CULTURAL PRACTICES FOR MAXIMIZING FORAGE PRODUCTION IN WHEAT

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Summary

Continued expansion of the use of winter wheat for pasture in the Southern Great Plains has created a need for more information on how to enhance forage production, particularly in combination with grain production. Cultural practices for maximizing forage production often differ from those recommended for grain production. These differences include earlier seeding date, higher seeding rate, greater fertilizer needs, and greater attention to pest problems. Fall and winter forage production is most often limited and also is most responsive to proper management. Another critical cultural practice is management of grazing itself to maximize forage production without reducing grain yields. To assure adequate forage in northern areas, grazing must not start until plants are well established, and stocking rates must be adjusted to allow stockpiling of forage for winter months when growth slows. Rotational grazing systems may assist this effort and also increase forage yields, especially when grazing is continued on through spring (graze-out). For grain production, grazing must be terminated prior to elevation of the apical meristems to grazing height or yields will be drastically affected.

The primary area which needs further attention appears to be cultivar development for increased forage production. Current wheat breeding programs are designed primarily to increase grain yield potential, and no current cultivars consistently produce superior forage yields. Other areas needing further evaluation include additional descriptions of optimum seeding dates and rates for specific locations, benefits of narrower rows, irrigation scheduling, grazing with reduced tillage systems, development of effective pesticides without grazing restrictions, optimum grazing systems, and the establishment and acceptance of grazing termination guidelines based on plant development rather than calendar dates.

Introduction

Small grains have long been recognized as a valuable source of high quality forage for grazing livestock (Staten and Heller, 1949). Most of the extensive use of small grains pasture occurs in Texas, Oklahoma, and Kansas, where producers typically utilize winter wheat for grazing during its vegetative growth stage in fall, winter, and early spring. Livestock are then removed in spring shortly after floral initiation before rapid culm elongation begins (jointing stage) to allow reproductive development for grain production. If grazing intensity is not excessive and grazing is terminated before the apical

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meristems reach grazing height, grain yields may not be greatly affected and may actually be increased under certain conditions (Croy et al., this publication). However, a considerable portion of winter wheat acreage is used exclusively for grazing on through spring until regrowth ceases and plants eventually mature (graze-out). Graze-out can result in approximately three times greater total forage yields (McMurphy, 1976), since winter wheat accumulates most of its total dry matter after floral initiation (Shanahan, 1982). With depressed grain prices in recent years, interest in the latter practice has increased. Interest has been particularly high during the past year since the Federal Government's payment-in-kind (PIK) program allowed graze-out on qualified acres as a method of removing those acres from grain production.

Most of the research on cultural practices for winter wheat has concentrated on grain production. Cultural practices for maximizing forage production in winter wheat, particularly for encouraging greater availability of fall and winter forage, are somewhat different than those recommended for maximizing grain production. The objectives of this presentation are to review some of the studies which have evaluated forage production and to summarize recommendations for cultural practices designed to maximize forage production in winter wheat. Emphasis will be placed on winter wheat due to its more extensive use and great ability to produce grain following termination of grazing, although other small grains such as rye, oats, barley, triticale, sterile wheat hybrids, and various small grain mixtures have also been evaluated, and some of them may provide more forage under certain conditions (Cook, 1968; Atkins et al., 1969; Denman and Arnold, 1970; Cowley et al., 1971; Malm et al., 1973; Finkner, 1974; McMurphy, 1976; Gardenhire and Wilkerson, 1980; Rommann et al., 1982). Species and variety effects on forage production are reviewed in more detail elsewhere in these proceedings (Croy, this publication). Major cultural practices which should be considered for forage production in winter wheat include: seeding date, seeding rate and row width, soil fertility management, irrigation management (where practiced), cultivar selection, grazing management (stocking rates, rotations, starting and termination dates), seedbed preparation, and pest control (weeds, insects, diseases). All of these practices will interact with two critical environmental factors, precipitation and temperature, to determine actual forage production. As a result of the importance of precipitation and temperature effects, results from one location or one year may not always apply to other locations or years.

Review of Literature

Seeding Date. The effect of seeding date on forage production has probably been studied more than any other cultural practice, and indeed it may be one of the most important management factors determining the potential for fall and winter forage. Studies conducted over several years in South Central Oklahoma near Ardmore (Bates, 1975-1983) have consistently shown an advantage to planting wheat and other small grains in mid-September or early-October compared to late-October or early-November for fall and winter forage production (through late-February or early-March). However, in most years, total forage production through May (simulated graze-out) has been slightly greater with the later planting date. These results indicate that spring forage production increased with later planting more than enough to offset the fall and winter advantage of earlier planting. Harper (1961) also showed that small grains planted in mid-September produced twice as much fall and winter forage as when planted in mid-October near Admore, Oklahoma.

Further north at Perkins, Oklahoma, Phillips (1975) showed that delayed seeding from August 22 resulted in a decrease in fall and winter forage which averaged over 500 lb/acre/week in 1972-73 (Table 1) and over 400 lb/acre/week in 1973-74 (Table 2). As in the reports of Bates (1975-1983), spring forage production following jointing was greater with the later planting dates. However, spring growth was unable to make up for the difference prior to jointing, such that total production (simulated graze-out) was decreased with delayed seeding by approximately 400 lb/acre/week in 1972-73 and 300 lb/acre/week in 1973-74 (Tables 1 and 2). Seeding date did not have a significant effect on grain yields in either unclipped control plots or in plots last clipped on March 17 in 1972-73. However, grain yield was reduced for all seeding dates by the March 17 clipping. In 1973-74, maximum grain yield for unclipped controls was produced with an October 17 planting date. This was expected, since the recommended seeding date for grain production in this area is October 1-15. However, Phillips (1975) also showed that the lower grain yields associated with planting on August 23 or September 18 in 1973-74 were increased to the levels of the unclipped control planted in October if fall forage was removed in December (Table 3). Thus, fall forage removal (simulated grazing) enhanced grain yields in the early seeded treatments.

Elder (1960) compared six planting dates over four seasons with clipping every 30 days using a winter pasture mixture of rye, wheat, oats, and vetch at Stillwater, Oklahoma. September 10, September 25, and October 10 seeding dates gave the same total forage production through May, but the September 10 seeding date produced twice as much forage before January 1 as the October 10 seeding date. Seeding after October 25 resulted in no measureable forage before March and also decreased total forage production.

In Texas, Holt et al. (1969) also found that September or early-October seeding was important for fall forage production with small grains at College Station but did not produce highest total forage yields for simulated graze-out. October 15 was the optimum date for total forage production. They suggested that the major problems with earlier planting are increased chance of drought and increased incidence of weeds and insects.

For irrigated wheat in Southeastern New Mexico, Malm et al. (1973) found two-thirds more forage production prior to jointing in March with September 1 or September 15 planting compared to October 1 planting. Planting October 15 or November 1 produced no measureable winter forage and considerably less forage prior to jointing (Table 4). The one month delay in planting from September 15 to October 15 decreased

Table 1. Accumulated wheat forage production as affected by seeding date at Perkins, Oklahoma, 1972-73 season.

Seeding Date	Accumulated Production Through:				
	Nov. 3	Dec. 1	Mar. 17	Apr. 26	May 23
	lb/acre				
Aug. 22	2170	2670	4770	6630	7380
Sept. 5		1510	3740	5920	6570
Sept. 19			2720	4660	5350
Oct. 3			1530	4360	4930

From Phillips (1975)

Table 2. Accumulated wheat forage production as affected by seeding date at Perkins, Oklahoma, 1973-74 season.

Seeding Date	Accumulated Production Through:				
	Oct. 26	Dec. 14	Mar. 25	Apr. 18	May 22
	lb/acre				
Aug. 23	1930	2500	4420	5510	6180
Sept. 18		1250	3160	4090	4870
Oct. 17			1400	2700	3310
Nov. 30				1160	1900

From Phillips (1975)

Table 3. Wheat grain yield as affected by seeding date and time of last forage harvest at Perkins, Oklahoma, 1973-74 season.

Last Forage Harvested On	Seeding Date Aug. 23	Sept. 18	Oct. 17	Nov. 30
	---------- bu/acre ----------			
Never Harvested	13	19	27	24
Oct. 26	21	No. Hv.[1/]	No. Hv.[1/]	No. Hv.[1/]
Dec. 14	30	26	No. Hv.[1/]	No. Hv.[1/]
Mar. 25	19	16	21	No. Hv.[1/]
Apr. 18	0	2	3	4

[1/] Forage growth was insufficient to have a harvest at this early date after seeding or it was before seeding.

From Phillips (1975)

Table 4. Accumulated irrigated wheat forage production and grain yield following grazing as affected by seeding date in Southeastern New Mexico, 1970-71 and 1971-72 seasons.

Seeding Date	Accumulated Production Through: December	February	March	Grain Yield
	------ lb/acre ------			lb/acre
Sept. 1	1680	2880	4540	1602
Sept. 15	1980	3400	5160	1874
Oct. 1	--	1280	2860	2105
Oct. 15	--	--	1280	2433
Nov. 1	--	--	680	1461

From Malm et al. (1973)

forage production prior to jointing by almost 4000 lb/acre. This is about double the rate of yield reduction with delayed planting reported by Phillips (1975) under non-irrigated conditions in Oklahoma. Grain yields following termination of forage harvests at jointing were greatest with the October 15 planting, and decreased for successively earlier dates or for the November 1 planting date (Table 4).

Fuehring (1981) also noted the importance of early planting for maximizing forage yields of irrigated wheat in the High Plains of New Mexico. Fall and winter forage yields were reduced drastically when planting was delayed past early-September. However, for simulated graze-out, planting date had only a small effect on total forage production. Grain yields were not greatly influenced by planting date. However, delaying the date of final forage harvest by approximately one-week intervals during March gradually increased forage yields but decreased grain yields.

Since these studies all indicate the necessity of seeding earlier than recommended for grain production to assure fall and winter forage production potential, we have initiated more detailed studies to further evaluate the optimum seeding date at five different locations throughout Oklahoma. Where adequate fall moisture was received in 1980-81 at Haskell, Oklahoma (East Central), seeding in mid-August resulted in highest accumulated forage yields throughout all forage harvests (Table 5). With lower fall moisture in 1982-83, a similar trend was observed, but the differences were not as large. Under irrigation at Goodwell, Oklahoma (Panhandle), optimum seeding date appears to be late-August or early-September. Maximum accumulated forage production for all clippings was greatest for the September 2 seeding in 1980-81 (Table 6) and the August 30 seeding in 1982-83 (Table 7). Mid-August planting was similar to mid-September planting for fall and winter production in 1980-81, but the latter produced 600 lb/acre more total forage by the end of May.

Unfortunately, fall moisture has been so limited at the other three locations during the first two years of this study that very little fall and winter forage was produced with any seeding date. Under these conditions, seeding date had little effect on spring forage production either, since all treatments were "evened-out" due to the slow establishment. These results simply point out the critical role of moisture in wheat forage production over which the non-irrigated producer has little control. Denman and Arnold (1970) and McMurphy (1976) both noted that limited fall moisture in Southwestern Oklahoma usually prevents early fall establishment of winter wheat for forage production. However, there may still be an advantage to early planting in dry soil in some situations, since later rainfall will allow germination and quick establishment. A potential problem is that enough rainfall to germinate seeds may be received, but not enough to keep seedlings alive, thereby resulting in a poor stand. Perhaps the problem is more likely with August planting when rainfall is often received in smaller increments than during later fall months.

Table 5. Accumulated wheat forage production as affected by seeding date at Haskell, Oklahoma, 1980-81 season.

Seeding Date	Accumulated Production Through:			
	November 20	February 27	April 1	April 23
	lb/acre			
Aug. 14	2151	3079	6630	6981
Aug. 28	1520	2511	6118	6486
Sept. 11	247	961	4254	4652
Sept. 25	--	311	3257	4062

Table 6. Accumulated irrigated wheat forage production as affected by seeding date at Goodwell, Oklahoma, 1980-81 season.

Seeding Date	Accumulated Production Through:					
	January 9	March 17	March 31	April 16	April 30	May 28
	lb/acre					
Aug. 18	2403	3605	4665	5192	5670	6460
Sept. 2	2436	3958	5243	6215	6560	7592
Sept. 17	1636	3278	4476	5356	5700	7060
Oct. 3	492	1887	3385	4289	4972	6218

Table 7. Accumulated irrigated wheat forage production as affected by seeding date at Goodwell, Oklahoma, 1982-83 season.

Seeding Date	Accumulated Production Through:					
	January 19	March 1	March 30	April 12	May 12	June 21
	lb/acre					
Aug. 30	798	1817	4765	5902	8333	10932
Sept. 17	--	378	2775	3586	6077	9262
Sept. 27	--	--	2273	3355	5999	9097
Oct. 11	--	--	835	1666	4733	8094

Seeding Rate and Row Width. Only a few studies have reported on the effects of seeding rate and/or row width on forage production. However, recommendations for small grain forage production have often suggested seeding rates 50 to 100% higher than normally recommended for grain production (Fribourg, 1973). Holt (1959) found forage production of oats by January 3 at Crystal City, Texas, was increased by 1300 lb/acre with 96 lb of seed per acre compared to 48 lb per acre. However, accumulated forage production by March 18 was only 500 lb/acre greater with the higher seeding rate. Small advantages to higher seeding rate have also been reported in other studies in Texas by Holt et al. (1969). They found less advantage to 100 lb seed/acre vs. 50 lb seed/acre for wheat compared to oats or rye at College Station.

Shipley and Regier (1972) showed a much greater response to higher seeding rate for irrigated wheat in the Texas High Plains. The difference in fall and winter forage production (August 30 to March 1) (Figure 1) was much greater than the difference in spring forage production (March 1 to June 4) (Figure 2). There was no effect of seeding rate without irrigation. In another year, 90 or 120 lb of seed per acre resulted in more fall and winter forage under irrigation than did 60 lb of seed per acre. Grain yields were not influenced by seeding rate in these studies.

Rao et al. (1969) found no difference in winter forage yield for 60, 75, or 95 lb seed per acre in winter wheat at College Station. However, averaged over all seeding rates, 6-inch rows gave a significant increase (11%) over 9- or 12-inch rows. Bishnoi (1980) also showed an advantage of 5-inch row width over 10-inch row width for winter forage production of wheat and rye in Northern Alabama. Seeding rates of 75 or 100 lb per acre also resulted in higher forage production than 50 lb per acre. However, seeding at 50 lb per acre produced highest grain yields whether plots were clipped for winter forage or not. Holt et al. (1969) found no advantage to broadcast seeding over 12-inch rows.

Thus, it appears that higher seeding rate and narrow row spacing may be advantageous for early fall forage production, especially under high moisture or irrigation with early seeding dates. However, as Holt et al. (1969) noted, the tillering characteristic of small grains tends to compensate for low plant populations and row width differences, such that little forage benefit from higher seeding rate or narrower rows is observable by spring. Indeed if grain is also to be produced, high seeding rate may be a disadvantage, since too high plant population may lead to decreased numbers of spike-bearing tillers (Puckridge and Donald, 1967).

Soil Fertility Management. The primary nutrient usually associated with limiting potential small grain forage production is nitrogen (N). The basis for the high N demand for forage production is a matter of simple arithmetic. Winter wheat forage containing 25% crude protein will contain approximately 4% N. Thus, one ton of dry forage will contain 80 lb of N. A reasonable forage production goal for graze-out in Oklahoma is 2-3 tons/acre, which would require 160-240 lb N/acre. Oklahoma Cooperative Extension Service soil test recommendations (Johnson and Tucker, 1982) base N requirements on yield goal and in-

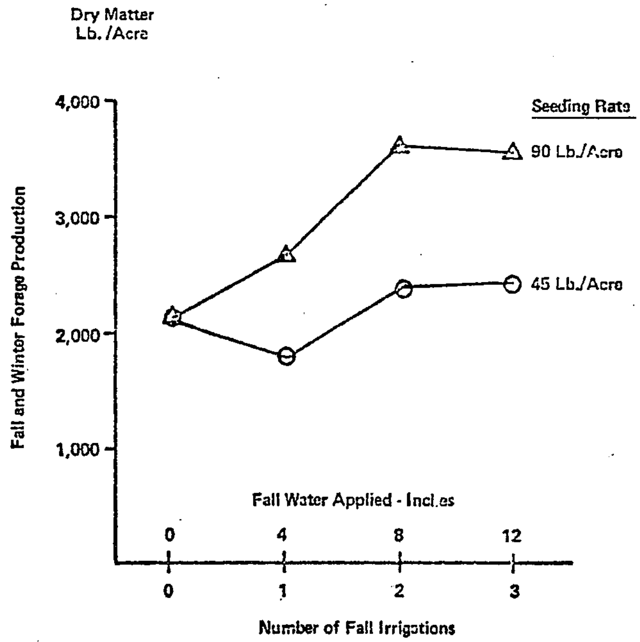

Figure 1. Forage production of irrigated winter wheat from emergence on August 30 to March 1, irrigated wheat grazing study, North Plains Research Field, Etter, Texas, 1970-71. (From-Shipley and Regier, 1972).

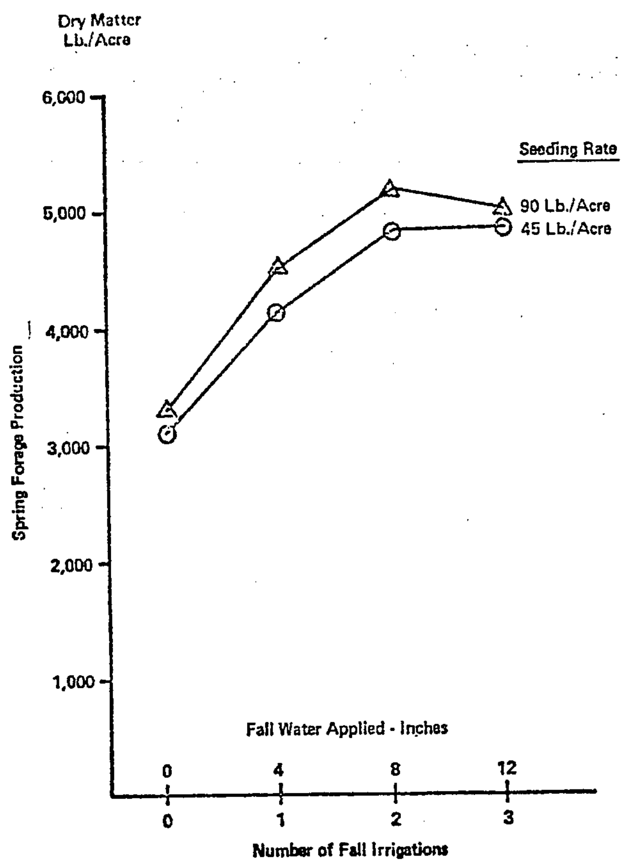

Figure 2. Forage production of irrigation winter wheat from March 1 to June 4, irrigated wheat grazing study, North Plains Research Field, Etter, Texas, 1970-71. (From-Shipley and Regier, 1972).

dicate 60 lb N/acre required per ton of forage for grazing small grains. In addition, 2 lb N/acre per bushel of grain yield goal is required, if both forage and grain are produced. Nitrogen fertilization according to yield goal and forage removal seems to be the best approach, since actual comparisons of small grain forage yields to fertilizer application have produced varied responses. Nitrogen fertilization appears to have little effect on forage quality in Oklahoma (Denman and Arnold, 1970).

In actual fertilization studies, Holt et al. (1969) reported increases of 1200 to 1500 lb of forage per acre for 120 vs. 60 lb N/acre at Mt. Pleasant, Texas. This would be consistent with the 80 lb N per ton of forage suggested earlier. Fall and early winter growth increased as pre-plant N increased from 30 to 120 lb N/acre. However, at College Station, responses were not as great. In Georgia, Morris and Gardner (1958) found 120 lb N/acre increased forage yields by March 15 only 750 lb per acre compared to 60 lb N/acre. Phillips (1975) compared 60 lb N/acre at planting to 180 lb N/acre split among planting, November 8, and March 15 at Perkins, Oklahoma. The high N increased total forage production averaged over four seeding dates from 5310 to 6062 lb per acre (Table 8). However, the greatest increase was in fall and winter production (611 lb/acre) compared to the increase during spring (142 lb/acre). The lack of consistency in N responses is probably related to differences in organic matter, temperature effects on mineralization of N, moisture interactions, other nutrient levels, and other factors.

Split application of N has been suggested to increase forage yields of small grains for grazing (Fribourg, 1973). Holt et al. (1969) reported increased yields in response to split application between planting and winter (December or January) at several locations in Texas. Two post-planting applications were of no advantage, however. Atkins et al. (1969) indicated a small response to an additional 30 lb N/acre in mid-winter at College Station. In Oklahoma, Elder (1967) found no advantage to split application of N between fall and spring. It appears that the principle advantage of split application would be the ability to adjust N needs to forage removal, since unpredictable environmental factors make it difficult to estimate total N needs at planting. If conditions are favorable for heavy grazing removal in fall and/or spring, then additional N may be needed, especially if a grain crop is to be taken. For early forage production, sufficient N for a reasonable forage yield goal should be applied at planting or before.

Phosphorus (P) is also critical and has been shown to have an even greater effect than N on fall forage production under some conditions in Oklahoma (Edler, 1967). Cook (1968) showed that P alone did not increase forage yields significantly, but a combination of N and P resulted in higher yields than either alone. Cook's results averaged over five years at Temple, Texas, are summarized in Table 9. Baker and Tucker (1971) showed that the potential for NO_3-N accumulation in wheat forage was reduced by P application. Oklahoma Cooperative Extension Service recommendations (Johnson and Tucker, 1982) for P and K on winter wheat are based on soil test levels and are equivalent for forage and/or grain production.

Table 8. Effect of seeding date and nitrogen fertilization on forage yields of Centurk wheat at Perkins, Oklahoma, 1972-73 season.

Seeding Date	Forage Production		
	Through March 17	After March 17	Total
	lb/acre		
	Low Nitrogen (60 lb N/acre)		
Aug. 22	4254	2342	6596
Sept. 5	2909	2766	5675
Sept. 19	2256	2793	5049
Oct. 3	905	3015	3920
Mean	2581	2729	5310
	High Nitrogen (180 lb N/acre)		
Aug. 22	4774	2610	7384
Sept. 5	3739	2832	6571
Sept. 19	2723	2629	5352
Oct. 3	1530	3411	4941
Mean	3192	2871	6062
$LSD_{(P=.05)}$	396	439	392

From Phillips (1975)

Table 9. Average effects of combinations of nitrogen and phosphorus on small grain forage yields at Temple, Texas, 1963-67 season.

N	P_2O_5 (lb/acre)			
(lb/acre)	0	30	60	Average
	lb/acre			
0	2700	2900	3050	2880
15	3040	3510	3630	3330
30	3450	3960	3990	3800
60	3520	3910	4040	3820
90	3790	4050	4180	4010
Average	3300	3660	3780	

From Cook (1968)

Irrigation management. Although a considerable portion of the irrigated winter wheat acreage in the High Plains is grazed, only limited studies of irrigation practices for optimizing forage production either in combination with grain production or for graze-out have been completed. At the North Plains Research Field at Etter, Texas, Shipley and Regier (1972) evaluated irrigation management effects on forage production using both clipping and grazing trials. In 1970-71, they compared one, two, or three fall irrigations of 4 inches each to no irrigation. Maximum total clipped forage yields for simulated graze-out were produced with 90 lb seed/acre and two fall irrigations. There was a significant increase in forage yields with two irrigations compared to one, but there was no advantage to a third fall irrigation (Figure 3). Greater effects of irrigation on forage production were observed during spring compared to fall and winter and at the 90 lb seeding rate compared to the 45 lb seeding rate (Figures 1 and 2). In 1971-72, the optimum date for the second fall irrigation was evaluated. Seeding date was September 1, and the first irrigation was November 1. Highest total forage yields were obtained with the second irrigation on January 15 compared to December 15, January 1, February 1, or February 15.

In the grazing trials, at the 90 lb seeding rate over three years, grain yields were increased by fall and winter grazing compared to ungrazed, irrigated control plots planted September 1. However, grain yields were as much as 30% lower than ungrazed wheat planted in October during two of the years. There was only a slight reduction in grain yield with different grazing termination dates from March 1 through April 10, but later termination dates greatly depressed yields. Within grazing treatments, grain yields following grazing were not affected by seeding rate or irrigation schedule, provided at least one fall irrigation was applied.

Cultivar selection. In general, although differences among cultivars for forage production have been noted within years at different locations, no consistent advantages of particular cultivars of winter wheat for forage production have been found during extensive testing in Oklahoma (Denman and Arnold, 1970; McMurphy, 1976; Rommann et al., 1976-1982). Most of the popular cultivars selected for grain production have shown the ability to produce good forage yields under favorable conditions. Cowley et al. (1971) reported similar inconsistent results from year to year when comparing wheat and other small grain varieties at Bushland, Texas. Malm et al. (1973) suggested an advantage for sterile wheat hybrids for graze-out since they exhibit delayed senescence. McMurphy (1976) noted that the most important consideration is selection of a cultivar which is capable of rapid fall growth since fall and winter forage is usually limiting in Oklahoma. Since most producers are primarily interested in grain production, winter wheat cultivars are usually selected on the basis of grain yield potential rather than forage yield potential as noted by Holt et al. (1969). Additional notes on cultivar and species effect on forage quantity and quality are reported herein (Croy, this publication).

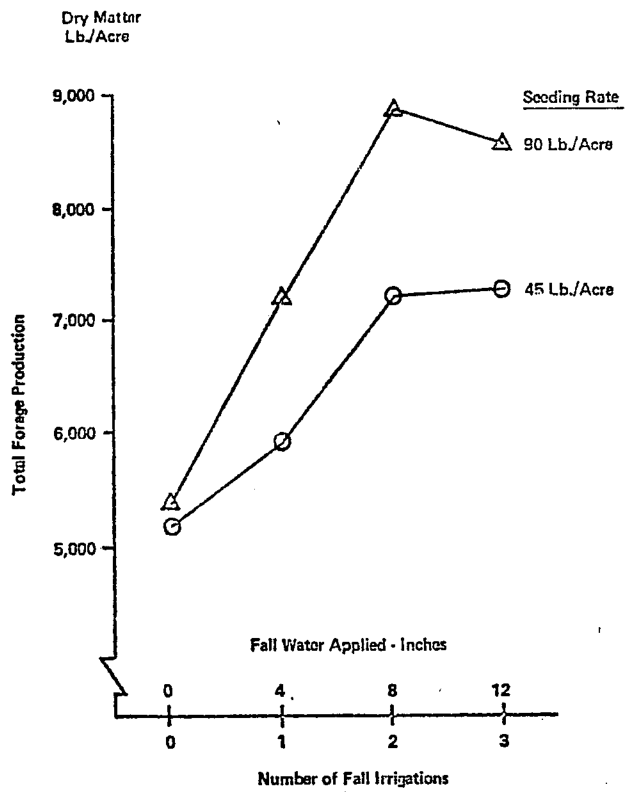

Figure 3. Forage production of irrigated winter wheat from emergence on August 30 to graze-out on June 4, irrigated wheat grazing study, North Plains Research Field, Etter, Texas, 1970-71 (From-Shipley and Regier, 1972).

Table 10. Effect of foliage removal in fall and winter on wheat forage production following planting on August 23, 1972, at Perkins, Oklahoma.

Harvest Dates	Harvest Treatment 3 harvests	2 harvests	1 harvest
	lb/acre		
Oct. 9	1790	No Clip	No Clip
Dec. 1	989	2370	No Clip
Mar. 15	2300	1962	4008
Total	5079	4332	4008

From Phillips (1975)

Grazing Management. The effects of grazing management on grain yields following termination of grazing are of major concern to producers using winter wheat for forage plus grain. It is well established that grazing must be terminated prior to elevation of apical meristems on potential spike-bearing tillers to grazing height to avoid serious grain yield reductions (Dunphy et al., 1982). Effects of grazing management during the grazing period on grain yields are less well defined and relate to factors such as starting date, grazing intensity, continuous grazing vs. rotation or limit grazing, the specific timing of grazing termination based on a recommended "safe" calendar date compared to actual plant development which varies from year to year, and interactions with environmental factors. More detailed discussions of some of these factors are included elsewhere (Croy et al., this publication).

Grazing management also has a significant impact on forage production and utilization, whether using graze-out or forage plus grain systems. Since an entire session of this symposium has been devoted to this area, only a brief reference will be made here. Holt et al. (1969) summarized work in Texas on grazing management and related the importance of delaying first grazing until small grain plants were well established with 8-10 inches of topgrowth and sufficient root development to resist uprooting by grazing, then managing subsequent grazing either to maintain residual leaf area or allow a recovery period between grazings. Clipping oat forage each time plants reached 4-6 inches produced only half as much forage as clipping at 10-12 inches.

In southern portions of the wheat grazing area, forage production can be expected to continue throughout the winter months. However, further north when temperatures drop below 40^{o}F, wheat makes very little growth (Holt, 1962). Therefore, forage must be stockpiled to carry the livestock through January and February (Rommann et al., 1975-1982). Forage growth occurs at a faster rate during the spring, and two-thirds of the total production occurs after jointing in Oklahoma. Thus, producers should expect to be able to graze the same number of livestock on one-half of the acreage during spring graze-out compared to that needed for fall and winter. If sufficient fall forage is produced, Phillips (1975) showed that total forage production was increased by removing fall forage which reached 8-10 inches in height (Table 10). Fall forage removal also enhanced grain yields of early seeded wheat as previously indicated (Table 3). However, once jointing occurred, forage removal in spring actually decreased potential forage yield by removing apical meristems and slowing growth. These results probably help explain why rotational grazing increased carrying capacity by 15-20% in the spring but not in the fall in East Central Oklahoma (Elder, 1967).

Seedbed Preparation. Little research on specific seedbed preparation techniques for enhancing forage production has been conducted. However, a major proglem which limits fall forage production of winter wheat under non-irrigated conditions in most of the Southern Plains is the frequent lack of available soil moisture for seed germination and plant establishment at the desired August or early-September seeding dates (McMurphy, 1976). Therefore, a primary concern in seedbed preparation during the entire fallow period from previous crop harvest to planting should be moisture conservation. As such, tillage should be performed only as needed to control weed growth and produce a suitable seedbed. The development of reduced tillage systems which may result in better moisture conservation during the fallow period may seem attractive. However, recent emphasis on developing reduced tillage systems for winter wheat grain production in Oklahoma have not evaluated grazing as a part of the systems (E.G. Krenzer, pers. comm.). Research in Texas (Unger, 1971) has shown that grazing small grain crops leads to increased soil compaction measured by bulk density or soil penetrometer. Effects were greatest in the top three inches of the soil profile and when soil water content was near field capacity. The primary tillage operation immediately following termination of grazing (grazeout) or grain harvest in conventional tillage systems is usually moldboard plowing which breaks up compact surface layers. One potential problem with reduced tillage systems is that moldboard plowing as a primary tillage step is eliminated. This may limit the effectiveness of such systems in combination with grazing where surface soil compaction is likely.

Pest Control. Pest problems (diseases, insects, weeds) in winter wheat are similar whether the crop is used for forage, grain, or both. However, management practices used to promote forage production may alter the potential for damage by certain pests. Although most of the specific discussion here applies to Oklahoma, the same principles may apply to other pest problems at different locations.

Holt et al. (1969) noted that diseases are less of a problem in forage production than in grain production because most diseases seldom become serious until early spring after major forage needs have been met. As a result, disease problems in winter wheat grown for both forage and grain are of greater conern than in that grazed out. However, warm soils and high temperatures associated with early planting for forage production in either system are more favorable for development of several diseases such as seedling blights caused by the root rot pathogens *Helminthosporium* and *Fusarium* (Williams et al., 1980). Forage yield reductions of 77% have been reported in root rot infested areas due to stand losses. Thus, fungicide seed treatment for control of seedling diseases is very critical with early seeding. Another disease which is more prevalent in Oklahoma with early planting, especially when volunteer wheat is not adequately controlled, is wheat streak mosaic (Williams and Young, 1977). The vector (wheat curl mite) and virus survive during the fallow period on volunteer wheat. Although symptoms may not appear in the fall, early planting allows a longer time in the fall for the disease to be transmitted and develop. Powdery mildew is a disease which may be more prevalent with lush fall growth following early seeding and high fall moisture, but a good method of control is grazing itself to remove the excess vegetative growth. Fall grazing is also a method of reducing leaf rust (Williams, 1978). For most other disease problems in Oklahoma, management for grazing probably has no different effect than management for grain (R.A. Johnston, pers. comm.). However, selection of resistant cultivars and following recommended cultural practices to reduce incidence of any disease should benefit both grain and forage yield potential.

Insect problems which may be intensified by grazing management include the false wireworm, which is most likely to damage seed which is planted early in warm, dry soil and does not germinate immediately. Early seeded wheat also may be a target for infestations of fall armyworms and greenbugs during some years in Oklahoma (R.A. Johnston, pers. comm.). In Kansas, the importance of delyaed seeding to reduce the potential for damage by Hessian fly has long been recognized (Laude et al., 1955) and creates a potential problem of reduced grain yields for susceptible cultivars seeded early to promote fall forage production.

Several concerns related to weed control problems with wheat pasture should be mentioned. Of primary importance are the grazing restrictions which exist on many herbicides. For example, no effective herbicides for wild oats ("Hoelon", "Fargo", etc.) are registered for use due to full season grazing restrictions. The extensive use of winter wheat for grazing in Oklahoma and Texas make it difficult to even get effective products with grazing restrictions labelled for grain production in these states (T. Peeper, pers. comm.). There are also restrictions related to crop development which may interfere with grazing use. For example, "Sencor" can be used for cheat control on certain wheat varieties, but it cannot be applied until wheat plants are well tillered, then there is an additional 14 day grazing restriction. This delay may cut into potential grazing time. Small grain pasture mixtures have often been promoted (Elder, 1960), but a potential weed problem may appear when the producer wants to return the area to a single species and has grown a pasture mixture containing rye or vetch which then volunteer readily. Another problem with use of soil-applied herbicides followed by grazing is maintaining a uniform distribution of a herbicide layer against the trampling action of the livestock which re-distribute soil and herbicides, especially when the soil is too wet (T. Peeper, pers. comm.). Grazing small grains also reduces the ability of the crop to shade weeds as it normally does without grazing. This may lead to increased weed development, especially with graze-out systems. On the positive side, grazing animals may graze some weedy species and retard their development compared to ungrazed conditions. These examples have been given simply to show that grazing may create some different pest problems which the producer should be prepared to address.

Conclusions

This summary of the literature on studies relating to cultural practices for enhancing forage yields in winter wheat has provided some general guidelines which should be followed. Most of the benefits due to proper management are apparent in fall and winter forage production rather than in spring forage production. This is critical since fall and winter forage is more limited for most producers. In addition, management is more critical for combination grazing-grain systems than for graze-out systems.

Seeding 4 to 6 weeks earlier than recommended for grain production is usually beneficial for fall and winter forage. Seed treatment for insects and diseases and careful monitoring of potential disease, insect, and weed problems are more critical with earlier seeding. Doubling the seeding rate over that normally recommended for grain production is advantageous with early planting, especially under irrigation. Narrower rows may produce small benefits, but they may not be practical if they require a change in planting equipment. Although nitrogen is the fertilizer nutrient most frequently needed, a balanced soil fertility program should be emphasized for maximum forage production. For example, reports have shown response to nitrogen may be limited by low levels of soil available phosphorus. Thus, fertilizer recommendations should be based on soil test results, and nitrogen rates should be adjusted for yield goals of both forage and grain. Split application of nitrogen has produced variable responses. However, its major advantage is that it provides a good method of adjusting nitrogen fertilizer needs to actual forage production and utilization throughout the season.

Early seeding of wheat often results in reduced grain yields since excessive fall growth may lead to high fall water use or increased disease or insect problems. However, fall forage utilization by grazing of early seeded wheat may prevent grain yield reductions and help control foliar diseases. Therefore, once plants are well established in fall, grazing of excess forage is generally beneficial for maintaining grain yield potential. In addition, total forage production has been shown to increase with removal of fall forage which reaches 8-10 inches in height. To assure adequate winter forage in northern areas, stocking rates must be adjusted to allow stockpiling of forage for winter months when growth slows. Rotational grazing systems may help meet these objectives and also increase forage yields, especially when grazing is continued on through spring for graze-out. For grain production, grazing must be terminated prior to elevation of the developing spikes to grazing height to prevent serious grain yield reductions. Additional concerns relating to grazing management on forage and grain production are reviewed elsewhere in these proceedings.

Areas of Needed Research

This literature review has revealed several potential areas for which additional information would be helpful. These additional research needs on cultural practices for winter wheat forage production include the following:

(1) Selection of cultivars for both forage and grain yield potential, since selection for cultivars under current breeding programs emphasizing grain yields has apparently not produced any cultivars with superior forage yield potential.

(2) Integration of grazing management with reduced tillage systems for winter wheat production.

(3) Development of effect weed control herbicides for grassy weeds without grazing restrictions.

(4) Effects of grazing termination date on grain yields based on plant development related to variable environmental factors rather than a calendar date.

(5) Further development of grazing systems which result in optimum production and utilization of fall and winter forage.

(6) A more accurate analysis of the specific optimum early seeding dates for specific locations, including effects on both forage production and grain yield response following grazing.

(7) Further evaluation of row-width effects which may be more important than seeding rates.

(8) Further evaluation of optimum irrigation scheduling in view of decreasing water supplies.

(9) Additional studies on effects of soil fertility status on forage yields, particularly on potassium and liming to correct soil pH which have not been adequately addressed.

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