YIELDS, COMPOSITION, AND FEEDING VALUE OF WHEAT, BARLEY, AND OAT SILAGES

by

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WHEAT, BARLEY, AND OAT SILAGES FOR BEEF CATTLE

INTRODUCTION

In Kansas, cereal crops are potentially important sources of high-quality forage. Harvesting cereals for silage rather than as grain may mean increased dollar returns per acre. Cereal silages represent more total nutrient yield per acre than does cereal grain and, when fed to beef cattle, result in increased beef production. Basically, the net return from beef produced per acre from cereal silage compared with that from grain tells a farmer whether to harvest cereals as silage or grain.

Harvesting wheat, barley, or oats for silage has many advantages. Early summer crops, particularly wheat and barley, can be used with fall-harvested crops in a year-round forage program. That allows greater use of existing silage facilities during the summer. In many instances land may be double-cropped after a late-May or early-June cereal harvest. Harvesting cereal crops for silage, compared with harvesting them for grain, decreases the risk of crop loss from rain, wind, or hail. Finally, if yields of fall-harvested crops are low in dry years, early summer forage would be a reserve source of winter feed.

Making wheat, barley, or oat silage has disadvantages, however, and certainly is not recommended for all farmers. To produce silage from such cereal crops, the farmer must (1) invest in harvesting and storage equipment, (2) expend more labor than is required for grain production, and (3) merchandize through cattle; hence, it is not so liquid an asset as grain. (Commonly, cattle are simply allowed to graze out the stand as spring pasture. Though field losses are higher with that method, no investment in harvest or storage equipment is required. Making hay causes less field loss than grazing, but requires more labor and equipment.) Silage harvested in the proper stage of growth and ensiled correctly may be preserved for long storage periods with minimal nutrient loss.

In any case, wheat, barley, and oat forages are high-quality, high-protein feeds and maximum production per acre is realized by harvesting, storing, and feeding them as silage.

THE ENSILING PROCESS

Before a farmer can make good-quality cereal silage, he must understand the basic principles of ensiling. Silage is produced by controlled anaerobic fermentation of green forage. Ensiling forage allows only a minimal loss of nutrients. Bacteria produce organic acids (notably lactic acid), which serve as the agents of preservation. Initially acetic acid is formed, but within a short time other bacteria begin converting available carbohydrates into lactic acid. These acids lower the pH of the forage, thereby slowing enzyme action and stopping fermentation. Ideally, that results in a desirable silage with a pleasant odor, good palatability, and little nutrient loss.

If fermentation continues (that is, if the pH is not lowered enough from insufficient lactic acid production), more acetic, succinic, and other minor acids are formed; silage is then less palatable. If fermentation continues, butyric acid forms, resulting in excessive nutrient loss, putrefaction, lowered protein digestibility, and lowered palatability to livestock.

FACTORS AFFECTING CEREAL SILAGE FERMENTATION

Good-quality silage and minimal nutrient losses depend on several factors, most importantly: correct moisture content, availability of fermentable carbohydrates, and exclusion of air in the ensiled mass.

Moisture in Cereal Silages.

The most desirable acid is formed when the moisture content of the ensiled crop is correct. A range of 55 to 70% moisture for material going into the silo is recommended, with 60 to 65% the optimum, depending on the kind and size of silo. Larger diameter upright silos and deeper trenches or bunkers permit drier forage to be stored.

Wheat and barley may become excessively dry (less than 60% moisture), and water may need to be added. The benefits of increasing the moisture content to 60 to 65% are substantial. Normally, wheat and barley that have been direct-cut in the early-dough stage contain an acceptable 60 to 65% moisture.

If the forage is excessively dry, air is not easily excluded, so fermentation is inhibited. As mold and yeast grow and oxidation creates high temperatures, spoilage and protein degradation increase. On the other hand, if the crop is exceedingly wet, butyric acid is likely to be produced because of dilution of the acids; that results in a relatively high pH. Seepage losses of soluble nutrients also are a problem.

Carbohydrates.

Fermentation of soluble carbohydrates produces lactic acid needed to preserve silage. A high ratio of available carbohydrates to dry matter is desirable. Grain or molasses must be added to many grasses and legumes to provide fermentable carbohydrates to produce sufficient lactic acid.

Anaerobic Conditions.

Anaerobic conditions are necessary for proper fermentation. When forage is exposed to air or entrapped air, undesirable fermentation can occur. Excessive butyric acid is then produced, and the silage eventually becomes putrid and moldy.

Because cereal stems are hollow and filled with air, fine chopping is critical for good packing to exclude entrapped air. The crop should be harvested rapidly; the silo then should be filled as quickly as possible, with the forage being packed well. The use of covers, as plastic sheets, immediately after the silo filling will help decrease losses and make a better silage.

INFLUENCE OF STAGE OF MATURITY ON CEREAL SILAGE YIELD AND QUALITY

Forage yield and feeding value are affected by the stage of maturity of the cereal at ensiling time. Cereals are commonly harvested for silage in the boot, milk, or dough stages, described here for wheat, barley, and oats:

Boot. . .Head, remaining inside stem, visibly distends sheath of flag leaf. Head of main stem usually enters boot stage first, followed by the tillers. Stage lasts about 10 days.

Fertilization and watery-ripe. . .Flowering, fertilization, and initial development of grain occur. Plant is green, but lower leaves have begun to die.

Milk. . .White, milklike fluid occupies kernel, made up of water and many starch granules. More leaves die; embryo develops fully. Stage lasts 10 to 14 days.

Dough. . .Water content of the kernel decreases to dough consistency. Leaves are dying; plant changes from green to yellow. Stage lasts 10 to 14 days.

Ripe. . .Plant is entirely yellow; kernel is firm and flintlike. Plant becomes brittle and kernels fragment when crushed.

Silages were made from several varieties of hard and soft winter wheats and winter barleys at different stages of maturity in 1974 and 1975 at Manhattan. Yields are shown in Figure 1; silage composition and digestibility in Tables 1 and 2. Hard wheat, soft wheat, and barley had similar yields.

Basically, the quantity of cereal forage increases and the quality decreases as the plant matures. Nutrient content is greatest in the boot stage, but tonage per acre is lowest. Silage harvested in the boot stage must be wilted before ensiling to achieve proper moisture content. Milk-stage silage, which is the least palatable to livestock, produces slower and less efficient gains than does dough-stage silage. Dough-stage silage, although lowest in crude protein, produces the greatest forage yields. Generally, total digestible nutrient (TDN) yield per acre is 35 to 45% less for boot-stage silage than for dough-stage silage.

Optimum silage-harvest time is shorter for wheat, barley, or oats than for corn or sorghum. Harvesting at the dough stage, a critical 10- to 14-day period, requires good management. It may be wise to start early, when moisture is 65 to 70%, so harvest will not extend beyond the dough stage of maturity. As harvest draws to a close, it may be necessary to add water to dry forage or to blend wet forage (such as direct-cut alfalfa) with it at the silo.

Cereals reach boot, milk, or dough maturities at different times, depending on species, location, and weather. Barley usually matures a week earlier than wheat does and wheat one to three weeks before spring oats do. Dry, hot weather hastens maturity. Dough-stage hard wheat has been harvested as early as June 3 (1977) and as late as June 14 (1975) at Manhattan.

TIPS FOR MAKING CEREAL SILAGE

Preserving maximum nutrients per acre from cereal silages requires careful forage and silo management. These six recommendations are based on our experiences:

Harvest in the dough stage.

Chop fine, using a recutter screen or short length of cut.

Ensile at about 65% moisture; add water or forage with more moisture if necessary.

Fill the silo rapidly.

Pack well to exclude air.

Cover and seal the surface to reduce spoilage.

Usually harvest, to be completed during the optimum stage, must begin early in the dough stage or even the late milk stage. Rain may delay the harvest-another reason to start harvesting early, so as to "make silage while the sun shines."

If harvest is at the boot stage, field wilting this wet forage is necessary. As cereals mature, moisture decreases rapidly. Start adding water to the forage when it drops below 60% moisture (usually at about mid-dough stage). How much water to add or whether to add any depends on the kind and size of silo.

A 60 to 65% moisture content in the ensiled material is desirable for most silos. However, 50 to 60% moisture cereals may be ensiled satisfactorily in large upright, concrete silos; deep horizontal trench and bunker silos; or oxygen-limiting silos.

Table 3 shows the amount of water needed to increase forage moisture content to 60 or 65%.

GRAIN AND FORAGE YIELDS, CHEMICAL COMPOSITION, AND DIGESTIBILITY OF WHEAT, BARLEY, AND OATS

Yields of 12 varieties of wheat, barley, and oats grown and harvested at Kansas Agricultural Experiment Station sites in Manhattan and Hutchinson are shown in Table 4. Because plots were hand-harvested, forage and grain yields were somewhat higher than if they had been harvested by machine. Cereals were harvested in early to mid-dough stage of maturity from experimental plots fertilized and seeded at rates typical for the area. In most years, wheat, barley, and spring oats produced similar forage yields, although years and varieties differed somewhat. For example, hard wheat and oat varieties had the highest forage yields at Hutchinson in 1977. Grain yields were highest for barley varieties, and soft wheat varieties had higher yields than did hard wheat varieties.

Forage yields were more consistent than grain yields from year to year. When conditions favored grain production, increases in total grain and forage yields were accounted for by the increased grain yields. The small differences in forage yields, however, were important because the presence of grain increased the energy content of the silage. Therefore, species and varieties with more grain than forage are more valuable as livestock feeds. Barley has the greatest grain-to-forage ratio, followed in order by soft wheat, hard wheat, and oats.

Composition of the forages grown at Hutchinson in 1975 through 1977 is shown in Table 5. Because plots were hand-harvested, crude protein values were slightly lower and crude fiber values slightly higher than would be expected if the cereals had been machine harvested. Barley had the highest digestibility and grain-to-forage ratio; oats, the lowest. Soft wheat had a higher digestibility and grain-to-forage ratio than did hard wheat. Varieties with the lowest crude fiber had the highest digestibilities.

Figure 2 shows digestible dry matter yields, averaged across varieties at Hutchinson. Yields were higher in 1976 than in 1975 or 1977. Barley had the highest yields in 1975 and 1976, but the lowest in 1977. The cold winter of 1976-77 caused an obvious stand reduction in barley. In 1975 soft wheat yields were lower than hard wheat yields because of the low forage yield and digestibility of Blue Boy II. In 1976 and 1977 hard and soft wheat yields differed little. Overall, hard wheat was the most consistent because forage yields varied less than did yields of soft wheat or barley. Oats had the lowest digestibility and yielded the least digestible dry matter. Although barley apparently has the greatest cereal forage potential, cold, dry winters may severely reduce barley stands.

FEEDING VALUE OF WHEAT, BARLEY, OAT, AND CORN SILAGES FOR BEEF CATTLE

Wheat, barley, oat, and corn silages were fed to steers in seven trials at Kansas State University during the past five years. The forages were whole plant and had been harvested in the dough stage except as indicated. Silage was made in concrete silos (10 x 50 feet). When necessary, water was added to provide a moisture content of at least 60% in the ensiled forage. Cereal silage varieties included awnless soft red winter wheats: Blue Boy, Blue Boy II, and Arthur; awned hard red winter wheats: Parker, Eagle, and Sage; awned winter barleys: Paoli and Kanby; and spring oats: Trio and Lodi.

Growing Rations.

In the five growing trials (in five successive falls and winters), steers were full-fed twice daily a ration of 86% silage and 14% supplement (on a dry-matter basis):

Trial I-63 Angus steers (average initial weight, 516 pounds), 1972-73;
Trial 2-126 Hereford, Angus and mixed breed steers (average initial weight, 586 pounds), 1973-74;
Trial 3-120 Hereford steers (average initial weight, 588 pounds), 1974-75;
Trial 4-74 mixed breed steers (average initial weight, 666 pounds), 1975-76;
Trial 5-108 Hereford and Angus steers (average initial weight, 640 pounds), 1976-77.

Each year the steers grazed native bluestem range for five months before being put on the silage rations. Results are summarized in Table 6.

In all five trials, steers fed corn silage gained faster and more efficiently than did steers fed any of the wheat silages. In Trials 2, 3, and 5, steers receiving corn silage performed better than those receiving barley silage, but in Trial 4, gain and feed efficiency were slightly better for steers fed barley silage.

In Trial 1, steers fed Blue Boy wheat-head silage consumed more feed and gained faster than did steers fed Parker wheat-head silage.

In Trial 2, Paoli barley silage, Arthur wheat silage, and a mixture of equal parts of corn silage and Parker wheat-head silage produced similar performances. Steers fed Parker wheat silage or Parker wheat-head silage gained the slowest, consumed the least feed, and tended to be the least efficient.

In Trials 3 and 5, steers fed barley silage performed better than steers fed any of the wheat silages. In Trial 3, steers fed Blue Boy II wheat silage gained slower and less efficiently than did steers fed either Arthur or Eagle wheat silages. In Trial 5, steers fed Arthur or Sage wheat silages performed similarly.

In Trial 5, steers fed Trio or Lodi oat silages had the lowest performance. They consumed about 10 pounds less silage daily and gained 1.0 to 1.5 pounds less per day than did steers fed corn, barley, or wheat silages. Drought in June caused very low grain content of the oat silages and undoubtedly contributed to their poor showing.

Finishing Rations.

Two finishing trials were used to compare wheat silage and corn silage as sources of roughage in feedlot rations.

In Trial 6, 60 Angus, Hereford, and crossbred yearling steers (average initial weight, 724 pounds) were fed corn silage or Parker wheat-head silage during a 123-day period in the winter and spring of 1973. Each silage was fed as 10 and 20% of the ration on a dry-matter basis. The grain in the rations was equal parts of dry-rolled corn and steam-flaked milo.

In Trial 7, 40 yearling crossbred steers (average initial weight, 864 pounds) were fed corn silage or Eagle wheat silage during the winter and spring of 1976. Each silage was fed as 13% of the ration on a dry-matter basis. The grain in the rations was either dry-rolled milo or high-moisture milo.

Results are summarized in Table 7. In Trial 6, steers fed corn silage or wheat-head silage performed similarly. In Trial 7, however, corn silage supported a slightly faster and more efficient gain than did wheat silage. In both trials, dressing percentage, carcass quality, and yield grades were not affected by silage treatment.

SUMMARY

Wheat and barley silages are excellent forages for growing cattle. Yearling steers can be expected to gain 1.5 to 2.5 pounds per day when fed rations containing 85% good-quality wheat or barley silage, supplemented with appropriate protein, mineral, and vitamin components. Weights and condition of the cattle, weather severity, dry-matter intake, and nutrient and dry-matter content of the silage all affect actual rates of gain. In our research, steers fed corn silage gained 1.9 to 2.7 pounds daily as did those fed barley silage; those fed wheat silage gained less (1.5 to 2.3 pounds daily). Dry matter intake of barley silage was similar to that of corn and usually was 1 to 4 pounds per day more than that of wheat silage. Compared with feeding corn or barley, feeding wheat silage required 1 to 2 pounds additional dry matter per pound of gain. Because the protein content of wheat and barley silages was higher than that of corn silage, less supplemental protein was required when those silages were fed.

Wheat silage may be a valid alternative to other silages as a roughage source for feedlot rations. Our research showed that finishing steers fed wheat and corn-silage rations (at 10 and 20% of the dry matter in the ration) consumed similar amounts. Steers fed corn silage gained .08 to .19 pounds per day faster than did those fed wheat silage.

<u>These conclusions regarding cereal silages are based on six years of research and practical experience</u>:

Cereals harvested and fed as silage produce more beef per acre than grain.

Cereals ensiled at 60 to 65% moisture make the best silage.

As cereals mature from boot to dough stages, silage yield increases but silage crude protein decreases.

Cereals harvested in the mid-dough stage of maturity produce maximum TDN and (when consumed by cattle) beef per acre.

Winter wheat, winter barley, and spring oats have similar dough-stage silage yields - 6 to 9 tons per acre.

Wheat, barley, and oat silages are usually about 2 percentage units higher in crude protein than are corn and sorghum silages.

Barley and corn silages are about equal in feeding value.

Rations high in wheat silage support about 80% of the level of performance that those high in corn silage do when fed to growing cattle.

The higher the grain content of wheat, barley, or oat silage, the higher will be the silage feeding value.

Wheat and corn silages fed to finishing cattle in high-grain rations support similar feedlot performance.

Table 1. Percentages of dry matter (DM) and crude protein (CP) of forages harvested at different stages of maturity.

	Hard wheat		Soft wheat		Barley		Mean	
Stage	DM	CP	DM	CP	DM	CP	DM	CP
Boot	17.5	14.9	15.8	15.1	14.0	15.8	15.8	15.3
Milk	33.4	11.1	30.4	10.5	23.3	11.3	29.0	11.0
Dough	47.7	9.8	37.5	9.2	34.8	9.6	40.0	9.5

Table 2. Percentage of *in vitro* dry-matter digestibility (IVDMD) and tons per acre of *in vitro* digestible dry matter (IVDDM) of forages harvested at different stages of maturity.

	Hard wheat		Soft wheat		Barley		Mean	
	IVDMD	IVDDM	IVDMD	IVDDM	IVDMD	IVDDM	IVDMD	IVDDM
Stage	%	T/a	%	T/a	%	T/a	%	T/a
Boot	64.1	1.92	61.2	1.66	63.4	1.69	62.9	1.76
Milk	57.7	2.91	57.7	2.80	58.1	2.46	57.8	2.72
Dough	55.9	3.09	57.4	2.88	60.9	2.89	58.1	2.95

Table 3. Water needed to bring a ton of forage to desired moisture.[1]

Moisture in forage	Desired moisture in ensiled forage			
	60%		65%	
%	lbs/ton	gal/ton	lbs/ton	gal/ton
40	1,000	120	1,428	171
42	900	108	1,314	156
44	800	96	1,200	144
46	700	84	1,086	130
48	600	72	971	117
50	500	60	857	103
52	400	48	743	90
54	300	36	629	75
56	200	24	514	62
58	100	12	400	48

[1]For example, if the chopped forage is 56% moisture, and the desired amount to go into the silo is 65%, 514 pounds (or 62 gallons) of water must be added per ton of 56% moisture material.

Table 4. Yields of wheat, barley, and oats harvested at the dough stage.

Specie and variety		1974	1975		1976		1977	
		Manhattan	Manhattan	Hutchinson	Manhattan	Hutchinson	Manhattan	Hutchinson
		(Forage yields: tons 35% DM/acre; grain yields: bushels 12% moisture/acre)						
Barley								
Paoli	Forage	16.4	9.1	9.7	---	10.0	---	8.6
	Grain	90.5	92.1	84.8	---	66.5	---	65.5
Jefferson	Forage	17.0	---	---	---	---	---	---
	Grain	78.4	---	---	---	---	---	---
Kanby	Forage	---	11.9	10.6	9.5	11.5	---	6.8
	Grain	---	87.3	78.5	58.9	79.2	---	48.2
Soft wheat								
Arthur	Forage	16.4	11.6	8.7	8.7	10.9	8.2	9.0
	Grain	79.7	60.6	46.2	22.0	55.6	---	46.6
BlueBoy II	Forage	16.8	12.2	10.6	---	---	---	---
	Grain	79.7	63.4	48.5	---	---	---	---
Abe	Forage	---	---	---	13.0	10.6	---	8.5
	Grain	---	---	---	20.6	54.9	---	48.5
Hard wheat								
Parker	Forage	15.9	---	---	---	---	---	---
	Grain	53.0	---	---	---	---	---	---
Eagle	Forage	15.7	---	10.9	---	10.1	---	9.7
	Grain	52.5	---	41.5	---	41.4	---	46.2
Sage	Forage	---	---	10.8	---	11.2	6.5	9.6
	Grain	---	---	32.8	---	50.4	---	36.6
Oats								
Pettis	Forage	---	---	---	---	10.7	---	9.6
	Grain	---	---	---	---	73.2	---	52.9
Trio	Forage	---	---	---	8.1	---	7.3	---
	Grain	---	---	---	33.2	---	---	---
Lodi	Forage	---	---	---	7.2	9.2	---	10.3
	Grain	---	---	---	20.0	34.8	---	39.1

Table 5. Compositions of varieties of barley, wheat, and oats harvested at Hutchinson, compared.

	No. years	DM(%)	CP (%)	CF (%)	Gr/For	IVDMD (%)
Barley						
Paoli	3	36.3	7.5	23.6	.48	62.7
Kanby	3	35.2	7.1	26.1	.36	59.9
S. Wheat						
Arthur	3	43.6	6.5	26.6	.40	56.1
BlueBoy II	1	39.4	6.6	28.8	.36	50.5
Abe	2	44.8	7.2	24.8	.42	58.2
H. Wheat						
Eagle	3	46.3	6.4	29.5	.33	55.9
Sage	3	45.0	6.5	31.0	.32	56.4
Oats						
Pettis	2	41.5	8.0	31.7	.25	50.8
Lodi	2	38.5	8.6	34.7	.15	50.1

[1]DM = dry matter; CP = crude protein; CF = crude fiber; Gr/For = DM yield of grain/DM yield of forage; IVDMD = *in vitro* dry matter digestibility.

Table 6. Performance of growing steers fed wheat, barley, oat, or corn silages.

Silage	Avg. daily gain, lbs.	Daily feed intake, lbs.[1]	Feed/lb. gain, lbs.[1]	Silage DM %	Silage CP %[1]	Forage harvest date
Trial 1 (122 days) 1972-73						
Corn	1.92	15.3	8.1	33.4	8.7	---
BlueBoy wheat-head[2]	1.53	14.4	9.5	35.7	13.6	June 11
Parker wheat-head	1.43	13.4	9.5	36.6	13.2	June 9
Trial 2 (100 days) 1973-74						
Corn	2.48	18.6	7.5	40.9	8.3	---
Barley	2.28	17.4	7.7	32.9	9.5	June 1
Arthur wheat	2.09	17.4	8.4	36.9	7.5	June 8
Parker wheat	1.54	14.7	9.6	34.6	7.4	June 6
Parker wheat-head	1.75	14.8	8.1	41.2	9.9	June 7
Corn + Parker wheat-head	2.22	18.0	8.1	---	---	---
Trial 3 (90 days) 1974-75						
Corn	2.83	19.3	6.8	34.8	9.1	---
Barley	2.60	17.5	6.9	34.8	12.0	May 29
Arthur	1.91	15.0	7.9	32.2	11.2	June 5
BlueBoy II wheat	1.56	14.3	9.5	36.9	11.2	June 5
Eagle wheat	1.91	16.3	8.5	34.3	9.6	June 5
Trial 4 (87 days) 1975-76						
Corn	2.45	18.8	7.7	37.8	7.8	Aug. 29
Barley	2.70	18.9	7.0	35.3	11.5	June 4
Arthur wheat	2.32	18.9	7.9	36.9	10.8	June 13
Eagle wheat	2.11	16.9	8.1	37.8	8.4	June 14
Eagle wheat-milk stage	1.97	16.0	8.2	33.8	9.9	June 5
Trial 5 (89 days) 1976-77						
Corn	2.52	19.1	7.6	37.2	8.3	Aug. 20
Barley	2.33	19.5	8.4	35.7	9.0	June 2
Arthur wheat	2.06	18.7	9.1	39.2	11.2	June 7
Sage wheat	1.96	19.2	9.9	41.2	8.3	June 9
Trio oats	1.09	14.6	13.5	30.1	12.6	June 17
Lodi oats	1.02	14.7	14.5	31.2	10.1	July 2

1. 100% dry matter basis.

2. Upper ½ of plant.

Table 7. Performance of finishing steers fed corn or wheat silages.

Treatment	Avg. daily gain, lbs.	Daily feed intake, lbs.[1]	Feed/lb. gain, lbs.[1]
		Trial 6 (123 days) 1973	
10% corn silage	2.49	17.4	7.02
20% corn silage	2.68	18.6	6.96
10% Parker wheat-head silage	2.54	18.2	7.32
20% Parker wheat-head silage	2.47	18.6	7.53
		Trial 7 (82 days) 1976	
Corn silage	2.60	20.5	7.99
Eagle wheat silage	2.41	20.9	8.76

1. 100% dry matter basis.

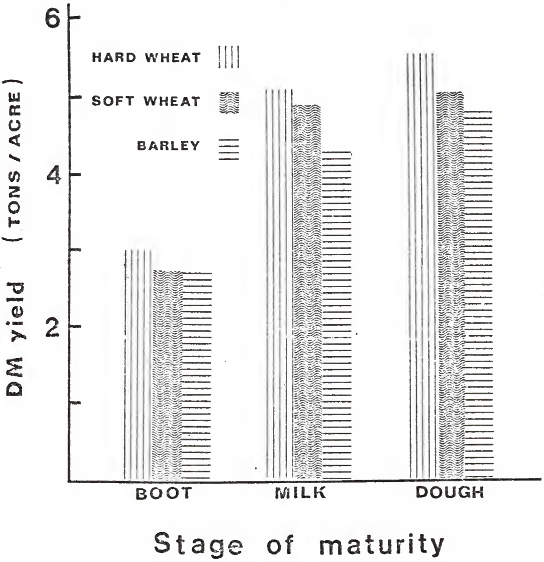

Figure 1. Dry matter yields of cereal forages (hard wheat, soft wheat, barley) as affected by stage of maturity.

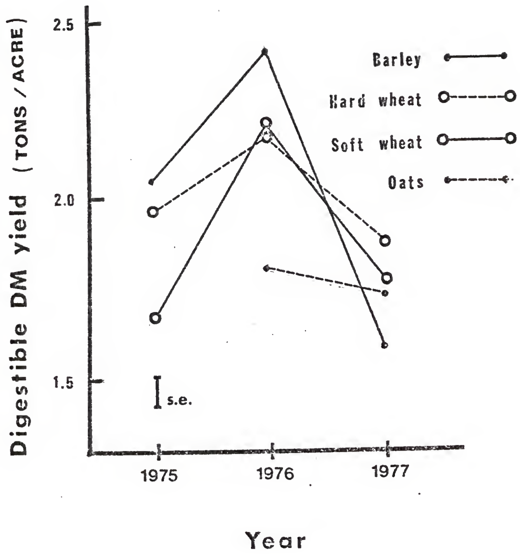

Figure 2. Yields of digestible dry matter of these cereal forages: hard wheat, soft wheat, barley and oats.

FORAGE AND GRAIN YIELDS AND FORAGE QUALITY OF BARLEY, WHEAT, AND OATS

ABSTRACT

Crops such as wheat (Triticum aestivum L.), barley (Hordeum vulgare L.) and oats (Avena sativa L.) are potential livestock feeds. Limited data exist on the characteristics of these plants when harvested as forage. We evaluated the dry matter (DM) yield, chemical composition, and in vitro dry matter digestibility (IVDMD) of wheat, barley, and oat cultivars common to Kansas in 1975, 1976, and 1977. Harvest was at the dough stage of maturity.

Forage DM yields (metric ton/ha) were greater for hard wheat (8.22) and oats (8.04) than for barley (7.54) and soft wheat (7.70). Yields were least in 1977. A significant cultivar x year interaction occurred, demonstrated by significant winter kill in 1977 when Kanby barley yielded lowest (5.50 metric tons/ha), but in 1976 yielded highest (9.00 metric tons/ha). Grain dry matter yields were highest in 1977 and averaged 3.44, 3.06, 2.64, and 1.63 metric ton DM/ha for barley, soft wheat, hard wheat, and oats, respectively. Grain DM yields divided by forage DM yields (G/F) were greatest for barley cultivars and lowest for oat cultivars.

Crude protein (CP) content was greater for barley forages than for hard wheat forages. Oat forages were most variable. In 1976 crude fiber (CF) and acid detergent fiber were least for barley and wheat, but greatest for oats. Acid detergent fiber and neutral detergent fiber tended to parallel CF values.

In vitro DM digestibility was greatest in 1976. Barley was greater than wheat (average, 61.3% vs. 56.0%), except in 1977 when Kanby barley was less digestible. Oat cultivars were least digestible (average, 50.4%). IVDMD was most highly correlated to CF (r = -0.33) but not correlated to CP (r = 0.13). G/F was higher for the more digestible cultivars within species. Digestible DM yield (IVDMD x forage DM yield) was highest in 1976 and lowest in 1977. Year also affected ranking of species, with barley having the highest yield in 1975 and 1976, but the lowest in 1977. Hard wheat yielded most consistently, and was greater than soft wheat in 1975 and 1977. Oats yielded least in 1976.

Feeding value of these forages, related to IVDMD and CF, is similar to the other forage crops, but somewhat less than corn silage. When cereal forage is incorporated in a properly supplemented ration, about twice as much beef production per hectare is possible for cereal forage production over grain production.

INTRODUCTION

Wheat (Triticum aestivum L.), barley (Hordeum vulgare L.), and oats (Avena sativa L.), normally harvested for grain in the United States, are potential forage sources for ruminants. These cereals may be harvested as whole-plant hay or silage, which usually results in a greater dry matter yield than grain harvest or pasture grazing. Further, economic conditions may result in cereal forage being more profitable than cereal grain.

Cereal forage dry matter yield, chemical analyses, and digestibility are influenced by stage of maturity, climatic conditions, soil fertility, cultivar, and cereal species. Wide variations in yield are reported in the literature. Differences in yield between species and cultivars have been inconsistent (9), but yield generally increases with stage of plant maturity through the milk stage (9, 11). Conflicting data show yields from the milk to the dough stage increasing slightly (5, 15), remaining similar (11) or decreasing slightly[3] depending upon the particular variety and climatic conditions. Lawes and Jones (1971) applied 75 kg N/ha and reported a 60 to 100% increase in yeild over no fertilization; higher levels of nitrogen fertilization supported less additional response, which agrees with data reported by Cannell and Jobsen

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[3]Miller, C. N., J. T. Huber, R. E. Blaser, R. A. Sandy, and C. E. Polan. 1967. Nutritive value and yields of barley silage at three stages of growth. J. Dairy Sci. 50:616. (Abstract).

(1968). Fertilization increases crude protein content of the forage (5); but crude protein decreases with maturity through the dough stage (9, 11). Crude fiber increases through the boot stage, then decreases as grain formation begins, and is lowest for dough stage forages (11, 13).

Cereal forage dry matter digestibility decreases as the plant matures through the milk stage (11, 12). As the plant matures from the milk to the dough stage, data about forage digestibility disagree. Noller _et al_. (1959) and Polan _et al_. (1968) found dough stage digestibilities lower than milk stage for both oat and barley silages. Stallcup and Horton[4] report no digestibility differences between stages. Cannell and Jobsen (1968) observed conflicting results within wheat and barley cultivars. Increases in dough stage digestibilities over the milk stage for cereals are reported by Meyer _et al_. (1957) and Bolsen and Berger (1976). Because dry matter yields increase faster than digestibilities decrease, dough stage produces the greatest digestible dry matter per unit land area (5, 15).

The present study was undertaken to observe dough stage forage dry matter yields of barley, wheat, and oat cultivars common to Kansas. Another objective was to determine chemical composition and _in vitro_ digestibility of these forages.

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[4]Stallcup, O. T., and O. H. Horton. 1957. The nutritive value of oat silages made from plants ensiled in the boot, milk and hard dough stages of maturity. J. Dairy Sci. 40:620. (Abstract).

MATERIALS AND METHODS

Three field experiments were conducted on Clark-Ost Complex soils (Clark loam-Typic Calciustolls, Fine-loamy, Mixed, Thermic Family; Ost-clay loam-Typic Argiustolls, Fine-loamy, Mixed, Thermic Family) at the South Central Kansas Experiment Field, Hutchinson, Kansas, in 1975, 1976, and 1977. Plot areas received 81-102-0 kg/ha of N-P-K incorporated at a depth of approximately 2.5 cm each fall before seeding.

Cultivars were: Paoli and Kanby all 3 years, winter barley; Arthur-71 all 3 years, Blue Boy II in 1975, and Abe in 1976 and 1977, soft winter wheat; Eagle and Sage all 3 years, hard red winter wheat; Pettis and Lodi in 1976 and 1977, spring oats. Barley, wheat, and oat cultivars, respectively, were seeded at rates of 111, 69, and 74 kg/ha; depth of seed was 5 cm covered with 2.5 cm soil. Planting dates for barley and wheat were 2 October, 1974, 2 October, 1975, and 13 October, 1976; planting dates for oats were 19 March, 1976, and 2 March, 1977. Rainfall was measured with a standard U.S. Weather Bureau rain gauge (Fig. 3).

The experiment was arranged in a split-plot design, each variety as a full plot, with a part of the plot harvested for forage, and a part for grain. Each variety was randomly represented as a 30.5 x 1.8 m plot in each of four blocks.

Forage harvest was at the dough stage of maturity (dates give in Table 8); the whole aerial plant was removed from a 6.1 x 0.8 m section of each plot. After chopping, the forage was sampled for dry matter (DM) content by oven-drying at 60 C for 72 hours. Proximate analysis, Van Soest fiber analysis (7), and *in vitro* dry matter digestibility (16) were determined for each cultivar. Grain yields were measured by randomly harvesting three 0.935 m^2 sections of each plot, and DM and crude protein were determined (1).

Statistical analysis was by Least Squares Analysis of Variance, with Duncan's Multiple Range Test used to compare significant treatment means.

RESULTS AND DISCUSSION

Dry Matter Yields

Forage and Grain Dry Matter Yield. Forage yields in metric tons/ha ranged from 5.50 to 9.00 for barley, 6.85 to 8.55 for soft wheat, 7.78 to 8.76 for hard wheat, and 7.42 to 8.65 for oats (Table 9). These forage yields are less than those reported for spring cereals in the United Kingdom (5, 9), and more than spring cereal yields in Saskatchewan, Canada[5] (8). Overall, oats and hard wheat outyielded barley and soft wheat ($P<.05$) which agrees with results reported by Lawes and Jones (1971). Other United Kingdom data show oat yields highest followed in order by spring barley and spring wheat (5). In contrast, Hingston et al. (1976) found spring durum wheat higher yielding (at 6.2 metric tons/ha) than spring barley or oats. Yields in 1977 were less than in 1975 or 1976 ($P<0.01$). Cultivar difference within specie was not statistically different, but a significant cultivar x year interaction occurred, as shown in the table. In 1977 Kanby barley had the lowest yield ($P<0.05$) of 5.50 metric tons DM/ha, when an extremely cold 1976-1977 winter caused considerable winter kill. After 1975-1976 winter conditions, however, Kanby yielded 9 metric tons DM/ha, the highest reported overall. An unexplained low yield was obtained for Arthur-71 in 1975. Eagle was the only

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[5]Crowle, W. L. 1976. Annual crops for forage. Silage Seminar 76. Saskatchewan Dep. of Agric. p. 14-19.

cultivar that declined in yield from 1975 to 1976, and Lodi the only cultivar that declined in yield from 1976 to 1977, although neither was a significant change. Grain yields parallel those of forage yields within specie and year (Table 2).

Grain to Forage Ratio. Grain DM yields divided by forage DM yields is defined as the grain to forage ratio. Grain to forage ratio was greatest for barley cultivars all three years followed in order by soft wheat, hard wheat and oat cultivars (Fig. 4).

Crude Protein

Forage Crude Protein. Barley forages contained more crude protein than hard wheat forages and tended to be higher than soft wheat forages (Table 10). Oat forages were higher in crude protein than wheat or barley forages in 1976. Forage values are less than those reported by Stallcup *et al*. (1960) and Fisher, Lessard and Lodge (1972). Year to year variation occurred with forage crude protein highest in 1977 for barley and wheat, lowest for oats. Further, cultivar differences confounded the data. For example, within wheat and barley species, cultivars being lowest in crude protein in 1975 or 1976 (Kanby, Arthur-71, Sage) were highest in 1977. This cultivar x year interaction may be associated with the lower forage yields in 1977.

Grain Crude Protein. Wheat grain contained more crude protein than barley, while oats varied considerably, being highest in 1976 (Table 10). Grain crude protein levels were least in 1976 for wheat and Kanby barley. As with forage, a cultivar x year interaction occurred with Kanby, Arthur and Sage having their highest levels in 1977.

Forage Quality

Crude Fiber. Crude fiber content varied with year, species and cultivar (Table 11). Hard wheat and oats contain more crude fiber than barley or soft wheat; oats having the highest crude fiber in 1976. Soft wheat crude fiber was higher than barley in 1975, but lower in 1977. Within species, Kanby barley, Sage wheat and Lodi oats contained more crude fiber than Paoli barley, Eagle wheat and Pettis oats, respectively. Oat forages averaged 33.3% crude fiber compared to only 25.3% crude fiber for oats in a study reported by Stallcup *et al*. (1960). Wheat crude fiber varied among cultivars and years which agrees with studies by McCullough and Sisk (1966) and Bolsen *et al*. (1976). Fisher *et al*. (1972) reported higher crude fiber in spring barley compared to average crude fiber for winter barley in our study (29.1 vs. 24.9%).

Neutral Detergent Fiber (Cell Wall). Hard wheat contains more neutral detergent fiber (NDF) than barley, with soft wheat being intermediate (Table 11). Highest NDF was 78.0% for oats in 1976; lowest, 56.4% for barley in 1976. Hard wheat increased in NDF from 1975 through 1977. Cultivar differences within species showed higher NDF for Kanby barley and Sage wheat than for Paoli barley and Eagle wheat, respectively.

Acid Detergent Fiber. Acid detergent fiber (ADF) was higher for wheat than barley, except for Kanby barley in 1977 (Table 11). In 1977 hard wheat contained more ADF than soft wheat. Within species; barley and hard wheat were lowest in ADF in 1976, while barley was highest in 1977 and wheat highest in 1975. Oats had more ADF in 1976 than 1977. Comparing cultivars ADF for Kanby barley and Lodi oats were higher than ADF for Paoli barley and Pettis Oats, respectively.

Forage Dry Matter Digestibility. *In vitro* dry matter digestibility (IVDMD) was highest for all species and cultivars in 1976 (Table 11). Barley was higher in IVDMD than wheat in 1975 and 1976, agreeing with data by Bolsen and Berger (1976) and Cannell and Jobsen (1968), but IVDMD for Kanby barley was lower than IVDMD for Abe or Sage wheats in 1977. Among species, Paoli barley was consistently more digestible than Kanby barley. Oat cultivars had lowest IVDMD overall.

Digestible DM Yield. As with IVDMD, digestible DM yields, averaged over cultivars for each specie and year, were highest in 1976; lowest in 1977 (Fig. 5). Year affected digestible DM yield ranking of species, with barley having the highest yield in 1975 and 1976; the lowest yield in 1977. Soft wheat was never the highest yielding but hard wheat was highest yielding in 1977. Digestible DM yields for hard wheat were the most consistent among years. Higher digestible DM yields were reported in the United Kingdom when spring barley and oats outyielded spring wheat (5,9). In Canada, durum wheat produced more digestible DM than spring barley, and both outyielded oats (8).

IVDMD Correlations. *In vitro* dry matter digestibility, the best measure of feeding value determined in this study, is related to other measures of forage quality (Table 12). IVDMD was correlated most highly with crude fiber ($r = -0.83$). Grain yield, acid detergent fiber, and grain to forage ratio were somewhat related to IVDMD with greater grain to forage ratios indicating the more digestible cultivars within species. Crude protein content had no effect on IVDMD ($r = -0.13$).

IMPLICATIONS FOR LIVESTOCK FEEDING

Barley, wheat and oat forages are potential feedstuffs for ruminants. These crops may be stored as silage or hay and most research indicates that their feeding value is lower than that of corn silage[6,7] (4). However, Bolsen et al. (1976) reported dough-stage winter barley silage similar in feeding value to corn silage.

If we assume feeding value and IVDMD are highly correlated, then yield of digestible DM is a measure of animal production potential per hectare. Barley has highest production potential (Fig. 5), but an extremely cold and/or dry winter will reduce yields below that of wheat, as in the 1976-77 Kansas growing season. Hard wheat has a consistent digestible DM yield. Average in vitro digestible DM yields of hard wheat forage (yielding 4.6 metric tons DM/ha) will produce about 920 kg steer weight gain per hectare, assuming 5 kg TDN (TDN is approximately equal to IVDMD) per kg weight gain. By comparison, hard wheat grain (88% TDN and yielding 2.6 metric tons DM/ha) will produce 460 kg beef/ha, half as much as for hard wheat forage.

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[6] Whetzal, F. W., L. B. Embry, and L. B. Dye. 1967. Performance of steers fed corn silage, oat haylage or sorghum silage. South Dakota State Univ. Beef Cattle Field Day Report.

[7] Baxter, H. D., J. R. Owens, M. S. Montgomery, J. T. Miles, and C. H. Gordon. 1971. Digestibility and feeding value of corn silage fed alone and in combination with boot stage wheat and alfalfa silage. J. Dairy Sci. 54:455. (Abstract).

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Table 8. Date of forage harvest at the dough stage of maturity

Specie	1975	1975	1976
Barley	26 May	20 May	23 May
Wheat	5 June	4 June	1 June
Oats-Pettis	---	16 June	10 June
Oats-Lodi	---	22 June	20 June

Table 9. Mean dry matter yields of cereal forage and grain.

Specie and Variety	1975		1976		1977		Average	
	Forage	Grain	Forage	Grain	Forage	Grain	Forage	Grain
	metric tons/ha							
Barley							7.54	3.44
Paoli	7.62 abcd*	4.14	7.88 abcd	3.24	6.91 cd	3.20		
Kanby	8.33 abc	3.83	9.00 a	3.86	5.50 e	2.35		
Soft Wheat							7.70	3.06
Arthur-71	6.86 d	2.81	8.55 ab	3.40	7.28 bcd	2.84		
BlueBoy II	8.31 ab	2.96	---	---	---	---		
Abe	---	---	8.32 ab	3.35	6.90 cd	2.96		
Hard Wheat							8.22	2.64
Eagle	8.54 ab	2.53	7.93 abcd	2.52	7.83 abcd	2.82		
Sage	8.45 ab	2.67	8.76 a	3.08	7.78 abcd	2.23		
Oats							8.04	1.63
Pettis	---	---	8.65 ab	2.38	7.76 abcd	1.72		
Lodi	---	---	7.42 bcd	1.13	8.29 ab	1.27		

*Means within forage yield with similar letters do not differ significantly ($P<0.05$).

Table 10. Mean crude protein values of cereal forage and grain.

Specie and	1975		1976		1977	
Variety	Forage	Grain	Forage	Grain	Forage	Grain
	%, DM basis					
Barley						
Paoli	7.4	11.4	7.3	11.5	7.7	11.3
Kanby	6.5	11.4	6.6	10.8	8.1	12.1
Soft wheat						
Arthur-71	5.3	13.2	6.8	12.9	7.4	13.5
BlueBoy II	6.6	14.0	---	---	---	---
Abe	---	---	7.1	13.3	7.2	13.4
Hard wheat						
Eagle	6.3	14.1	6.3	13.1	6.7	13.8
Sage	5.9	13.9	6.0	12.4	7.5	14.0
Oats						
Pettis	---	---	9.2	17.3	6.9	12.0
Lodi	---	---	9.7	17.9	7.5	13.3

Table 11. Mean fiber and *in vitro* dry matter digestibility values of cereal forage.

Specie and	1975				1976				1977			
Variety	CF[1]	NDF	ADF	IVDMD	CF	NDF	ADF	IVDMD	CF	NDF	ADF	IVDMD
	---------------------------------%, DM basis---------------------------------											
Barley												
Paoli	22.7	58.2	29.8	60.7	22.0	53.8	29.2	66.1	26.1	67.8	30.2	61.2
Kanby	24.7	60.1	32.6	58.5	24.9	59.0	31.9	64.9	28.7	71.3	36.8	56.3
Soft wheat												
Arthur-71	31.0	63.2	42.1	51.2	23.1	59.9	37.0	61.0	25.8	62.5	33.4	56.1
BlueBoy II	28.8	63.6	40.3	50.5	---	---	---	---	---	---	---	---
Abe	---	---	---	---	24.2	57.5	32.6	59.3	25.4	72.7	33.7	57.0
Hard wheat												
Eagle	31.9	60.0	39.9	53.5	26.4	66.6	37.0	59.9	30.4	79.1	39.4	54.2
Sage	34.8	67.3	44.3	53.7	27.0	71.3	35.5	59.9	31.2	80.6	39.5	55.5
Oats												
Pettis	---	---	---	---	33.2	81.6	41.5	52.4	30.3	68.3	36.0	49.2
Lodi	---	---	---	---	34.8	74.4	45.6	50.7	34.7	70.3	42.5	49.4

[1]CF is crude fiber, NDF is neutral detergent fiber, ADF is acid detergent fiber, IVDMD is *in vitro* dry matter digestibility.

Table 12. Correlation of IVDMD and other parameters.

Parameter	r
Forage yield	0.08
Grain yield	0.72**
Forage crude protein	-0.13
Forage crude fiber	-0.83**
Forage NDF	-0.49*
Forage ADF	-0.66**
Grain to forage ratio	-0.64**

*, **Significance at the 5 and 1% level of probability, respectively.

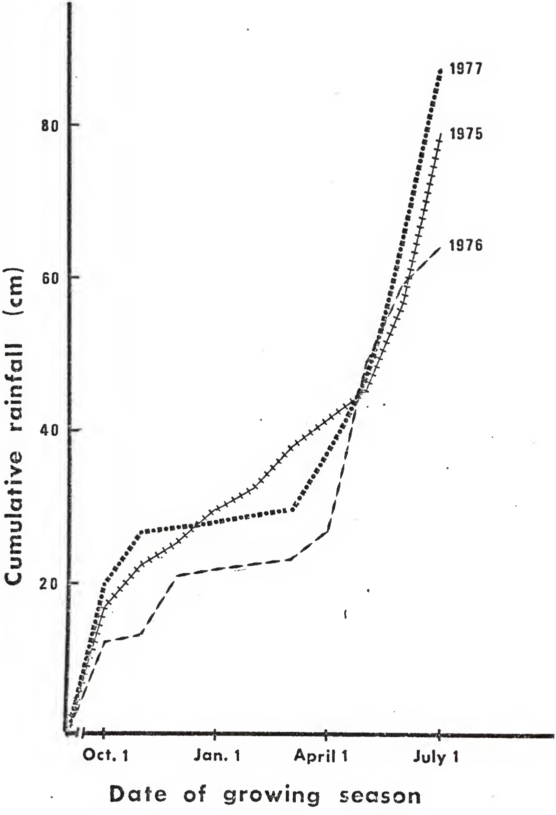

Figure 3. Cumulative rainfall at the South Central Kansas Experiment Field, Hutchinson.

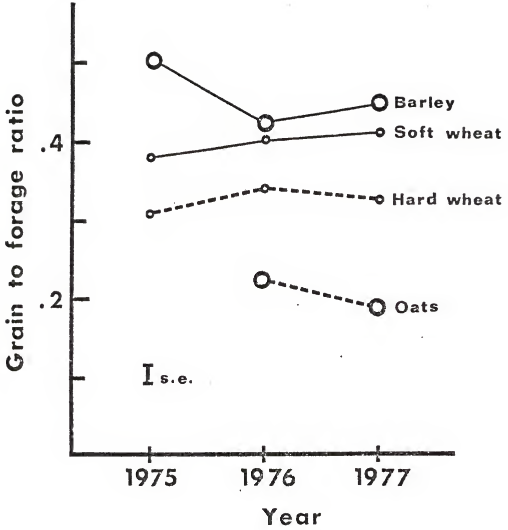

Figure 4. Grain to forage ratio of barley, wheat, and oats.

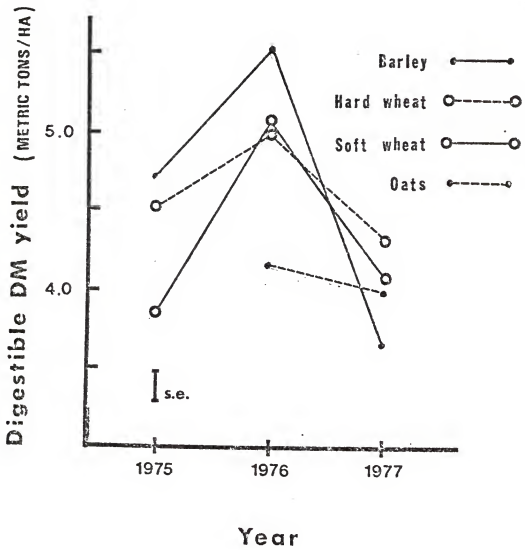

Figure 5. In vitro DM yields of cereal forage.

YIELDS, COMPOSITION, AND FEEDING VALUE
OF WHEAT, BARLEY, AND OAT SILAGES

by

JAMES WILLIAM OLTJEN

B.S., Kansas State University, 1975

AN ABSTRACT OF A MASTER'S THESIS

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requirements for the degree

MASTER OF SCIENCE

Department of Animal Sciences and Industry

KANSAS STATE UNIVERSITY

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Wheat, barley, and oats are livestock feeds common to Kansas but limited data were available about these crops harvested as forage. However, our research shows that cereal forages produce more total nutrients and beef cattle gain per unit land area than does cereal grain. Cereal silages should be harvested in the dough stage of maturity; finely chopped; ensiled at 60 to 65% moisture; packed well in a rapidly filled silo; and covered and sealed at the silo surface.

Dough stage cereal silages and corn silages were compared in five steer growing trials and two finishing trials at the Kansas Agriculture Experiment Station, Manhattan. Results indicate that yearling steers can be expected to gain 0.7 to 1.1 kg/day when fed rations containing 85% good-quality wheat or barley silage, supplemented with appropriate protein, mineral, and vitamin components. Weights and condition of the cattle, weather severity, dry matter intake, and nutrient and dry matter content of the silage all affect actual rates of gain. Steers fed corn or barley silages gained 0.8 to 1.2 kg/day; those fed wheat silage gained slightly less (0.7 to 1.0 kg/day). Dry matter intake of barley silage was similar to that of corn and usually 0.5 to 2.0 kg/day more than that of wheat silage. Compared with feeding corn or barley, feeding wheat silage required 1 to 2 kg additional dry matter per kg gain. Because the protein content of wheat and barley silages was higher than that of corn silage, they required less supplemental protein. Wheat silage may be a valid alternative to other silages as a roughage source for finishing rations. Steers fed wheat and corn silage rations (at 10 and 20% of the ration dry matter) consumed similar amounts. Steers fed corn silage gained 0.04 to 0.09 kg/day faster than did those fed wheat silage.

Experimental plots were grown in 1975, 1976 and 1977 at the South Central Kansas Experiment Field at Hutchinson to evaluate the dry matter (DM) yield, chemical composition, and _in vitro_ DM digestibility (IVDMD) of wheat, barley, and oat cultivars common to Kansas. Harvest was at the dough stage of maturity. Forage DM yields (metric ton/ha) were higher for hard wheat (8.82) and oats (80.4) than for barley (7.54) and soft wheat (7.70). Yields were lowest in 1977. The significant cultivar x year interaction that occurred was due to winter kill and reduced barley stands in 1977. Grain DM yields were highest in 1977 and averaged 3.44, 3.06, 2.64, and 1.63 metric ton/ha for barley, soft wheat, hard wheat, and oats, respectively. Grain DM yield divided by forage DM yield (G/F) was highest for barley cultivars and lowest for oat cultivars. Crude protein (CP) content was higher for barley forages than for hard wheat forages. Oat forages were most variable in crude protein. In 1976 crude fiber (CF) and acid detergent fiber were lowest for barley and wheat and highest for oats. Acid detergent fiber and neutral detergent fiber tended to parallel CF values. _In vitro_ dry matter digestibility was highest in 1976. Barley IVDMD was higher than wheat (average, 61.3 vs. 56.0%). Oat cultivars were least digestible (average, 50.4%). *In vitro* DM digestibility was most highly correlated to CF (r = -0.83) but not correlated to CP (r = -0.13). Grain to forage ratio was higher for the more digestible cultivars within species. Digestible DM yield (IVDMD x forage DM yield) was highest in 1976 and lowest in 1977. Year also affected ranking of species, with barley having the highest yield in 1975 and 1976, but the lowest in 1977. Hard wheat yielded most consistently and was higher than soft wheat in 1975 and 1977.