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EQUIPMENT FOR HARVESTING HAY AND SILAGE

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Lifting, chopping and loading silage hay with a forage crop harvester.

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INTRODUCTION

Forage crops may be harvested as dry hay or as silage by many different methods and by means of various types of equipment. There is no single method or group of machines which is suitable for all farms and all conditions of operation. The system used in harvesting will depend primarily on the amount of hay harvested, investment in equipment, climatic conditions, man labour requirements, storage methods and location, topography of the land, and on many other factors. Cutting and raking of the crop does not present so many problems as there are in curing and transferring the crop to storage. The hand loading method is costly in manual labour, while the investment in equipment is low. With combination harvesters much less heavy manual labour is required but a large investment in equipment is necessary.

To economically harvest a crop it is extremely important that labour should be used efficiently and that equipment be properly maintained. Some farmers harvest twice as much hay as others when using the same crew and method. Machinery where it can be used satisfactorily, efficiently and economically, will aid in harvesting by reducing heavy manual labour which is normally required, by increasing the speed of operations and by lowering the cost per ton in collecting the crop. However, if not properly maintained and efficiently utilized, machinery will only partially demonstrate its value and may increase the cost of harvesting the crop.

The amount of labour required to harvest crops by various methods has been measured as "man hours per ton". This makes it possible to compare the labour requirements of various methods and to determine the total amount of labour used in any combination of operations. The following examples illustrate the meaning of the term "man hours per ton". If 4 tons of hay is harvested by six men in 2 hours, there has been 6 times 2 or 12 man hours of work for the 4 tons, or 3 man hours of work for each ton or simply "3 man hours per ton". If 3 man hours per ton is needed for harvesting and storing the crop, 1 man hour for cutting and $\frac{1}{2}$ man hour to rake a ton, the total would be 4·5 man hours per ton for all three operations. Normally the term "man hours" is meant to infer that able bodied men are involved and does not distinguish between light or heavy work. This factor can be accounted for to some extent, if desired, by giving a boy credit for one-half the work of a man on certain types of work.

The calculated costs of harvesting operations and machine costs as presented in this bulletin, are based on machinery records of the Dominion Experimental Farms Service, and on other literature dealing with this topic. Practically every type of equipment mentioned in this publication has been used in agricultural engineering experiments. To determine the cost per ton in each operation it has been necessary to select certain specific values and rates derived from recorded and estimated data. All of the assumptions, methods and values used in computing costs are stated in the text or tables. Factors included in estimating machinery costs are depreciation, interest, housing, repairs and service labour, fuel and oil. The cost of any operation will depend on the conditions which exist on each individual farm. It is suggested, therefore, that the data presented be used as a general guide to costs and efficiency and that the values be adjusted to conform with local conditions.

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CUTTING HAY

The operation of cutting or mowing hay normally presents fewer problems than do storage operations. Usually the crop is cut more quickly than it can be stored, and the equipment and labour required for cutting per acre or per ton is relatively low.

Equipment

Mowers are built in four general types, namely: (1) horse drawn traction mowers, (2) tractor trailer power driven mowers, (3) semi-mounted power drive mowers, and (4) fully mounted power tractor mowers. Trailer mowers can be

Semi-mounted mowers can be attached to practically any type and make of tractor. With a power-take-off driven cutter bar, the mower can operate at a higher speed and in heavy crops.

attached to any make of tractor but as they are a trailed type of machine they can not be manoeuvered so easily as the other types. Semi-mounted mowers are attached directly to a plate on the drawbar and are carried on one or two castor wheels. This style of machine can be attached to any make of tractor, can be readily manoeuvered and can be quickly removed so that the tractor can be used for other work. Full mounted mowers that are carried directly on the tractor are very flexible in operation and these units are often used where a relatively large amount of hay is involved, but they can not be attached to all types of tractors and usually they are not easily attached or removed from a tractor. In some cases the drawbar can not be used when the mower is on the tractor. The side mounted type, however, which has the cutter between the wheels permits the best vision of the cutter bar and, therefore is suitable for higher speed operation.

In cutting hay a good divider is needed on a mower when cutting a heavy tangled crop so that there is plenty of clearance for the shoe of the mower on each

following round. Without a suitable divider the mower often clogs and much valuable time may be lost during the cutting operation. Windrow attachments which consist of a series of parallel metal straps fastened to the cutter bar are sometimes used to windrow the crop as it is cut. This attachment is suitable for use when cutting hay for silage or when cutting very light crops for dry hay. Heavy crops dry more rapidly if left in the swath and then windrowed some hours later. Hay mowers can be obtained with cutter bars having a length of 4 to 7 feet. The length of bar used depends on the power which is used to draw the mower as well as on the general method used in harvesting hay. Most of the balers and forage harvesters now in use can only handle a windrow from a 5 foot mower in heavy crops, but some special styles of balers will operate on a large double windrow of hay. For more details refer to the section dealing with baling operations.

The number of acres of hay which can be cut per hour will depend on the land surface, kind of crop involved, condition of the equipment, type of mower used, size of field and on other related factors. It is important, therefore, that fields be clear of obstructions, and that machines be in good condition. Valuable time is often lost by making loops at the corners of fields when these are not necessary.

TABLE I.—CUTTING HAY WITH HAY MOWERS

Rate of Operation and Man Hours per Ton—Assumed Yield, 1½ Tons per Acre

Method of Equipment	Crew Size	Acres per Hour		Man Hours per Ton	
		Range	Ave.	Range	Ave.
Tractor and 6′–7′ bar	1	1·0 to 2·5	1·7	0·67 to 0·26	0·39
Horses and 5′–7′ bar	1	0·7 to 1·2	0·9	0·95 to 0·6	0·74
Tractor and horse mower	2	0·8 to 1·7	1·2	1·66 to 0·78	1·11

Side mounted tractor mowers permit a clear view of the cutter bar. Some types of side mowers can not be quickly mounted on or removed from a tractor.

Some operators cut $1\frac{1}{4}$ acres per hour with a team and mower while others take over an hour to cut one acre. Theoretically, a mower with a 6 foot bar should cut more than a 5 foot unit but this is not necessarily the case due to the many other factors involved. Tractor type mowers when in good mechanical condition and when operated efficiently can cut a larger area per day than horse drawn mowers. Where it is necessary to reduce the time required for cutting hay, a tractor mower can be used to advantage.

Investment and Costs

On the basis of the calculations in this publication it costs about $1 to cut one ton of hay with a team and horse mower when cutting about 60 tons per year. With a power mower on a two-plough tractor the estimated cost is 50 to 55 cents per ton when 100 to 200 tons are cut per year, and 71 cents when 60 tons are cut each year. The lower cost for power mowers is primarily due to the larger acreage which can be cut per hour and not necessarily due to the greater mechanical efficiency of the machine. The above costs for horse or tractor methods can be reduced 20 per cent by more efficient field operation. The cost, when power mowers are used on large tractors may be 75 cents to $1 per ton. (See Tables 14 and 15).

RAKING, COCKING AND TRIPODING OPERATIONS

After a crop is cut it is desirable to wilt, cure or dry it as rapidly as possible to a point where it is suitable for storage. The equipment and methods used during this part of the harvesting operations vary considerably in accordance with climatic conditions and the method of gathering the hay after it has cured.*

* "Alfalfa for Hay, Silage and Pasture", Publication 735, and "Silage Production", Publication 525, Experimental Farm Service, Ottawa.

In harvesting operations the crop should be raked into even, straight windrows to uniformily cure the crop.

Tractor type power-take-off side delivery rakes are being used on some farms. A heavy duty high speed rake is desirable for tractor operation.

During field wilting or curing one or more of the following operations might be used: raking, tedding, coiling or cocking, or roller crushing of the crop. Following cutting, however, the crop is normally left in the swath where it undergoes the first stage of curing, when the upper layer of the swath dries considerably. The subsequent operations of raking or coiling etcetera are performed to aid in curing or to facilitate other operations in harvesting the crop.

Raking Operations

Two types of rakes are commonly used in haying operations namely, the dump rake and the side delivery rake. For smaller farms and particularly where horses are used the dump rake is most suitable because of its relatively low initial cost. Side delivery rakes are usually combination machines that may be used for raking on the one hand or for tedding when the cylinder rotation is reversed, but some types can only be used for raking or for turning the windrow. As standard side rakes are not particularly suitable for operating at high speeds with tractors, more sturdy types of tractor rakes are now being placed on the market. In cases where the hay is to be picked up by a forage harvester or baler it is almost necessary to use a side delivery rake since it is not easy to form an even continuous windrow by using a dump rake.

TABLE 2.—RAKING, TEDDING, COCKING, AND TRIPODING HAY
RATE OF OPERATION AND MAN HOURS PER TON

Method or Equipment	Crew Size	Rate per Hour for Crew in Acres.		Man Hours per Ton	
		Range	Ave.	Range	Ave.
Tractor and side rake	1	1·4 to 4·0	2·2	0·47 to 0·16	0·39
Horses and side rake	1	1·2 to 2·4	1·6	0·55 to 0·28	0·41
Tractor and dump rake	1	1·6 to 2·8	1·9	0·41 to 0·04	0·35
Horses and dump rake	1	1·4 to 2·4	1·8	0·48 to 0·28	0·38
Hand turning hay	1	0·3 to 1·0	0·4	.....	1·66
Hand cocking hay*	1	0·3 to 1·3	0·6	1·8 to 0·50	1·11
Tripoding hay and setting tripods**	1	.....	0·3	1·8 to 3·0	2·0

* Approximately 60 lb.–90 lb. of hay per coil or cock. Cocking from windrow.
** Approximately 650 lb. of hay per tripod.

The time required to rake an acre of hay may range from 20 to 45 minutes depending on the power used and on the rate of travel. Horse drawn rakes cover about $1\frac{3}{4}$ acres per hour while tractor units usually rake over 2 acres per hour. On smaller farms with 60 tons of hay where a dump rake and horses are used, the cost of raking per ton is approximately 40 to 50 cents. When 120 tons of hay is raked with a side rake and horses the calculated cost is 45 to 55 cents while with a two-plough tractor the cost per ton is 35 to 45 cents. If a three-plough tractor is used to haul a rake, the cost of raking is likely to exceed 55 cents per ton. There is, however, little difference in the per acre cost of raking light or heavy crops.

In raking hay, the work should be arranged to keep the rake in continuous operation so that there is no lost travel. It should also be kept in mind that raking is done to move the hay into an even windrow for a following operation. Loaders, balers and harvesters work better on an even straight windrow, as bunching of the hay causes the machines to plug or overload. Uneven and large windrows usually result in uneven drying of the hay.

Cocking and Tripoding Hay

When the climatic conditions are not favourable for ordinary field curing, the hay is sometimes placed in cocks or on tripods after it is raked. Hay coils or cocks will shed a certain amount of water and only the outside layer will bleach to any extent. In tripoding, the hay is built up on a stake or three-pole tripod for curing. By placing hay or tripods a good quality of hay can usually be obtained even under severe weather conditions. Under adverse weather conditions and, where the volume of hay involved will justify the use of equipment, the crop might be stored in a silo as an alternative to the tripoding method.

Tripods are built from three poles, each eight feet long which are wired together at the top, and three lighter poles about seven feet long that are fitted to these legs near the bottom of the tripod. Holes $\frac{1}{4}''$ in diameter are drilled in the legs at the top in order to fasten the legs together by a piece of wire, and holes

Tripods are made from three poles which form the legs and three horizontal poles which connect the legs together. Tripoding aids in curing hay but involves additional manual labour in harvesting operations.

are also drilled in the legs about 20 inches from the bottom for attaching the lighter horizontal poles. In using the tripod method, the hay is usually wilted in the swath, then gathered in bunches by means of a dump rake or push rake and then placed on the tripod by the use of a hand fork. Five to ten tripods may be required per acre. When building the tripod a forkful of hay is first placed on the projecting poles at the corner and then three or four fork loads are placed directly on top of each pole between the legs. After building the hay to the top of the tripod, the sides are combed down to aid in shedding water. Some 500 to 1,000 pounds of hay may be placed on each tripod. Hay cured on tripods is usually moved to the barn by wagons or by sweep rakes.

Cocking and tripoding is normally a manual operation which involves practically no equipment. The man time required for these operations depends primarily on the energy and skill of the worker as well as on the yield of the crop. With labour at 45 cents per hour it may cost about $1.25 per ton to put hay on tripods. Moreover, when hay is tripoded it is normally necessary to hand load the hay onto wagons and remove the tripods from the field. Although machines have been devised which reduce the labour required for tripoding, the hand fork method is being used almost exclusively at the present time. To cock hay it requires about one hour of labour per ton or approximately 2 hours per acre depending on the yield and other factors. At 45 cents per hour for labour, it therefore costs 45 cents per ton for cocking hay.

Roller-Crushers

A machine consisting of two rollers which crush hay as it is picked up from the windrow has been introduced to a limited extent in some parts of this continent. By crushing the stems of the plants the crop dries more rapidly. Although this machine has not been tested extensively in Canada other experiments show that it is more effective on plants which have heavy succulent stems or leaves than on other crops and, therefore, it may not be particularly adapted to a crop having a large proportion of timothy or similar plants. On coarse, heavy, succulent plants the drying time might be reduced from 15 to 45 per cent. A combination machine consisting of a mower, pick-up, rollers and gasoline engine would cost about $2,000 while smaller units may cost approximately $900.

METHODS OF COLLECTING, HAULING AND STORING HAY AND SILAGE

In moving the crop from the windrow into storage numerous methods are used and these methods vary with the conditions which exist on each individual farm. The value of equipment involved may range from $100 to $6,000 depending on the method employed and on the volume of hay being harvested. Where the work is primarily done by hand it may require 4 man hours per ton to harvest the crop while only 1·0 man hour might be used in conjunction with power equipment.

Hand Loading Method

The hand loading method of gathering hay is used on many farms where the volume of hay handled is relatively small. With this method the labour required is high and laborious while the cost of equipment is low. In cases where only a few tons of hay are harvested, where fields are small, irregular, stony or rough, the hand method may be the most suitable and economical means of collecting the crop.

Equipment

When hay is coiled or cocked, hand loaded and placed in the mow or stack by means of slings or a fork, the equipment may only consist of a wagon, rack and barn hay track. The total new cost of a team of horses and the equipment required for this method might not exceed $500.

Labour Requirements and Costs

On the average it is estimated that 3·5 man hours per ton are required to move hay from the field to the mow by the hand loading method. In other words it requires 35 hours of manual labour to gather 10 tons of hay. More skilled and energetic workers can, however, by good management gather twice as much hay in the same time under favourable conditions. If 3·5 man hours are used to hand load and store hay, the labour cost is $1.57 per ton at 45 cents per hour. The equipment and horse charge is about 83 cents for harvesting the hay on the basis of 30 to 60 tons of hay per year. By adding $1.40 for cutting and raking, the total cost from the standing crop to the barn is approximately $3.80 per ton. This cost can be reduced considerably by more efficient use of man labour, by keeping equipment in good working condition, by hauling larger loads on low wagons and by growing higher yielding crops.

Hay Loader Method

The hay loader method involves a modest investment in equipment, a medium amount of labour, and it is one of the most commonly used methods of harvesting hay. But, in using the loader, the time required to load a wagon is about three-quarters the time needed to load with a hand fork. Although the hay loader method is flexible and adaptable to a wide range of conditions a considerable amount of heavy labour is involved in loading and in storing the hay.

Equipment

Hay loaders are made in two general types, one being the slat style which is only suitable for dry hay and the push bar style which is a heavy duty machine suitable for dry hay or green forage for silage. When using a loader, straight even windrows facilitate operations. In turning corners the windrow should be kept under the center of the loader to prevent jamming and possible damage to the pick-up reel.

Hay loaders are used extensively in harvesting hay. The push-bar type of loader will elevate green hay for silage or dry hay.

Hauling Hay

The average rate of travel to and from the field is for horses and wagon 2·5 miles per hour; tractor and wagon 5 miles per hour; and motor truck 5 to 15 miles per hour. On the basis of a ¼-mile haul from the field to the barn, a complete trip and return requires approximately the following time, horses and wagon 10 to 15 minutes, and tractor and wagon 6 to 10 minutes. The loads carried on wagons in haying operations vary considerably but normal loads are as follows: long hay, hand loaded 1,600 to 2,000 lb., long hay from hay loader 1,800 to 2,500 lb., baled hay on high wagons 2,200 to 3,300 lb., baled hay on motor trucks 2,800 to 3,800 lb., baled hay on low rubber tired wagons 3,000 to 3,700 lb., chopped hay short cut 1,200 to 1,600 lb., and chopped hay long cut 1,000 to 1,500 lb. Where the hauling distance is long it is desirable to use large loads. The size of load carried is usually larger when low wheeled rubber tired wagons are used.

Labour Requirements and Costs

By the hay loader method it may take 12 to 30 hours of labour to move 10 tons of hay from the windrow to the mow with an average of about 25 hours. If two men gather and mow one ton each 75 minutes or if three men handle one ton each 50 minutes the rate is 2·5 man hours per ton. Some operators can, however, with suitable equipment gather and store 2 tons in the same length of time. To obtain a better than average labour efficiency with the hayloader method superior operators have improved the hauling, unloading and mowing sections of the operation rather than the actual loading operation. With a loader, low rubber tired wagons having broad racks, tractor, hay fork, hay hoist with pull back rope, a chute to deflect the hay towards the side of the barn as it drops from the fork, good roads, smooth fields, a ¼-mile haul, and with good management two operators can put up a ton of hay in 36 minutes or at an average of 1·2 man hours per ton. Auxiliary equipment such as hay hoists, minor pieces of equipment such as well built wide wagon racks, small conveniences such as a suitable hitch for the hay loader, well maintained equipment, and efficient labour management play an important part in improving the hay loader method. A detailed study should be made of each individual operation used in harvesting the crop to determine where time might be saved by changing the method or by using other equipment in order to reduce the cost or labour in storing the crop. Refer also to the sections dealing with auxiliary equipment for details on racks, hoists, and slings.

Assuming that two men with loader, horses, wagon and grapple fork move 0·8 tons of hay from the windrow to the mow in one hour (2·5 man hours per ton) the cost per ton with an annual tonnage of 60 tons is approximately $2.46. This cost is made up of the following items; loader 57 cents, wagon 2 cents, rack 1 cent, track and fork 11 cents, horses 63 cents, and labour $1.12. If the two men handle one ton per hour the cost is reduced to $2.01.

Sweep Rake Method

This method of gathering hay is often used where the hauling distance is less than ¼ to ½ mile, where the amount of hay harvested is 60 tons or less and where the fields are reasonably smooth and firm. Sweeps may be mounted on a tractor or on an automobile or truck chassis. Tractor sweep rakes usually operate on a shorter hauling distance than auto units due to their lower speed. If fields contain very sandy soils, muck, dead furrows, or other such obstructions the teeth of the rake are often broken as they penetrate the soil or hit obstructions. Although a tractor or auto chassis is required for this method of collecting hay the investment in the actual haying device or rake is relatively low, as wagons or loaders are not required. Moreover the man labour involved is reasonably low ranging from 1·2 to 2·5 man hours per ton with an average of 1·8 man hours for gathering and storing the crop. Where the sweep can be used it is often a low cost and efficient method.

Equipment

Both commercially built and homemade sweeps have been successfully used. When mounted on tractors, sweeps are more often placed on the front of the tractor than on the rear, due to the fact that a speed of 6 to 10 miles an hour is needed for loading the rake. In some cases extra wheels are used to carry the rake and thus prevent overloading of the tractor front wheel bearings, but direct mounting of the rake is satisfactory on most tractors, where the amount of hay handled is small and where the loads are light. When mounted on the rear of an automobile or truck chassis numerous methods have been used in attaching the rake and in providing power to elevate the rake teeth. Occasionally much of the auto chassis is redesigned, with the rear axle turned upside down to obtain three reverse speeds, with the seat and steering wheel turned to the rear to readily operate the machine in driving it backwards, and with a power drive from the fan belt, transmission power-take-off or hydraulic pump for hoisting the rake when hauling the hay to the barn. If an old auto is to be fitted for a rake, it is desirable to use a heavy car or motor truck unit to obtain sufficient power and strength in the unit. With auto sweep rakes it is often necessary to use an auxiliary water tank in conjunction with the cooling system to prevent over heating of the motor.

Both commercially made and home-made sweep rakes are used in harvesting operations. The sweep rake method, where it can be satisfactorily used, eliminates heavy manual labour in gathering hay.

In constructing a sweep it is extremely important that the rake be properly designed and sturdily constructed to prevent loss of time during harvesting operations. The following are some of the features which should be considered when building a rake: Teeth should be twelve feet long, spaced 11″ on centers, 3″ x 3″ at the butt, 2″ x 2″ at the tip, straight grained fir or hardwood, or metal teeth of equivalent strength. Tips of the teeth should be tapered just at the end from both the top and the bottom, not just on the bottom, and fitted into metal sweep rake points. When in operation the butt end of the teeth should be not more than 6″ from the ground. Two 4″ x 4″ pieces 11½ feet long, set parallel, and 18″ apart may be used to carry the teeth in conjunction with a 2″ x 4″

hardwood strip under the front 4″ x 4″ and below the teeth or the equivalent in metal framing. The backboard or vertical section should be four feet high and adequately attached to the frame as the rake teeth are lifted by a cable attached to the top of this frame. A hoist should lift the tips of the teeth 4 feet from the ground. There is considerable work involved in making a sweep rake and, therefore the purchase of a commercially built rake might be considered. Most commercial rakes have a dependable hoist mechanism which is an important part of a sweep rake.

Operational Details

Hay may be picked up from either the swath or the windrow with a sweep, but most operators prefer the windrow as the raking often facilitates curing of the crop and gathering a larger load on the sweep. By putting a half load on the sweep and then unloading, a second load can be gathered and deposited on top of the first, thus making it possible to pick up a double load for hauling to the barn or stack. Loads vary from 500 to 1,000 lbs. depending on the design of the rake, the method of loading and on the type of hay involved. A speed of 6 to 10 miles per hour is needed to load the rake. At the barn the hay can be elevated by means of a blower, cutter box with blower, or by slings. When using slings at the stack or barn, two fork fulls of hay are spread out on the ground, the slings are laid on top of the hay and the sweep load is then deposited onto the slings. The hay under the slings aids in unloading the sweep rake. On farms where tractor sweep rakes are used, the amount of hay harvested averages 30 to 50 tons. For short hay extra ropes are added to the slings. Well constructed heavy duty sweeps are sometimes used to gather sheaves at threshing time. In this operation a half load is usually collected by the sweep and the other half hand loaded. A rope around the load is sometimes used to aid in unloading, and an extension feeder is used on the thresher. Refer also to the section dealing with combination sweep stackers and hay blowers.

Labour Requirements and Costs

With the sweep rake method a crew of 2 or 3 men is commonly used, the tonnage per hour for the crew ranges from 1 to 2 tons, and 1·2 to 2·5 man hours or an average of 1·8 man hours may be required per ton. By this method the heavy work of loading and unloading hay is eliminated. The cost of a rake is about $200 or possibly $350 where a more elaborate power lift is included. The calculated cost of gathering and storing one ton of hay with a sweep, two-plough tractor, 3 men at 45 cents per hour, at a rate of 1·4 tons per hour on a $\frac{1}{4}$-mile haul is $1.65 per ton. For more exact cost for an individual farm these costs should be adjusted according to the actual rate of operation, to existing labour rates, and other factors. The tables on machine costs and costs of operations may be used as a guide or method of compiling the cost data. (See Tables 3, 4 and 14).

TABLE 3.—COLLECTING AND STORING HAY

Rate of Operation and Man Hours per Ton From Windrow to Storage

Method of Equipment	Crew Size	Rate per Hour for the Crew in Tons		Man Hours per Ton	
		Range	Ave.	Range	Ave.
Hand loading	3	0·7—1·5	0·86	4·3—2·0	3·5
Sweep rake, A	2	0·8—1·7	1·1	2·5—1·2	1·8
Sweep rake, B	3	1·2—2·0	1·4	2·5—1·5	2·1
Hay loader, A	2	.....	0·9	2·8—1·2	2·3
Hay loader, B	3	1·0—2·5	1·2	3·0—1·2	2·5
Baler	5	—3·5	2·1	—1·4	2·3
Field harvester	4	1·5—3·2	2·5	2·5—1·2	1·6

Barn Curing

In the standard or commonly used methods of harvesting a crop for dry hay, the crop is dried in the field to a moisture content of 25 per cent or less and then it is placed in a barn or stack for storage. When the barn curing or barn finishing method is followed the hay is partially cured in the field to a moisture content of about 35 per cent whereupon it is placed in a mow fitted with a barn curing unit. The barn curing device is then used to remove additional moisture from the hay as it cures in the barn. By collecting the hay at this higher moisture content fewer leaves are lost, and the hay is subject to weather conditions for a somewhat shorter time, but a larger tonnage must be handled because of the higher moisture content.

Equipment

Barn curing equipment consists of a slatted floor or set of air ducts placed on the floor of the barn, a fan which delivers air into the ducts or beneath the slatted floor and a motor to drive the fan. In most cases cold air is supplied by the fan to the hay, but a furnace or heating unit is sometimes used to supply heated air. Occasionally the heat from a gasoline engine is used to partially warm the air when this type of power is used to operate the fan. Curing equipment of this general type has also been used under hay stacks as well as in barns.

Where a slatted floor installation is used it consists of a series of 2 x 6's placed on edge and set two feet apart and covered with 4″ slats spaced $1\frac{1}{2}$″ apart to act as air openings to distribute the air through the hay. This slatted section covers the mow floor to within five feet of the walls of the building. A main duct usually located at the center of the mow carries the air from the fan to the slatted floor distribution unit. The size of this duct varies according to the installation and would be about 2′ x 4′ where a 5 H.P. motor is used. When curing baled hay it may be placed on a slatted floor or for temporary installations the bales can be piled in such a manner that they form ducts or channels for the distribution of air. Fans of various types may be used ranging from propeller units to cage type ventilation units. It is suggested that the fan deliver a minimum of 20 cubic feet of cold air per minute per square foot of mow area at not less than one inch of static pressure. Manufacturers of fans and electric motors can supply details on the capacity of various types of fans for different sizes of installations, as well as corresponding motor requirements for any desired volume of air. Where cold air is used the fan and motor are usually placed in a compartment on the mow floor adjoining an outside wall of the mow. Electric motors are normally used to drive the fan as they can be readily operated continually since both night and day operation is required. However, gasoline engine units can be used in cases where electric power is not available and will also supply a certain amount of heat. A five horse power electric motor is required to deliver 15 cubic feet per minute for a mow having 800 square feet. In most districts 3 to 5 H.P. motors are the largest motors which can be placed on standard rural electric power lines. The cost of a motor, fan, materials for ducts and labour for a mow 28 x 32 feet would be about $600 to $700 not including the cost of installing a power line to the motor. With a 5 H.P. unit, that handles 30 tons per year, the cost of operation including depreciation, and with electric power at 2 cents per K.W.H. may range from $3.00 to $3.75 per ton.

Heat when used in the curing operation reduces the time required for drying but it involves additional equipment, the cost of fuel, and a fire hazard unless a suitable installation is made. Crop drier units consisting of a motor or engine, an oil burner and fan have just been placed on the market at a price of from $700 to $1,800 depending on the capacity involved. These drier units might be used for drying other materials such as seed corn, etc., as well as hay, but little detailed information is as yet available on their general utility.

Factors in the Barn Curing of Hay

Experiments conducted by the Dominion Experimental Farms Service have shown that there are definite limitations in the barn curing method. Barn curing equipment using cold air was introduced in an attempt to obtain a better quality of hay and to eliminate some of the weather hazards in field curing the crop. Although this device may be of value in some regions it can not be considered a regular dehydration plant in which large quantities of green or slightly wilted crop can be dried regardless of weather conditions.

In using this method, the moisture content of the material should not exceed 30 to 40 per cent, loose hay should be spread evenly in the mow, the supply of cold air should be at least 20 cubic feet per minute per square foot of mow with at least 1″ of pressure, and the fan should run almost continuously throughout the curing operation even if it is raining or humid. When loading the mow with hay at 35 per cent a single loading should not exceed 7 to 8 feet under favourable weather conditions and the total depth for more than one loading should not exceed 13 feet. Even when following these stipulations it can not be concluded that hay can be successfully cured under all conditions without moulding in parts of the mow. The time required for drying each filling of hay in the mow usually ranges from 8 to 20 days depending on the particular conditions which are involved. If heated air is used, however, and if the additional cost of fuel can be justified the curing time can be reduced appreciably.

The Baler Method

In the harvesting of hay, balers form the hay into bundles which can usually be moved more readily than loose long hay. The baler method will, therefore, be used to the greatest advantage under the following conditions. (a) Where the crop is being shipped some appreciable distance by truck or train, (b) where the storage space is limited, (c) where during feeding operations the hay is moved from one building to another or into a feed lot, and (d) where it is convenient to temporarily divide the harvesting operations by hiring a custom operator to assist with the harvest work by baling the crop, or to quickly package the hay so that it will withstand some rain and thus allow more time for hauling and storing operations. The introduction of the baling operation, however, involves another

Automatic balers are available which tie the bales with wire. When baling hay it is necessary to properly cure the crop before commencing baling operations..

machine operation and also the cost of twine or wire for the bales. Although baled hay will shed some water and dry off when the weather is favourable, baling does not overcome all of the weather hazards as the hay must be properly cured before baling. Unless the hay is as dry as or slightly drier than ordinary long hay when ready for storage, the bales will mould in the center. Though bales may be more convenient to move than long hay the total time required to move baled hay from the windrow into storage may be about equal to the time used in moving loose hay by the loader method.

Equipment

Both stationary and field pick-up balers are being manufactured. At present the stationary type of baler is being used for baling hay or straw after it has been stored in a stack or mow. A large crew is required when using a stationary baler in the field in conjunction with wagons and loaders for harvesting the crop. Field pick-up balers are made in two types, namely the hand-tie unit and the automatic machine. Wire is used for tieing the bales on hand-tie units while automatic balers are designed to use wire or twine. The twine used with some balers is a special heavy duty twine while other balers use ordinary binder twine. On balers which form rectangular bales a mechanism similar to a binder knotter ties the twine while on balers which form a round bale the twine is wrapped into the bale without using a knot. Wire tied bales may be preferred if the hay is to be shipped long distances but in normal farm operations either twine or wire may be used.

Field balers may be operated from the tractor power-take-off shaft or from a separate engine mounted on the baler. Machines with auxiliary engines cost more than power-take-off units but balers with engines are more flexible for uneven windrows and they can be drawn by a small tractor. In general, engine driven balers are preferred by custom operators who wish to bale a large tonnage per day from windrows which might be too large or irregular for convenient operation with power-take-off machines. With round bale machines the forward motion of the baler is stopped while the bale is warpped and discharged. For this type of baler a tractor with a continuous power-take-off drive is definitely advantageous as it is only necessary to push in the tractor clutch while the bale is put through the machine. With a standard tractor it is necessary to operate the clutch twice and move the gear shift twice each time a bale is formed.

Broad throat, round bale machines can operate on a heavy windrow. As the baler is stopped to discharge each bale a tractor with a continuous power-take-off is usually used with this baler.

Automatic twine tying balers may be used to bale straw, hay and similar materials. Balers with auxiliary engine are often preferred for custom work operations

Operational Details

It is important that windrows be adjusted to the proper size for balers in order to prevent clogging of the machine. For balers with a broad throat such as the round bale units a heavy twin or double windrow can be used, while with narrow throat machines, a 5-foot swath is quite sufficient in a 2-ton crop. Both types of baler, however, may have the same tonnage capacity per day. Straight even windrows are desirable as a poorly cured bunch of hay when placed in a bale may spoil.

Under the most favourable conditions and without loss of time it is possible to bale 5 to 7 tons per hour with automatic field balers but the average daily capacity is usually about 4 tons per hour with a seasonal capacity of $2\frac{1}{2}$ to $3\frac{1}{4}$ tons per hour. On reasonably level land a two-plough tractor will haul an engine driven baler. For a power-take-off baler at least a two-three plough tractor is needed and a three-four plough tractor is normally used on rolling land or where a loaded wagon is hauled behind a baler. As balers and forage crop harvesters have numerous moving parts it is extremely important to have a thorough knowledge of these machines in order to operate them at their maximum capacity and efficiency. Only by keeping these machines in good repair and adjustment can they be successfully and profitably operated. For information on bale loaders refer to the section dealing with auxiliary equipment.

Labour Requirements and Costs

In cases where only the baling operation is involved and where the bales are dropped to the ground behind the automatic baler, the crew may consist of one man. If three tons can be baled per hour, the baling requires $\frac{1}{3}$ of a man hour or 20 minutes per ton. In a separate operation three men may load, haul and place in the mow about 1·5 tons per hour or at a rate of 2 man hours per ton. Under these assumed conditions 2·3 man hours are required for the two operations or almost the same total time as by the hay loader method. Under more favourable conditions and efficient management the total labour might be reduced to 1·6 man hours per ton.

Where baling, hauling and storing of the crop are carried out simultaneously, a larger crew is required, more equipment is usually necessary for hauling and more co-ordination of work is involved. By hauling a wagon behind the baler, however, there can be some saving in labour by direct loading of the wagon. If the capacity of the baler, length of haul, and storage operations permit 5 men to bale and place in the mow 2·5 tons per hour it requires two hours of work or 2 man hours per ton to collect the crop by this method. Depending on conditions of operation and management this may range from 1·4 to 3·0 hours per ton. Owing to the many variations that may be involved in such a combined operation it is not possible to present more precise rates without detailed explanations of the various items for each set of operating conditions. It should be noted, however, that although only a small amount of labour is required in baling the hay, a considerable amount is required to place the bales in a hay mow. Where the bales are loaded by hand, unloaded and placed on slings, and hand placed in the mow a considerable amount of hand work is involved. Normally two to three times the amount of labour is required on a hand-tie baler as on an automatic field baler. Although the baler method does not materially reduce the hours of work per ton, it packages hay which can be more conveniently handled than loose hay, it makes it possible to hire a custom baler to aid in harvesting the crop and it permits the farmer who purchases a baler to do custom work where all of his time is not required on the farm.

The cost of baling a ton of hay varies considerably and primarily depends on the tonnage baled per hour and on the tonnage baled per year as there is a relatively high investment in equipment for this type of operation. In addition to the depreciation, interest, fuel and labour costs there is a twine or wire cost of

TABLE 4.—COMPARATIVE COSTS FOR HARVESTING HAY AND SILAGE*

To Move Hay or Silage From the Windrow Into the Mow or Silo

Method or Equipment	Assumed man hours per ton	Comparative Cost per Ton According to Annual Tonnage of Machine				
		30 tons	60 tons	120 tons	300 tons	600 tons
		$ cts.	$ cts.	$ cts.	$ cts.	$ cts.
Hand load	3·5	2 40	2 40	2 40	.....	.....
Hay loader	2·5	.....	2 25	2 00	.....	.....
Sweep and tractor	1·8	1 90	1 60	1 50	.....	.....
Baling						
A. Baler P.T.O.	0·4	.....	.....	2 25	1 75	1 70
Storage	2·0	.....	.....	1 30	1 10	1 00
Total	2·4	.....	.....	3 55	2 85	2 70
B. Baler Eng.	0·3	.....	.....	2 85	1 85	1 55
Storage	2·0	.....	.....	1 30	1 10	1 00
Total	2·3	.....	.....	4 15	2 95	2 55
Forage Crop Harvester						
Dry Hay	1·6	.....	.....	2 75	2 05	1 95
Grass Silage	1·0	.....	.....	1 85	1 35	1 25
Corn Silage	0·8	.....	.....	.....	1 22	.....

* Costs include all machinery and equipment costs, man labour at 45 cents per hour, fuel costs, horse labour at 25 cents and twine costs at 75 cents per ton. Tractor costs as per attached table.

All methods include loading, hauling, and placing crop in storage but not cutting or raking. Corn silage from the standing crop into the silo. Costs based on 1948 prices.

Costs do not include transportation charges from farm to farm or insurance fees, etc., on machinery.

approximately 70 to 80 cents per ton. With a power-take-off baler, 2-3 plough tractor and one man, the estimated costs are, baler $1.05, twine 75 cents, tractor 27 cents, labour 18 cents, or a total of $2.25 per ton on the basis of 2·5 tons per hour for 120 tons per season. This cost is reduced to $1.75 if 300 tons are baled per year. These costs include depreciation, interest, repairs, and fuel. Custom charges for baling have recently ranged from $2 to $4 per ton.

For combined baling, hauling and storing operations the costs may range from $3.55 per ton to $2.55 per ton according to the volume of hay involved and the efficiency of the harvesting operation. (See Tables 3 and 4.) For more exact costs, these estimates should be adjusted to fit the conditions, prices, and labour rates on each individual farm.

Forage Crop Harvester Method

With a forage crop harvester, the amount of manual labour required to gather and store a crop is reduced to a minimum while the investment in equipment is relatively large in comparison with some other methods. By using a harvester, an unloader and blower, grass silage, corn for silage and dry chopped

This two-way power take-off driven forage crop harvester will pick-up chop, and load grass for silage or dry hay. On rolling land the wagon may be hauled beside the harvester by a separate tractor.

hay can be placed in storage without manually handling the crop. However, to economically utilize this method it is necessary to move a reasonably large tonnage per year in order to keep the equipment investment charges within reasonable limits. Forage crop harvesters range in price from about $1,000 to $3,000. depending on the capacity of the machine and whether power-take-off or engine driven.

Equipment

Forage harvesters are built in three types. One-way machines are fitted with a direct cutter and can only be used for harvesting grass or similar crops for silage. Two-way machines are supplied with a pick-up that may be used for picking up dry hay or green hay from the windrow. Three-way machines have a pick-up and also a corn head attachment for harvesting corn as silage. The harvester consists of three sections, a cutter bar or pick-up or corn head, a cutter which may chop the crop into lengths ranging from $\frac{1}{4}$ to 4″, and a blower or conveyor that places the cut material in the box of a wagon. Most machines are equipped with a blower which will deliver the chopped crop to a wagon that is trailed behind the forage harvester or to a wagon hauled at the side of the havester by a separate tractor.

In conjunction with a harvester a blower is required for elevating the crop into a silo, barn or stack. These units consist of a cross conveyor or feeder, and a fan. If power-driven wagon unloaders are to be used the feeder should be long enough to extend across the entire width of a $7\frac{1}{2}$-foot wagon box. Moreover, a feeder which can be raised to allow a wagon to pass and which can be lowered behind the wagon eliminates the necessity of backing the wagon up to the blower. For large scale operations a blower should have a silage capacity of 10 tons per hour and a dry hay capacity for 4″ hay at least 5 tons per hour.

Operational Details

A two-three plough tractor at full throttle will operate a power-take-off harvester on level firm land and haul a wagon when picking up a light windrow of dry hay or silage. If an engine-driven harvester is used a two-plough tractor will draw a harvester and wagon under reasonably favourable conditions. A three-plough tractor is more suitable for a power-take-off harvester and will draw and power the machine in corn yielding up to 15 tons per acre. For heavier corn crops a four-plough tractor or an engine-driven harvester is desirable. Where a tractor has difficulty hauling both the harvester and a wagon, the wagon can be hauled at the side of the harvester by a separate tractor. Harvesters with wheel-type cutters have throats measuring 12 to 18 inches. Machines with 12-to 15-inch throats are normally used on smaller individual farms, machines with 14- to 16-inch throats are common on medium sized farms or for some custom work, while 15- to 18-inch machines are for large farms or extensive custom work.

The capacity of forage crop harvesters varies according to the size of the machine, the power supplied, the crop involved and the condition of operation. Medium sized units have a capacity of 3 to 4 tons of chopped hay per hour, 5 to 10 tons of grass silage per hour and 7 to 15 tons of corn per hour. In harvesting dry hay or silage from the windrow it is extremely important to adjust the size of the windrow to the capacity of the machine and it is preferable to have the windrow small as a heavy windrow plugs the machine. In a crop yielding 2 tons a 5-foot mower is usually the most suitable while in a one ton hay crop a 7-foot cut is satisfactory when using a medium sized harvester. It is also important that the windrows be straight and even to obtain uniform drying and to prevent overloading the throat of the harvester. With corn the output of the machine depends primarily on the yield of the crop and averages about one ton per hour for each ton of yield. Dry hay when cut with a $2\frac{1}{2}$″ setting on the machine requires about half the storage space of long hay, and it can be stored at a moisture content at or below 20 per cent if it is not packed. If cut in 4″-lengths, dry hay can be stored at or below 25 per cent moisture which is the same moisture at which long hay is stored provided it is not tramped in the mow, and it requires the same space as long hay. At these moisture contents hay must be blown into the mow and not tramped or walked on under any circumstances. Silage that is harvested directly from the stand with a cutter bar on the harvester usually has a moisture content of 75 to 85 per cent and, therefore, a preservative is normally

added to the crop as it is placed in the silo. The length of cut setting on the machine should be as short as possible, for all methods of making grass silage and it is recommended that a $\frac{3}{8}$ or preferably a $\frac{1}{4}$-inch cut be used. For further details on silage refer to the section dealing with factors in making silage and also to "Silage Production", Dominion Department of Agriculture, Publication No. 525.

In operating a harvester it is usually necessary to pick up the hay from the windrow as the swath may be too wide for the pick-up unit on the harvester. To keep the power requirements at a minimum, the cutter knives should be sharpened after each 5 hours of operation. Sharp knives that are set close to the cutter plate will give a clean short cut which is desirable for silage. Machines as supplied may only have a theoretical cut ranging from $\frac{1}{2}$ to $2\frac{1}{2}$ inches but usually special sprockets can be secured to obtain a range of $\frac{3}{8}$ to $3\frac{1}{2}$ inches. Stones will often severely damage a harvester and, therefore, this equipment is not suitable on stony land unless the stones can be picked off or rolled into the soil so they are not picked up with the hay. When operating a harvester it is very important that the operator carefully judge the capacity of the machine and adjust the amount of material entering the unit accordingly. Where the harvester has an auxiliary engine the tractor speed of travel can be adjusted so that the machine is not overloaded. Where a power-take-off unit is being used, the tractor should be slipped out of the forward gear at the first indication of overloading so that all of the power can be taken by the harvester to prevent clogging of the cutter. In operating any machine with a large number of moving parts special safety precautions should be taken to prevent accidents which may injure the operator or any other person working with such machines.

Labour Requirements and Costs

With a forage crop harvester the size of the crew used for gathering dry hay is normally 3 or 4 men, and for silage operations the crew usually ranges from 4 to 7 men. In some instances, however, farmers have stated that they have successfully harvested and stored dry chopped hay with a one-man crew. Motor trucks are being used on some farms where there is a long haul for hay and silage to keep the crew at a minimum.

If a crew of 6 men harvest 5 tons of grass silage per hour the labour requirement is 1·2 man hours per hour or about one-third of the labour used in the loader and cutter method. Depending on the conditions of operation 0·8 to 1·8 man hours per ton may be required for moving grass silage from the windrow to storage. If a crew of 4 men harvest 2·5 tons of dry hay per hour, 1·6 man hours are being used and it may be expected that this may range from 1 to 3 man hours according to the conditions involved. Although the cost of moving dry hay from the windrow into the barn may cost $2.00 per ton for both the harvester and loader method when 200 tons of crop is involved, the harvester eliminates the heavy manual labour used in the loader method. In the case of corn harvesting 0·5 to 1·2 man hours are usually required in the forage crop harvester method where a crew of 4 to 7 men is used. When the corn binder and cutter method is used a crew of 10 to 15 men is normally required and about 1·4 to 2·2 hours of heavy work is consumed per ton.

The cost of harvesting with a two-way or three-way harvester can be based on a relatively large tonnage as farmers have reported that these machines are harvesting 100 to 2,000 tons of hay and silage per year. On the basis of 300 tons of crop harvested per year, the estimated cost of moving the crop from the windrow into the mow is $2·05 per ton for dry hay and $1.35 for silage. For corn the calculated cost is $1.22 per ton by the harvester methods with a crew of 7 and $1.50 per ton by the binder and cutter method with a crew of 12 men paid at a rate of 45 cents per hour when 300 tons of crop is involved and when 8 tons per hour is being harvested by both methods. At present the custom rate for a harvester, blower, tractor, fuel and one man ranges from $5 to $11 per hour for corn silage operations.

TABLE 5.—ESTIMATED TOTAL COSTS FOR HARVESTING HAY INCLUDING CUTTING AND RAKING

Costs for Cutting, Raking, (baling or chopping) Loading, Hauling and Storage

		Cost per Ton
Hand Loading		
Cutting	horse mower, 1·3 tons per hour, 0·74 man hours per ton, 30 tons per year	$ 1.13
Raking	horse rake, 2·7 tons per hour, 0·38 man hours per ton, 30 tons per year	0.56
Loading	hauling, and storage with hay fork, 3·5 man hour per ton	2.38
Total	4·6 man hours per ton. Investment in equipment $445, power $350	$ 4.07
Hay Loader A		
Cutting	horse mower, 1·3 tons per hour, 0·74 man hours per ton, 60 tons per year	0.96
Raking	horse rake, 2·7 tons per hour, 0·38 man hours per ton, 60 tons per year	0.47
Loading	hauling and storage at 2·5 man hours per ton	2.25
Total	3·62 man hours per ton. Investment in equipment $645, power $250	3.68
Hay Loader B		
Cutting	tractor mower, 2·5 tons per hour 0·39 man hours per ton, 120 tons per year	0.55
Raking	side rake T. 3·0 tons per hour 0·33 man hours per ton, 120 tons per year	0·46
Loading	hauling and storage at 2·3 man hours per ton	1.96
Total	3·02 man hours per ton. Investment in equipment $1,065, power $1,000	$ 2.97
Sweep Rake		
Cutting	horse mower, 1·3 tons per hour 0·74 man hours per ton, 60 tons per year	$ 0.96
Raking	horse rake, 2·7 tons per hour 0·38 man hours per ton, 60 tons per year	0·47
Loading	hauling and storage, 1·8 man hours per ton	1·60
Total	2·9 man hours per ton. Investment in equipment $425, power $1,000	$ 3.03
Baler Method A		
Cutting	tractor mower, 2·5 tons per hour 0·39 man hours per ton, 120 tons per year	$ 0.51
Raking	side rake T., 3·0 tons per hour, 0·33 man hours per ton, 300 tons per year	0.46
Baling	hauling and storage at 2·0 man hours per ton, 300 tons per year	2.80
Total	2·7 man hours per ton. Investment in equipment $1,285, power $1,400	$ 3.77
Baler Method B		
Cutting	(as above)	$ 0.51
Raking	(as above)	0.46
Baling	hauling and storage at 2·0 man hours per ton, 600 tons per year	2.65
Total	2·7 man hours per ton. Investment in equipment 2,625, power $1,400	$ 3.62
Forage Harvester Method A—dry hay		
Cutting	(as above)	$ 0.51
Raking	(as above)	0.46
Chopping	hauling and storage at 1·6 man hours per ton, 300 tons per year	2.03
Total	2·3 man hours per ton. Investment in equipment $2,880, power $3,800	$ 3.00

Survey of Forage Crop Harvester Operations

To obtain detailed information on the use of combination forage crop harvesters as operated on private farms, a questionnaire was forwarded to one hundred farmers who owned harvesters. It is estimated that there were about 25 to 35 harvesters in use in Canada in 1945, and that 175 to 200 units were in use in 1948 At the Central Experimental Farm the harvester method of gathering silage corn has been successfully used for over 20 years. When combination harvesters designed for hay, grass and corn became available this type of machine was

Corn harvesters are specially designed for silage corn operations. With all power-take-off harvesters a large tractor is required where the corn yield is high.

SUMMARY OF REPORTS RECEIVED FROM FARMERS ON FORAGE CROP HARVESTER OPERATIONS IN 1947

Items	Highest	Lowest	Normal
Tonnage of all crops harvested in 1947	2,090	60	310
Tonnage of chopped hay	200	5	100
Tonnage of grass silage	300	15	105
Tonnage of corn	2,000	30	225
Tons per hr. for chopped hay	5	1·1	2·9
Tons per hr. for grass silage	10	1·9	4·4
Tons per hr. for corn	12	2·5	7·2
Crew used for chopped hay operation	9	1·0	3·0
Crew used for grass silage operation	8	2·0	5·0
Crew used for corn silage operation	9	1·0	6·0
Length of cut for chopped hay	6	0·7	1·5
Length of cut for grass silage	1½	¼	¼–½
Custom charge per hr. tractor, harvester, blower, fuel, and one operator	$11	$3	$6
Wilting of grass silage in hours	4	0	1¼
Horse power of tractor on harvester	38–50	12–20	25–30
Man hours per ton, chopped hay	3	0·5	1·4
Man hours per ton, grass silage	2·5	0·3	1·2
Man hours per ton, corn silage	1·5	0·3	0·9

obtained to determine its value in harvesting operations. To obtain additional information on the farm use of these machines questionnaires were distributed. The data obtained from the questionnaires is summarized in the accompanying table and lists of advantages and disadvantages of this method of harvesting crops.

According to the reports received 89 per cent of the harvesters were power-take-off driven while 11 per cent were fitted with auxillary engines. In nine out of ten cases the wagons were hauled at the rear of the harvester. Both tractors and teams were used to haul loaded wagons to the buildings and in some cases motor trucks were used for hauling silage. Reports on the quality of grass silage indicated that 56 per cent was of good quality, 31 per cent fair and 13 per cent poor. Operators of harvesters owned farms which had herds of cattle ranging from 26 to 450 head.

DISADVANTAGES OF FORAGE HARVESTER METHOD AS REPORTED BY OWNERS

Followed by Percentage of Operators referring to each item

	per cent
(1) A narrow mower cut must be used in heavy crops when cutting crop for harvester method	26
(2) High investment in machinery and tractors	21
(3) Large tractor needed on p.t.o. driven harvester	16
(4) Chopped hay dusty when ripe or too dry	14
(5) Stones picked-up in hay severly damage harvesters	9
(6) Chopped hay must be drier than long hay for storage	7
(7) No disadvantages	7
(8) Special wagon racks needed for dry hay	7
(9) Soil must be reasonably dry to operate machine on corn crop	5
(10) Long hay preferred to chopped hay	5
(11) Must not cut dry hay too short as it may heat	5
(12) More danger of spontaneous combustion	5
(13) Forage blowers too small, harvesters too light	5
(14) Broad headlands required	2
(15) Engine needed on harvester to obtain greater capacity	2
(16) Hay silage freezes to silo wall more than corn	2

ADVANTAGES OF THE FORAGE HARVESTER METHOD AS REPORTED BY OWNERS

Followed by the Percentage of Operators referring to each item

	per cent
(1) Less labour required to harvest crops	71
(2) Smaller crews can be used, 6 to 8 less men for corn	30
(3) Eliminates heavy manual labour	33
(4) Less storage space required for dry hay	31
(5) Harvests fields clean, and the corn feed is clean	16
(6) The only method for making hay silage	21
(7) Good for harvesting straw after combine	14
(8) Eliminate mowing of hay and less work in feeding hay	16
(9) No hay wasted in feeding and better hay obtained	16
(10) Hay silage eliminates weather hazards at harvest time	12
(11) Hay silage superior to corn	5
(12) Can feed all hay and corn silage, no dry hay	5
(13) One man can harvest dry hay with harvester method	5
(14) Harvester can be co-operatively used by 2 or 3 farmers	4
(15) Corn can be placed directly in silo	2
(16) Machinery investment no greater than loader, binder, etc., for corn	2
(17) Would not attempt to grow corn wlthout harvester	2

AUXILIARY EQUIPMENT

There are numerous auxiliary devices that are used with various methods of harvesting crops which are often worthy of consideration. Items such as hay slings, sliding racks, quick coupling wagon hitches, hay hoists, and various other pieces of equipment, might be included in this category. Before purchasing equipment of this type, each of the detailed operations in gathering and storing the crop should be carefully studied to discover the time-consuming jobs which might be improved. Sometimes a small and inexpensive device will materially improve a certain operation. All such equipment should be properly installed and sturdily constructed to obtain efficient operation during the harvest season.

Hay Carts

Where a small tonnage of hay is loaded by hand, the work in loading can be reduced by using a very low hay cart or wagon. Such a cart may consist of a 8′ x 14′ platform supported by a cross axle located at the rear and a set of dolly wheels at the front. The frame of this wagon may consist of two 6″ x 6″ x 13′ stringers spaced 5′ apart at the rear and fastened together at the front where the dolly wheels are attached. With 2′ diameter wheels the platform is about $1\frac{1}{2}$′ above the ground. Many variations of this type of cart or wagon have been used for hauling hay.

Preservative Application Equipment

When a preservative such as molasses is added to grass or legume silage it is occasionally applied by means of a garden sprinkling can, but there are much better means of adding preservatives to the silage. For silage cutters and for silage blowers most manufacturers can supply a molasses pump attachment

A preservative such as molasses may be fed into a blower by a power driven molasses pump or by gravity from an elevated barrel fitted with control valves and supply hose to the blower.

which consists of a pump and an automatic regulating valve. With this equipment, molasses is drawn from a barrel by the pump, flows through a regulator valve which is set according to the quantity of molasses required, then through a control valve which is operated from the feed roll on the cutter in such a manner that the molasses is shut off when no material is being fed into the machine.

In cases where a molasses pump is not available, the preservative can be fed into the blower by gravity. The barrel is placed on a stand at least 4 feet high. A pipe fitting is attached to the barrel with two valves one of which acts as a control device for the amount of molasses required while the second conveniently located valve acts as a shut-off when no material is being fed into the blower. It is preferable to feed the preservative into the side of the blower or fan housing

near the bottom through a suitable pipe fitting so that as surplus molasses will not collect on the feed table. As molasses does not flow readily by gravity it is usually diluted with an equal amount of water and then double the amount of solution is fed into the machine. By keeping molasses barrels in the sun the warmth causes the material to flow more readily. Normally about 50 to 80 pounds of molasses as supplied in drums is used per ton. If 60 pounds per ton is being used, it would require about 5 gallons of molasses per ton of silage or about $7\frac{1}{2}$ gallons per wagon load of $1\frac{1}{2}$ tons. Twice as much is used if the molasses is diluted 1 to 1. Care should be taken to shut off the molasses when the silage is not entering the blower as it will cause the blower pipe to clog.

Grapple Forks, Slings and Harpoon Forks

In general the harpoon fork is a suitable tool for unloading long hay from wagons and it is very efficient in this operation. The grapple fork is, however, sometimes preferred for hay from a second cut or poor crop when the hay length is rather short. In addition some types of adjustable grapple forks can be used in hoisting baled hay and they usually lift eight bales per load. Slings are capable of satisfactorily lifting larger loads of loose hay than forks but it is necessary to take the slings to the field and place them in the load as the load is being formed. If 600 to 800 pounds are lifted on slings a sturdy hay hoist rope and hay track is required. Slings are very suitable for hoisting hay which is hauled with a sweep rake. By placing a small hand fork full of hay on the ground or on the mow floor, spreading the slings over it, and dropping the sweep load on top of them the sweep will easily unload as it is backed away. Bales may also be hoisted into the mow with slings.

Carriage or One-Man Racks

A carriage unit can be built and used on any sturdy flat top hay rack. The carriage consists of a platform 8′ x 8′ mounted on two axles with four 5″ steel rope pulleys as wheels. These wheels run on two tracks consisting of two pieces of $\frac{3}{4}$″ pipe or $\frac{3}{4}$″ angle iron each 16 feet long which are fitted on top of the main rack and spaced $4\frac{1}{2}$ feet apart. Two front end standards of 2″ x 3″ x 6′ material are placed on the front of the carriage. At the top of these standards is fitted a roller and crank with a piece of rope to crank the carriage from the rear to the front of the main rack when it is loaded. Suitable pins should be used to lock the carriage in the rear or forward positions so that it will not roll free and hit the ends of the main rack when going up or down hill. In operation, the carriage is placed at the rear of the wagon and loaded from a hay loader and then it is cranked ahead to the front of the wagon where upon the rear section of the main rack is loaded with hay. Some farmers consider that the carriage saves much work in loading operations. When loading green hay that is to be used as silage it eliminates some of the heavy work in moving the green material to the front of the rack.

Bale Loaders and Elevators

Loaders have been devised which will pick up bales that are lying in the field and lift them to a convenient height so that one man can load a wagon or truck. These units are drawn alongside the wagon and may be traction or engine driven. Some loaders are combination units which are used for field loading and also for elevating bales into a hay mow. Under favourable conditions a loader will lift four tons of hay per hour and may average about two tons per hour. A two-man crew can hand load a wagon at the same rate. Although detailed experiments have not been conducted with loaders, it appears that they will not be extensively used unless they are improved and sell at a somewhat lower price. In cases where the combined operation of baling and storing can be carried on at the same time it is often possible to haul a wagon directly behind the baler in which case one man could pile 3 tons of hay on the wagon per hour.

Elevators may be used to advantage when stacking baled hay in the field. It is usually necessary to manually lift the bales at each end of the baler. *(Courtesy Coden Corp.)*

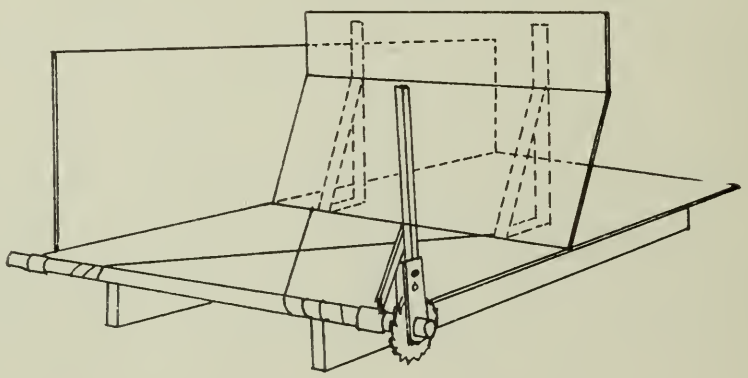
The attacking of bales is a time consuming hand operation connected with the baler method of harvesting hay. It appears that elevators or conveyors would only be of value in saving time under some circumstances as the bales are manually handled at both the bottom and the top of the conveyor. Hay tracks, often to be found in barns, can be used to elevate bales by means of slings or a grapple fork. If storage space is not severely limited bales can be dropped at random in the barn from the slings thus eliminating the hand piling of bales. In using this method, however, about half of the first supply of bales will be broken when dropped onto the floor of the hay loft, but after the floor is covered with bales fewer bales are broken as they drop from the slings. When using a four prong grapple fork to unload bales it is necessary to systematically load a wagon so that the bales are located directly over one another in order to conveniently pick up eight bales at a time with the fork.

Wagon Unloaders for Hay and Silage

Commercial wagon unloading devices which are now available will move a load from a wagon into a blower in a very satisfactory manner. One type of unloader consists of a conveyor chain with slats similar to that used in a manure spreader. Another type unloads the wagon by means of a canvas placed in the box and which carries off the load as the canvas is rolled onto a shaft at the rear of the wagon. A third type utilizes a movable false front end gate that is pulled back by cables and a hand ratchet as it drags off the load. Motor trucks with dump bodies are also being used for hauling silage to facilitate unloading. Another type of unloader consists of a hoist which lifts up the front wheels of the wagon. With either the dump truck or hoist the load slides off too rapidly for the blower and, therefore, it is necessary to check the movement of the silage by an end gate and then feed the silage into the blower with a hand rake. The chain slat and canvas unloaders are driven by a half horse power electric motor or gas engine and a gear reduction box. Speed reduction boxes cost from $100 to $175 motors about $30 and conveyor devices approximately $40 to $80 per wagon.

A flat top wagon rack with high slatted side sections, a canvas hood to retain chopped material, a hinged end gate, and a power unloader is a desirable unit for use with forage harvesters.

For canvas unloaders, some farmers have purchased gear reduction boxes to drive the unloader and have constructed their own canvas conveyor for each wagon. The gear reduction box is needed to reduce motor speed from 1,800 R.P.M. to 2 R.P.M. as required by the canvas roller shaft. To construct a canvas conveyor for a 7′ x 14′ wagon the following materials are required: a suitable gear box; eight pieces of No. 6 eighteen-ounce water-proofed canvas, 30″ x 78″ sewn together with a double seam to form a $6\frac{1}{2}$ x 20 foot sheet; one 2″ heavy duty pipe $7\frac{1}{2}$ feet long fitted with a square steel shaft at one end, and two brackets fitted onto the back of the rack to support the pipe roller. Standard



HAND OPERATED UNLOADER

Hand operated devices for unloading forage can only be used on loads of less than $\frac{1}{2}$ to 1 ton. This loader consists of an end gate, two cables or chains, and handle and ratchet for rotating a piece of pipe.

tractor power-take-off shafts and universal joints can be used to connect the pipe roller to the gear box. This style of unloader has very satisfactorily unloaded chopped silage from wagons carrying $2\frac{1}{4}$ tons as fast as it can be taken by a heavy duty blower. When using this type of unloader the canvas should be given a lap or fold 2 feet wide each time it is laid on the bottom of the rack to divide the movement of the load and reduce the strain on the canvas.

Hand-operated ratchet-type unloaders which drag off a load by means of a false front end gate are satisfactory for light loads of less than one ton. Where power unloaders are used in conjunction with forage crop harvesters crops can be harvested and stored without manually handling the crop. However, unloaders can only be used economically where a large tonnage is involved or where it is advantageous to use a minimum amount of man labour.

Power Hay Hoists

Under certain conditions of operation hay hoists may be of value in harvesting operations. Since the cost of an electric motor and wiring or a gas engine represents a considerable portion of the equipment involved, power hoists are more likely to be used where the motor or engine can also be utilized on other work such as feed grinding. A properly installed hoist with control ropes can be effectively operated by the man located on the load of hay who is handling the harpoon fork.

A hoist consists of a rope or cable drum 6″ to 8″ in diameter and 24″ long with side flanges, a clutch to operate the drum, an emergency brake on the drum and in some cases a secondary drum for a pullback rope. The main drum should be wide enough to hold sufficient rope to pull up the hay and a 6″ drum should revolve at 120 R.P.M. to give a rope speed of 200 feet per minute when exerting a pull of 400 to 600 pounds. With this arrangement a 3 H.P. electric motor will pull 500 pounds of hay out of the wagon and hoist it while a 5 H.P. motor would tear free and hoist 900 pounds of hay. Corresponding gasoline engines should have a rating of 5 or 8 H.P. Where there is no pullback drum, the hay carrier can be returned along the track by a rope and counter weight. A hay hoist should be suitably located and is normally placed, outside of the barn on the ground, on the mow floor in a box near the loading door or just below this location on the ceiling in the main part of the barn. With two control ropes the hoist can be operated by a man on the load of hay. It requires about one kilowatt hour of power to hoist three tons of hay.

Ropes and Wire Cables

The life of a hay rope varies considerably but usually ranges from 3 to 5 years. Very often undue wear is caused by faulty pulleys and by dragging the rope over small sharp stones or other such materials. Wire cables have an estimated life of about 9 to 12 years. They can be satisfactorily used to hoist hay provided they are used in pulleys with proper guides that keep the cables from coming off the wheel and provided that kinking of the cable is avoided. A $\frac{3}{8}$-inch cable can be used in place of a $\frac{3}{4}$-inch rope.

Hay Blowers

To eliminate the labour in storing hay some farmers have used a hay blower in conjunction with a sweep rake in hay harvesting operations. With this device the long hay is blown into the barn and thus hand mowing and spreading is practically eliminated.

In some instances long hay blowers have been developed from the straw blower of a discarded grain thresher. Where these blowers have suitable characteristics for moving hay they operate satisfactorily. A fan for blowing hay

Blowers suitable for long hay are sometimes made from a discarded thresher blower. The unit illustrated has a suitable fan and housing, but a flat or horizontal feed table would be more satisfactory.

into a barn loft should have the following features:— diameter 38″ to 40″, width 12″, discharge pipe diameter 12″ to 13″, blade width 6″ to 8″, and inlet diameter 24″. Fan blades require a side clearance of 2″, and a 2″ to 4″ tip clearance. The feed table usually consists of a level, slightly dished, metal sheet about 38″ wide and 40″ long. Such a fan at 1,000 revolutions per minute would elevate about 3 to 4 tons per hour with a 20 to 30 horsepower tractor. With an adjustable straw blower pipe deflector at the end of the discharge pipe, hay can be spread over a distance of 36 feet. Hay which is dropped near the blower from a sweep rake is hand fed at an even rate into the fan housing.

The sweep rake and blower method of harvesting hay does not involve heavy manual labour and one ton of hay can be readily harvested with each 80 minutes of labour. It does, however, involve two power units consisting of a tractor for the sweep or buck rake and a tractor or stationary engine of approximately 20 horsepower for the blower. Another limitation is that of the hauling distance as a tractor sweep rake is for the most part limited to a quarter mile haul. If only one tractor were used to operate the sweep and to run the blower the tonnage per hour would be reduced considerably. Although the man labour required is relatively low for this method the cost per ton is higher than the hay loader method primarily because of the two tractors required to power the sweep and the blower. With a blower, two tractors and a sweep rake the cost may range from $2.50 to $3 when about 60 tons are harvested per year. Under conditions suitable to buck rake or sweep rake operations, where the amount of hay handled is not too great and where heavy manual labour needs to be eliminated the sweep and blower method may be a suitable method of harvesting dry hay.

Hay Stackers

The hay crop can be stored in buildings or in stacks when gathered from the field by almost any method used in harvesting the crop. Although hay is stacked in all sections of the country it is often stored in buildings in Eastern Canada. Stacks are more commonly used in the Prairie Provinces where the climatic

conditions for stacking are more favourable than in areas of higher rainfall. The amount of hay which is stacked depends to some extent on the type of farming followed and on the methods of feeding which are employed. The success with which hay can be field stacked is often dependent on the art of building stacks to shed rain. Where hay is placed in stacks in the field it is not fully protected from the weather, but this method of operation eliminates the necessity of hauling the hay any distance during the harvesting operations and also eliminates or reduces the cost of storage buildings. Very often hay which has been stacked can be moved to the livestock building when there is more time available than in the harvest season. In some instances hay can be fed to livestock directly from the stack.

Although low stacks of hay can be built by hand by forking hay from a wagon, there are numerous types of devices used to aid in stacking operations. Very often the stacker used is chosen by personel preference of the farmer as there are several styles which give equal results in speed of operation and in manual labour requirements. The general types used include, overshot, boom and derrick, cable and combination sweep stackers. Combination units for sweeping hay and elevating it onto the stack normally operate with tractors while the other types are operated with either tractors or horses. Overshot, some types of boom, and combination stackers are only suitable where sweeps are used to gather hay in the field.

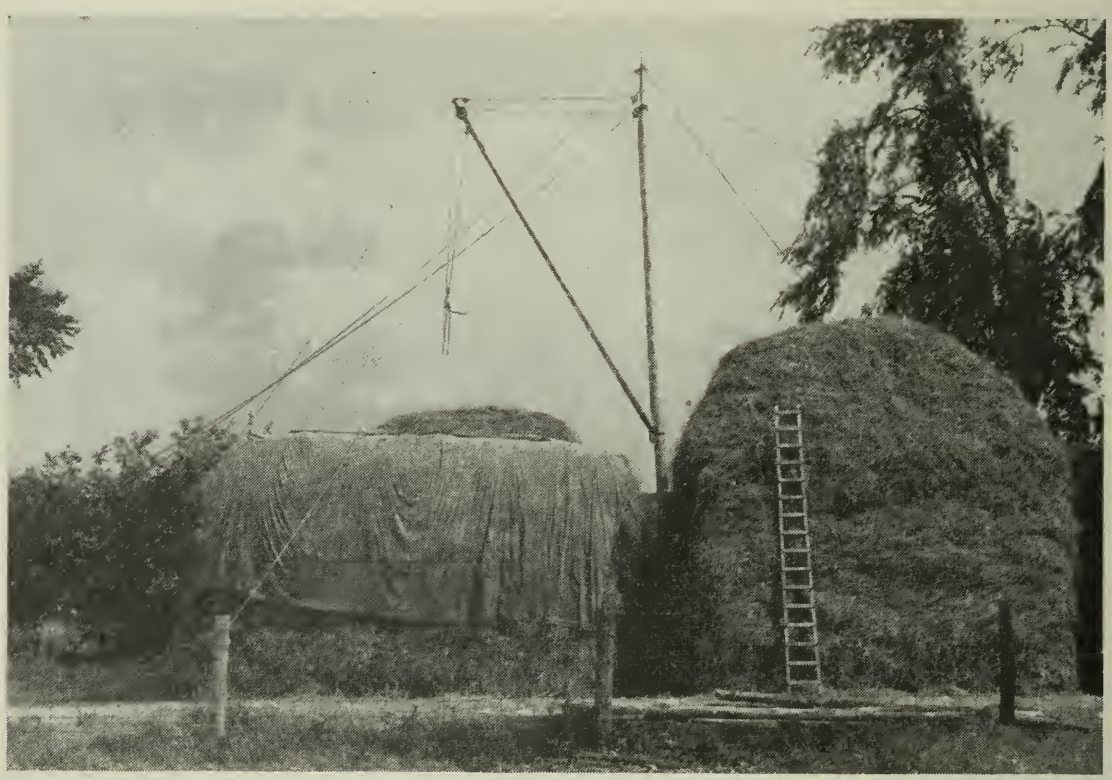
Overshot stackers are used in conjunction with sweep rakes as the hay on the sweep can be readily deposited on a similar set of teeth that form part of the overshoot stacker. Stacks about 16 feet wide and of any length can be formed with an overshot unit. Some 12 to 20 tons of hay may be added to the stack at each setting of the stacker. Depending on length of the stacker arms, stacks are built to a height of 16 to 24 feet. From 500 to 900 pounds is elevated to the stack each time the stacker arms are pulled up by means of a rope drawn by a team or tractor. Overshot stackers are built on skids and can be readily moved from place to place by a tractor. Occasionally movable frames or forms are used in

When using an overshot stacker and tractor sweep rake the tractor sweep deposits the hay on the stacker and then a team or tractor is used on the stacker draw rope to elevate the hay unto the stack.

Boom stackers built on a frame with runners can be readily moved. In the above photo the hay is being hauled on a rack fitted with skids. The entire load is being hoisted at one time by the use of slings.

conjunction with stackers as an aid in building or forming the stack. These units consist of a slatted wall or frame about 12″ x 12″ placed in a vertical position on either side of the stack.

Mast and boom, derrick and boom, and cable stackers are usually used to lift the hay to the stack by means of a harpoon fork or slings. Where slings are used,



There are many different types of stackers. With the mast and boom stacker four stacks can be built at each setting of the stacker.

hay can be taken from a wagon or from a sweep rake but when forks are used the hay is unloaded from wagons. With these stackers, as with the overshot stacker a tractor or team is used to hoist the loaded fork or slings. Mast and boom stackers require guy wires for bracing the mast and when using this unit a nest of four stacks about 16 feet square and 16 feet high are built with one setting of the stacker. Derrick and boom stackers are self supporting and can be moved more readily than mast stackers. The cable, on a cable stacker serves the same purpose as a hay track in a barn to support a carriage. The cable is anchored at each end and supported in an elevated position over the stacking area by a pair of poles at each end of the stack that hold the cable about 18 feet above the ground across the stack. For building a small stack a simple boom stacker can be made by fastening a suitable 25-foot pole or boom to a sturdy tree with the butt of the pole at the base of the tree and the top of the pole tied to the tree with a rope about 15 feet long.

When using combination sweep stackers for gathering and stacking hay, an ordinary tractor sweep is often used in conjunction with the stacker as an aid in gathering the hay on large fields.

Combination sweep stackers are constructed in various forms with some types being fully mounted on a tractor while other types are mounted on two wheels and are pushed in front of the tractor. The unit consists of a regular hay sweep fitted to a pair of arms or other mechanism by which the sweep can be lifted about 12 to 16 feet by traction lift, hydraulic hoist, or similar type of device. A combination stacker may be the only piece of equipment used in the hay harvesting operation or it may be used in conjunction with one or two ordinary sweep rakes which gather the hay while the combination unit lifts the bunches of hay to the top of the stack. Tractor mounted sweep stackers can only be used where the land is firm and smooth for gathering and transporting the hay. Loads on sweeps usually range from 500 to 800 pounds of loose hay. With a short haul, favourable conditions for using a sweep, and with an experienced crew, hay can be gathered and stacked at a rate of 1 to 1·5 man hours per ton when using a combination stacker and a crew of 2 or 3 men.

Combination tractor sweep stackers are used to gather hay from the windrow and deposit it on a stack. By field stacking hay storage building costs are reduced.

Stacking Hay

To successfully use stacks it is necessary to properly construct a stack which will shed rain. When building a hay stack, the center should be kept high, the edges should be firmly packed, the sides should slant slightly out rather than in, and the hay on the top or peak should be laid or raked to give a thatching effect to shed rain. Canvas stack covers will keep rain out of the stack, but if allowed to remain on a stack while the hay is curing they restrict ventilation, and the hay often moulds at the top, just under the canvas. Although some means of ventilation might be provided, raising the canvas at the top of the stack often subjects the canvas to wind damage. In some districts the top of small stacks are protected by a light cottage roof frame which is supported by four poles placed at the corners of the stack and which can be raised by ropes and pulleys attached to the corners of the movable roof as the stack is being built. With overshot stackers and other stackers that handle loose hay the stack must be built in a direction dictated by the wind and thus stacks sometimes have the shape of an "L" or a "T" because of changes in the direction of the wind. In using sweep stackers it is necessary to bring up or elevate the hay against the wind or it will be blown off the sweeper.

Stacking Baled and Chopped Hay

Baled hay can be stacked by hand or with the aid of a conveyor or boom stacker fitted with slings. When properly field cured, baled hay can be as successfully stacked as long hay. In the case of twine-tied bales, the twine on the bales on the ground may rot. Stacks are usually square or rectangular with a pyramid form on top. Sometimes a stack is formed which is flat on top in which case long loose hay is placed on the bales to form a circular crown. This hay is held on top of the bales by laying strands of wire across the stack that are connected to wood poles at the sides of the stack. Chopped hay has been successfully stored in stacks but as yet there is no detailed information on the best method of stacking. As chopped hay can not readily be moved it is only stacked where it can be fed from the stack. Round stacks, about 18 feet in diameter, have been made with conical tops by using two rounds of snow fence to form the stacks. It is reported that only the outer edge of the stack is tramped and that the top will shed rain. Long hay might be used of course to top or cover the stack.

APPENDIX

Factors in Making Grass or Legume Silage

Ensiling Without a Preservative

(1) Cut the crop as close to the proper stage of maturity as possible.
Alfalfa or alfalfa and clover—1/10 bloom to $\frac{1}{2}$ bloom.
Clovers, red or alsike—$\frac{3}{4}$ bloom to full bloom.
Grasses, as timothy—before bloom or part bloom.
Grains, barley or oats—late milk to early dough stage.

(2) Ensile at a moisture content of 60 to 70 per cent.

Example—With an extra heavy alfalfa-clover crop, cut at 1/10 bloom, that would yield $2\frac{1}{2}$ tons of dry hay, wilt the crop for 2 to 3 hours on a moderately good drying day when the temperature is 65 to 75 degrees and when there is a moderately bright sun, average humidity and a light breeze. If the crop is lighter, the weather warmer, with low humidity, wilt a shorter time ranging from 1 to 2 hours. If the crop is more immature or the weather dull or humid wilt the crop for a longer period. At 65 to 70 per cent moisture a sample of chopped alfalfa, when firmly squeezed in the hand, will just leave a very light trace of moisture on the hand.

Arrange the cutting schedule to correspond with the ensiling operations as closely as possible. If part of the crop becomes a little drier than desired it can be mixed with freshly cut material as the crop is loaded to obtain the desired moisture content.

(3) Chop the crop into short lengths setting the machine for a 3/8-inch cut or preferably a $\frac{1}{4}$-inch cut. Keep the knives sharp and set them close to the cutter plate.

(4) Tramp the silage thoroughly as it is put into the silo and tramp it each 3 days for about 15 days after filling.

(5) Fill the top 4 feet of the silo with green material freshly cut.

(6) Use a tight silo to eliminate wall spoilage.

Ensiling With a Preservative

A number of different preservatives may be used when ensiling crops. Complete details on the production and ensiling of various crops are contained in the Dominion Department of Agriculture publication 525 "Silage Production". In general the same procedure is used when ensiling crops either with or without a preservative. Where additives are used, however, it is possible to ensile a crop with a higher moisture content and although materials such as molasses may make a sweeter smelling silage, the addition of molasses or grain will not necessarily provide a high quality of feed unless the crop is properly ensiled. The following table lists the quantities of two of the materials commonly added to crops when they are placed in a silo. Molasses weighs 12 pounds to the gallon and the cost per pound in 1949 was $2\frac{1}{2}$ cents.

TABLE 7.—PRESERVATIVES PER TON OF GRASS SILAGE

Crop	Molasses 55% sugar	Ground barley or corn
	lb.	lb.
Legumes—alfalfa, clover, etc.	55—70	100—150
Grasses and cereals, timothy, oats, etc.	30—40	100
Mixed legumes and grasses	40—60	125

Factors in the Storage of Chopped Hay

(1) Hay chopped in 4″ lengths or longer can be stored at the same moisture content as ordinary long hay which will store in a mow without spoilage. With a machine setting of 4″ to 5″ the same storage space is required as with long hay.

(2) Hay chopped with a machine setting of $2\frac{1}{2}$″ may be stored when the moisture content is below 20 per cent. This is much drier than long hay would be for satisfactory storage. Hay cut at this length requires about one-half the storage space of dry hay.

(3) *Do not tramp or walk on chopped hay* when it is being stored in the mow. Mow the hay entirely by distributing it from the blower pipe. Frequently adjust the blower pipe nozzle to obtain even distribution.

(4) Form even swaths and even windrows in the field to obtain uniform field curing of the crop.

Silos for Grass Silage

Any type of silo normally used for corn can be used for grass silage provided it has sufficient strength to hold higher pressure developed by grass silage, and if the silo is properly constructed, in good condition, and with reasonably tight fitting walls and doors. A strong well constructed silo is required as grass silage may under some conditions exert pressures of 1 to $1\frac{1}{2}$ times that produced by corn. All of the following types of styles of silos have been used for grass silage, wood-stave, tile block, concrete block, concrete stave, timber or scantling crib, wooden-hoop, metal, fibre board, monolithic concrete, fence and trench silos. There is no means of determining the strength of a silo without detailed information on its construction and condition of the silo. Most silos built for corn have plenty of strength to take grass silage while others that were built with inferior materials and light weight materials and which are old or in a poor state of repair may not be strong enough for grass silage. Almost all silos including stave, block, metal, fibre-board and monolithic concrete types, can be easily reinforced by placing additional metal hoops on the outside of the silo.

TABLE 8.—STORAGE SPACE REQUIREMENTS FOR HAY AND SILAGE

Material	Approximate wt. per cu. ft.	Approximate cu. feet per ton
	lbs.	
Hay—loose in shallow mows	4	510 to 550
—loose in deep mows	4·5	440 to 500
—baled in tight bales	20	100
—baled in loose bales	15	130
—baled in small loose bales	10	200
—chopped extra long 4″–5″	4	500
—chopped long 2″–3″	8	250 to 300
—chopped short cut 1″–2″	11	175 to 225
Silage—shallow silos under 25 feet	30	67
—high silos	50	40
Straw—loose	4	500
—baled	12	170
Shavings—baled, slightly mosit	20	100
Concentrates	45	45
Grain (wheat at 60 lb. per bu.)	48	42

NOTE.—Approximately 150 to 200 cubic feet of silo space is required to hold one ton of dry matter. On the dry matter basis, one ton of loose dry hay requires about 560 to 620 cubic feet of space.

TABLE 9.—CAPACITY OF SILOS AT FILLING

Tons of Corn Silage at Time Silo is Filled and Without Refilling

Inside diameter in feet	Depth of Silage in Feet													
	8′	10′	12′	14′	16′	18′	20′	22′	24′	26′	28′	30′	32′	34′
10	7	9	11	14	17	20	23	26	29	33	37	41	.....	.....
12	10	13	16	20	24	28	33	38	42	48	53	58	64	70
14	13	17	22	27	33	38	45	51	58	65	72	79	87	95
16	17	23	29	35	43	50	58	67	75	85	94	104	114	124
18	22	29	37	45	54	64	74	84	96	107	119	132	144	157
20	27	35	45	55	67	79	91	104	118	132	147	162	178	194
22	32	43	55	67	81	95	110	126	143	160	178	196	215	235
24	38	51	65	80	96	113	131	150	170	199	212	234	256	279

TABLE 10.—CAPACITY OF SILOS AFTER SETTLING

Tons of Corn Silage in Silos After Settling One to Six Months

Inside diameter in feet	Depth in feet												
	10′	12′	14′	16′	18′	20′	22′	24′	26′	28′	30′	32′	34′
10	13	16	20	24	28	32	36	39	43	47	51	55	60
12	18	24	29	35	40	46	51	57	62	68	74	79	86
14	25	32	40	47	55	62	70	77	85	92	103	108	117
16	33	42	52	62	71	81	91	101	111	121	131	140	153
18	42	53	66	78	89	102	115	128	140	153	166	179	193
20	51	66	81	97	110	127	142	158	173	189	205	221	239
22	62	80	98	117	134	153	172	191	209	228	249	267	289

TABLE 11.—SILO CAPACITY AND SIZE OF HERD

Amount of Silage in a Two-Inch Depth for Silos of Various Diameters

Diameter of silo feet	Pounds of silage in 2-inch depth	Number of animal units necessary to consume silage	Diameter of silo feet	Pounds of Silage in 2-inch depth	Number of animal units necessary to consume silage
9	409	14	15	1,149	38
10	510	17	16	1,307	44
11	617	21	17	1,476	49
12	735	24	18	1,654	55
13	863	29	19	1,843	61
14	1,001	33	20	2,045	68

NOTE.—Silage consumption based on feeding dry hay and corn silage.

TABLE 12.—APPROXIMATE SILAGE REQUIREMENTS FOR DAIRY CATTLE AND STORAGE REQUIREMENTS

Per cow of 1,000 lb. weight	Feeding Hay and Silage			Feeding Silage		
	240 days	210 days	175 days	240 days	210 days	175 days
Daily	30 lb.	30 lb.	30 lb.	60 lb.	60 lb.	60 lb.
Season	7,200 lb.	6,300 lb.	5,250 lb.	14,400 lb.	12,600 lb.	10,500 lb.
Storage space	160 cu. ft.	140 cu. ft.	117 cu. ft.	320 cu. ft.	280 cu. ft.	233 cu. ft.

TABLE 13.—APPROXIMATE HAY REQUIREMENTS FOR DAIRY CATTLE AND STORAGE REQUIREMENTS

Per cow of 1,000 lb. weight	Feeding Hay			Feeding Hay and Silage		
	240 days	210 days	175 days	240 days	210 days	175 days
Daily	25 lb.	25 lb.	25 lb.	15 lb.	15 lb.	15 lb.
Season	6,000 lb.	5,250 lb.	4,375 lb.	3,600 lb.	3,150 lb.	2,625 lb.
Storage space loose hay	1,530 cu. ft.	1,167 cu. ft.	970 cu. ft.	760 cu. ft.	700 cu. ft.	580 cu. ft.

NOTE.—The bedding requirements for a dairy cow is approximately 6 lb. per day in stanchion barns. The seasonal bedding requirements range from 1,000 lb. to 1,500 lb. per cow depending on the number of barn feeding days.

TABLE 14.—ESTIMATED COST OF HARVESTING OPERATION

Operation or Machine	Machines, Size or Type	Power Units and Size	Crew	Acres and Tons per Hour		Tons per Year	Man Hours per Ton	Cost of Machine per Ton	Cost of Power per Ton	Cost of Man Labour per Ton	Total Cost per Ton	Investment	
				Acres	Tons							Equipment	Power
								$	$	$	$	$	$
Mowing	Horse 5–6′	2 horses	1	0·9	1·3	60	0·74	.25	.38	.33	.96	130	250
"	"	"	1	1·2	1·8	120	0·56	.16	.28	.25	.69	130	250
"	Tract 6–7′	2p. Tract	1	1·7	2·5	120	0·39	.23	.16	.18	.55	200	1,000
"	"	"	1	2·5	3·7	180	0·27	.17	.11	.12	.40	200	1,000
"	"	2–3p. Tract	1	1·7	2·5	180	0·39	.17	.22	.18	.74	200	1,400
Rake, dump	Horse	2 horse	1	1·8	2·7	60	0·38	.11	.19	.17	.47	70	250
"	"	"	1	2·5	3·7	60	0·27	.11	.14	.12	.37	70	250
"	"	2p Tract	1	2·0	3·0	120	0·33	.06	.13	.15	.34	70	1,000
Rake, side	"	2 horse	1	1·6	2·4	120	0·41	.17	.21	.18	.56	180	250
"	"	"	1	2·4	3·6	120	0·28	.17	.14	.13	.44	180	250
"	"	2p Tract	1	2·0	3·0	120	0·33	.17	.14	.15	.46	180	1,000
"	"	"	1	3·0	4·5	120	0·22	.17	.09	.10	.36	180	1,000
Hand load	Wagon St.	2 horses	3	0·53	0·8	30	3·5	.02	.63	1.57			
	Rack							.01					
	Slings							.15			2.38	245	250
Hayloaders L	Hayloader	2 horses	2	0·6	0·9	60	2·3	.31	.56	1.03			
	Wagon, fork							.14			2.04	445	250
Hayloader H	Hayloader H	2 horses	3		1·2	60	2·5	.57	.42	1.12			
	Wagon St.							.02					
	Rack							.01					
	Slings							.16			2.30	565	250
Hayloader H	Hayloader H	2p Tract	3·5		1·3	120	2·7	.31	.32	1·21			
	Wagon R., fork										1.84	685	1,000
Hayloader	(as above)	2p Tract	3·5		1·5	129	2·3	.41	.28	1.03	1.72	685	1,000
	" "	2–3p Tract	3·5		1·3	120	2·7	.41	.48	1.21	2.00	685	1,400
	" "	2p Tract	3·5		1·0	120	3·5	.41	.41	1.58	2.40	685	1,000
Sweep Rake	Sweep	2p Tract	3		1·5	60	2·0	.44	.28	.90	1.62	225	1,000
" "	"	"	2		1·2	60	1·7	.44	.35	.76	1.55	225	1,000
" "	"	"	2		1·2	30	1·7	.77	.35	.76	1.88	225	1,000
" "	"	"	2		1·5	60	1·3	.33					
	Blower	"						.41	.55	.68	2.97	470	2,000

Baler P.T.O.	Baler and twine	(Baling only)	1	A	2·5	120	0·4	1·05					
	or wire	2–3p Tract						.75	.27	.18	2.25	1,200	1,400
" "	(as above)	3–4p "	1	C	3·3	120	0·33	1.80	.23	.14	2.17	1,200	1,800
	"	2–3p "	2	D	3·0	120	0·66	1.80	.23	.30	2.33	1,200	1,400
	"	2–3p "	1	F	2·5	300	0·4	1.22	.35	.18	1.75	1,200	1,400
Baler Eng.	"	2–3p "	1	G	3·0	120	0·33	1.68					
	"							.75	.26	.15	2.84	2,000	1,400
" "	"	2–3p "	1	H	3·5	300	0·29	1.46	.23	.13	1.82	2,000	1,400
	"	2–3p "	2	I	3·5	300	0·58	1.46	.23	.26	1.95	2,000	1,400
	"	2–3p "	1	J	3·0	600	0·33	1.15	.26	.15	1.56	2,000	1,400
Forage Harvester	Dry Hay	2–3p Tract	4		2·5	300	1·6	.39	.25				
With Hauling and Storage	Blower	2p "						.11	.20				
	3 wagons R.	2p "						.30	.16	.72	2.10	2,500	3,900
Forage Harvester	Dry Hay	3–4p "	4		3·0	300	1·3	.80					
With Hauling and Storage	Blower	2–3p "											
	3 wagons R.	2p "							.66	.58	2.04	2,500	3,900
Forage Harvester	Hay or Silage	3–4p "	6		5·0	300	1·2	.39	.17				
With Hauling and Storage	Blower	2–3p "						.11	.14				
	3 wagons R.	2p "						.30	.10	.54	1.75	2,500	3,900
Forage Harvester													
With Hauling and Storage	Corn	3–4p "	6		8·0	300	0·75	.39					
	Blower	2–3p "						.11					
	3 wagons R.	2p "						.30	.41	.35	1.56	2,500	3,900
Hauling and storing bales	Wagon slings	2 horses	3	W	1·5	120	2·0	.02					
								.06	.33	.90	1.31	245	250
" "	"	2 horses	3	X	1·8	120	1·7	.08	.27	.75	1.11	245	250
" "	"	2p Tract	3	Y	2·2	120	1·4	.09	.23	.63	.95	375	1,000
" "	Loader	2p "	3	Z	2·5	300	1·2	.12					
	Wagon							.03					
	Slings							.06	.16	.54	.91	750	1,000
Baling	Hauling and storing Baled Hay, items A and W at 2·4 man hrs. per ton, 120 tons/year										3.56	1,445	1,400
"	Hauling and storing Baled Hay, items F and Y at 1·8 man hrs. per ton, 300 tons/year										2,70	1,445	1,400
"	Hauling and storing Baled Hay, items J and Z at 1·6 man hrs. per ton, 600 tons/year										2.47	2,750	1,400

Labour at 45c. per hour; horse labour at 25c. per hour; refer also to tables on machines, horse and tractor costs.
Investment in equipment includes wagons and all other equipment used. This combined table should serve only as example of operations.
For any specific operation on an individual farm costs should be based on prevailing rates, etc. Costs based on 1948 prices.

TABLE 15.—ESTIMATED COST OF OPERATING HARVESTING MACHINES

Machine	New Cost	Annual Use in Tons	Depreciation Interest Housing	Repair and Labour % Cost	Repair and Labour Cost	Annual Cost	Cost per Ton
	$		$		$	$	$
Mower, horse 6′	130	30	10.40	1·7	2.21	12.61	.42
		60	10.40	3·5	4.55	14.95	.25
		120	10.40	7·0	9.10	19.50	.16
Mower, tractor 6–7′	200	60	19.32	2·0	4.00	23.32	.39
		120	19.32	4·0	8.00	27.32	.32
		180	19.32	6·0	12.00	31.32	.17
Rake, Dump 10′ H	70	30	5·60	0·6	.42	6.02	.20
		60	5.60	1·2	.84	6.44	.11
		120	5.60	2·4	1.68	7.28	.06
Rake, side T	180	60	17.38	1·0	1.80	19.18	.32
		120	17.38	2·0	3.60	20.98	.17
		180	17.38	3·0	5.40	22.78	.13
Hay Loader, Light, H	200	60	16.00	1·2	2.40	18.40	.31
		120	16.00	2·4	4.80	20.80	.17
		180	16.00	3·6	7.20	23.20	.13
Hay Loader, Heavy, T	320	60	30.91	1·0	3.20	34.11	.57
		120	30.91	2·0	6.40	37.31	.31
		180	30.91	3·0	9.60	40.51	.23
Hay Tedder, H	120	60	9.60	1·0	1.20	10.80	.18
		120	9.60	2.0	2.40	12.00	.10
		180	9.60	3·0	3.60	13.20	.07
Sweep Rake, T (Buck Rake)	150	30	14.49	1·8	2.70	17.19	.57
		60	14.49	3·6	5.40	19.89	.33
		120	14.49	7·2	10.80	25.29	.21
Sweep Stacker T	250	60	24.15	1·8	4.50	28.65	.48
		120	24.15	3·6	9.00	33.15	.28
		180	24.15	7·2	13.50	37.65	.21

Stacker, Stationary H	250	120	20.00	1·8	4.50	24.50	.20
		180	20.00	2·7	6.75	26.75	.15
		240	20.00	3·6	9.00	29.00	.12
Hay Press, T	500	30	48.30	0·5	2.50	50.80	1.69
		60	48.30	1·0	5.00	53.30	.89
		120	48.30	2·0	10.00	58.30	.49
Hay Press, H	500	30	40.00	0·5	2.50	42.50	1.42
		60	40.00	1·0	5.00	45.00	.75
		120	40.00	2·0	10.00	50.00	.42
Pick-up Baler T Twine not included	1,200	120	115.92	0·8	9.60	125.52	1.05
		240	115.92	1·6	19.20	135.12	.56
		300	115.92	2·0	24.00	139.92	.47
Pick-up Baler T Twine not included	2,000	120	193.20	0·4	8.00	201.20	1·68
		240	193.20	0·8	16.00	209.20	·87
		300	193.20	1·0	20.00	213.20	·71
Forage Harvester T	1,000	120	96.60	0·8	8.00	104.60	.87
		240	96.60	1·6	16.00	112.60	.47
		300	96.60	2·0	20.00	116.60	.39
Blower, forage T	320	120	30.91	0·4	1.28	32.19	.27
		240	30.91	0·8	2.56	33.47	.14
		300	30.91	1·0	3.20	34.11	.11
Blower, long hay T	250	30	24.15	0·1	.25	24.40	.81
		60	24.15	0·2	.50	24.65	.41
		120	24.15	0·4	1.00	25.15	.21
Chopper Blower T	400	180	38.64	0·6	2.40	41.04	.23
		240	38.64	0·8	3.20	41.84	.17
		300	38.64	1·0	4.00	42.64	.14
Bale Elevator T	350	180	33.81	0·5	1.75	35.56	.20
		240	33.81	0·6	2.10	35.91	.15
		300	33.81	0·7	2.45	36.26	.12
Hay Hoist T	150	60	14.49	0·3	.45	14.94	.25
		120	14.49	0.6	.90	15.39	.13
		180	14.49	0·9	1.35	15.84	.09
Hay Track, Fork H	75	60	6.00	0·5	.38	6.38	.11
		120	6.00	1·0	.75	6.75	.06
		180	6.00	1·5	1.13	7.13	.04
Hay Crusher Mower	2,000	180	193.20	0·4	8.00	201.20	1.11

TABLE 15.—ESTIMATED COST OF OPERATING HARVESTING MACHINES—*Concluded*

Machine	New Cost	Annual Use in Tons	Depreciation Interest Housing	Repair and Labour % Cost	Repair and Labour Cost	Annual Cost	Cost per Ton or hour
	$		$		$	$	$
		Hours					per hour
Wagon, Standard H	120	(400)	9.60	0·6	.72	10.32	.03
		(800)	9.60	1·2	1.44	11.04	.01
Wagon, Rubber T	250	(400)	24.15	0·8	2.00	26.15	.07
		(800)	24.15	1·6	4.00	28.15	.04
Hay Rack H	50	(200)	4.00	1·0	.50	4.50	0.2
							per ton
Hay Silage Rack	150	(100)	14.49	0·5	.75	15.24	.15
Wagon Unloader	150	(300)	14.49	0·5	.75	15.24	.05

Depreciation based on 20 years for horse type equipment and on 15 years for power equipment.

Interest at 5% on one-half the new cost. Housing at ½% of new cost. Fuel at 20c. per gallon. Estimates do NOT include operator's wage, wire, twine, and fuel for mounted engines.

H—Horse type or horse-drawn equipment.

T—Tractor type or tractor-drawn equipment.

TABLE 16.—ESTIMATED COST OF OPERATING TRACTORS

Tractor	New Cost	Average Annual Use in Hours	Depreciation, Interest, Housing	Repairs Labour and Oil	Fuel Cost at 20¢ per gal.	Annual Cost for Average Use	250 Hours Use per Yr.	500 Hours Use per Yr.	750 Hours Use per Yr.
							Estimated Cost per Hour		
	$		$	$	$	$	¢	¢	¢
1 Plough Tractor	700	500	67.62	25	.....	92	.....	.....	.....
Light Load	(3 gal. per 10 hrs.)			.....	30	122	38	24	20
Medium Load	(5 gal. per 10 hrs.)			.....	50	142	42	29	24
Heavy Load	(7 gal. per 10 hrs.)			.....	70	162	46	33	28
2 Plough Tractor	1,000	500	96.60	40	.....	136	.....	.....	.....
Light Load	(5 gal. per 10 hrs.)			.....	50	186	56	37	31
Medium Load	(7 gal. per 10 hrs.)			.....	70	206	62	41	35
Heavy Load	(10 gal. per 10 hrs.)			.....	100	236	67	47	41
2-3 Plough Tractor	1,400	600	135.24	65	.....	200	.....	.....	.....
Light Load	(9 gal. per 10 hrs.)			.....	108	308	83	56	47
Medium Load	(12 gal. per 10 hrs.)			.....	144	344	89	62	53
Heavy Load	(16 gal. per 10 hrs.)			.....	192	392	97	70	61
3-4 Plough Tractor	1,800	700	173.88	90	.....	263	.....	.....	.....
Light Load	(10 gal. per 10 hrs.)			.....	140	403	1.02	68	56
Medium Load	(14 gal. per 10 hrs.)			.....	196	459	1.10	76	64
Heavy Load	(18 gal. per 10 hrs.)			.....	252	515	1.18	84	72

NOTE A—To determine the cost of operating tractors on a specific farm, adjust the new cost, fuel cost, etc., to local prices. Costs based on 1948 prices.

NOTE B—Interest, 5% on one-half the new cost; housing at ½ % of new cost; depreciation based on 15 years or 6.66%.

NOTE C—Operator's wage is NOT included in the above tractor costs.

NOTE D—To obtain tractor costs on 1949 prices, increase the cost per hour by 20 per cent.

TABLE 17.—ESTIMATED COST OF HORSE LABOUR

ANNUAL COSTS	$	$	COMMENTS
Feed Costs—			
Grain, 2,500 lbs. at 2¢ per lb.	50.00		*Note 1.* The average use of horses is approximately 600 hours per year.
Hay, 3 tons at $12.00	36.00		
Pasture and fencing 3 acres at $3.00	9.00		
Bedding, ½ ton at $8.00	4.00		*Note 2.* The cost of horse labour will vary according to the methods of feeding, cost of feed, etc., labour hours and man labour costs as well as on other factors. At 600 hours per year the cost per horse may range from 10¢ to 40¢ per hour.
		99.00	
Man labour—75 hrs. at 45¢ per hr.	33.75		
		33.75	
Fixed Costs—			
Depreciation—10% on $125 valuation	12.50		
Interest, 5% on one-half the valuation	3.12		*Note 3.* Cost of a 2 horse team per 10 hour day (600 hours per year) is $5.00 without operator. At 700 hours per year a team would cost $4.40 per 10 hour day.
Buildings	8.00		
Shoeing and miscellaneous	4.63		
		28.25	
Harness—cost per year	5.00	5.00	
Total cost per year		166.00	*Note 4.* The prices for grain and hay are calculated on the bases of estimated production costs, and not on market prices.
Credit of manure, 8 tons at $1.50		12.00	
Net cost per year		154.00	
Cost per hour for one horse—			*Note 5.* To obtain a more exact cost for horse labour recalculate each item on the bases of local prices for labour, feed, etc.
400 hours of use per year		38¢	
600 hours of use per year		25¢	
1,000 hours of use per year		15¢	

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