TECHNICAL NOTE

A constant flow rate surface-banded liquid manure applicator for research plot use

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Bishop, G.A., A.G. Todd and M.J. Garand 2005. **A constant flow rate surface-banded liquid manure applicator for research plot use**. Canadian Biosystems Engineering/Le génie des biosystèmes au Canada **47**: 6.35 - 6.37. Better understanding of the interactions between field application of livestock manure and various agronomic and environmental factors has prompted more small-plot nutrient management research. Cost and availability of a suitable applicator to be used with certain crop production systems have been hurdles for some manure management studies. A 2.0 m wide surface-banded liquid manure applicator was designed for small-plot manure management research on forage crops. The applicator is a constant rate gravity flow unit capable of applying manure treatments at rates of 18 to 218 m^3/ha. Applied volume is measured by displacement from the tank. Three years of experimental data showed that manure application rates were within 15% of target values with coefficients of variation between 2 and 18%. Construction costs, excluding the used manure tanker, were approximately $2000. **Keywords:** manure, land application, small plots.

La recherche sur la gestion des nutriments en petites parcelles a résulté en une meilleure compréhension des interactions entre l'épandage de lisier et différents facteurs agronomiques et environnementaux. Le coût et la disponibilité d'applicateurs adaptés à l'épandage pour certains systèmes de production ont été des obstacles pour certaines études de gestion du fumier/lisier. Une rampe d'épandage de 2,0 m de large a été conçu pour l'application en surface sur les petites parcelles de recherche en plantes fourragères. L'applicateur est une unité à débit gravitaire à taux constant capable d'épandre le lisier à des taux de 18 à 218 m^3/ha. Le volume appliqué est mesuré par le niveau de lisier dans le réservoir. Les données expérimentales recueillies sur trois ans ont montré que les taux d'application du lisier obtenus ne variaient pas de plus de 15% des valeurs désirées avec des coefficients de variation entre 2 et 18%. Les coûts de construction, excluant l'utilisation du réservoir à lisier, se sont élevés à environ 2 000$. **Mots clés**: lisier, épandage, parcelles expérimentales.

INTRODUCTION

Many of the potential nutrient losses associated with land application of livestock manure occur during the process of spreading, depending on the method of application and the uniformity of the application equipment (Wall et al. 1998). To improve the utilization of manure as a primary nutrient source, several types of applicators have been developed (Laguë 1991; Wetterauer and Killorn 1998; Bary et al. 2001) with the ability to broadcast or inject manure on small research plots. Application equipment for small-plot manure management research continues to impose some restrictions where accurate application and placement is needed as manure use is integrated into different crop production systems. Furthermore, the cost of specialized application equipment may be prohibitive. This paper describes the construction of a small constant flow rate liquid manure spreader with a drop tube applicator, similar to the surface-banding applicator described by Bittman et al. (1999), for use on forage plots and the metering system used to measure manure application.

DESCRIPTION

Manure spreader

The plot manure spreader is based on a commercial liquid manure spreader consisting of a 2400-L cylindrical steel tank mounted on a single axle and fitted with 10.00-20 tires. Wheel spacing is fixed at 2.0 m. Figure 1 shows the current configuration of the plot manure spreader. Manure application is done entirely by gravity flow since the tanker's pump has been removed. The original tank shut-off valve was removed and replaced with a 100 mm diameter ball valve. A 45° elbow was installed immediately behind the valve to direct the flow downward.

From the single central supply valve, distribution of manure across the width of the spreading apparatus is accomplished by means of two troughs mounted one above the other on the rear of the spreader. Each trough is 2.2 m long and is centered on the longitudinal axis of the manure tank. A 2.4 x 0.3-m frame, made from 50-mm square tubing, was mounted on the rear of the spreader to support the troughs. The function of the upper trough (Fig. 1 #2) is to distribute manure from the center to the ends of the trough and to restrict manure flow into the lower trough (Fig. 1 #3) to maintain an approximately equal head for each outlet. The upper trough, mounted just below the outlet valve, is triangular in shape and constructed from 12-mm plywood. Two 180-mm wide panels, hinged at the top, form the sides of the trough. Top width is set at 240 mm and the bottom opening is approximately 20 mm. Ends of the trough are sealed by inserting a piece of plywood between the panel ends and the

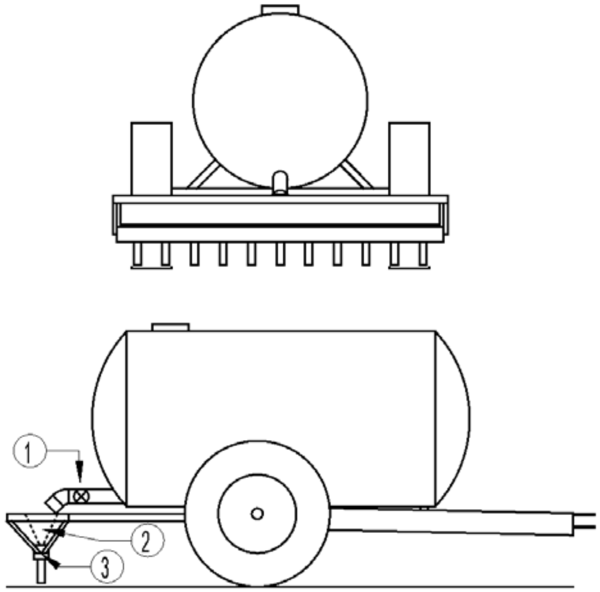

Fig. 1. Configuration of the plot manure spreader showing distribution of drop tubes and (1) location of ball valve, (2) upper distribution trough, and (3) lower distribution trough.

steel support frame. The second trough is located 50 mm below the upper trough and is centered under the upper trough opening. The lower trough is constructed from 100 x 100-mm steel channel with each end sealed by a steel plate and contains eleven 50-mm diameter drop tubes, spaced 200 mm apart. Drop tubes were fabricated by drilling 50-mm diameter holes through the bottom of the trough and welding a 25-mm length of round tubing on the bottom to clamp the drop tubes on. This resulted in drop tubes with square edge entrance openings. Lengths of braided rubber tubing (200 mm long) are used as drop tubes to convey manure directly to the ground surface. Manure is discharged from the drop tubes approximately 25 mm above the ground. Space between manure bands is about 150 mm. Overall spreading width is 2.0 m.

Spreader calibration

The volume of the manure tank was calibrated for each 25-mm increment of depth by filling the tank with water using a tipping bucket flow recorder and the measurements confirmed by calculation. Volume of water in the tank at each increment of depth was recorded and the information entered in a depth-volume chart for easy reference. A measuring stick graduated in 25-mm increments is used to measure initial manure depth and the final manure depth after each application. Applied volumes are determined from the depth-volume chart and recorded for each plot.

Application procedure

Manure was obtained at a nearby dairy farm and transported to the site in the manure tanker. A sample was taken following agitation of the manure storage and analyzed to determine the manure volume required to meet the desired treatment nutrient levels. Application rate was determined by adjusting the tractor ground speed between a minimum of 0.13 m/s and a maximum of 1.13 m/s. Several practice applications were done to determine appropriate tractor gear ratios while finer adjustments were made by changing engine speed. Three passes were required to cover each 6.0-m wide plot. Depth of manure in the tank was measured after each pass and the tractor speed adjusted to apply approximately one-third of the total plot volume per pass.

Three people are needed to apply manure, a driver, a person to open and close the valve, and another person to collect samples and measure the tank volume. The outlet valve operator walked behind the spreader to make minor valve adjustments as necessary to ensure that manure level in the lower trough remained as consistent as possible as the tank level dropped. Once the manure level in the lower trough appeared to be stable, the valve operator watched for plugging of the drop tubes. The valve operator wore rubber boots and a rain suit and was usually able to walk in the space between manure bands. Plugging occurred occasionally due to debris in the manure and was cleared by sweeping the drop tube openings with a 10-mm diameter wooden dowel. Between passes the lower trough was cleared by pushing debris down through the drop tubes.

The outlet valve was opened manually to a setting which allowed sufficient flow to spread manure across the width of the upper trough and keep the lower trough approximately half full. This setting was marked and used as a starting point for subsequent passes. Spreading was always done in an up-slope direction. On plots with side-slopes, manure flowed to the down-slope side of the applicator troughs creating some variation across the width of the plot but, the volume applied per plot remained the same. A simple trough leveling system would correct this problem but was not implemented in the current design because of the limited distance (25 mm) from the drop tube outlets to the ground. Raising one end of the trough system could result in the drop tubes on the opposite end contacting the ground and blocking manure flow. Research plots with minimal side slopes were selected to compensate for this characteristic of the applicator.

Manure flow and application accuracy

The gravity flow application method encountered continuous problems with plugging if manure obtained from the storage exceeded 20% solids. Obtaining a supply of manure while moisture content was at a maximum substantially reduced plugging of the drop tubes. Applications made using manure with approximately 10% solids resulted in one or two blocked drop tubes for each application pass.

Fluid flow through the applicator is dependent on head levels in the system as manure is applied on each plot. Constant flow rate is established by adjusting the ball valve as head is reduced in the tank to maintain an approximately consistent level in the lower trough. Flow through the drop tubes is a function of the head maintained in the lower trough and the resistance of flow into the drop tube openings and in the drop tubes themselves. Maintenance of an exact head in the lower trough is not possible with the manual adjustment system, however over the 14-16 m length of the plots, head in the lower trough could be maintained within an approximate range of 25-75 mm so each of the drop tube openings was covered. Variation in flow through each drop tube will occur because of either fluctuation of head in the lower trough or inequalities in head level caused by operating on side slopes.

The plot manure spreader was used in two different experiments. Experiment 1 ran for three years between 2000 and 2002. Two application dates with four rates of manure

Table 1. Application volumes, standard deviation, and coefficient of variation from two experiments utilizing the surface banded plot applicator.

Year	Replicates treated	Target volume (L)	Mean (L)	SD (L)	CV (%)
2000[a]	3	350[b]	330	58	18
	3	700[b]	680	76	11
	3	1200[b]	1200	50	4
	3	1700[b]	1700	50	3
2001	8	350[b]	390	35	9
	8	700[b]	760	42	6
	8	1400[b]	1390	52	4
	8	2100[b]	2090	50	2
2002[c]	4	150[d]	160	25	16
	8	300[d]	340	32	9
	8	350[b]	380	27	7
	4	450[d]	500	41	8
	4	600[d]	590	48	8
	8	700[b]	740	42	6
	4	900[d]	940	25	3
	8	1400[b]	1390	52	4
	8	2100[b]	2090	50	2

[a] Experiment 1 (one application date: 3 of 4 replicates)
[b] Experiment 1 (application volumes)
[c] Experiment 2 (one application date)
[d] Experiment 2 (application volumes)

application and four replicates were used. Plot size was 6 x 16 m. Experiment 2 was started in 2002 and consisted of two application dates with six rates of manure application and four replicates. Plot size was 6 x 14 m. Table 1 summarizes the application data compared to target volumes during each year for the two experiments. Volumes applied on the plots represented rates ranging from 18 to 218 m^3/ha. The average volume removed from the circular tank for each 25-mm depth increment was 50 L. Application volumes were rounded to the nearest 50 L to account for measurement error. Coefficient of variation (CV) (ASAE 1997) was calculated to measure the uniformity of distribution for the surface banded spreader and to compare performance data with other plot size applicators. The highest CV values were recorded for the lower rates of application which was probably due to measurement error due to the variable volume of the circular tank with each 25-mm increment of depth.

CONCLUSIONS and RECOMMENDATIONS

A constant flow rate surface-banded manure applicator was constructed for use in small-plot nutrient management experiments. Costs for materials and labour, over and above the cost of the used manure tanker, were approximately $2000. Application accuracy on plots was within 15% of target volumes. CV ranged from 2 to 18%, which was comparable to other small-plot manure applicators. The gravity flow application method had few blockages when manure moisture content was above 90%. To ensure maximum uniformity across the width of the applicator, the plots chosen should be as level as possible or with a slope in only one direction. Applying manure on side slopes caused manure to flow toward the low side of the distribution apparatus resulting in uneven coverage across the plot.

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