function with respect to seeding rate and planting date equal to zero and solving them simultaneously. Knowledge of the estimated regression parameters, and relevant prices can be used to determine the profit-maximizing seeding rate and planting date. For the six growing seasons the average price received by Oklahoma farmers for wheat in June was $0.13 kg $^{-1}$. The high of $0.20 kg $^{-1}$ occurred in June of 1996 and the low of $0.09 kg $^{-1}$ occurred in June of 1993.

Determining the value of standing fall–winter wheat forage is less direct. Prices for standing forage are not routinely reported. However, some wheat producers lease their pasture to livestock owners and, in informal surveys over the time period of the field trials, farmers reported an average lease rate of $0.66 kg $^{-1}$ to $0.73 kg $^{-1}$ of beef gain for winter wheat pasture (Doye and Kletke, 1997). In these lease arrangements, payments from livestock owners to wheat producers are based upon net live weight gain attributable to the wheat pasture. These lease arrangements are made based upon price expectations and are typically not changed if the price of cattle increases or decreases beyond the expected levels. In some cases the fencing and water are provided by the landowner. However, in other cases the livestock owner covers some or all of these costs.

The quantity of winter wheat forage required per kilogram of beef gain has not been precisely determined. Based upon the National Research Council net energy equations used to estimate livestock requirements and based upon nutrient analysis of wheat forage, an average of 7 kg of forage would be required per kilogram of gain for a 200-kg steer gaining 0.9 kg per day for 115 days. Seven kilograms would be the minimum possible allowance, assuming 100% harvest efficiency, and no allowance for nonconsumptive loss (Krenzer et al., 1996). The procedure used to measure forage production did not harvest all forage, but left 560 to 840 kg ha^{-1} of residual forage. It is assumed that this quantity of residual forage should cover some of the nonconsumptive loss. For our purposes it is assumed that a kilogram of beef gain is expected to require 10 kg (dry matter) of standing wheat forage. By this measure, over the time period of the study, the value of standing fall–winter forage was approximately \$0.066 (\$0.66/10) to \$0.073 (\$0.73/10) kg^{-1} dry matter. Additional field research would be required to refine the estimate.

Optimal planting dates for different combinations of fall–winter forage, wheat grain, and wheat seed values are presented in Table 3. For an expected wheat grain price of \$0.13 kg^{-1}, an expected wheat seed price of \$0.26 kg^{-1}, and an expected value of fall–winter forage of \$0.066 kg^{-1}, the estimated optimal planting date is 27 September. As expected, for relatively low grain prices (\$0.11 kg^{-1}) and relatively high forage values (\$0.066 kg^{-1}) it is optimal to plant early and produce relatively more fall–winter forage and relatively less grain. Alternatively, if wheat grain prices are high relative to fall–winter forage value it is optimal to plant late and produce relatively more grain and relatively less fall–winter forage.

Optimal seeding rates for different combinations of wheat seed, fall–winter forage, and grain prices are presented in Table 4. For an expected wheat grain price of \$0.13 kg^{-1}, an expected wheat seed price of \$0.18 kg^{-1}, and an expected value of fall–winter forage price of \$0.066 kg^{-1}, the estimated optimal seeding rate is 83 kg ha^{-1}. As expected, when it is optimal to seed early to increase expected fall–winter forage production, it is optimal to increase the seeding rate. For example, with a seed price of \$0.18 kg^{-1}, wheat grain price of \$0.11 kg^{-1}, and forage value of \$0.066 kg^{-1} it is optimal to plant early and to use a high seeding rate. Alternatively, if wheat grain prices are high relative to fall–winter forage value it is optimal to plant a lower seeding rate at a later date.

5. Implications

There are a number of important implications of the tradeoff between fall–winter forage production and grain yield for producers, researchers, crop insurance providers, lenders, and for public policy makers. The optimal planting date for dual-purpose wheat depends primarily upon the relative value of fall–winter forage and price of wheat grain. If the value of fall-winter forage is expected to be high relative to the value of wheat grain, producers should use a high seeding rate and plant early. On the other hand, if the value of wheat grain is expected to be high relative to the value of fall–winter forage, late planting and lower seeding rate are indicated. The estimated response functions also suggest that producers in the region who plant wheat to produce only grain should delay planting until October.

The analysis also provides several implications for research. It is clear that in the region with the varieties used in the study the expected grain yield from dual-purpose wheat is less than the expected grain yield from grain-only wheat as a result of the difference in planting date. Although there are a number of factors associated with early planting that result in lower yields, the precise cause of the lower yields remains to be identified.

The conventional practice of selecting wheat varieties for the region based upon grain yield and grain quality from planting in mid-October should be re-evaluated.

Given that millions of hectares in the US Southern Plains and elsewhere are used for dual-purpose production it may be appropriate to implement a parallel variety development program designed to select dual-purpose varieties for seeding in mid-September.

Research is also necessary to determine if mechanical clipping of forage is sufficient to simulate grazing pressure. The consequences of grazing pressure and stocking density on grain yield also remain to be determined.

The results of this study also have important implications for public policy. Historically, US federal commodity programs based deficiency payments in part upon the base grain yield. No differentiation was made between dual-purpose wheat and grain-only wheat. However, the expected yield from earlier planted dual-purpose wheat would have been lower than the expected yield of grain-only wheat.

Historically, under certain program provisions and adverse environmental conditions, dual-purpose wheat producers in some regions were eligible for federal disaster payments for a wheat pasture as a nonprogram crop. If a regional drought resulted in relatively low fall–winter forage yields (a wheat pasture disaster), participating producers may have been eligible for disaster payments. Historically, the fall–winter forage yield was assumed to be a positive linear function of wheat grain yield. The results of this study suggest that fall–winter forage yield and grain yield are negatively rather than positively correlated.

In addition, the results of this study suggest that a fair wheat grain yield crop insurance premium may need to consider planting date. In the absence of differences in insurance costs and conditions for demonstrated loss, dual-purpose wheat producers would clearly have an opportunity to exploit a crop insurance program based upon grain yield.

6. Conclusions

The conclusions from prior studies that properly managed fall–winter grazing does not decrease grain yield may be correct but they are misleading. These prior conclusions were derived from designed research trials in which planting date was fixed and not a treatment variable. For a given planting date, properly managed fall–winter grazing may not reduce grain yield. However, producers will optimally plant wheat intended for dual-purpose use earlier than wheat intended for grain-only. The expected yield from the earlier planted dual-purpose wheat is lower than the expected yield of the later planted grain-only wheat. It was determined that fall–winter forage production is not significant in explaining grain yield. However, in the region, early planting (pre-October) clearly reduces expected grain yield. Dual-purpose production requires pre-October planting. Hence, the expected grain yield of dual-purpose wheat is lower than the expected grain yield of later planted grain-only wheat as a result of the earlier planting date.

The estimated response functions suggest relatively large differences in expected fall–winter forage yield and expected grain yield across planting date. For example, a 3-week change in planting from 1 to 21 September is associated with an expected

44% increase in grain yield. However, the expected fall–winter forage yield from the 21 September planting date is only 32% as much as the expected fall–winter forage yield from the 1 September planting date.

Acknowledgments

Journal paper AEJ-241 of the Oklahoma Agricultural Experiment Station, Project H-2237. This material is based upon work supported in part by the USDA-CSREES, under agreement No. 93-34198-8410.

References

Bowden, R.L., 1997. Disease management. In: Wheat Production Handbook. Cooperative Extension Service C-529, Kansas State University, Manhattan, Kansas, pp. 18–24.

Brorsen, B.W., Bailey, D., Thomsen, M.R., 1994. Oklahoma cattle and the satellite video auction: location of buyers, location of cattle purchased, and quality premiums. Oklahoma Current Farm Economics 67, 3–13.

Carver, B.F., Krenzer Jr., E.G., Whitmore, W.E., 1991. Seasonal forage production and regrowth of hard and soft red winter wheat. Agronomy Journal 83, 533–537.

Christiansen, S., Svejcar, T., Phillips, W.A., 1989. Spring and fall cattle grazing effects on components and total grain yield of winter wheat. Agronomy Journal 81, 145–150.

Doye, D. G., Kletke, D., 1997. Oklahoma pasture and cropland rental rates. Cooperative Extension Service CR-216, Oklahoma State University, Stillwater, Oklahoma.

Epplin, F.M., 1997. Wheat yield response to changes in production practices induced by program provisions. Journal of Agricultural and Resource Economics 22, 333–344.

Epplin, F.M., Beck, D.E., Krenzer Jr., E.G., Heer, W.F., 1993. Effects of planting dates and tillage systems on the economics of hard red winter wheat production. Journal of Production Agriculture 6, 265–270.

Heer, W.F., Krenzer Jr., E.G., 1978. Soil water availability for spring growth of winter wheat (*Triticum aestivum* L.) as influenced by early growth and tillage. Soil and Tillage Research 14, 1048–1053.

Holliday, R., 1956. Fodder production from winter-sown cereals and its effect upon grain yield. Field Crop Abstracts 9, 129–135, 207–213.

Judge, G.G., Hill, R.C., Griffiths, W.E., Lutkepohl, H., Lee, T.C., 1988. Introduction to the Theory and Practice of Econometrics. John Wiley and Sons, New York.

Knapp, W.R., Knapp, J.S., 1978. Response of winter wheat to date of planting and fall fertilization. Agronomy Journal 70, 1048–1053.

Krenzer, Jr., E.G., 1994. Wheat for pasture. Cooperative Extension Service F-2586, Oklahoma State University, Stillwater, Oklahoma.

Krenzer, E.G. Jr, Tarrant, A.R., Bernardo, D.J., Horn, G.W., 1996. An economic evaluation of wheat cultivars based on grain and forage production. Journal of Production Agriculture 9, 66–73.

Paris, Q., 1992. The von Liebig hypothesis. American Journal of Agricultural Economics 74, 1019–1028.

Pinchak, W.E., Worrall, W.D., Caldwell, S.P., Hunt, L.J., Worrall, N.J., Conoly, M., 1996. Interrelationships of forage and steer growth dynamics on wheat pasture. Journal of Range Management 49, 126–130.

Ralphs, M.H., Graham, D., Galyean, M.L., James, L.F., 1997. Research observation: influence of overwintering feed regimen on consumption of locoweed by steers. Journal of Range Management 50, 250–252.

Redmon, L.A., Horn, G.W., Krenzer Jr., E.G., Bernardo, D.J., 1995. A review of livestock grazing and wheat grain yield: Boom or bust? Agronomy Journal 87, 137–147.

Redmon, L.A., Krenzer Jr, E.G., Bernardo, D.J., Horn, G.W., 1996. Effect of wheat morphological stage at grazing termination on economic return. Agronomy Journal 88, 94–97.

Rodriguez, A., Trapp, J.N., Walker, O.L., Bernardo, D.J., 1990. A wheat grazing systems model for the US southern plains: Part I model description and performance. Agricultural Systems 33, 41–59.

Shroyer, J.R., Dhuyvetter, K.C., Kuhl, G.L., Fjell, D.L., Langemeier, L.N., Fritz, J.O., 1993. Wheat pasture in Kansas. Cooperative Extension Service Report C-713, Kansas State University, Manhattan, Kansas.

Warmann, G.W., 1997. Wheat cost–return budget in south central Kansas. Cooperative Extension Service Report Farm Management Guide MF-574, Kansas State University, Manhattan, Kansas.

Washko, J.B., 1947. The effects of grazing winter small grains. Journal of the American Society of Agronomy 8, 659–666.

White, K.J., 1993. SHAZAM, the Econometrics Computer Program. Version 7.0 Users Reference Manual. McGraw-Hill, New York.

Winter, S.R., Musick, J.T., 1993. Wheat planting date effects on soil water extraction and grain yield. Agronomy Journal 85, 912–916.

Winter, S.R., Thompson, E.K., 1990. Grazing winter wheat: I. Response of semidwarf cultivars to grain and grazed production systems. Agronomy Journal 82, 33–37.