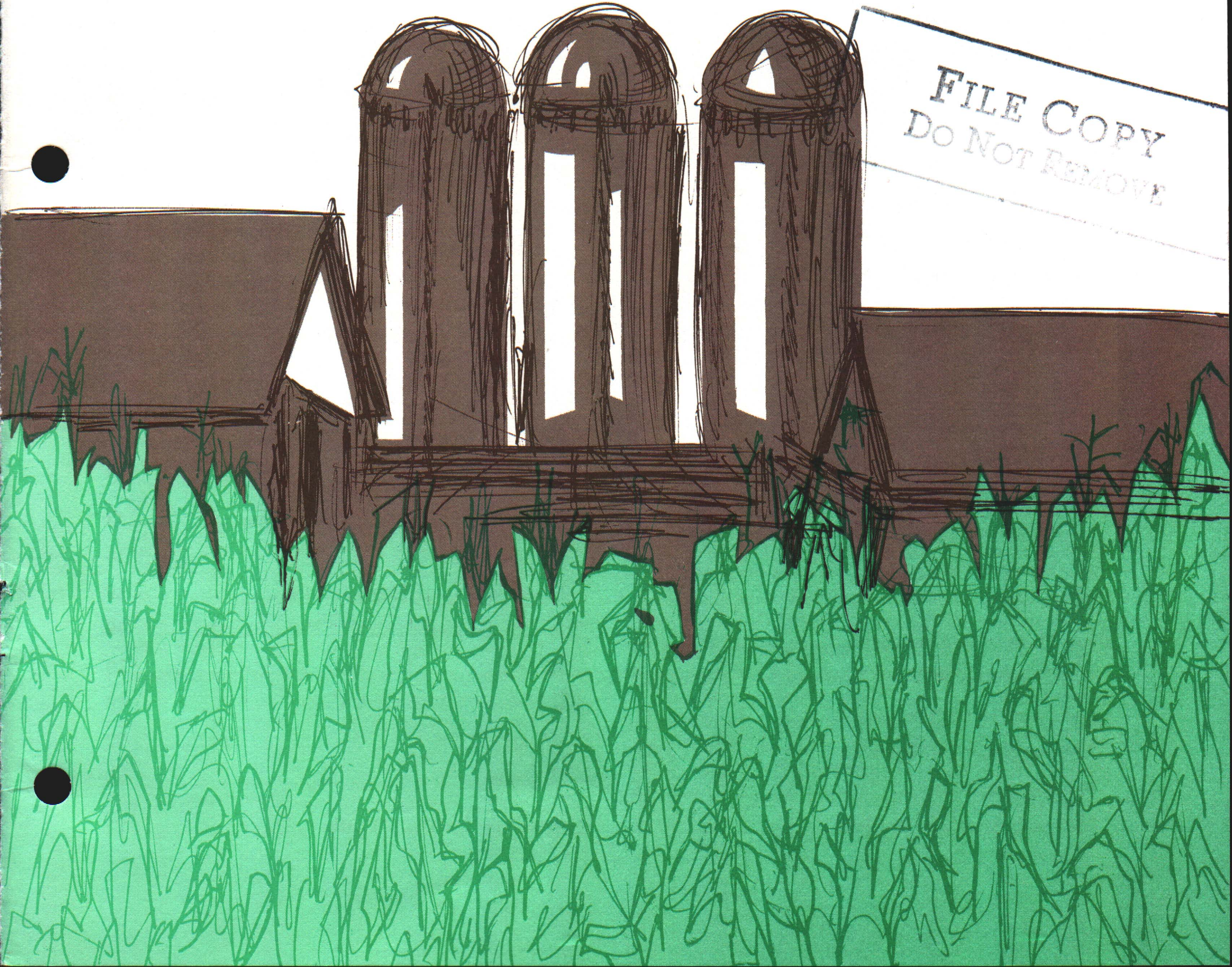
EXTENSION BULLETIN E-665 — FARM SCIENCE SERIES SEPTEMBER 1969

Corn Silage

production — harvest — storage in michigan

COOPERATIVE EXTENSION SERVICE MICHIGAN STATE UNIVERSITY

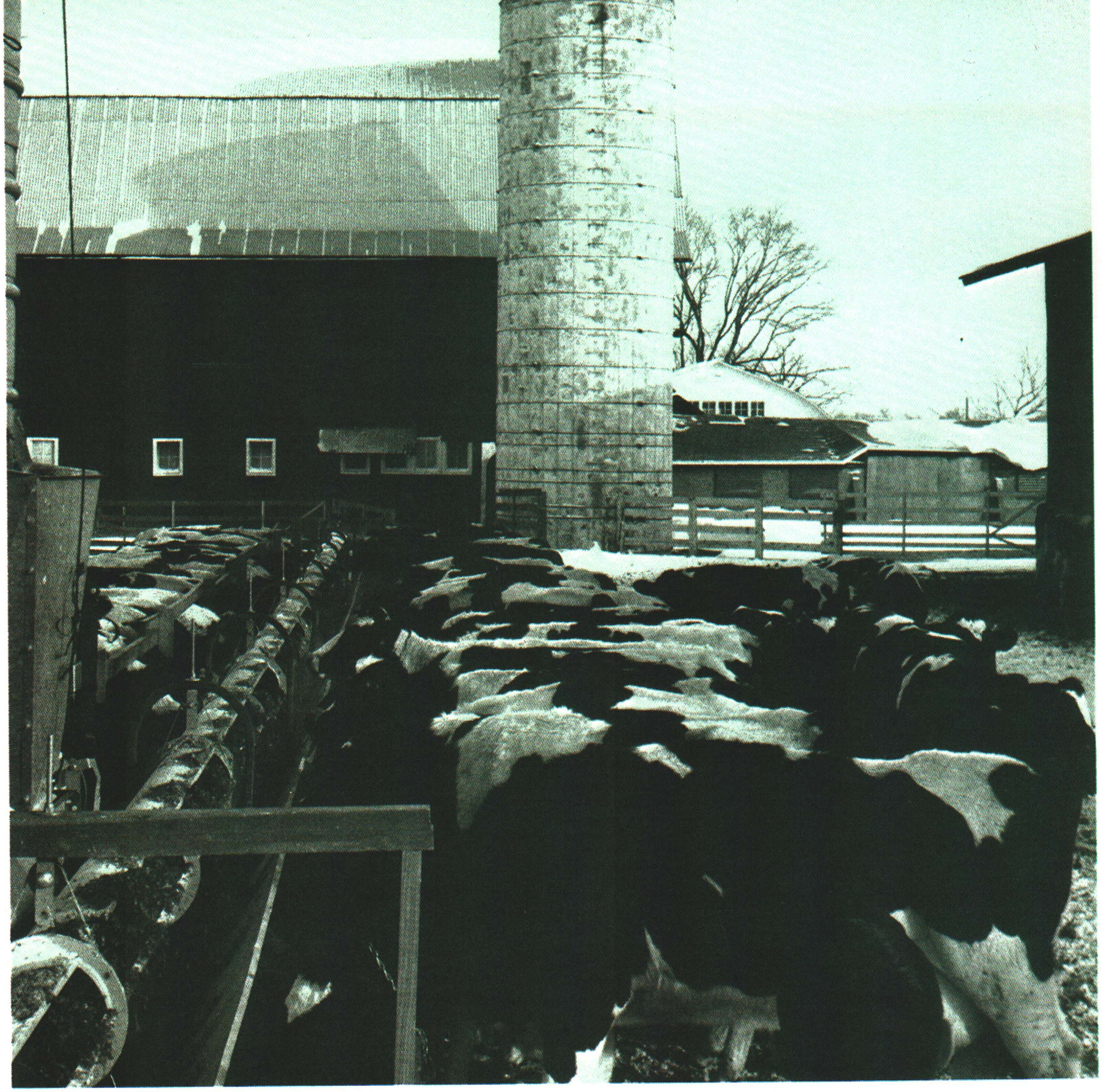


Corn Silage

THE AUTHORS

S. C. HILDEBRAND AND L. V. NELSON
Extension Specialists in Crop Science
H. E. HENDERSON
Extension Specialist in Animal Husbandry
DONALD HILLMAN
Extension Specialist in Dairy
C. R. HOGLUND
Department of Agricultural Economics
R. L. MADDEX AND R. G. WHITE
Extension Specialists in Agricultural Engineering

TABLE OF CONTENTS



ON LAND SUITABLE FOR CORN PRODUCTION, no other feed crop grown in Michigan will equal corn silage in pounds of digestible energy produced per acre.

Corn silage is becoming an increasingly important feed in Michigan, with over 20 percent of the state's corn acreage harvested as silage. Livestock producers are harvesting 4 million tons of corn silage or 50 percent more than they did 10 years ago. The tonnage of harvested legume-grass crops has remained about the same but the acreage used for grazing has been reduced substantially.

The trend toward feeding more corn silage will continue because of the low cost of feed nutrients compared to other crops and the possibility of nearly complete mechanization of harvesting and feeding. As dairy herds and beef fattening operations become larger, it becomes more economical to feed out of storage and eliminate grazing or daily chopping.

Rapid technological advances which have increased corn yields at a more rapid rate than that of any other feed crop, have made high yields relatively easy to attain. Reduced cost of protein resulting from feeding low-cost urea is another factor encouraging increased use of corn silage.

costs of growing and buying silage

How do costs of production and storage compare between corn grain and corn silage? Recent MSU research provides some answers.

Total costs to grow, harvest and store one acre of corn grain and corn silage were calculated for two yield levels. These levels represented moderately productive and highly productive cropland — 90 and 120 bushel-per-acre corn grain and 16 and 20 ton-per acre silage. The costs in Table 1 will vary between areas and farms. Individual dairymen can substitute their own input costs where they differ from those in the table.

According to the MSU research, it costs roughly $75 to $100 per acre or 80¢ to 90¢ per bushel to grow and harvest corn grain. Costs of storage, including losses, add $7 to $10 per acre.

Table 1 — Total Cost to Produce One Acre of Corn Grain and Corn Silage — 1968.

ITEM	Grain		Silage	
	COSTS Harvested yield per acre			
	90 bu.	120 bu.	16 tons	20 tons
Land value per acre	$375.00	$500.00	$375.00	$500.00
Cost to grow, harvest and store				
Land charge	26.25	35.00	26.25	35.00
Fertilizer	11.00	15.00	18.00	22.00
Herbicide	5.80	5.80	5.80	5.80
Seed & lime	2.80	3.20	2.80	3.30
Plow & prepare	6.00	6.00	6.00	6.00
Plant & apply chemicals	3.50	3.50	3.50	3.50
Cultivate	2.50	2.50	2.50	2.50
Harvest & haul	21.50	26.00	24.00	30.00
Cost to grow & harvest:				
one acre	79.35	97.00	88.80	108.10
per unit harvested	.88	.81	5.50	5.35
Storage	3.60	4.80	4.80	6.00
Loss in storage	3.60	4.80	8.80	11.20
TOTAL COSTS				
Per acre	86.55	106.60	102.40	125.30
Per unit	1.02	.94	6.83	6.66

Total cost of growing and harvesting corn silage will vary from $80 to $110 per acre or $5.00 to $6.00 per ton depending largely on yields, acres harvested and cost differences on individual farms. Storage costs, including value of losses during storage, add from $0.80 to $1.00 per ton. Thus, total costs to produce, harvest and store corn silage yielding 16 to 20 tons per acre will be $100 to $130 per acre or $6.50 to $7.50 per ton. These costs are based on good management practices in growing, harvesting and storing the crop. With average management and lower yields, per ton costs may range from $7.50 to $9.00.

Large acreages of land in Michigan are not adapted to intensive production of the corn crop. On lighter textured soils or those subject to erosion, corn silage may well be grown to a limited extent and fed with alfalfa. On these soils, feed nutrient costs are more nearly equal for corn silage and alfalfa.

Contract Production

Most Michigan livestock producers find it profitable to grow their own silage corn, especially those beef cattle feeders and dairymen who now have adequate cropland and do not expect to expand much beyond their present livestock numbers.

However, the trend is definitely toward purchase of more of the feed inputs. In the future, as dairy and beef-fattening farms become larger and more specialized, purchasing silage will likely be profitable for many operators. A market price for grain is readily available but a contract for the delivery of corn silage which is equitable to both seller and buyer is not as easily determined.

The price paid for corn silage must take into account the value of the corn grain in a ton of silage, the dry matter content of the silage, and extra costs of harvesting and hauling the silage. The following is a rough guide as to the bushels of corn grain in a ton of silage:

Yield of corn grain	Bushels per ton
Less than 90 bushels	5.0
90 - 110 bushels	5.5
110 - 130 bushels	6.0
130 and more bushels	6.5

A buyer and seller may agree on establishing a value for corn grain at the elevator during a specified marketing period. Let's assume that the seller delivered 16 tons of 30 percent dry matter corn silage per acre to the feeder and that the corn grain price averaged $1.10 a bushel.

5.5 bushels	X	$1.10 = $6.05
$6.05	=	base price
1.50	=	allowance for harvesting and delivery to silo
——		
$7.55	=	price for 30 percent DM silage
$7.55	÷	600 pounds dry matter = 1.26¢ per pound dry matter

A 32 percent dry matter corn silage would have 640 pounds dry matter per ton.

640 pounds x 1.26¢ = $8.26 price paid per ton for 32 percent dry matter silage.

Table 2 shows the returns over costs per acre when corn is harvested for grain or silage and priced on the basis of the formula used.

Table 2 — Value of Crop, Variable Costs and Returns Above Variable Costs for One Acre of Corn Grain and Corn Silage.

Item	Grain	Silage
Harvest yield	90 bushels	16 tons
Moisture at harvest	25%	70%
Price per unit	$ 1.10	$ 7.55
Value per acre	$99.00	$120.80
Variable costs		
Picker sheller	$ 8.00	
Drying (10¢ bushel)	$ 9.00	
Hauling (5¢ bushel)	$ 4.50	
Harvest & haul		$ 24.00
Extra cost of fertilizer (for stalks removed)		$ 6.00
Total variable costs	$21.50	$ 30.00
Returns above variable costs	$77.50	$ 90.80
Difference in return — 70% moisture silage		+$ 13.30
Difference in return — 68% moisture silage		+$ 24.66

corn plant development

Maximum yields per acre of corn silage can be obtained if the crop is allowed to reach physiological maturity before harvest. As a guide to when this point is reached in the development of a corn plant the following information is submitted based on studies from Michigan State University (unpublished data) and Iowa State University (Iowa State Univ. Spec. Report 48):

Period in Corn Growth	Range in Days
Planting to emergence	6 to 21
Emergence to silking	60 to 70
Silking to physiological maturity (about 35 percent moisture in kernels)	50 to 55

These studies have shown that the silking to maturity period is the least variable, and is relatively constant for all hybrids. It may be influenced by severe drought conditions.

Additional information from Iowa studies show the approximate moisture loss per day as corn progresses from silking to physiological maturity:

Number of days	Moisture in kernels	Moisture reduction (%) per day
20	silking to 75%	1.00 to 1.59
19	75% down to 50%	1.32
19	50% down to 35% (maturity)	0.76

58 days — total — from silking to maturity

Maximum grain accumulation occurs during the period when the grain develops from 75 to 35 percent moisture. This period covers 35 to 40 days. A 150-bushel crop averages about 4 bushels per acre per day of accumulation during this period. Premature frost or silage harvest would reduce the yield about 4 bushels per day.

At physiological maturity the corn kernels or grain would contain about 35 to 38 percent moisture, ear corn 40 to 45 percent moisture and the entire plant about 62 to 68 percent moisture. If corn hybrids of the proper maturity were being used for silage, some of the leaves and most of the stalks would be green. The kernels would be in about the hard dent stage.

Farm operators could use the following to plan the approximate time for silage harvest:

1. Note on a calendar the dates your fields of corn are 50 percent in silk.

2. Sometime before 45 days after silking date you should get "tooled" up for making corn silage.

3. With tower silos, check your field 50 days after silking and if the kernels are in the hard dent stage or slightly softer, it is time to make silage. With bunker silos you might check the corn at 45 days after silking date. The corn will not have accumulated all of its dry matter at 45 days but silage going into a

bunker silo should carry a little more moisture to insure good packing and preservation. In this case, a compromise between maximum dry matter and moisture content of the silage is necessary to obtain the most desirable end product.

While corn plant development and the thumb nail test give some good clues to the best time to ensile corn, more precise methods might be used, once you know the corn is about ready. A complete discussion of time to harvest follows in another section of this bulletin.

corn production practices

No single production practice is responsible for high yield of high quality silage corn. Excellent hybrids of the proper maturity, proper plant population, good soil fertility, planting at the right time and good weed control have an important role in corn production. If management fails on one or more of these factors the optimum yield is not realized.

Hybrid Selection

Corn hybrids vary considerably in their yield ability. Two hundred thirty-eight different hybrids were tested in the 1967 MSU hybrid corn trials at 17 locations. The highest yielding group of hybrids averaged 128 bushels per acre (21.3 T. silage), the medium group 102 bushels (18.5 T. silage) and the lowest group averaged 74 bushels (16.8 T. silage) of corn per acre. In other years there were similar groups of high yielding, medium yielding and low yielding hybrids.

Silage yields were obtained at four locations in 1967. The various hybrids differed markedly in grain production, total dry weight and percent grain in the silage (grain/stover ratio). The following summary was taken from the 1967 Huron County silage trial which included 64 hybrids.

Factor	Average for all hybrids	Range for hybrids Low	High
Green weight-tons/acre	21.7	13.8	28.0
Dry weight-tons/acre	7.8	5.9	9.1
Percent grain in silage	48	41	60

For most purposes, those hybrids which produce high yields of grain also produce high yields of high quality silage. For a particular locality hybrids of similar maturity should be chosen for both grain and silage use.

A hybrid adapted for silage production must be ready for silage harvest some time prior to the average time of the first killing frost. For highest quality silage and maximum tonnage the corn should reach physiological maturity or nearly so (about hard dent stage) and harvested before a killing frost. The period of time you need to allow for silage-making before this frost depends on the acreage of corn, equipment available for harvest and operating crews. See section on harvesting equipment for details.

Current information on corn hybrids for grain and silage is published in MSU Extension Bulletin 431, *Corn Hybrids Compared.* These tests show the wide range in yielding ability of hybrids. Well managed, unbiased tests are a good method of selecting the best hybrids to grow.

TYPES OF HYBRIDS

The best *single cross* and *3-way hybrids* have a genetic potential for higher grain yields when fertility, moisture and management factors are at the optimum.

The best *double cross hybrid* may do as well as any other if maximum dry weight is the major objective and the seed cost will be less.

A *silage blend* is usually a mixture of leftover grades and hybrids and may not be the same mixture each year. Blends usually do not yield as well as the best hybrid in the blend.

Sweet dent and *high sugar hybrids* have been compared with normal dent hybrids in several studies. The normal dent produced 10 to 15 percent more TDN (total digestable nutrients) per acre.

CALENDARIZING HYBRIDS

Livestock producers growing large acreages of corn for silage find it difficult to make quality silage from the entire acreage when it is planted to hybrids of the same maturity. The harvest season is not long enough; some silage would be too wet and some too dry for highest quality. One answer is to choose three hybrids differing slightly in maturity. Plant the early maturing hybrid first, the latest maturity hybrid last. A 2-week spread in planting will give about a 3-week spread in silage harvest.

Planting Date

Early planting is equally important whether corn is harvested for silage or grain. Research at Michigan State University shows that for each day of delay in planting in southern Michigan after May 1-10, there is a loss of 1 bushel per acre of corn. In silage tests with early planting, the plants have been slightly shorter and the grain/stover ratio higher as shown by the information in Table 3.

Table 3 — Effect of Time of Planting on the Yield per Acre of Silage Corn.

Planting date	Pounds per acre (dry weight)			Grain (%) in silage
	Grain	Stalk	Total	
May 9	7,600	6,600	14,200	54
May 22	6,200	7,000	13,200	47
June 3	5,500	7,400	12,900	43

Plant Population, Row Width

Tests involving plant population have been conducted with a large number of hybrids in MSU Hybrid Corn Trials in Ingham, Monroe and Saginaw counties for several years. On the average, when comparing populations of 18,000 to 20,000 with those of 23,000 to 26,000 plants per acre, there were only minor differences in yield, depending on the season and location. In a very favorable season there was a slight advantage for the higher population; in an average season the advantage was with the lower population.

The tests have shown that on some of the better soils in Michigan there was no advantage to having a final plant stand of more than 20,000 to 22,000 plants per acre in seasons with good rainfall. On many Michigan soils a plant stand of 16,000 to 18,000 plants per acre is more practical. A critical factor during the summer months in Michigan is moisture. Even under irrigation and high fertilization, a stand of 22,000 plants per acre equalled the grain yield of a 30,000 per acre stand on a sandy loam soil at East Lansing.

Most of the seed corn sold today is of excellent quality; however, no seed lot is perfect. In order to arrive at a desired plant population, plant extra kernels to allow for some seed mortality, loss of plants from cultivation and injury from other causes. Table 4 shows the amount of seed required per acre to obtain a desired plant population per acre under average conditions. If you are planting early (May 1-15), these seeding rates should be increased an additional 5 to 10 percent. The table also shows the seed spacing in the row you will need to obtain the desired plant population.

Plant population usually has a greater effect on corn yields than row width. Thirty-inch rows have averaged 5 to 6 percent more and 20-inch rows have averaged 15 percent more corn per acre than conventional 36 to 40-inch rows. These differences are most likely to occur at high yield levels, above 100 bushels per acre. If the yield per acre is less than 100 bushels, other management factors should be looked at first before considering a change to a narrower row width.

Insect and Weed Control

Currently much insect and weed control is by means of insecticides and herbicides. In applying chemicals be especially careful to note the restrictions on the use of the pesticides for silage corn. There are differences in materials used for corn grain and corn silage and notations are made in the appropriate MSU Extension bulletins and on labels of the pesticide containers. Pesticide container labels should also be checked for clearances and precautions.

Consult MSU Extension Bulletin 439, *Corn Insect Control,* for recommendations of material, rate and method of application of insecticide for the control of corn insects.

Table 4 — Seed Spacing in the Row to Get a Desired Plant Population Under Average Conditions.

Desired Plants per acre (PPA)	Kernels per acre for PPA	Approximate kernel spacing in the row (inches) for PPA for various row widths							
		28	30	32	34	36	38	40	42
12,000	13,200	17.0	15.8	14.8	14.0	13.2	12.5	11.9	11.3
14,000	15,400	14.5	13.6	12.7	12.0	11.3	10.7	10.2	9.7
16,000	17.600	12.7	11.3	11.1	10.5	9.9	9.4	8.9	8.5
18,000	19,800	11.3	10.6	9.9	9.4	8.8	8.3	7.9	7.5
20,000	22,000	10.2	9.5	8.9	8.4	7.9	7.5	7.1	6.8
22,000	24,000	9.3	8.6	8.1	7.7	7.2	6.8	6.5	6.2

Consult MSU Extension Bulletin 434, *Weed Control in Field Crops,* for recommendations of material, rate and method of application of herbicides for the control of weeds in corn. Cultivation remains an excellent means for controlling weeds, either alone or in combination with a herbicide. In cultivation be sure not to damage the root system.

Soil Fertility and Fertilization

In corn silage production almost all of the plant is removed from the field. Therefore, continuous cropping under a silage program may result in serious soil fertility problems. Under a continuous grain program the stalks and leaves are plowed down and this serves to maintain soil tilth, water holding capacity, furnish food for soil organisms, etc.

If silage is grown continuously, heavy applications of manure must be applied and rye or ryegrass winter cover crops utilized.

A more practical approach might be to alternate a silage program with corn for grain where stalks would be plowed down at least every other year, along with applications of manure and use of rye and ryegrass cover crops.

Corn is grown on many different soils and in many different cropping systems. Therefore, the fertilization program must vary considerably from field to field and farm to farm. A good fertilizing program is based on a soil test for phosphorus and potassium, a crop history of the field and a yield goal. Consult MSU Extension Bulletin 550, *Fertilizer Recommendations for Vegetable and Field Crops in Michigan,* to determine specific fertilizer requirements.

when to harvest for silage

The following are some of the important factors in determining the best time and practices to use in harvesting corn silage:

— Maximum dry matter per acre.

— Maximum digestibility of nutrients in the silage.

— Maximum dry matter stored per cubic foot of silo capacity.

— Minimum of seepage loss from the silo.

To best meet these goals, start harvesting when the kernels are in the early dent to late dent stage of maturity and complete harvest as soon as possible. At this time the dry matter of the corn plant is from 30 percent to 40 percent. Dry matter in the kernels will vary from 50 to 65 percent. Calendarization of hybrids discussed under hybrid selection, will help to meet these objectives.

If corn silage is harvested when the dry matter is 30 percent or less, extensive seepage will occur, especially with silos 60 feet or taller. This results in a loss of nutrients (seepage is about 8 percent dry matter) and severe erosion of the walls and hoops of tower silos. There is also danger of the silo collapsing due to extreme pressures generated from the added weight of the material. To eliminate excessive seepage in tower silos the dry matter content of the silage must be above 35 percent.

In bunker silos seepage will not normally occur nor will extreme pressures be a problem with 30 percent dry matter silage. You may have to begin harvest slightly earlier than the maximum yield stage because extra moisture in the silage is necessary to insure exclusion of air, good packing and proper fermentation.

If you wish to be more exact as to the amount of dry matter or moisture in the silage before starting to ensile, a relatively accurate moisture tester to weigh, dry and reweigh the dried material is available. It

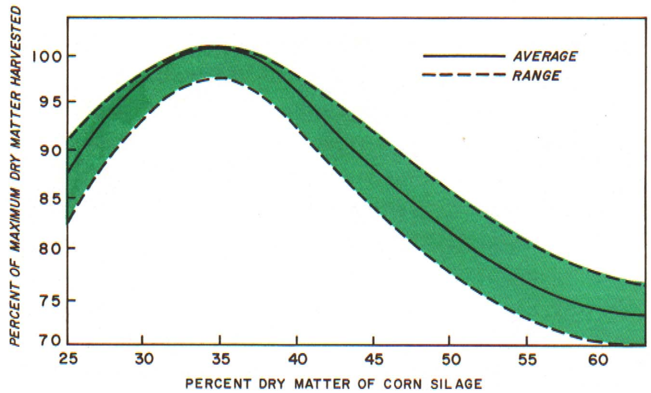


Figure 1 — Effect of Stage of Maturity of Corn Silage on Dry Matter Harvested Per Acre.
(Summary of research conducted at Michigan, Indiana and U.S.D.A.)

requires about 30 minutes to run. The forage harvester must be run in the corn field to obtain a good sample of silage for the moisture test. An information sheet is available from the departments at MSU involved in the preparation of this bulletin.

Another method of telling when corn is ready for harvest is to shell kernels from several ears and take them to the elevator for a moisture test.

Effect of maturity on dry matter yield per acre — Research data from Michigan State University and other experiment stations relating stage of maturity of corn silage to dry matter yield per acre are summarized in Figure 1.

These data show that yield per acre increases until the plant reaches approximately 35 percent dry matter or until the first killing frost. It will then level off for 5 to 10 days (depending upon the extent of frost, wind and rain) and then begin declining at a rapid rate. This is due to the loss of leaves and tassels from standing stalks and the loss of the entire stalk from lodged plants.

Figure 2 shows dry matter accumulation in the corn plant for typical 120-day corn, assuming no frost during the 120-day growing season and no loss of leaves, tassels and whole plants due to lodging.

Both Figures 1 and 2 show that there is no advantage in delaying corn silage harvest after it has reached 35 percent dry matter or after all kernels are in the hard dent stage of maturity.

Effect of maturity on nutritive value — High quality corn silage is not only highly digestible for protein and dry matter but has a high percentage of its total dry matter in the form of organic acids, particularly lactic acid.

Recent research conducted at Michigan State University and Ohio State University shows a significant relationship between percent dry matter of corn silage at harvest and digestibility of protein and dry matter. Both are maximized in the 30 to 40 percent range with a slight drop in digestibility beyond 40 percent. However, production of lactic acid drops off very rapidly beyond 40 percent dry matter.

Effect of maturity on silo capacity — In research at Michigan State University during the 1966 harvest

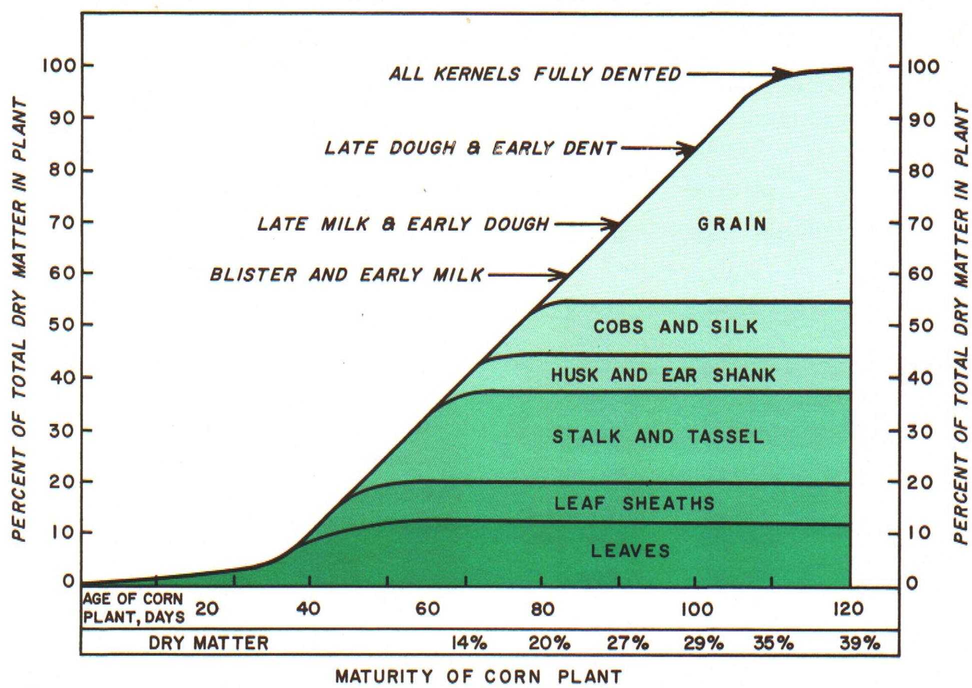


Figure 2 — Effect of Stage of Maturity of Corn Silage on Total Dry Matter Accumulation.
Source: Iowa State University Special Report No. 48

season, silo capacity was substantially reduced by delaying harvest from the early dent (28 percent DM) to a very late stage of maturity (48 percent DM). See Table 5.

Effect of maturity on steer performance — In two feeding trials at Michigan State University, steers gained faster and required less feed to produce 100 pounds of gain when fed 28 percent dry matter silage than when fed 48 percent dry matter silage. Results are shown in Table 6. This was true even though the 28 percent silage was higher in moisture than desired and subject to higher seepage losses.

Somewhat similar results were obtained in trials with dairy animals.

How Fine to Chop

Corn silage should be chopped at lengths of ¼ and ⅜ inch irrespective of the stage of maturity or dry matter content. Fine chopping has these advantages:

- Improves the palatability of the silage.
- Improves the type of fermentation which occurs in the silo.
- Increases the amount of dry matter stored per cubic foot of silo capacity.
- Reduces the amount of oxidative losses during storage.

The value of fine chopping increases as the crop advances in maturity and becomes extremely important at 35 percent dry matter and above. In contrast, as the corn crop matures and loses moisture, it toughens and becomes more difficult to chop fine.

Table 5 — Effect of Stage of Maturity of Corn Silage on Pounds of Dry Matter Stored per Cubic Foot of Silo Capacity.

Harvest date	DM	DM stored per cu. ft. silo capacity	Reduction from 28% DM harvest
	%	Pounds	%
Sept. 13, 1966	28	12.27	
Oct. 17, 1966	48	10.99	10.60

Source: Expt. AH-BC-666, Beef Cattle Research Center, MSU.

Table 6 — Effect of Stage of Maturity of Corn Silage on Rate of Gain and Feed Efficiency of Feedlot Steers.

Harvest date	DM	Average daily gain	Feed required per cwt. gain
	%	Pounds	Pounds
Sept. 13, 1966	28	2.87	661
Oct. 17, 1966	48	2.70	693
Sept. 18, 1967	31	2.58	669
Oct. 19, 1967	43	2.45	716

Source: Expt. AH-BC-666 & 676, Beef Cattle Research Center, MSU.

Most modern field harvesters will chop corn silage at ¼- to ⅜-inch lengths without difficulty when the dry matter is 30 to 35 percent. However, when the dry matter is 35 to 40 percent the same machines will require a 2½- to 3-inch screen inserted beneath the knives in order to maintain the ¼- to ⅜-inch chop. At 40- to 50-percent dry matter, a 2- to 2½-inch screen is necessary.

In order to spread the total power required between the field harvester and the silo blower, a recutter fitted with appropriate screens may be used instead of inserting screens in the field harvester. In either case, total power requirements will be increased. See section on power requirements for harvesting.

Studies were conducted at MSU in 1966 and 1967 to determine the effect of fineness of chop on silo storage capacity. Identical 16 inch x 50 inch concrete stave silos were used and the corn was harvested on two dates each year. The results are shown in Table 7.

Table 7 — Effect of Fineness of Chop of Corn Silage on Pounds of Dry Matter Stored per Cubic Foot of Silo Capacity.

Harvest date	DM in silage	DM per cu. ft. of silo		Increase
		¼″-⅜″ chop	⅝″-¾″ chop	
	%	Pounds	Pounds	%
Sept. 18, 1967	31	12.32	11.55	6.7
Sept. 13, 1966	28	13.40	11.14	20.3
Oct. 19, 1967	43	13.15	12.13	8.4
Oct. 17, 1966	48	11.99	9.96	20.4
Average increase (all trials)				14.0

Source: Expt. AH-BC-666 & 676, Beef Cattle Research Center, MSU.

These data show a substantial reduction in dry matter stored per cubic foot of capacity when the length of chop was increased from ¼-⅜ inch to ⅝-¾ inch, regardless of the dry matter content of the silage.

Effect of fineness of chop on steer performance — The results of studies conducted at MSU in 1966 with 2 lengths of chop and 2 stages of maturity are summarized on Table 8.

Table 8 — Effect of Fineness of Chop of Corn Silage on Rate of Gain and Feed Efficiency of Feedlot Steers.

Harvest date	DM in Silage	Length of chop	Average daily gain	Feed required per cwt. gain
	%	Inches	Pounds	Pounds
Sept. 13, 1966	28	3/8	2.89	678
Sept. 13, 1966	28	5/8	2.85	650
Oct. 17, 1966	48	3/8	2.78	689
Oct. 17, 1966	48	5/8	2.63	703

Source: Expt. AH-BC-666, Beef Cattle Research Center, MSU.

preservation and storage of silage

Silage Fermentation

When corn is ensiled, the plant cells and microorganisms respire (absorb oxygen) and use up fermentable carbohydrates in the silage materials. Carbon dioxide is released and the temperature of the silage rises to about 80 to 100 degrees F. under good conditions. When the entrapped air supply is gone the plant cells die and respiration ceases. This is called the *aerobic* phase of silage fermentation.

In the next stage of fermentation, microorganisms that live without air (anaerobic) compete for available food (carbohydrates). Under favorable conditions the *lacobacillus* bacteria multiply rapidly and inhibit the production of other organisms and enzymes. Eventually the carbohydrate supply is used up and/or the lactic bacteria inhibit their own growth and production when the silage pH drops to 4.2 or below. Corn silage normally contains lactic acid equivalent to 4 to 8 percent of the dry matter.

Under most conditions the silage-making process takes about 2 to 3 weeks. The total loss of dry matter due to both aerobic and anaerobic fermentation is normally only 3 to 5 percent of the material when proper attention is given to good ensiling procedures.

Corn Silage Additives

UREA

Urea may be added to corn at the time of ensiling to increase the crude protein-equivalent of the silage. Ten pounds of urea per ton of forage ensilage (34 percent dry matter) increases the protein-equivalent content to about 13.3 percent from a value of 9.3 percent without urea as shown in Table 9.

The main reason for adding urea to corn silage is to reduce the need for other protein supplement. Feeding urea corn silage can result in considerable reduction in cost of protein supplements when corn silage is used as the major forage and common protein supplements are relatively expensive.

Urea is usually added to silage by spreading it over the top of loads when power-unloading wagons are used. Calibrated metering devices that add urea directly to the blower or into the field chopper have also been used. One hundred cubic feet (100 cubic feet) in the wagon box is equivalent to one ton of corn silage.

For example: A wagon box is 12 feet long x 8 feet wide, and silage is 4 feet deep: 12 feet long x 8 feet wide = 96 square feet x 4 feet deep = 384 cubic feet ÷ 100 cubic feet/ton = 3.84 tons. Ten pounds urea per ton x 3.84 tons = 38.4 pounds urea added to this load of corn for silage.

Ten pounds urea per ton is the maximum amount recommended since larger quantities may exceed the amount that organisms in the rumen can readily convert to microbial protein for use by the ruminant animal.

About one half the urea changes to ammonia in the silage. The ammonia is combined with acids produced by fermentation of the silage to form ammonium salts of lactic and acetic acid. For best results silage should contain enough moisture to allow normal fermentation but not so much that excessive seepage occurs. Silage containing 60-70 percent moisture (30-40 percent dry matter) is most suitable for preserving corn silage with urea. Urea should not be added to silage that contains less than 28 percent or more than 40 percent dry matter when ensiled in tower silos. In bunker silos urea can be added to 25 percent dry matter.

The addition of urea increases concentrations of lactic and acetic acids 10-50 percent depending on the moisture content in the silage. The acidity (pH) of silage containing urea is similar to but usually slightly higher than untreated silage. Both average 3.8 to 4.2.

Silage additives which contain urea and limestone (calcium carbonate — $CaCO_3$) are available commercially. Most of these contain about one-half limestone. Thus, if 10 pounds urea is to be added per ton of silage, 20 pounds of the mixture must be used. Always check the urea content of commercial additives to avoid disappointing results.

Table 9 — Effect of Adding Urea on Protein-Equivalent and Organic Acid Content of Corn Silage Dry Matter.

	Untreated corn silage	Urea corn silage
Dry matter (% average)	34.1	34.5
Protein-equivalent (% of DM)	9.3	13.3
Lactic acid (% of DM)	4.2	5.4
Acetic acid (% of DM)	.9	1.2

SULFUR

Sulfur may become a limiting element in the ration when urea and corn are fed as the major sources of protein. In proteins, the ratio of nitrogen to sulfur is 15:1. For rumen bacteria to make their own protein and grow properly, a narrower ration (proportionally more sulfur) may be required in the diet. Recent evidence indicates some improvement in growth and milk production of dairy cattle when sulfur was added to diets containing high levels of urea and low levels of sulfur.

Gypsum (calcium sulfate) contains about 16.8 percent sulfur and is inexpensive. It can be added to corn silage at the rate of 1.8 pounds per ton of silage to furnish the needed sulfur when ten pounds urea per ton is added to silage. Sodium sulfate (22.5 percent sulfur) may also be used to provide the sulfur but is usually more expensive.

LIMESTONE

Limestone (calcium carbonate) has been added to corn silage at the rate of 10 to 20 pounds per ton to increase the formation of lactic and acetic acid in the silage since these acids are used directly by ruminants for energy. Research has shown that it effectively increases the acid content by 20-80 percent depending on moisture content and other conditions of the silage.

Feeding trials have not shown a consistent improvement either in growth rate or feed efficiency when limestone-treated silage was compared to untreated silage.

No improvement in milk production of dairy cows was shown in any of five trials comparing the limestone-treated with untreated silage.

Silage Preservatives

Preservatives are not necessary for making good corn silage. Harvesting corn at the proper moisture content, fine chopping, even distribution in the silo and tight storage are the best assurance of good silage preservation. When these conditions are not controlled, good results from using any type of preservatives should not be expected. Enzyme preparations, which are usually products of other fermentations, have not consistently increased lactic and reduced acetic acids in corn silage.

NOTE: Preservatives must not be confused with nutrient additives that improve the nutritional content.

silage harvesting and equipment

Silage harvesting equipment is available either as pull-type or self-propelled units. Attachments are available for single or multi-row harvesting, with row spacing varying from 20 to 40 inches. In addition, windrow pickup and direct cut attachments are available for most models, making the machines adaptable for harvesting a wide variety of crops.

Pull-type forage harvesters are available in a wide range of sizes, and will hereafter be referred to as "small", "medium", and "large" capacity machines. While not absolutely true in all cases, there is a general correlation between machine cost and capacity. Due to the increased maneuverability of the self-propelled machines, they are generally rated at a higher capacity in tons per hour than their pull-type counterparts.

Weather Probabilities

Weather — an uncertain factor in all farming operation — is particularly critical for harvesting. Table 10 shows probabilities of having *good, moderate, poor* or *very poor* weather for harvesting corn silage.

Good weather is classified as being able to perform harvesting operations 2 days out of 3.

Moderate weather is working 1 day out of 2.

Poor weather is working 1 day out of 3.

Very poor is working only 1 day out of 4 during the harvest season. Table 10 shows the frequency, or number of years out of 10 that harvesting weather "this good or better" can be expected. It is *not* the intent of this table to specify how far to go in mechanizing against weather hazards. The intent is to point out the frequencies, or the number of years out of 10, that one can expect weather at harvesting time to permit harvesting operations to be carried out on a given number of days out of the season. An operator

Table 10 — Corn Silage Harvesting Time Available in a Three-Week Harvesting Season, as Affected by Weather and Hours Per Day the Operator is Available.

Harvesting conditions	Estimated frequency of Col. 1 harvesting conditions	Hours of corn silage harvesting time per 3-week season			
		6-hour work day	8-hour work day	10-hour work day	12-hour work day
	Years out of 10	Hours			
Good Weather Harvest 2 days out of 3	3 to 4	72	96	120	144
Moderate Weather Harvest 1 day out of 2	5 to 6	54	72	90	108
Poor Weather Harvest 1 day out of 3	7 to 8	36	48	60	72
Very Poor Weather Harvest 1 day out of 4	8 to 9	27	36	45	54

must select a harvesting system based on the extent to which he is willing to "gamble" on the weather. The most logical solution is to mechanize sufficiently to complete silage harvesting operations, 6 years out of 10, within a planned length of time.

Length of Harvest Season

Timeliness of harvesting operations is of utmost importance, since it affects both the quantity and quality of the harvested crop. The optimum range of moisture content of corn silage stored in tower silos is approximately 62 to 68 percent (32 to 38 percent DM). This sets some fairly specific limits on the length of time available for harvest. Harvesting operations should start when the corn is in the early to hard dent stage (see section on when to harvest) and should be completed as quickly as possible. Generally, there is a time span of 10 days to 2 weeks after corn is in the hard dent stage before a killing frost, assuming that hybrids of proper maturity are used. It is usually possible to continue silage harvesting operations after the first killing frost for 5 to 7 days before foliage losses become excessive. This gives a workable corn silage harvest season of about 3 weeks. Calendarizing hybrids, discussed in a previous section, could extend this period another 5 to 7 days.

Harvesting operations should be planned, and equipment and labor should be available, to permit completing silage harvesting operations with a 3-week period at least 6 years out of 10.

Harvest Hours per Season

The tonnage of silage that can be harvested within any set length of season is influenced by the capacity of the harvester, the weather probabilities and the number of hours per day the harvester can be operated. Many farms with limited labor supply and considerable chores can perform harvesting operations

Table 11 — Capacity Ranges for Forage Harvesters*.

Harvester size	Tons of Silage harvested per hour
Small	8 to 16
Medium	14 to 25
Large	18 to 30
Self-propelled	20 to 34

*Based on a well-managed operation. Includes about 35 percent lost time for adjustments, repairs, changing wagons, etc. Under less favorable conditions, and/or with older machines, these figures should be discounted by 10 to 25 percent.

only a limited number of hours per day. Table 10, in addition to showing the weather probabilities, indicates the number of harvesting hours available per 3-week season, depending on whether the weather is *good, moderate, poor*, or *very poor* and how many hours per day the operator is available to perform harvesting operations. Many dairymen find they can harvest corn silage only 6 hours or less per day, while other farmers may assign full-time crews and operate equipment 8 hours or more per day.

Machine Capacities

Machine capacity is important in planning a forage harvesting system. There is a wide range of sizes and capacities of forage harvesters on the market. Most manufacturers rate their machines 100 percent theoretical capacity. This does not allow for time lost in turning at field ends, for changing wagons, or for making adjustments, repairs or lubrication. From a practical point of view, one cannot normally figure on a forage harvester doing productive work more than two-thirds of the time. The percentage of time the machine is doing productive work is known as the *Field Efficiency Factor*, and this may vary considerably from farm to farm due to field topography, length of haul, age of machine, management ability of the operator, etc. Table 11 indicates typical capacity ranges for small, medium, large and self-propelled forage harvesters. This table is based on the average hourly production to be expected from these machines throughout the season. Forage harvesters for which only a one-row corn head is available would generally be classed as "small" machines. Larger machines with two- or three-row corn heads are classified as "large" machines, while those in between are classified as "medium". Every operator should achieve at least minimum production from his machine, and should plan and reorganize his operations so as to come near the top end of the range.

Matching Machines to Needs

The selection of harvesting equipment necessitates the matching of equipment capacity to the quantity of forage to be harvested. The entire forage harvesting setup must be planned as a system. Equipment must be selected and sized so as to provide a uniform flow of material from field to storage. Mismatching of pieces of equipment will result in bottlenecks that will ultimately determine the maximum harvesting rate of the entire system. Weather probabilities and the availability of equipment operators also affect the type of equipment needed.

Estimated harvesting capacities in tons per season for the various-sized forage harvesters are shown in Table 12. This table also takes into consideration the probabilities of weather suitable for silage harvesting occurring, and the number of hours per day that operators are available for the equipment.

Power Requirements

Adequate power for both the forage harvester and the blower are basic requirements for a successful forage harvesting operation. With forage harvesters the fineness of cut is particularly significant in determining power requirements.

A theoretical length of cut of ¼ to ⅜ inch is desirable in terms of utilization of silo space and exclusion of air in the silo. As the season advances and moisture in the plant lowers, fineness of cut becomes more important. With late-season operation, a recutter screen may be necessary in order to obtain the desired fineness of cut for adequate packing, exclusion of air and minimum of spoilage in the silo. A 2½ screen is usually adequate. A recutter screen also helps to crack corn kernels that might go into the silo as whole kernels. This screen will reduce harvester capacity, possibly by as much as 20 percent, or increase power requirements by about 20 percent, if the same production capacity is maintained.

Power requirements for operating forage harvesters are shown in Figure 3. Note that power requirements increase as the length of cut is reduced. A ½-inch length of cut will not give adequate packing to control spoilage and provide maximum capacity for the silo. Power requirements shown are the maximum observed PTO tractor power, and are minimum power requirements when operating under favorable conditions. Approximately 12 PTO horsepower are required to move the chopper and haul the forage wagon on level ground under favorable conditions. These re-

Table 12 — Estimated Tons of Corn Silage that Can Be Harvested in a Three-Week Harvesting Season, As Affected by Machine Size, Weather, and Harvest Hours per Day.

Harvesting conditions as affected by soil and weather	Forage harvester size & capacity	Tons of silage harvested per season — Work day: 6-hour	8-hour	10-hour	12-hour
	(Hours per Season)	(72)	(96)	(120)	(144)
Good Weather (Harvest 2 days out of 3)	Small — 8 to 16 tons per hour	580-1160	770-1540	960-1920	1150-2300
	Medium — 12 to 23 tons per hour	860-1660	1150-2200	1440-2760	1730-3310
	Large — 15 to 30 tons per hour	1080-2160	1440-2880	1800-3600	2160-4320
	S. P.* — 18 to 36 tons per hour	1290-2370	1720-3160	2160-3960	2590-4750
	(Hours per Season)	(54)	(72)	(90)	(108)
Moderate Weather (Harvest 1 day out of 2)	Small — 8 to 16 tons per hour	430- 860	580-1160	720-1440	860-1720
	Medium — 12 to 23 tons per hour	650-1240	860-1660	1080-2070	1230-2480
	Large — 15 to 30 tons per hour	810-1620	1080-2160	1350-2700	1620-3240
	S. P. — 18 to 33 tons per hour	970-1780	1300-2380	1620-2970	1940-3560
	(Hours per Season)	(36)	(48)	(60)	(72)
Poor Weather (Harvest 1 day out of 3)	Small — 8 to 16 tons per hour	290- 580	380- 760	480- 960	580-1160
	Medium — 12 to 23 tons per hour	430- 830	580-1100	720-1380	860-1660
	Large — 15 to 30 tons per hour	540-1080	720-1440	900-1800	1080-2160
	S. P. — 18 to 33 tons per hour	650-1190	860-1580	1080-1980	1300-2380
	(Hours per Season)	(27)	(36)	(45)	(54)
Very Poor Weather (Harvest 1 day out of 4)	Small — 8 to 16 tons per hour	220- 440	290- 580	360- 720	430- 860
	Medium — 12 to 23 tons per hour	320- 620	430- 930	540-1040	650-1240
	Large — 15 to 30 tons per hour	410- 820	540-1080	680-1360	810-1620
	S. P. — 18 to 33 tons per hour	490- 890	650-1190	810-1490	970-1780

*Self-propelled.

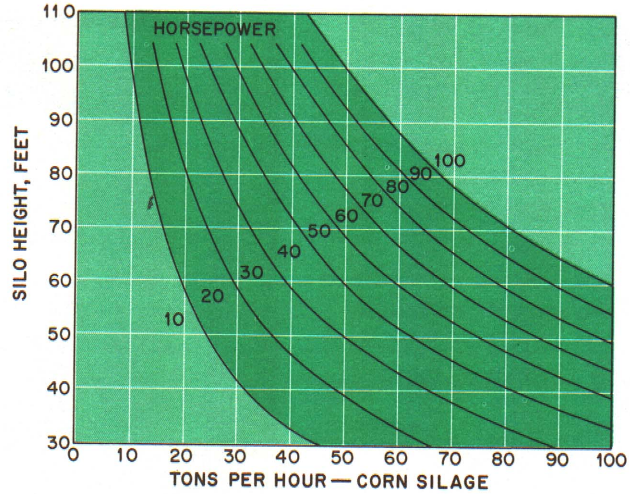


Figure 3 — Tractor PTO Horsepower Required for Operating Forage Blowers.

quirements could more than double under adverse conditions. Figure 3 is not intended to imply that the capacity of any forage harvester will increase indefinitely if adequate additional power is supplied. Each harvester has a maximum design capacity level and the application of additional power will not materially exceed this level.

Forage Blowers

Forage blowers are an easy and convenient way for delivering silage to tower silos but they are relatively low in power efficiency, generally not exceeding 10 percent. Their efficiency drops off rapidly with taller silos. Figure 4 shows the minimum power requirements for delivering corn silage to upright silos of various heights. Power requirements listed are maximum observed PTO horsepower. Maximum tonnage can be put through a blower only when the rate of feeding is fairly constant. Automatic self-unloading forage wagons tend to give the most uniform rate of unloading, and thereby tend to provide maximum blower capacity.

Forage Wagons

Forage wagon sizes range from approximately 300 to 700 cubic feet, or a load capacity of 3 to 7 tons. Typical sizes are 7′ x 14′ or 7′ x 16′. Running gears should have a rated capacity of 10 to 25 percent more than the maximum capacity of the wagon. An 8-ton gear should be used with a wagon capacity of 5 to 8 tons. Use tires adequate to handle the load, and inflate to at least 36 pounds.

Rear unloading wagons cannot be used with hopper-type blowers, but may be used with table-type blowers or for hauling to horizontal silos. Dump-type wagons or trucks may be used only for hauling to

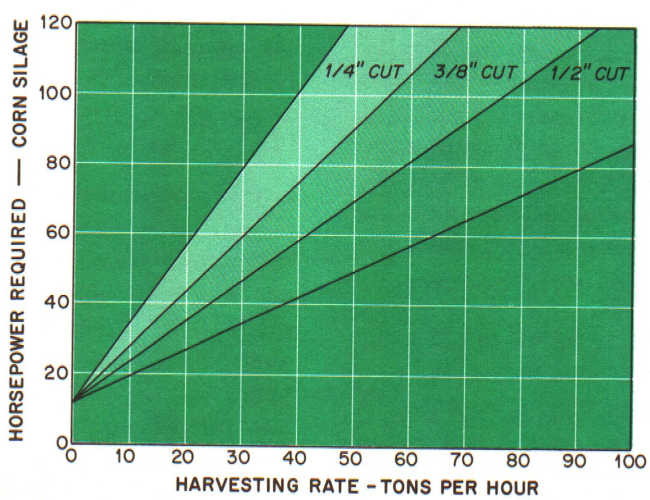


Figure 4 — Tractor Horsepower Required for Operating Forage Harvesters.

horizontal silos unless the blower conveyor is below ground level and a dumping apron is provided, from which the silage may be shoved into the conveyor by means of a tractor and blade.

Equipment Maintenance

Maximum production can be obtained only from equipment that is kept in excellent mechanical condition. Forage harvesters do their cutting by passing a knife past a shear bar:

1. Knives must be kept sharp.

2. The shear bar must have a good square edge and the knife must pass very close to the shear bar to obtain good, uniform chopping with minimum power.

3. Dull knives and worn shear bars are usually the cause of ragged cutting and high power requirements.

Many forage harvesters have built-in knife sharpeners. These are excellent for touching up cutting edges but are not well-adapted for major sharpening jobs. For best results:

(a.) Use the built-in knife sharpeners several times each day to insure good, sharp cutting edges.

(b.) Remember that the use of a knife sharpener automatically increases the clearance between the knife and the shear bar. Periodic adjustment of the knife to the shear bar is necessary; and with most machines, the shear bar can be removed and turned to two or more positions to provide a new, sharp-cornered shearing edge.

With blowers, the clearance between the fan blades and the blower housing materially affects blowing efficiency. Clearance between the end of the blade and the fan housing should not exceed ⅛ inch. Side clearances should be within the ¼- to ½-inch range. Blower pipes should be straight, free of dents and have smooth, relatively tight joints. The condition of the blower pipe becomes much more critical with silo heights above 60 feet.

Where it is necessary for the blower to set away from the base of the silo, precautions should be taken to keep the pipe from sagging or bowing appreciably.

Refer to your owner's manuals for detailed information relatively to service and maintenance for forage harvester or blower.

silo structures and their selection

High quality silage can be made in all types of structures. Quality will vary depending on the condition of the silo, moisture level, stage of maturity when harvested, fineness of chop, and other management factors. Because of the relatively low storage losses for corn silage it is considered uneconomical to use sealed storage, especially when silos are filled only once. Important factors in selection of silos are (1) size, (2) feeding arrangements, (3) materials other than corn silage that may be stored in silo and (4) investment required for total storage and feeding systems.

Losses in Storage

Tight structures, good leveling and packing practices and use of a plastic cover properly weighted down are essential in keeping losses low in bunker silos. Losses in bunker silos are also influenced by depth and width of material stored. Less surface is exposed for the deeper silos. In well-managed operations, silage losses are estimated at 5 to 10 percent for concrete tower silos and 10 to 15 percent for bunker silos.

Tower Silo

The design of the tower silo is determined by the manufacturer. Silos sold in Michigan have proven satisfactory if reasonable silo maintenance practices are followed. Silage juice is the worst enemy of tower silos. Continual seepage from silage high in moisture (70 percent or higher) will cause deterioration of all types of tower silos. An adequate foundation for silos, on well drained soil, becomes increasingly important as silos increase in size and height. In addition, it is necessary to provide drainage for seepage away from the silos to protect the foundations.

Bunker (Horizontal) Silo

A permanent silo of this type can be constructed using a concrete floor and pole-plank or concrete sides. When silage depths are greater than 8 feet, reinforcement of side walls is usually necessary. For silos built completely above ground, the maximum pressure on side walls will occur during packing at the time of filling. For bunker type silos which are partially in the ground, the maximum side wall pressure may occur from soil pressure on the sides, after silage has been removed. It is important that walls for horizontal or bunker silos be well-braced and anchored to withstand all pressures.

Feeding Systems

The selection of silos and feeding systems should be considered together.

The tower silo couples well with mechanical conveyors. Capacities of silo unloaders and bunk feeding devices are compatible. The units also lend themselves to automatic controls and push-button operation.

The horizontal (bunker) silo is usually associated with fenceline feeding using a wagon. Again, capacities of tractor loading devices and wagon distribution are very compatible.

Silo Capacities

Farm operators frequently miscalculate silo capacity and total size requirements. Increasing the size of a silo by one-third, one-half, or even double, will usually cost much less than adding the same additional capacity at a later time. To help determine the size of silo needed, tables showing total capacity and the amount of silage for the recommended feeding depth are given.

TOWER SILO

The determination of silo size should be based on both total capacity needed and amount fed daily. A minimum of 2 inches of silage should be removed daily to avoid spoilage during warmer weather. The total capacity of tower silos is shown in Table 13.

The volume per foot of depth and the amount of silage in 1-, 2-, and 3-inch depths are shown in Table 14. The number of animals required to consume a 2-inch layer for different feeding rates is shown in Table 15.

There is no objection to removing more than 2 inches of silage per day, except that the most economical storage usually works out to be a size near the 2-inch removal rate.

Table 13 — Silage Capacities and Investments for Major Sizes and Types of Silos and Unloaders Used for Storing and Unloading Corn Silage — 1968 Prices, Michigan[1].

Silo type and size (Feet)	Silo capacity[2]	Investment[3]						
		Silo	Roof	Total silo	per ton capacity	Unloader	Total	Total per ton capacity
Concrete tower	Tons	Dollars						
18 x 50	320	4,200	550	4,750	14.84	1,550	6,300	19.69
20 x 50	394	4,850	650	5,500	14.00	1,600	7,100	18.02
20 x 60	483	5,800	650	6,450	13.35	1,600	8,050	16.66
20 x 70	574	6,800	650	7,450	13.00	1,600	9,050	15.77
24 x 50	570	6,100	1,200	7,300	12.81	2,200	9,500	16.66
24 x 60	697	7,200	1,200	8,400	12.05	2,200	10,600	15.21
24 x 70	827	8,450	1,200	9,650	11.71	2,200	11,850	14.33
26 x 60	818	9,000	1,500	10,500	12.83	2,250	12,750	15.58
26 x 70	970	10,500	1,500	12,000	12.37	2,250	14,250	14.70
30 x 60	1,087	11,300	2,500	13,800	12.70	2,400	16,200	14.90
30 x 70	1,290	13,100	2,500	15,600	12.10	2,400	18,000	13.96
36 x 70	2,000						22,500	11.25
Sealed storage								
20 x 50	375			11,800	31.46	2,600	14,400	38.40
20 x 60	470			13,700	29.15	2,600	16,300	34.60
Other sizes								
Steel	600-1,000							26-34
Concrete	500-900							24-30
Bunker[4]	500				6 to 8			
	1,000				5 to 7			
	2,000				4 to 6			
	4,000				3 to 5			

1 Based on information from manufacturers.
2 Tons based on 32% dry matter corn silage.
3 Includes structure, foundation and roof for concrete and sealed tower silos, and concrete floor and tongue-and-groove treated plank sides and poles for bunker silo, and labor for constructing both types.
4 Size of bunker should fit quantity of silage fed daily. The deeper the structure, the lower the investment per ton and the lower the storage cost.

Table 15 is based on research data and has also checked out closely with some large farm silos where corn silage was weighed in and out.

Table 14 — Amount of Silage in Inch Layers For Silos of Different Size (Tower).

Silo diameter	Volume per foot of depth	Pounds of silage in layer based on 50 pounds per cubic foot		
Feet	Cubic feet	1 Inch	2 Inches	3 Inches
12	113.1	470	940	1,410
14	153.9	640	1,280	1,920
16	201.1	840	1,675	2,510
18	254.5	1,060	2,120	3,180
20	314.2	1,308	2,615	3,924
22	380.1	1,583	3,165	4,749
24	452.4	1,885	3,770	5,655
26	530.9	2,215	4,430	6,645
28	615.8	2,565	5,130	7,695
30	706.9	2,945	5,890	8,835
36	1,017.4	4,240	8,480	12,720

BUNKER SILO

Approximately 3 to 4 inches of silage should be removed from the face of a horizontal silo daily. Thus, the cross section (height and width) should be determined, based on daily silage requirements. The length of the silo is determined by the number of feeding days for which storage is required.

The capacity shown for bunker silos shown in Table 16 is based on 40 pounds per cubic foot. The density will vary more with the amount of packing than with the usual horizontal silo depths. A close estimate of the capacity for horizontal silos of different depth can be determined from this table by dividing the amount shown for a given width by 12 and then multiplying by the new depth. For example, the capacity of a 40′ width by 100′ long by 8′ high would be:

$$\frac{960 \text{ ton}}{12 \text{ foot}} = 80 \text{ ton per foot of depth}$$

$$80 \text{ ton} \times 8 \text{ feet} = 640 \text{ ton in silo.}$$

Table 15 — Number of Animals Fed Per 2-Inch Silage Layer for Various Size Tower Silos, and Feeding Rates*.

Silo diameter	Approximate pounds of Silage in 2-inch layer	Pounds of silage per day per animal: 20	30	40	50	60	70	80
Feet	Pounds	Number of animals to consume 2-inch silage layer at above rates						
16	1,675	84	56	42	34	28	24	21
18	2,120	106	71	53	42	35	30	28
20	2,615	131	87	65	52	43	37	33
22	3,165	158	105	79	63	53	45	39
24	3,770	188	126	94	75	63	54	47
26	4,430	222	144	111	88	74	63	56
28	5,130	256	171	128	103	86	73	64
30	5,890	295	196	147	118	98	84	74
36	8,480	424	283	212	169	141	121	106

*To determine height of silo, multiply 2 inches by feeding days and divide by 12.

Example: To feed 98 animals at a rate of 60 pounds per day would require a 30 foot diameter silo.
To feed 98 animals at this rate for 365 days =

$$\frac{2 \text{ inches} \times 365}{12 \text{ inches}} = 61 \text{ feet of silage}$$

Thus, 61 feet of silage plus 5 feet of unused silo from settling requires a 66-foot high silo.

Table 16 — Capacity of Bunker Silos (12-feet deep) and Amount of Silage per Slice.

Length (feet): 60	80	100	120	140	160	200	Width	Amount of silage per slice, Thickness: 4 in.	12 in.
Tons							Feet	Tons	Tons
288	384	480	576	672	768	960	20	1.6	4.8
432	576	720	864	1,008	1,152	1,440	30	2.4	7.2
576	768	960	1,152	1,344	1,536	1,920	40	3.2	9.6
720	960	1,200	1,440	1,680	1,920	2,400	50	4.0	12.0
864	1,152	1,440	1,728	2,016	2,304	2,880	60	4.8	14.4
1,152	1,536	1,944	2,292	2,688	3,072	3,840	80	6.4	19.2

investments for harvesting, storing and handling

Complete investments for machinery and equipment to harvest and handle, and facilities to store corn silage will vary greatly between farms. Investments per head fed are reduced with increased size of operation. Degree of mechanization, type of silo selected and the extent to which machines are also used to harvest alfalfa haylage or other silage crops affect economy of investments.

Harvesting

Initial investments for forage harvesters, chopper wagons and blowers are shown in Table 17. Since there is much variation in the capacity and costs of different makes of forage choppers, a range is shown for both investments and tonnages harvested seasonally for three sizes of pull-type and for self-propelled harvesters.

Silos and Unloading

Investments per ton of silage storage capacity will vary because of differences in size of structure, accessories furnished such as a roof, type of structure and difference in dealer prices.

Table 17 — Investments in Corn Silage Harvesting Equipment.

Equipment	Range in cost	Economical for following tonnages
	Dollars	Tons
Forage harvester		
Pull type		
Small	$1,900 - $ 2,600	400 - 1,800
Medium	2,600 - 3,500	800 - 2,600
Large	3,200 - 5,000	1,000 - 3,600
Self-propelled	8,000 - 12,000	1,500 - 4,000
Chopper wagons	1,200 - 2,600	
Dump trucks	3,500 - 6,000	
Silage blower	800 - 1,200	

Table 18 — Investment in Bunker Silos, 1,500 Ton Capacity (1968)[1].

Item	Concrete: Below ground	Concrete: Above ground	Wood plank above ground
360′ x $1.25 x 12′ (height)	$5,400		
360′ x $2.20 x 12′ (height)		$9,500	
360′ x $1.40 x 12′ (height)			$6,048
6,400 sq. ft. conc. floor x $0.45	2,880	2,880	2,880
Total investment	$8,280	$12,380	$8,928
Investment per ton capacity	$ 5.38	$ 8.05	$ 5.81

1 Does not include cost of excavations or drive along perimeter of bunk area.

Table 19 — Investments and Annual Ownership and Maintenance Costs for Harvesting, Storing and Handling 500 to 4,000 Tons Corn Silage.

Type of Silo	Tons silage: 500	1,000	2,000	4,000
Concrete tower silos	— — —	dollars	— — —	
Investments				
Harvesting & filling	$ 5,400	$ 6,700	$ 9,500	$18,000
Storage & feeding	8,900	16,600	30,700	61,200
Totals	14,300	23,300	40,200	79,200
Per ton capacity	28.60	23.30	20.10	19.80
Annual costs				
Harvesting & filling	1,080	1,340	1,900	3,600
Storage & handling				
Silos	620	1,250	2,500	5,000
Unloaders & loading	300	420	630	840
Feed bunks	240	400	720	1,400
Plastic cover	40	80	160	320
Storage loss	280	560	1,120	2,240
Subtotal	1,480	2,710	5,130	9,800
Total Annual Costs	2,560	4,050	7,030	13,400
Per ton preserved				
Harvesting & filling	2.35	1.45	1.03	0.98
Storage & handling	3.22	2.94	2.80	2.66
TOTAL	5.57	4.39	3.83	3.64
Bunker Silos				
Investments				
Harvesting & filling	5,800	7,300	10,300	19,000
Storage & feeding[1]	5,300	8,500	14,400	22,400
Totals	11,100	15,800	24,700	41,400
Per ton capacity	23.60	15.80	12.35	10.35
Annual costs				
Harvesting & filling	1,160	1,460	2,060	3,800
Storage & handling				
Silos	455	715	1,170	1,820
Unloaders & loading	240	360	600	720
Feed bunks & drive[1]	110	220	440	880
Plastic cover	200	300	400	700
Storage loss	525	840	1,400	2,520
Subtotal	1,550	2,435	4,010	6,640
Total Annual Costs	2,690	3,895	6,870	10,440
Per ton preserved				
Harvesting & filling	2.72	1.66	1.15	1.04
Storage & handling	3.58	2.76	2.22	1.81
TOTAL	6.30	4.42	3.37	2.85

1 Include investment of $0.60 per ton and annual cost of $0.10 per ton capacity for drive along perimeter of bunk area.

Investments in silos and unloaders for some important sizes of concrete and sealed storage units sold in Michigan are shown in Table 13. These investments are based on information from manufacturers and from farmers who bought silos in recent years before 1969. Investments in silo and unloader ranged from $19.70 for the small diameter to $14.00 for the 30 foot diameter concrete tower silos per ton of capacity. Investments in sealed storaged are 2 to 2½ times as high per ton of storage capacity.

Investments in bunker silos vary with size of silo and material used. Initial cost per ton of storage capacity will range from $3 to $8. Bunker silos using tilt-up or poured concrete sides may cost the same or $2.00 more per ton storage capacity than silos built with treated 2-inch tongue-and-groove planks. The following are estimates of costs of material and labor:

Material	Cost/Unit
Tongue-and-groove planks[1]	$1.40/ft. height/linear ft.
Concrete (poured or formed)[2]	$1.25/ft. height/linear ft.
Concrete (poured or tilt-up)[3]	$2.20/ft. height-linear ft.
Concrete floor	$0.40 - $0.50/sq. ft. (4″ thick)

1 Includes cost of poles, braces and labor.
2 Below ground structures needing limited supports.
3 Above ground includes cost of pilasters and labor.

On the basis of 40 pounds per cubic foot for corn silage, a 40′ x 160′ bunker silo filled to an average depth of 12 feet would have a storage capacity of 1,536 tons.

2 sides x 160′ + 40′ = 360 linear feet of sides.
40′ x 160′ = 6,400 square feet concrete floor.

Table 18 shows the comparative investments in a 1,500-ton capacity bunker silo, when built of concrete and wood planks.

Investment and Annual Costs

Investments and annual ownership and maintenance costs were calculated for complete corn silage systems using concrete tower and bunker silos. These were calculated for 500-, 1,000-, 2,000- and 4,000-ton capacity silos.

Investments for field choppers, mechanical wagons or dump trucks and filling equipment are essentially the same for systems using tower and bunker silos (Table 19). Unit costs are much less for the larger operations.

Total investments for harvesting, storing and handling of corn silage ranged from $28.60 per ton for 500 tons to $19.80 per ton for 4,000 tons storage capacity using concrete tower silos. These investments were considerably lower for the systems using bunker silos, ranging from $23.60 to $10.35 for these quantities.

Annual costs for complete silage systems include depreciation, maintenance, insurance and interest on the investments, plastic cover and value of estimated storage losses.

On the basis of one complete filling and a 20-year depreciation period for both concrete and bunker silos, and 10 years for harvesting and handling equipment, annual costs per ton of silage preserved ranged from $5.57 to $3.64 for the systems with concrete silos and from $6.30 to $2.85 for the systems with bunker silos. The break-even point in costs per ton for the two systems was at about the 1,000-ton capacity. With 500 tons, the tower silos are more economical and when 2,000 or more tons of corn silage are harvested and fed, the bunker silo system is more economical.

nutrient components and their value

Corn silages contain a broad range of components, some of which are characteristic of the original corn plant and others that are products of the fermentation process. The average approximate composition of the corn silages tested in recent years is shown in Table 20. The average dry matter for all silages was 34 percent with a range of 20 to 60 percent for all samples. All percentages in Table 20 are expressed as percent of the dry matter.

Carbohydrates

Corn silage is high in digestible carbohydrates as shown by the high concentration of nitrogen-free extract (Table 20), which is mostly starch and sugars. Fiber is composed largely of cellulose, hemi-cellulose and pentosans which are digested by bacteria in the ruminant stomach to form acetic, propionic and butyric acids which are used for energy by animals.

Small variations in total digestible nutrients of silage are due mainly to differences in the content and digestibility of the nitrogen-free extract and the crude fiber. The state of maturity of the corn at

Table 20 — Approximate Composition and Digestibility of Corn Silage Dry Matter.

	Crude protein	Crude fiber	N-Free extract	Ether extract	Ash	TDN[1]	Digestible protein
	Percent						
Average 34% as fed — Dry Matter	3.1	7.2	20.6	1.8	1.7	23.3	1.7
Average (dry basis)	9.4	21.3	60.8	5.4	5.0	68.6	5.1
Range (dry basis)	5–15	20–35	40–66	2–6	3–6	63–72	—
Digestibility (dry basis)	52.8	60.8	73.4	73.7	—	—	—

1 TDN = Total digestible nutrients.

harvest appears to have very little effect on the TDN content of the dry matter of the silage. The reason may be that the fiber in immature corn is more digestible and the immature corn has a higher content of soluble carbohydrates (sugars).

The high-soluble carbohydrates content of corn stalks prior to ear formation may explain why some immature corn silages are highly digestible and why cows perform as well as when fed more mature silages with a higher grain content. Most of the sugars are fermented to lactic and acetic acids in the silo.

However, the higher yield of dry matter per acre and higher dry matter content of corn that has reached physiological maturity (35% dry matter or about hard dent stage) greatly favors more mature corn for silage.

Digestibility and Energy Value

Corn silage is highly digestible with 60 to 68 percent of the dry matter normally digested by ruminants. Similarly, corn silage dry matter is high in calories. Its high-energy value makes corn silage desirable feed for fattening beef cattle, and for high-producing dairy cows. The quantity of corn silage fed to dry cows, brood cows or developing heifers may have to be restricted to produce the desired results and avoid excessive fattening.

Protein Content

Corn silage dry matter contains 8.0 to 9.5 percent crude protein. Silage from immature corn is even higher in protein. Soil moisture conditions during the growing season notably affect the protein content of the plant. Drought conditions normally increase the crude protein, with most of the increase being due to accumulation of non-protein nitrogen in the form of nitrates, urea and ammonia. Silages harvested during a drought year averaged 10.1 percent protein with a range of 8.6 to 11.7 percent which is about 1.5 percent higher than under normal growing conditions.

Extremely wet weather that causes corn to be stunted and yellowish-green results in low protein silage — probably from nitrogen starvation. These silages usually average 1 to 2 percent lower in protein than normal corn silage on a dry matter basis.

For maximum milk production and fattening cattle, corn silage rations must be supplemented with protein such as oil meals, legume-grass forage or urea.

Nitrates

Nitrogen (N) may enter plants either in the form of nitrate (NO_3) or ammonium (NH_4) ions. Once inside the plant, either form can be converted into the necessary forms for protein synthesis. The nitrate content of lower stalks and leaves is high in young, rapidly growing plants, decreases as the plant matures, and is usually low at harvest time. Drought conditions, injury to the plant by hail, insects or herbicides may cause nitrates to accumulate in the lower parts since the leaves are unable to convert the nitrate to amino acids. During the silage fermentation process, much of the nitrate is reduced to ammonium which may be utilized by microorganisms in the rumen for formation of protein.

Plants are considered potentially dangerous to cattle when they contain more than 1.5 percent nitrate on a dry basis. A study of the nitrate content of fresh-chopped corn and corn silage samples indicates that only 2 to 3 percent of the corn grown under drought conditions contained more than 0.5 percent nitrates at harvest. Nitrate toxicity rarely occurs in cattle fed silage from corn grown under drought conditions in Michigan. Forages containing more than 2 percent nitrate should be diluted with other feeds or the quantity carefully controlled. Avoiding sudden, dramatic changes in the amount of forage fed helps cattle to adapt to high levels of nitrates. Cattle which are fed grain are more tolerant of high levels of dietary nitrate than those fed on roughages.

Carotene (Vitamin A Value)

The carotene content of corn silage decreases as the stage of maturity increases, and decreases markedly after exposure to frost. Poor storage conditions

Table 21 — Mineral Content of Michigan Feedstuffs and requirements for Cattle.

Element & symbol	Alfalfa hay	Corn silage	Grass hay	Shelled corn	Soybean meal	daily allowances required by cattle
	— — — — Percent of dry matter		— — — —	Percent of air-dry feed		Percent of dry ration
Calcium (Ca)	1.35	0.25	0.5-1.0	0.02	0.32	0.3
Phosphorus (P)	0.22	0.29	.15	0.27	0.67	0.3
Potassium (K)	1.50	1.21	1.21	0.29	1.97	0.7
Magnesium (Mg)	0.31	0.27	0.21	0.10	0.27	0.08
Sodium (Na)	0.05	0.03	0.02	0.01	0.34	0.11
Chlorine (Cl)	0.23	0.45	0.12	0.04	—	0.18
Sulfur (S)	0.28	0.12	0.12	0.12	0.43	0.15
	— — — — — — — — — Milligrams/kilogram or ppm* — — — — — — — — — — —					mg/kg of dry ration
Iron (Fe)	240	216	200	20	130	10
Manganese (Mn)	42	14	37	5.3	27.5	20
Copper (Cu)	15	14	6	4.0	36.3	6
Cobalt (CO)	0.14	0.10	0.16	—	—	0.1
Zinc (Zn)	22	22	—	—	—	8.6

Forage data from C. F. Huffman, C. W. Duncan and E. J. Benne, Mich. Agr. Expt. Sta. Corn and Soybean data from National Research Council Pub. 1349, 1966.
*1 kg = 2.2 lb. = 1,000 grams = 1 million milligrams.

in the silo also lower the carotene content. Silage made from corn plants retaining some green leaves will be higher in carotene than silage from dry, mature corn. Data from 14 corn silages show that carotene varied from 6.4 to 34.7 parts per million (ppm) or milligrams per kilogram and averaged 18.2 ppm on a dry basis (1 kilogram = 2.2 pounds).

Corn silage generally contains enough carotene to meet Vitamin A requirements of livestock. However, silage made from corn that is very dry and contains few green leaves, was frosted severely, or is damaged by overheating in storage should be supplemented with Vitamin A or with 2 to 5 pounds of good quality green, leafy hay.

In general, when cattle are fed corn silage as the only forage for long periods (200 days or more), supplemental Vitamin A should be provided.

Vitamin D

There is sufficient Vitamin D in corn silage for normal growth and reproduction in calves 6 months of age and older. Younger calves may not eat enough silage to prevent rickets and should receive some Vitamin D from other sources such as good quality hay or cod-liver oil. In recent research, corn silage, harvested when the bottom leaves were turning brown, contained from 122 to 165 USP Units of Vitamin D activity per pound of dry matter.

In a 4 year study at Michigan State University, daily intake of 0.7 to 1.0 pounds of silage dry matter per 100 pounds of body weight was effective in curing and preventing rickets in yearling calves and also supplied sufficient antirachitic material for normal growth and reproduction in dairy cows. Silage made from immature corn may be too low in Vitamin D to meet the requirements for livestock.

Minerals

Corn silage contains a wide range of mineral elements. A comparison of the mineral content of Michigan corn silage with other common feeds and mineral requirements for cattle is shown in Table 21. It is low in calcium and sodium, borderline in phosphorus and cobalt, and may be deficient in cobalt and iodine for ruminants in some areas. Iodine deficiency (goiter in calves) may be more acute when soybean products are the only protein supplement than when legume hay is also fed. Corn is low in sulphur compared to alfalfa and the oil meals and should be supplemented with sulphur when urea is added and silage is fed as the major or only roughage. In experiments with lactating cows at Michigan State University, no benefit resulted from feeding additional sulfur with urea corn silage when soybean meal was used as the protein supplement (13% grain ration).

Corn silage must be supplemented with sources of calcium and phosphorus such as dicalcium phosphate or steamed bonemeal, and trace mineralized salt which provides the required sodium, chloride, cobalt and iodine.

Corn Silage for Dairy Cattle

Corn silage is an excellent source of energy for milking cows. Cows fed corn silage as the only forage produce as well as those fed any amount of hay in experiments when the ration is properly supplemented. Such rations must be supplemented to provide adequate protein, salt, calcium, phosphorus, iodine, cobalt and vitamin A.

In general, dairy cows fed corn silage as the only forage consume about 2.0 pounds of corn silage dry matter per 100 pounds body weight plus 1.5 pounds of grain ration per 100 pounds of body weight. Thus 1,200 pound-cows will consume about 24 pounds of corn silage dry matter daily, or about 70 pounds of 35 percent dry matter silage, plus 15 to 18 pounds of grain ration containing 20 percent protein, or one pound of grain ration per 3.5 pounds of milk produced daily. When good quality legume hay replaces part of the corn silage, the protein content of the grain ration can be reduced so that the total air dry ration contains 12- to 14 percent protein.

Dairy cows fed corn silage to which 10 pounds urea per ton has been added at ensiling require a grain ration containing only 13 to 14 percent crude protein when fed at a rate of one pound of grain ration per 3.5 pounds of milk produced daily. Numerous experiments show that cows fed urea corn silage produce as well as those fed regular corn silage plus a 20 percent protein grain ration, at a savings in protein cost of about 7 cents per cow daily or $15 to $20 per cow annually.

When urea corn silage is fed as the only forage, additional urea should not be included in the grain ration.

If hay or other forage which contains no urea is fed with the urea corn silage, 0.3 percent urea can be contained in the grain ration for each 5 pounds of other forage that is fed per head daily up to a total of 1.5 percent urea in the grain ration. This allows for 0.35 pounds of urea per head daily for adult cattle. Higher levels may interfere with palatability or reduce milk production under some conditions.

Growing dairy heifers or dry pregnant cows may become excessively fat if allowed corn silage free choice. They should be limited to about 1.5 to 2.0 pounds of corn silage dry matter per 100 pounds of body weight per day or 4.5 to 6.0 pounds of 30- to 40-percent dry matter corn silage per 100 pounds body weight daily as required to produce the desired growth or body condition.

Dry cows fed corn silage need no additional grain since the dry matter of modern corn silage contains about one-half corn grain. Protein requirements for growing and pregnant cows can be met by providing 0.07 pounds of supplemental protein per 100 pounds of body weight daily.

A mineral supplement containing 3 parts calcium to 1 part phosphorus is desirable for cattle fed high corn silage rations. Trace mineralized salt should be provided at all times.

Issued in furtherance of cooperative extension work in agriculture and home economics, acts of May 8, and June 30, 1914, in cooperation with the U. S. Department of Agriculture. George S. McIntyre, Director, Cooperative Extension Service, Michigan State University, E. Lansing, Mich. 48823
1P—9:69—30M—SW