Supercow: A Liquid Manure Applicator for Small-Plot Research

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ABSTRACT

Small-plot research in manure nutrient management requires accurate manure applicators that are easy to operate and maneuver. Our objective was to design a small-plot liquid manure applicator that could apply variable rates of dairy manure containing up to 60 g kg^{-1} solids to perennial grass plots while avoiding traffic and compaction on the plots. The applicator consists of a 1000-L fiberglass agitation tank mounted on four load cells, a delivery pump and motor, and a side-mounted boom with four nozzles for manure application, all built onto a wagon and towed by a tractor. The side-mounted boom allows manure application without traffic on the plots. Manure application typically was within 7% of the target rate and had a coefficient of variation ranging from 2 to 17%, measured over a series of rates from 53 to 211 Mg ha^{-1} (wet weight). The precision, accuracy, and ease of operation of the applicator met our research requirements. Efficiency of operation could be improved using a larger agitation tank.

Farm-scale manure applicators lack the accuracy and maneuverability needed for small-plot nutrient management research (Wetterauer and Killorn, 1998). For our research with dairy manure slurry on perennial forage grasses, we needed an applicator that would simulate big-gun sprinkler application of slurry containing up to 60 g kg^{-1} solids and would be suitable for plots 2.4 by 6 m in size. Our objective was to design a manure applicator that could apply variable rates of liquid manure to small research plots in a uniform and repeatable manner over a range of soil moisture conditions while avoiding soil compaction and traffic damage to the plots.

MATERIALS AND METHODS

The applicator (supercow) consists of a 1000-L fiberglass tank mounted on four load cells, a delivery pump and motor, and a side-mounted boom with four nozzles for manure application, all built onto a four-wheel wagon (Fig. 1). The side-mounted boom allows manure application without traffic and compaction in the plots.

The fiberglass tank has a 40-cm opening on the top for filling and contains a mechanical agitator run by a 1.5 kW (2 horsepower) gasoline motor. It has a 2.5-cm drain line at the bottom for cleaning. The load cells (Model SSB-A3-2K-15P5, Revere Transducers[1], Tustin, CA; 900-kg capacity) are wired into a common digital readout. The application pump is a self-priming centrifugal chopper pump (T3A60-B, Gorman-Rupp[1], Mansfield, OH) run by a 15 kW (20 horsepower) gasoline motor. A tee in the pump outlet line connects to the manure delivery line and to a bypass line that returns to the tank. The delivery and bypass lines are made of 5-cm galvanized iron pipe and 5-cm high pressure flexible hose. The pump cycles the manure continuously through the bypass line and tank. A hand-operated valve in the delivery line opens to deliver manure to the boom. A valve in the bypass line allows adjustment of the flow rate to the boom. A smaller (2.5 cm) outlet line from the pump is used as a sampling port.

The side-mounted applicator boom is made of 5-cm PVC and has four brass floodjet nozzles [Model 1K-450, Tee-Jet (Spraying Syst. Co.)[1], Wheaton, IL] spaced at 0.69-m intervals. We originally used flat-fan nozzles, but the pressure of their flow tended to shred the grass leaves. The boom applies manure in a band 2.75 m wide. A 5-cm sealed swivel joint at the bottom of the manure delivery line allows us to swing the boom at a right angle to the wagon during manure application and fold the boom against the wagon when not in use. The supercow is mounted on a 2- by 2.6-m four wheel wagon that is towed behind a tractor. Typical tractor speed for manure applications ranges from 0.35 to 0.90 m s^{-1}, and manure flow rates range from 7 to 15 L s^{-1}.

Two people are needed to operate the supercow: one to drive the tractor and one to operate the valves and digital readout. The tractor drives in an alley alongside the plot, and the supercow operator opens the delivery valve when the boom is about 0.3 m in front of the plot edge. The operator closes the valve after the boom has passed 0.3 m beyond the end of the plot. The application rate is calibrated by adjusting tractor ground speed and the bypass valve. Application rates are uniform as long as the level of manure in the tank remains above 15% of the tank's capacity.

We used the results from a complete season of field applications at rates ranging from 53 to 211 Mg ha^{-1} manure (wet weight) per application to calculate precision and accuracy of the supercow. We applied the lower rates using a single pass of the supercow and used two passes to make the 211 Mg ha^{-1} applications.

RESULTS AND DISCUSSION

Table 1 shows the means and standard deviations of manure applications from 19 application sets done on eight dates during a season of manure application. Solids content of the manure ranged from 31 to 49 g kg^{-1}. Mean manure application rates were within 7% of the target rate for all but one application set (Table 1). The coefficient of variation within an application set ranged from 2 to 17% and decreased with increasing target rate. In a separate test, we measured the delivery rate of each of the four nozzles on the boom. The coefficient of variation among nozzles ranged from 2.9 to 4.7% (n = 11 trials, data not shown).

To determine the effectiveness of agitation in the supercow, we mixed high-solids slurry (53–67 g kg^{-1} solids) in the tank. We collected slurry from the sampling port at three times during the application cycle:

[1] Use of trade names is for informational purposes only and does not imply endorsement by Washington State University or Oregon State University.

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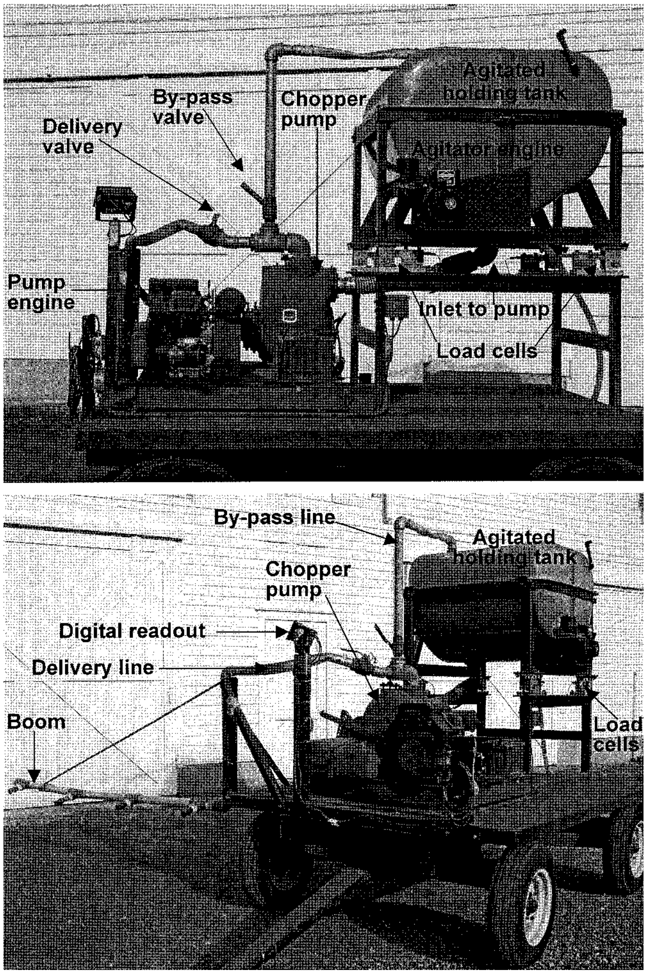

Fig. 1. Components of the supercow manure applicator for research plots.

when the tank was 100% full, 50% full, and 20% full. Mean manure solids content was the same (61 g kg^{-1}, mean of eight replicate tank loads) at all three times in the application cycle, indicating that agitation provided uniform mixing throughout the cycle.

The manure that we used was scraped directly from the loafing area and then diluted, and it sometimes contained small rocks, long grass, and other foreign matter. This caused occasional clogging of the delivery nozzles. When clogging occurred, the application was stopped and the clogs removed by hand. This likely accounted for some of the variability in application rate. In addition, the electronic board for the readout failed once because of water leakage. We subsequently protected the readout and junction while washing or storing the supercow.

Table 1. Means and standard deviations of supercow manure application rates.

Target rate	Date	No. of replicates	Manure liquid measured rate		
			Mean	SD	CV
Mg ha^{-1}			— Mg ha^{-1} —		%
53	3 May	4	53	2	4
	11 May	3	51	6	12
	12 July	12	54	9	17
	9 Aug.	12	59	6	11
	16 Aug.	12	50	5	10
106	1 Mar. (AM)	8	112	8	7
	1 Mar. (PM)	8	112	9	8
	3 May	8	108	12	11
	11 May	8	104	12	12
	12 July	16	103	9	9
	9 Aug.	20	99	10	10
	16 Aug.	20	100	13	13
211	1 Mar. (AM)	8	208	13	6
	1 Mar. (PM)	8	211	13	6
	3 May	8	217	12	5
	11 May	8	225	13	6
	12 July	4	219	15	7
	9 Aug.	3†	207	6	3
	16 Aug.	4	222	5	2

† Does not include one application where the tractor was run in the wrong gear.

The 1000-L tank was only large enough to cover one to four plots before refilling. Also, the manure tended to foam during agitation, reducing the effective volume of the tank. The small size of the tank combined with the large size of the pump probably increased the amount of foaming. The supercow could accommodate a larger tank, and we recommend a 2000-L tank as a future modification to increase volume and reduce the potential for foaming.

The applicator parts cost $15 900. The most expensive parts were the pump and motor ($7300) and the load cell and readout system ($5100). Both of these had more capacity than needed and could be reduced in size to reduce cost.

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REFERENCES

Wetterauer, D., and R. Killorn. 1998. Applicator for spreading liquid manures on small research plots. Soil Sci. Soc. Am. J. 62:486–488.