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Sizing of Liquid Manure Tank Wagons and the Economic Evaluation of Liquid Manure Injection

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Sizing of Liquid Manure Tank Wagons and the Economic Evaluation of Liquid Manure Injection

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ABSTRACT

LIQUID manure tank wagons were evaluated on a cost basis to determine the optimum size for a given livestock operation. Also the economics of adding a liquid injector to the tank wagon was studied for profitability.

INTRODUCTION

The proper selection of a liquid manure tank wagon is a problem faced by many progressive livestock producers with liquid manure systems. Selection of a manure tank wagon is usually based on the farmer's or dealer's opinion of what size is right rather than on a logical analysis including an economic analysis of the costs involved. This paper provides guidelines for selecting the proper size tank wagon for a given situation based on a least cost approach. Additionally, the economics of liquid manure injection is presented.

EXPLANATION OF THE PROBLEM

In order to select the proper size tank wagon, an economic comparison must be made. This comparison can be based upon the annual costs of using machinery of different sizes. Hunt (1977) gave the following equation for finding the approximate cost of a machine.

$$AC = [(FC\%)P/100] + (cA/SWe)\,[(R\&M)P + La + O + F + T] \quad \ldots\ldots \quad [1]$$

where:

AC = annual cost of operating a machine, \$/yr
FC% = annual fixed cost percentage
P = purchase price of machine, \$
c = conversion constant, 10
A = annual use, hectares
S = forward speed, km/h
W = width of action, m
e = field efficiency, decimal
R&M = repair and maintenance, decimal of purchase price/h
La = labor, \$/h
O = oil cost, \$/h
F = fuel cost, \$/h
T = cost of tractor use by machine, \$/h

TABLE 1. ASSUMED CONSTANT VALUES FOR USE IN THE ANNUAL COST EQUATION

Constant	Value
FC percent	16.00
R&M	0.00025
La	3.00
O	0.00
F	0.00
T	8.00

ASSUMPTIONS AND PROCEDURE

To use Hunt's equation for approximate annual costs for manure tank wagons requires some assumptions. The term cA/SWe represents hours of field use by a machine. Hours of tanker use will depend on the quantity of manure to be spread, on the tank capacity, and on the distance travelled to and from the disposal area. An assumption of 0.3-h round-trip travel time, which includes loading and unloading time, was made. Travel time multiplied by the number of trips required equals the total hours of annual machine use. The number of trips required is determined by dividing the quantity of liquid manure to be hauled annually by the wagon capacity. Values of other constants in equation [1] can be found in Table 1.

The purchase price of manure tank wagons can be expressed as a function of their capacity in liters. The purchase price per liter is not constant but varies according to capacity. Generally, the tanker price per liter decreases as the size increases with the form of the equation being:

$$p = PC\,(L)^{-y} \quad \ldots\ldots \quad [2]$$

where:

p = purchase price per liter
PC = price constant
L = tanker size in liters
y = an exponent defining the unit decrease in price for increased tanker size.

Based on 1977 retail prices obtained from several manufacturers the price per liter for vacuum tank wagons can be written as:

$$p = 4.44366(L)^{-0.18549} \quad \ldots\ldots \quad [3]$$

and for pump-filled tank wagons:

$$p = 4.25139(L)^{-0.19431} \quad \ldots\ldots \quad [4]$$

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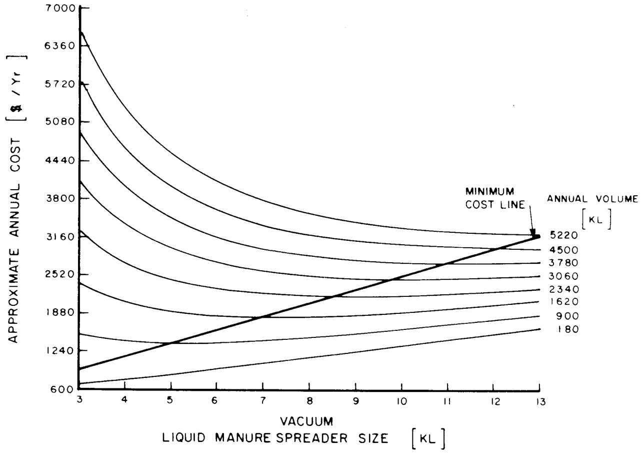

FIG. 1 Approximate annual cost of vacuum liquid manure spreaders as a function of spreader size and annual volume of manure to be hauled.

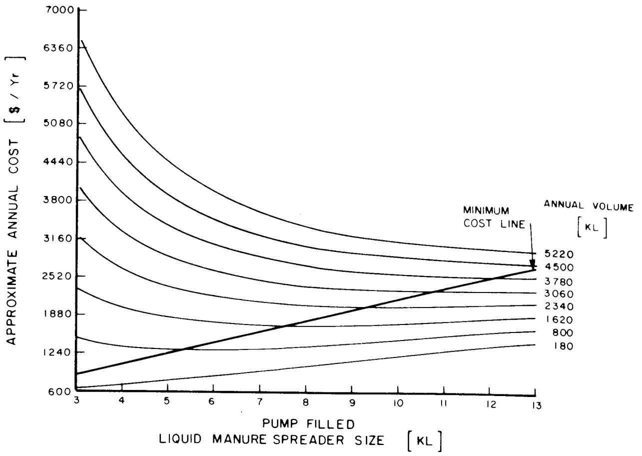

FIG. 2 Approximate annual cost of pump-filled liquid manure spreaders as a function of spreader size and annual volume of manure to be hauled.

Equation [1] can now be rewritten as:

$$AC = (0.16)\,pL + [(0.3)Tr]\,[(0.00025)pL + 3.00 + 8.00] \quad \ldots\ldots [5]$$

where:
Tr = number of round trips required.

RESULTS

Using 1977 retail prices in conjunction with equation [5], the approximate annual cost of operating vacuum-filled tank wagons as a function of tanker size and annual manure volume to be hauled is presented in Fig. 1. Fig. 2 illustrates the annual cost of pump-filled tank wagons as a function of size and manure volume hauled annually. For each volume of manure hauled annually, there is a manure tank wagon size which has the least annual cost as shown by the minimum cost line in Figs. 1 and 2. As an example, the minimum annual cost for hauling 2700 kL of manure annually with a vacuum-filled tank wagon would be associated with a tank wagon size of 9 kL (Fig. 1). Costs are higher for the smaller tank wagons because of the number of trips necessary and thus the extra time, fuel and labor costs. For the larger wagons, the higher investment cost outweighs the reduced operating costs.

Timeliness (that is, being able to accomplish the hauling operation in the least amount of time) was not considered in calculating the annual cost. In some situations, timeliness may be an important factor, possibly outweighing the cost factor. However, as illustrated in Figs. 1 and 2, selection of a tanker size larger than the optimum size does not have a large effect on the annual cost. Thus, if timeliness is a factor or if the optimum size tank wagon is not available, selection of a larger tank wagon would not cause a large increase in the annual cost. However, selecting a tank wagon smaller than the optimum size could greatly increase the annual cost.

Sensitivity Analysis

The price of a tank wagon, time required for a round trip, tractor costs, and labor costs are values which are not constant but may change with each situation. For Figs. 1 and 2, PC was calculated to be 4.44366 based on 1977 retail prices. Tractor and labor costs can be added together, resulting in an assumed value of \$11/h. Travel time was assumed to be 0.3 h for a round trip. Assuming that 2700 kL of manure is to be hauled annually, and using these values, the optimum size tank wagon required is found to be 9 kL.

In order to examine the effects of price on the model, the price equation for vacuum-filled wagons was changed to reflect a higher price. For a 9-kL tank wagon, the retail price was \$0.82/L. Replacing the constant PC = 4.44366 in equation [3] with a value of 5.0 results in a retail price of \$0.92/L for a 9-kL wagon. For this change in price the optimum size wagon is still the 9-kL wagon, although the approximate annual cost increases from \$2342 to \$2511. Thus small changes in the price do not appreciably affect the results. To check the effect of large price changes, the value of the constant PC was changed from 5.0 to 7.0 which represents a retail price of \$1.29/L for a 9-kL wagon. However, this large increase in retail price changed the optimum size tank wagon from 9 kL to 7 kL with the annual cost becoming \$3066. Large price increases thus result in smaller wagons owing to the increased investment cost.

Changing the tractor and labor costs from a total of \$11/h to \$12/h did not appreciably change the optimum size tank wagon or annual costs. However, a value of \$14/h for the tractor and labor costs caused the selection of an 11-kL wagon for the optimum size instead of the previously selected 9-kL size. The annual cost with the 11-kL size is \$2582. Thus tractor and labor costs do not have a large effect on the selection of the optimum size tank wagon and do not appreciably raise the annual cost.

The distance travelled by wagons varies for each farm situation, so the effect of travel time on the optimum tank wagon size was examined for the given conditions. The travel time was changed from 0.3 to 0.6 h of use for each round trip. This change resulted in the selection of a 14-kL tank wagon as the optimum size instead of the 9-kL size. The approximate annual cost increased to \$3273 with the use of the larger travel time. If larger tank wagons were available,

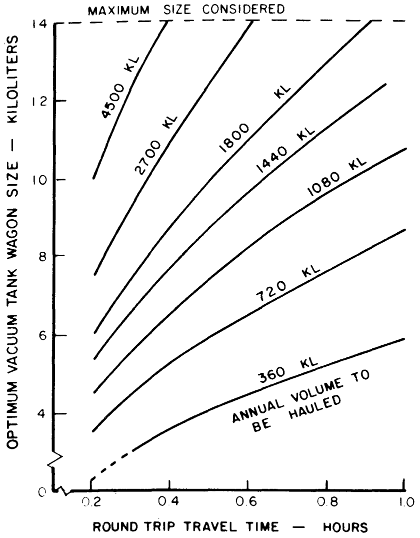

FIG. 3 Optimum vacuum tank wagon size as a function of round trip travel time and annual manure volume to be hauled.

an even larger size would have been declared optimum for a 0.8-h travel time. Thus larger operating costs involved with the larger travel time indicated that the use of a larger tank wagon would be more economical.

As previously indicated, the total manure volume to haul and the travel time of manure tank wagons are the major factors affecting the size selection and annual cost. These factors are dependent on each farm situation. Assuming that the price constant is 4.44366 and that $11/h is an appropriate tractor and labor cost, optimum tank wagon selection as a function of manure hauled annually and travel time can be obtained from Fig. 3. As an example, the optimum size wagon required to haul 2700 kL of manure annually with a travel time of 0.6 h would be 14 kL.

Injectors

Injectors for placing liquid manure underground serve two purposes: they reduce odor problems, and they reduce loss of nitrogen by volatilization.

It is difficult to assign a monetary value to odor control. For farmers living in rural areas with no close neighbors, odor control may not be a problem and surface spreading of the liquid manure is an acceptable alternative. For farmers operating near urban areas, odor control may be mandatory. In such a case, price is not the primary consideration.

In order to economically justify the cost of an injection system where odor control is not a factor and surface spreading is possible, the operating cost of injection must be less than the dollar value of nitrogen lost through volatilization. Under some conditions, injection may also reduce the loss of nutrients in surface runoff, but this will not be considered in the following analysis. Nitrogen loss from manure spread on the surface varies from 16 to 45 percent (Vanderholm, 1975) with an average loss of about 31 percent for surface-spread manure that is not incorporated for several days. Using a value of 6.0 kg of nitrogen per kiloliter of liquid beef manure and 6.6 kg of nitrogen per kiloliter of swine manure (Vanderholm, 1974) along with a nitrogen price of $0.22/kg, the dollar loss of volatilized nitrogen is $0.41/kL of beef manure and $0.45/kL of swine manure. The following figures and discussion are for beef manure. Using nitrogen values for swine manure, however, would result in similar conclusions.

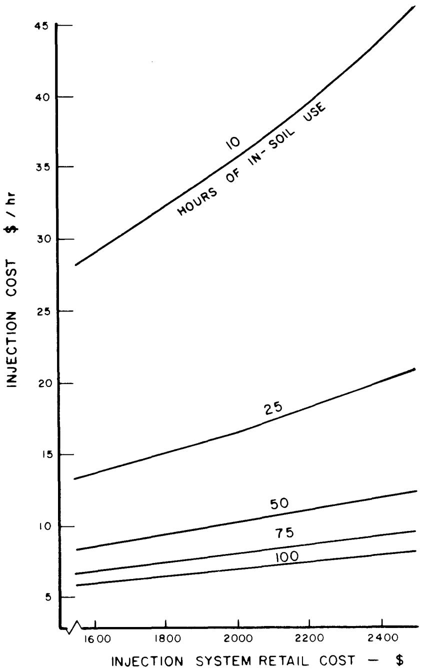

FIG. 4 Hourly cost of injection as a function of injection system retail price and hours of annual in-soil use.

Injectors add cost to the system in two ways: the cost of the additional power necessary to pull the injection chisels, and the investment cost of the injector unit. Horsfield (1974) calculated the additional power required when an injection system is used instead of surface spreading. For injection 0.2 m deep at 6.4 km/h, an additional 13.4 kW of power is needed per chisel. Using an average tractor cost of $0.11 per kW·, the additional power cost is $1.44/chisel/h. Using an injector set up with two chisels, the injection system costs $2.88 additional per hour of use. An unloading rate of 0.95 kL/min was used, which is approximately the same unloading rate as surface spreading. This unloading rate may not be achievable under all conditions, but farm experience has proved that is common. Thus the cost of the additional power to pull two chisels is $0.05/kL of manure injected.

The approximate annual cost equation including the additional power cost can be used to determine the operating cost of the injectors as a function of purchase price and hours of annual use. The results are presented in Fig. 4. As the purchase price increases, the hourly operating cost also increases. Similarly, decreased annual use also increases the hourly operating cost of the injector system.

Table 2 illustrates the hours of injector use for various herd sizes with an assumed unloading rate of 0.95 kL/min.

Using a 25 h in-soil use and a purchase price of $1550, the hourly operating cost is $13.42 (Fig. 4). The rate of manure injected is 57 kL/h, so the cost for injecting 1 kL of manure with 25 h of annual use would be $0.24. Assuming the time required to unload the

TABLE 2. HOURS OF INJECTOR USE FOR VARIOUS HERD SIZES

Dairy cows	Steers	Hogs	Kiloliter liquid manure/yr	In-soil injector, h
50	75	564	766.5	13.5
100	150	1128	1533	27
200	300	2256	3066	54
500	750	5639	7665	135

tank wagon is approximately the same for injection as for surface application, there would be no additional cost for labor or tractor use. Assuming a 5 percent nitrogen volatilization loss during and after injection and a nitrogen price of $0.22/kg, the volatilization loss for injection would be $0.07/kL. Thus the total cost of injection over surface spreading would be the volatilization loss plus the cost of the injection system per kiloliter for a total cost of 0.3/kL. The loss of nitrogen through volatilization for surface spreading would be values at $0.41 and $0.45/kL for beef and swine manure respectively. Both surface-spreading losses are substantially greater than the injection cost of liquid manure.

Three major factors determine whether manure injection is economically feasible: the nitrogen price, the retail price of the injection system, and the annual hours of in-soil use. For various combinations of these factors, there is a minimum nitrogen price for which injection is economically feasible. Fig. 5 illustrates the nitrogen price necessary to economically justify injection for a given annual usage and retail price. As an example, for a retail price of $1600 and 25 h of annual in-soil use, nitrogen prices must be above $0.15/kg to justify injection.

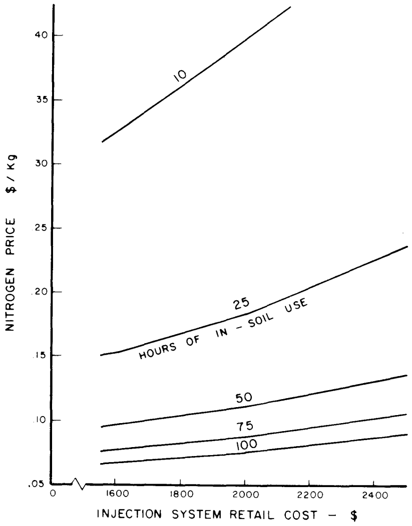

FIG. 5 Minimum nitrogen price necessary to economically justify injection as a function of injection system retail price and hours of in-soil use.

CONCLUSIONS

For each size of livestock operation, a least-cost manure tank wagon can be selected. Primary factors affecting the optimum selection are annual manure volume to be hauled, hauling time, and purchase price of the tank wagon. If timeliness is a factor, or if the optimum size tank wagon is not available, selecting a larger size wagon does not appreciably change the annual cost.

Two major factors affecting the cost of an injection system are retail price and the annual hours of in-soil use. Injection cost can be recovered through decreased nitrogen volatilization losses since injection has a lower volatilization loss than does surface spreading. At current nitrogen prices, injection of liquid manure can be economically justified for many livestock operations. Odor control was not assigned a monetary value, but would be an added benefit with injection.

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