weather is particularly favorable for curing. The field chopper is tractor drawn and often operates with power take-off, although some of the larger choppers have mounted motors. When field choppers are used for chopping and stationary blowers are used for storing in barns, an average of about six-tenths of a ton of hay is handled per hour of labor.

When the field chopper was used to chop 100 tons of hay and the same amount of silage crops in 1945, the estimated cost of use of the harvesting machinery and equipment, exclusive of the tractor power, averaged about $1.30 a ton. On farms where the chopper was used exclusively on hay crops, the cost of use of machinery and equipment averaged $1.30 a ton when 200 tons were handled annually, $2.30 a ton for 100 tons, and 75 cents a ton for 400 tons.

In the West, when chopped hay is stacked, the wagons often are equipped with slings, and the hay is unloaded with derrick stackers. Stationary blowers and elevators also are used for stacking chopped hay.

Farmers who have small tonnages of hay also have ways to make use of expensive equipment. Some buy the equipment and then obtain economic amounts of use and get back some of the costs by doing custom work for others. Some rent out their machines. Sometimes several farmers buy the equipment for use on each of their farms. A more common method is to hire the machines or have the work done by custom operators, whose charges are usually somewhat higher than the costs that result when the machine is purchased and used extensively—although the custom charges often are less than the costs incurred when the machine is bought but used only a little.

**THE AUTHORS**

Albert P. Brodell, senior agricultural economist in the Bureau of Agricultural Economics, has been engaged in studies of farm practices and costs for 27 years. One of his publications, F.M. 57, *Harvesting the Hay Crop*, treats of the economics of many aspects of haying.

Martin R. Cooper, principal agricultural economist in the Bureau of Agricultural Economics, has been engaged in research in farm management since 1912. He is a native of Ohio and has conducted studies of farm organization and cost in all regions of the United States. He has published many treatises of the subject.

**ENSILING HAY AND PASTURE CROPS**

J. B. SHEPHERD, R. E. HODGSON, N. R. ELLIS, J. R. MC CALMONT

Making part of the hay and pasture crops into silage has several advantages.

The grasses and legumes usually grown for hay and pasture are mostly biennial or perennial and are produced more cheaply than annual or cultivated crops. Silage can be made from them with about the same equipment (except a silage cutter) and labor that is needed for haymaking.

Because the crops are taken off the field and put into the silo soon after they are cut, there is little risk of weather damage during harvesting. About 80 to 85 percent of their value (as shown by experiments at Beltsville) is preserved for feeding; only 70 to 75 percent of the value of field-cured hay is preserved, even if it is made during good curing weather. Properly made grass silage will provide much more protein and several times more carotene in the ration than field-cured hay, increase materially the carotene and vitamin A content of winter milk, and help prevent an oxidized flavor in winter milk.
ENSILING HAY AND PASTURE CROPS

Surplus pasture herbage and heavy or weedy crops that might make only low-grade hay can be made into a palatable, nutritious silage, thus preventing waste. Silage is the best form in which to preserve surplus forage crops from one year to the next as insurance against drought. Ensiling also destroys the germinating powers of weed seeds and thus helps eradicate weeds from the farm.

Storing forage as silage ends the hazard of fire from spontaneous ignition of inadequately cured hay. Less space is needed to store crop dry matter as silage than as long, baled, or coarsely chopped hay. Silage is an easy form in which to feed forage to livestock; grass silage is particularly useful for feeding cattle and sheep.

About half of 1 percent of the American hay crop was ensiled in 1944—roughly equal to 1,500,000 tons of silage but relatively little as compared with the more than 40,000,000 tons made yearly from corn and the sorghums. In the Northeastern States, 1.6 percent of the hay crop was put into silos—in Massachusetts, 3.3 percent, and in Rhode Island 4.6 percent. But as farmers turn more and more to grassland farming and as they learn more about making grass silage and the advantages of feeding it, we believe the amount of the silage made from hay and pasture crops will increase greatly.

Many crops can be made into silage: Timothy, bromegrass, orchardgrass, Sudangrass, Kentucky bluegrass, Johnsongrass, succulent range grasses, alfalfa, soybeans, lespedeza, red clover, Ladino clover, cowpeas, kudzu, alsike clover, crimson clover, and others, even though they differ widely in physical characteristics, in chemical composition, and in yield, as well as palatability.

Some of them can be ensiled in the same manner as corn or the sorghums. Others need a somewhat different kind of treatment.

Legumes or grass and legume mixtures usually make a more nutritious silage than do grasses alone. Adapted, high-yielding crops are the most satisfactory. Especially suitable for use as hay, pasture, or silage are combination crops such as alfalfa with timothy or bromegrass, and timothy, bromegrass, or orchardgrass with Ladino clover and red clover or alsike clover.

A rule of thumb is that crops that are palatable when grazed or fed green or as dry hay also make a palatable silage. Likewise, crops that are unpalatable when grazed or fed green or dry are usually unpalatable as silage. Furthermore, feeding trials conducted with some crops indicate that the dry matter contained in silage of good quality will have about the same feeding value as an equal quantity of dry matter in good-quality hay made from the same crop, and better than the dry matter contained in poor hay.

The transformation of green crops into silage is brought about by the changes that take place when the green forage is stored in a silo in the absence of air. Plant respiration, enzymes present in plant cells, and bacteria, yeasts, and molds present on the crop when it is ensiled all take part in this change.

After the crop is ensiled, plant respiration continues until the oxygen present in the air and trapped in the forage is used up and replaced by carbon dioxide and nitrogen. There follows a rise in the temperature of the forage, the extent of the rise depending upon the amount of oxygen present.

Enzymes are also active during this time. They break down sugars into alcohol, carbonic acid, water, and acetic, lactic, and butyric acids. The enzymes act on proteins to some extent, forming amino acids, peptides, and some ammonia.

As plant respiration and the activity of the plant enzymes slow down, the activity of the bacteria, yeasts, and molds increases. Molds cease growing as soon as the air is exhausted, yeasts soon disappear, and only the bacteria remain active thereafter. Bacteria produce additional acid from soluble car-
Suggested Quantities of Preservatives To Use in Making Silages

[Per ton of crop ensiled]

<table>
<thead>
<tr>
<th>Silage</th>
<th>Molasses</th>
<th>Phosphoric acid (75 per cent)</th>
<th>Corn and cob meal</th>
<th>Ground corn, barley, or wheat</th>
<th>Whey, dried 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Legumes, fresh green:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alfalfa, red clover</td>
<td>80</td>
<td>20</td>
<td>200</td>
<td>150</td>
<td>40</td>
</tr>
<tr>
<td>Soybeans, Ladino clover</td>
<td>100</td>
<td>30</td>
<td>250</td>
<td>200</td>
<td>60</td>
</tr>
<tr>
<td>Legumes, wilted: All crops 2</td>
<td>60</td>
<td>15</td>
<td>150</td>
<td>100</td>
<td>30</td>
</tr>
<tr>
<td>Legumes and grasses mixed, before grass is headed out:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fresh green</td>
<td>80</td>
<td>20</td>
<td>150</td>
<td>100</td>
<td>40</td>
</tr>
<tr>
<td>Wilted 2</td>
<td>60</td>
<td>15</td>
<td>100</td>
<td>100</td>
<td>30</td>
</tr>
<tr>
<td>Legumes and grasses mixed, after grass is headed out:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fresh green 2</td>
<td>60</td>
<td>15</td>
<td>100</td>
<td>100</td>
<td>30</td>
</tr>
<tr>
<td>Wilted</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Grasses and cereals before heading out:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fresh green</td>
<td>60</td>
<td>20</td>
<td>150</td>
<td>100</td>
<td>40</td>
</tr>
<tr>
<td>Wilted 2</td>
<td>40</td>
<td>10</td>
<td>100</td>
<td>100</td>
<td>30</td>
</tr>
<tr>
<td>Grasses and cereals after heading out:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fresh green 2</td>
<td>40</td>
<td>10</td>
<td>75</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Wilted</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
</tbody>
</table>

1 Concentrated whey may also be used, applying 2 to 3 times the weight indicated for dry whey. Liquid whey can be used only with wilted crops, but may be added at 10 times the rate indicated for dry whey, as a means of utilizing the product.

2 Preservatives may be omitted when the silos are smooth and airtight, and when good silo filling methods are carefully followed.

Comparative Preservation of Dry Matter, Protein, and Carotene in Alfalfa Harvested and Stored as Field-Cured Hay and as Silage, 1945-46 1

<table>
<thead>
<tr>
<th>Alfalfa</th>
<th>Dry matter</th>
<th>Protein</th>
<th>Carotene</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total yield</td>
<td>In dry matter</td>
<td>Total yield</td>
</tr>
<tr>
<td>Wilted alfalfa silage</td>
<td>83</td>
<td>85</td>
<td>20.6</td>
</tr>
<tr>
<td>Field-cured alfalfa hay</td>
<td>75</td>
<td>69</td>
<td>18.2</td>
</tr>
</tbody>
</table>

1 Silages and hays from same crop and fields harvested at the same time. Averages for 3 crops harvested at Beltsville in which the constituents retained in the silo and in the haymow are compared with those present in the green material as cut.

Bohydrates and alcohol, and are responsible for further break-down products from the other constituents of silage, notably protein. They are responsible for most of the losses of dry matter and feeding constituents that occur during fermentation and storage. When the acidity of the silage increases beyond a certain point, bacterial action diminishes, and the silage-making process is completed.

The Massachusetts Agricultural Experiment Station found wide variations in the type of fermentation, the kinds
of acids produced, and the quality of the silage. Many investigators have learned that the type of fermentation produced and the quality of the silage produced can be modified by suitable methods of silage making. They also learned that the inclusion of acids and sugars or other readily available carbohydrates at the time of siloing modifies the type of fermentation, increases the acidity, and tends to reduce the breakdown of protein compounds. Thus the farmer can control pretty well the fermentation process and produce good grass silage from many crops under many conditions.

Standards by which the quality of silage may be judged were set up by the American Dairy Science Association committee on silage methods in 1942. These standards are:

a. Very Good: Clean, acid odor and taste, no butyric acid, no mold, slimmness or proteolysis, acid pH of 3.5 to 4.2, ammonia nitrogen less than 10 percent of total nitrogen.

b. Good: Acid odor and taste, trace only of butyric acid, acid pH of 4.2 to 4.5, ammonia nitrogen 10 to 15 percent of total nitrogen.

c. Fair: Some butyric acid, slight proteolysis or some mold, acid pH 4.5 to 4.8, ammonia nitrogen 15 to 20 percent of total nitrogen.

d. Poor: High butyric acid, high proteolysis, slimmness or mold, acid pH above 4.8, ammonia nitrogen about 20 percent of total nitrogen.

Several factors influence the type of fermentation produced, the nature and extent of the losses occurring during fermentation and storage, and the quality of the silage produced. Among them are the maturity and chemical composition of the crop, the ratio of soluble carbohydrates to the mineral base content of the crop, its percentage of moisture when stored, the rapidity and completeness with which air is excluded from the silo, and atmospheric temperatures when the crop is ensiled.

In handling the crop for silage, the farmer should cut the forage when it has a high content of protein and carotene and when the yield of total digestible nutrients per acre is high. He should ensile it in a way that will produce a good, palatable silage with the least loss of feed nutrients and the least wear and tear on the silo.

In doing so, he will need to give proper consideration to the stage of maturity at which to cut; the moisture content at which to store; the need for and use of preservatives; the length of cut to use; the distribution and packing of the crop in the silo; and the sealing out of the air when the silo is full. He will have to adapt his methods to the type and condition of his silo. He also will want to use methods that permit the most efficient use of labor and the power and equipment he has.

To produce grass silage that meets those specifications requires first that it be cut at an immature stage while it is still reasonably high in protein and carotene and relatively low in crude fiber. This stage corresponds closely with that recommended for early-cut hay from the various crops.

Most grasses should be cut after the heads have emerged but before the plants have started to bloom. Alfalfa should be cut at an early bloom stage (one-tenth to one-fourth in bloom). Most clovers should be cut when they have reached half to full bloom, but before the blossoms have turned brown. Soybeans, lespedeza, and cowpeas should be cut soon after the first seed pods have filled. Cereal crops like oats, wheat, and barley may be cut any time from a prebloom to a milk or early dough stage, depending upon the relative importance of a high protein and carotene content compared with a high total silage yield. Where mixtures of grasses and legumes are ensiled, the crop should be cut at a stage best suited to the kind of crop that predominates in the mixture.

The moisture content of the crop at the time of ensiling is the most important factor in determining the character of the silage fermentation, the extent and character of the losses
### Labor and Machinery Hours Required in Harvesting and Storing Alfalfa as Silage and as Hay, 1945-46

[Per ton of dry matter preserved]

<table>
<thead>
<tr>
<th>Hours and operations</th>
<th>Wilted alfalfa silage</th>
<th>Field-cured hay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Man-hours (all operations)</td>
<td>4.87</td>
<td>4.33</td>
</tr>
<tr>
<td>Tractor-hours (all operations)</td>
<td>1.35</td>
<td>1.57</td>
</tr>
<tr>
<td>Mower-hours (tractor-operated)</td>
<td>.47</td>
<td>.53</td>
</tr>
<tr>
<td>Rake-hours (tractor-operated)</td>
<td>.35</td>
<td>.84</td>
</tr>
<tr>
<td>Loader-hours (truck-drawn)</td>
<td>.48</td>
<td>.44</td>
</tr>
<tr>
<td>Truck-hours (loading, hauling, unloading)</td>
<td>1.66</td>
<td>1.19</td>
</tr>
<tr>
<td>Silo-filler-hours (tractor-operated)</td>
<td>.54</td>
<td></td>
</tr>
<tr>
<td>Hay-hoist-hours (tractor-operated)</td>
<td></td>
<td>.30</td>
</tr>
</tbody>
</table>

1 Average of 3 cuttings.

### Dry Matter, Protein, and Carotene Losses in Grass Silage, With Palatability Data

<table>
<thead>
<tr>
<th>Experimental difference</th>
<th>Moisture</th>
<th>Dry matter eaten ²</th>
<th>Losses in the silo exclusive of top spoilage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Percent</td>
<td>Pounds</td>
<td>Percent</td>
</tr>
<tr>
<td>Higher moisture</td>
<td>70.6</td>
<td>21.4</td>
<td>10.3</td>
</tr>
<tr>
<td>Lower moisture ³</td>
<td>45.0</td>
<td>24.8</td>
<td>8.3</td>
</tr>
<tr>
<td>Higher pH (4.76)</td>
<td>62.6</td>
<td>22.9</td>
<td>8.7</td>
</tr>
<tr>
<td>Lower pH (4.36), by molasses ⁴</td>
<td>61.5</td>
<td>24.2</td>
<td>8.6</td>
</tr>
<tr>
<td>Higher pH (5.18)</td>
<td>66.8</td>
<td>23.6</td>
<td>7.7</td>
</tr>
<tr>
<td>Lower pH (3.66), by 2-N acids ⁵</td>
<td>67.9</td>
<td>16.3</td>
<td>5.0</td>
</tr>
</tbody>
</table>

1 Averages obtained from a large number of trials.
2 Dry matter consumed per cow per day.
³ By wilting or added dry matter. Average of 25 comparisons.
⁴ Various additions of molasses. Average of 19 comparisons.
⁵ By additions of mineral acids.

through seepage and fermentation, and the quality of the silage produced.

An excessively high moisture content leads to large losses of liquid. Too little (under 60 percent) results in molding and spoiling of the silage. The silo should have adequate drainage so the silage will not become waterlogged and the silo damaged from too high pressures against the wall. Except during long dry spells, the moisture content of crops cut for silage at the stages of maturity indicated will usually range between 74 and 78 percent, but may sometimes equal or exceed 80 percent, being highest for the clover, soybeans, and grasses and cereals cut at a very immature stage. Lespedeza, an exception, usually does not contain more than 65 to 70 percent moisture when cut for hay or silage. During long dry spells, the moisture content of most crops may be down to 70 percent or below.

When crops are ensiled with a moisture content of more than 70 percent,
fermentation takes place at a rapid rate, there is considerable seepage from the silo, and losses of most feed nutrients, except carotene, are large. If no treatment other than chopping is given, the type of fermentation will be desirable and the silage will be of good quality provided the crop ensiled consists principally or entirely of grasses or cereals that are cut after heading out and that contain a medium or low amount of protein. On the other hand, the type of fermentation will be undesirable and the silage will be of poor quality and have a strong, offensive odor if the ensiled crop consists principally or entirely of legumes or of grasses and cereals that are cut before heading out and that have a high protein content.

Long experience at the Agricultural Research Center at Beltsville, the Ohio Agricultural Experiment Station at Wooster, and elsewhere, however, has shown that a desirable type of fermentation and a mild, good-quality silage can be produced from these high-protein crops by simply wilting them slightly in the field to a moisture content below 70 percent. When wilting is not possible because of unfavorable weather, the same results can be obtained by adding 5 to 15 percent of dry hay as the crop goes through the chopper. When the moisture content of the crop is reduced to 68 percent or below, the fermentation rate is reduced and seepage from the silo is eliminated. The best silage is made when the moisture of the material is not above 68 percent or under 60 percent. But occasional loads may contain as much as 70 percent or as little as 55 percent of moisture without materially affecting the quality.

Wilting high-moisture crops for silage, as we have indicated, not only produces a mild, palatable silage that will be consumed in normal roughage amounts; wilting also reduces the losses of nutrients (except carotene) that usually occur when the silo is filled with comparable unwilted materials.

For that reason, wilting all high-moisture crops for silage is advantageous regardless of whether preservatives are added. Even with the higher carotene losses, the carotene content of the silage will be considerably higher on a dry-matter basis than the carotene content of dry hay, and the liberal feeding of such silage will result in the production of winter milk with a higher vitamin A content than can be obtained from the feeding of dry hay. Furthermore, cows will eat more dry matter in wilted silage than they will in high-moisture silage. Wilting also reduces the weight of crop to be handled, causes less pressure against the silo walls and less softening of the mortar of masonry walls, and lowers the cost of ensiling.

But care should be taken not to wilt the crop too much, and the part that is wilted most should be placed in the lower part of the silo. The walls of silos used for wilted silage should be air-tight and smooth. Wood-stave silos that cannot be made practically air-tight by screwing up the nuts on the reinforcing bands should not be used for wilted silage because there is too little moisture in a wilted crop to swell the staves and cause them to tighten naturally.

A good deal of attention has been given to the possible benefits derived from the addition of other materials—commonly called preservatives—to grass silage. Investigators have tested many materials, including phosphoric acid, cultures of lactic acid bacteria, whey, molasses, ground corn, wheat and other cereals, salt, urea, dry ice (solid carbon dioxide), hydrochloric and sulfuric acid, and other acids.

Mineral acids increase the acidity of the crop immediately to a pH of 4.2 to 4.0 or below; prevent most of the plant respiration, enzyme action, and bacterial activity; and preserve the crop with the least change and with only small losses of nutrients.

Materials such as whey, molasses, and ground dry grains modify the natural fermentation process, produce a
more desirable type of fermentation, and increase somewhat the acidity of the silage (pH range of 4.0 to 4.5). Dry grains also lower the average moisture content slightly and reduce the seepage from high-moisture crops.

Generally speaking, an acid medium (whether obtained by direct addition of an acid or by desirable acid fermentation) is the best preservative of carotene and other constituents.

Salt has little effect on the fermentation process and is of little practical value in silage making.

No desirable effects and no practical value have been found from the use of urea, dry ice, or cultures of lactic acid bacteria added with or without salt.

The preservatives most generally used in this country are phosphoric acid (68 percent or more of P₂O₅), cane or blackstrap molasses, and ground corn or wheat. The operator should be cautious in handling phosphoric acid because of its corrosive nature. It is necessary to feed ground limestone or some source of calcium or sodium carbonate to the animal at the rate of approximately 1 ounce for each 10 pounds of silage in order to neutralize the mineral acid and prevent any undesirable effects it might have.

Preservatives are most useful with high-moisture crops and crops high in protein. They have the least value with low- or medium-protein crops and crops low in moisture; often the preservatives do little more than to make the silage more palatable. If the crop is extremely high in moisture, the silage may sometimes be of poor quality even though preservatives are added. It is therefore generally recognized that a better silage is produced when the crop is wilted slightly as well. When the crop is wilted, less of the preservatives is needed because at that moisture level the fermentation process is slowed down, less undesirable fermentation is produced, and the losses (except of carotene) are usually small.

If the crop has been wilted to below 68 percent moisture, undesirable fermentations are seldom produced in high-protein silage, even though the acidity is relatively low, and the actual need for a preservative has usually been eliminated. Nevertheless, some farmers prefer to use preservatives with slightly wilted crops to insure the best preservation of nutrients and carotene under such conditions.

Another factor to be considered in using preservatives is their added cost, which is sometimes quite high, particularly the cost of ground grains. It is true that a considerable part of the nutritive value of the preservatives is usually retained in the silage, but if sufficient forage is available these additional nutrients are not required for their nutritive value. The use of preservatives therefore should be limited to the actual need for them.

Experience at Beltsville, at several experiment stations, and on thousands of farms demonstrates that good silage can be produced without preservatives from almost any type of crop if the proper methods are followed.

Grasses and cereals cut after heading out or a mixture of such crops with legumes can be made into a mild, good-quality feeding silage without preservatives when ensiled in the fresh green state. The fermentation rate will be slowed down, fermentation and storage losses will be reduced, and the palatability of the silage will be increased by wilting the crop slightly before ensiling.

Immature grasses and cereals cut before heading out, or crops consisting principally or entirely of legumes, can be made into good silage by wilting them down to a moisture content of 68 percent or slightly less.

We have pointed out that control of the fermentation process through the use of preservatives increases the acidity of the silage and makes for a better preservation of feed nutrients and carotene.

Wilted silages made without preservatives usually have an acidity within the pH range 4.0 to 5.0, depending on the crop. Wilted alfalfa silage often has a pH of 4.6 to 4.8. Even with a pH
above 4.5, such silage nevertheless has good quality; the losses (except of caro-
tene) are smaller, and it has greater palatability (as shown by the consump-
tion of dry matter by dairy cows) than high-moisture silage made with pres-
servatives.

Wilted silages made without pres-
servatives also contain some protein break-down products, but these occur in only relatively small quantities if the silage is properly made. Part of these break-down products consist of amides and peptides, which are generally con-
ceded to have a high nutritive value.

They also contain some ammonia nitrogen, which has generally been thought to have little value. It is now known that ruminants, for which silage is usually made, however, can and do utilize ammonia nitrogen for protein under favorable conditions when the ration fed is low in protein, through the activity of the bacteria in the rumen or paunch. The presence of a small amount of ammonia nitrogen in mild, palatable, wilted silage is there-
fore of little economic significance, as the production of cows fed wilted si-
lage in feeding experiments at Belts-
ville demonstrates. We believe, then, that neither the pH of the silage nor the amount of ammonia nitrogen pro-
duced can be used as criteria of the quality of wilted grass silage in the same sense that they are used for high-moisture silage.

Sometimes farmers have failed to produce good silage by the wilting method. The cause can usually be traced to a failure to follow closely the methods required for handling and siloing the crop, to the use of a silo in need of repair, or to unfavorable weather during the silo-filling period. These failures are sometimes unavoid-
able and they demonstrate that making wilted silage without preservatives is not always practical.

As we stated previously, wilting slightly is desirable for all silage made from high-moisture crops. The discus-
sion that follows on crop wilting, length of cut, and silo filling and sealing ap-
plies to silage made with and without preservatives. The problems of silo filling are somewhat different for trench, stack, and temporary silos than for the ordinary permanent upright tower silo or the permanent round pit-
type silo.

In preparing the crop for silage, the usual tendency is to wilt it too much rather than too little, although with unfavorable weather it is sometimes impossible to wilt it as much as is de-
sirable. With a little practice, the farmer can readily determine when the proper stage is reached.

The aim should be to wilt the crop slightly, to a moisture content between 65–70 percent but not below 60 per-
cent. If the leaves become dry and curled, the wilting may have pro-
gressed too far unless the crop is heavy and the underside of the swath is in an unwilted state. The crop will have wilted sufficiently when the leaves and stems become limp. The stems can be readily twisted in two and the broken ends will have a dark, moist, but not excessively juicy, appearance. On rub-
bing the chopped crop between the hands, the material will feel cool and moist, but no free water will appear when a ball of the chopped crop is squeezed in the hands.

One or two hours on a good drying day may be sufficient to wilt the crop to the desired moisture level unless the crop is very heavy or very high in mois-
ture. On a good drying day, therefore, the crop should not be cut too far ahead of loading and silo filling. Dur-
ing prolonged dry weather, crops cut at the usual stage will be ready to ensile within a few minutes after mowing. On very humid days, a half day to a day may be required to wilt the crop sufficiently. During rainy spells, the mowed crop may sometimes be in the field 2 or 3 days before it wilts enough to be siloed.

Too rapid wilting in good weather may make desirable the use of a wind-
rowing attachment on the mower cut-
ter bar or a side delivery rake to fol-
low behind the mower. If the crop is
not too heavy, combining two mowed swaths into one windrow will speed the loading and filling operations. If part of the crop gets too dry and is dusty when chopped and blown into the silo, fresh unwilted forage should be run through the cutter along with the drier material. Both partially dry and fresh green forage can be hauled on the same load if field conditions permit.

When rain interferes with silo filling operations, the rain-wet portion can be siloed without wilting by filling the silo at the slow rate of 3 to 4 feet a day so that some heat will be generated; or it can be siloed at a normal rate by running dry hay (10 to 20 percent), ground dry grain (5 to 12 percent), or molasses (3 to 5 percent), through the cutter with the wet crop.

Except for short and very immature crops put up under special conditions, it is necessary to chop the crop as it is siloed. The length of cut to use will depend upon the moisture content at which the crop is siloed. If the moisture content is 72 percent or more, the cutter should be set for a 1/2- to 3/8-inch theoretical cut. (The actual average length of cut will be much longer than this because many of the crop stems go through the cutter crosswise.) Crops with a high moisture content will pack well with this comparatively long cut and are less apt to clog up the blower pipe than when a shorter cut is used.

When the moisture content of the crop is 70 percent or less as ensiled, the cutter should be set for a shorter cut of not more than one-fourth to three-eighths inch. If the crop is wilted considerably, the cut used should not exceed one-fourth inch. Here, too, many of the stems go through crosswise with an actual longer average length, and this short cut must be used in order to get the crop to pack satisfactorily and exclude the air. The drier crop is not apt to clog the blower when a short cut is used. Failure to use a fine cut when the crop is wilted will prevent close packing, will cause considerable air to be trapped in the silage, and also will cause some mold.

When a field chopper is used, more crop stems go through the chopper lengthwise and a shorter average cut is obtained with the same theoretical cut than where a stationary chopper is used. For this reason, the theoretical length of cut used with a field chopper may be five-eighths or three-fourths inch with crops containing 72 percent or more of moisture; and three-eighths to one-half inch with crops containing 70 percent or less of moisture. If the field chopper used will not cut the forage short enough, this can be accomplished by rechopping through a stationary silage cutter.

During silo filling the cutter knives should be kept sharp. Knives should be changed just as soon as they fail to cut clean and begin to shred the material. The cutter bar against which the cutter knives operate should be changed or turned before its edge becomes rounded enough to cause shredding rather than cutting.

In making grass silage, satisfactory results will be obtained only if the silo has smooth, airtight walls and tight doors. The silo should be well reinforced so that it will withstand high silage pressures. It should be provided with an adequate drain so that any excess moisture in the silage can drain off easily and quickly.

When the silo is being filled, the crop material should not be allowed to pile up in the center of the silo. It should be kept well distributed over the entire area and well tramped near the wall. This is particularly important when the crop is wilted slightly. Good distribution and thorough packing are absolutely necessary in the top part of the silo.

Only heavy, unwilted crops should be used for the last few loads so that enough weight and pressure will be provided to force the air out and keep it out. No preservative will be needed in this wet top layer even if the crop is high in protein, because the material at the top warms up sufficiently to prevent undesirable fermentations and naturally makes a mild, palatable silage.
After the silo is filled, the top should be thoroughly tramped once a day for 2 or 3 days and kept packed tightly against the wall for 2 or 3 weeks until the silage has completely settled. Top losses can be reduced by seeding oats on top to help make a good air seal.

Top losses can be reduced also by covering the top of the ensiled material with a heavy, reinforced, waterproof paper, which is lapped 10 to 12 inches at the seams and against the wall and covered with enough wet crop or other material to keep it packed tight against the wall and against the silage below. If the silage is to be stored for some time, more material should be placed on top of the paper than if the silo is to be opened soon.

The rate at which the silo is filled affects the rapidity with which the air is eliminated from the silo and, consequently, the temperature which the ensiled mass attains. If the silo is tight and is properly filled and sealed, the temperature will seldom exceed 100° F., except at the top, and may sometimes not exceed 90°. If the ensiled material is high in moisture, or if the weather is cool, silo temperatures will be lower than when the crop is wilted or the weather is warm. When the silo is filled with a high-moisture crop, particularly in cool, moist weather, there may be an advantage in filling at a slow or moderate rate; that will allow the ensiled material to warm up slightly. That procedure also will help to prevent an undesirable type of fermentation.

When the silo is filled during a long dry spell or with a wilted crop, it should be filled rapidly in order to hold silo temperatures down to a desirable level. Spoilage is apt to occur on the surface of the ensiled material if more than 2 days elapse between filling periods. When such an interval occurs, the top of the material should be kept tramped thoroughly in the meantime, and any spoiled silage removed before filling is resumed. Where one crop only partially fills the silo and another crop is put in some time later, the silo should be tramped, scaled, and weighted down between fillings to keep silage temperatures and losses as low as possible.

So far we have discussed mostly the making of grass silage in permanent upright silos or in pit-type silos. Where permanent silos are not available or are too small to hold the entire crop, trench, modified trench-stack silos, or temporary fence silos and stack silos can be used with little or no cash outlay. Good-quality silage can be made in these different types from most grassland crops and cannery waste by the same general principles outlined in the foregoing, although certain minor modifications may be needed to meet specific conditions.

A trench silo, as its name implies, is simply a trench dug into the ground. The size of its cross section is limited by the smallest number of animals to be fed each day, so that 2 or more inches are removed from the entire cross section or open face every 2 days.
Its length is determined by the duration of the feeding season.

A trench silo should be wider at the top than at the bottom. This shape causes the silage to pack tightly against the sides as it settles, and is generally required to prevent the sides from caving in. The type of soil generally governs the slope of the side walls; the lighter, more friable soils require a greater slope. The depth is governed by the ground-water level and the required cross-sectional area. These silos can be made for the expense or labor of removing the soil. The soil removed from the trench is generally piled along its sides to increase its depth and provide good surface drainage away from the silo. The bottom of the trench should never be below the level of the ground water and should always slope to one end to afford good drainage. Trench silos are often made permanent by lining with concrete, cement plaster, brick, or stone.

Trench silos can be filled economically. A blower is not needed, although it speeds up the operation by using less labor to distribute the chopped material evenly. The silage should always be kept level and thoroughly tramped or packed during filling operations. Packing can be done by driving animals or some machine back and forth through the silo as the filling progresses. In completing the filling of these silos, the crop should be piled high enough so that it will be above ground level after settling, with an arch to the top. The surface should be covered immediately with a thin layer of freshly cut crop or weeds, which in turn should be covered with 6 to 12 inches or more of earth. Or, the surface can be sealed with heavy fiber-reinforced waterproof paper. If paper is used, the joints should be lapped about 12 inches and the paper weighted with enough earth to give a good seal.

If the silo is filled too rapidly and the forage is not packed sufficiently while filling, the forage may settle below ground level within a few days after filling has been completed. This may permit surface water to enter and produce a strong-smelling, unpalatable silage.

When the ground-water level is high, a modified shallow-trench type of stack silo can be used. The stack should be built up above the ground level with the sides of the chopped material straight and even with the edge of the trench. The stack can be built 4 to 6 feet above the ground level at the sides, and 8 feet at the center. When stacking is completed, the top should be well arched and covered with weedy material or reinforced paper and weighted down with 12 to 18 inches of earth to provide weight for packing and sealing. As the stack settles, earth should also be placed along the sides and ends to provide a seal.

When the silage is fed out, only one end is opened and the feeding is done from the vertical end surface. To prevent spoilage, only a short section of the trench or trench stack is uncovered at one time.

Good silage can also be made when uncut material is placed in trench or modified trench stack silos. When uncut material is placed in these silos, special care must be used to see that it is properly distributed and compacted. The portion of the pile above ground level should be well formed and the surface well sealed and weighted. Silage thus made is a little more difficult to feed out, but when it is sliced off the end with a hay knife, broadax, or machete, the work involved is not excessive.

Fence silos built with successive rings of 2- by 4-inch-mesh welded steel, triangular steel mesh, or wood slat fencing, and lined with a fiber-reinforced paper are valuable in putting up silage in emergencies, when permanent silos are not available, or when the cost is not justified.

Fence silos should not be built to a height of more than twice their diameter unless poles are set at from 4 to 6 points around their circumference. Poles, when they are used, should be tied together at the top; the fencing
should never be fastened to them. When the silage is to be held from spring or early summer to winter feeding time, the silo should be lined with two thicknesses of paper.

These silos will make and preserve good silage, but care is needed during filling operations to keep the top of the silage level and well tramped. A space 12 to 15 inches wide should be leveled where the first ring of the fence is to rest. Special care is needed to keep this foundation level. When the first ring of fencing is half full, a second ring is placed inside the first, lapping 4 inches and temporarily lashed in place with twine. The lining for this ring is placed inside that for the first. When the second ring is half filled, a third ring is placed, and so on. When the third ring of fencing is half full, the twine binding the first and second rings together is cut to allow the second to telescope inside the first.

The chopped material should never be allowed to pile up in the center of the silo while filling but should be arched slightly at the top. An extra ring of paper extending 18 inches above the fence is valuable in sealing the top surface. This ring is filled with silage and after the surface settles and has been tramped for 2 or 3 days after filling operations cease, it is folded in and a layer of paper is placed over the top and weighted down. Such a covering is desirable where the silo is not to be opened for several months.

Stack silos are often used for preserving cannery refuse, pea vines, beet tops, or pulp, and can be used for grass silage. The loss is much higher than in other types of silos, however, and the quality of the silage is lower. Bundles or bales of forage placed in a circle can be used to support and protect a stack of chopped material. In that case, the bundles or bales should be supported by bands of No. 9 wire spaced from 2 to 4 feet on centers as required. This system protects the silage better and offers the advantage of having chopped material to feed.

The cost of putting up grass silage will vary with the size of the operation, the efficiency with which machinery is used, and the cost of fuel and power. The cost of labor is also a factor, as is the cost of preliminary treatment of the crop. The cost of machinery and equipment is another important consideration.
used, and what equipment is at hand. If a farmer ensiles several cuttings of forage crops, including pasture clippings, he will make much more silage with the same machines than a farmer who fills silos only once or twice a season. The machinery cost therefore will be lower. Labor can be saved by using a field chopper and a silage blower for filling operations.

A tractor mower with a windrow attachment offers a way to cut labor and equipment requirements. On light crops, a side-delivery rake can be used to throw two or more swaths or windrows together; loading operations are thus speeded up and labor and equipment requirements are reduced.

Studies on the cost of making grass silage at the New Jersey Dairy Research Farm show that the lowest cost per ton of silage is closely associated with high yield per acre and high tonnage per day. These costs are also lowest for the greatest mechanization. Since labor costs have gone up proportionately more than machinery since 1940, the efficient use of machines is a major factor in keeping down the costs of silage. Work at the Agricultural Research Center at Beltsville shows that more feed value per acre can be obtained from forage crops with only slightly more labor and with about the same equipment requirements when the crop is preserved as silage as when it is preserved as hay.

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