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Paper No. CSBE09-504

Characteristics of soil pockets resulting from AerWay rolling tines

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Written for presentation at the
CSBE/SCGAB 2009 Annual Conference
Rodd's Brudenell River Resort, Prince Edward Island
12-15 July 2009

ABSTRACT

Pocket injection method (defined as placing liquid manure into soil pockets created by a soil engaging tool, such as rolling tines) has been developed for liquid manure injection specifically in forage fields due to its low soil disturbance feature. In pocket injections, the characteristics of the soil pockets are very important, because they affect the manure placement and manure application rate. A field study was carried out in two forage fields in RM of Piney, Manitoba. One field was sandy soil, and the other was clay loam soil. AerWay box frame systems (for row crops) with two types of AirWay rolling tines (Shatter tine and Leaf tine) were used in the field study. Each type of rolling tine was operated at two different offset angles (0 and 5°) and two penetration depths (125 and 150 mm). The characteristics of the resultant pockets, including pocket distribution on soil surface, pocket opening dimension at the soil surface, and pocket volume and shape were measured. The results showed that Shatter tines could create larger soil pockets than Leaf tines. Larger pockets were observed in the clay loam soil than in the sandy soil. The 150 mm penetration depth resulted in large soil pockets than the 125 mm penetration depth. So did the 5° offset angle when compared to the 0° offset angle. Thus, the largest pockets were observed at the combination of Shatter tine arranged with the 5° offset angle and working at the 150 mm penetration depth in the clay loam soil. In this situation, the pocket opening at the soil surface had an average length of 182 mm, an average width of 44 mm, and an average area of 5555 mm^2, and the average pocket volume was 303 ml.

Keywords: AerWay, tine, soil, pocket, depth, offset angle, forage.

INTRODUCTION

Liquid manure has been used for crop production and soil improvement (Gilley and Risse 2000; Chen and Samson 2002). Injection of liquid manure below the soil surface reduces odour emissions compared to surface application (Hoff et al. 1981; Sutton 1994; Hanna et al. 2000; Chen et al. 2001). Researchers (Mueller et al. 1984; Gilley et al. 1999; van Vilet and Kenney 2000; Daverede et al. 2004) have found that injection of liquid manure also reduces surface runoff and erosion due to the soil stabilising effect of manure. Liquid manure injection systems evolved with time and currently many types of liquid manure injector are being used. Most of them are for annual crops.

Forage crops use large quantities of nutrient, and forage land poses less risk of leaching or runoff losses. Due to the high cost of chemical fertiliser, no or little chemical fertiliser is applied to forage crops. The lack of nutrients limits their production potential. Applying some of the manure to forage crops will be an economical option. In fact, more and more producers are interested in applying manure to forage fields.

Several technologies have been used for manure injection in forage fields. Those technologies included shallow injection with a disk opener, high pressure injection with a disk opener, shallow injection with a coulter and sweep (Rahman et al. 2001), as well as with runner openers (Chen et al. 2001). However, these technologies caused too much soil disturbance and are not suitable for forage fields.

SAF-Holland Equipment (Norwich, ON, Canada) developed a box frame system (BF) for manure application in row crops, and sub-surface deposition (SSD) for annual and forage crops. Both systems were developed based on their existing aerators, AerWay rolling tines. The main feature of AerWay rolling tines are their low soil disturbance, and they were originally designed for aerating grassland by creating soil pockets, which allows the movement of air and water in the soil. Those rolling tines were adapted in BF and SSD systems for manure application to improve manure infiltration (Rotz et al. 2007).

The BF or SSD systems consist of rolling tines and manure delivery nozzles placed behind the tines. As a tractor pulls the system along, the rolling tines penetrate the soil, creating soil pockets, and the nozzles deliver manure in bands over the pockets. Thus, some of the manure flows into the pockets, and some is placed on the soil surface between the pockets. Placing manure into pockets is desired, as manure is incorporated into the soil. Whereas placing manure between pockets on the soil surface is not desired as it will promote nutrient losses and odor emissions. However, due to their low soil disturbance feature, rolling tines are still considered the most appropriate tools to pursue for manure injection in forage fields, if one can overcome its drawback of placing manure on soil surface. In addition, a rolling-tine aerator can increase surface roughness and improve infiltration, conserve protective crop residues, and decrease runoff of sediment and contaminants (Harrigan et al. 2004).

In the past, there have been several studies on the AerWay aerators for manure applications. For example, McLaughlin et al. (2006) studied draft requirement of AerWay rolling tines. They found that travel speed had little effect on the draft, and increasing the offset angle (rolling tine shaft angle relative to pull direction) from 0 to 10° increased the draft. Turpin et al. (2007)

examined soil properties and found that the tine-disturbed soil had generally higher field saturated hydraulic conductivities than undisturbed soil. Studies on perennial grass showed that surface-banding slurry directly over aeration pockets using the SSD applicator reduced emission of NH_3 and odours and increased yield compared with surface broadcasting (Bittman et al. 2005; Lau et al. 2003).

Recently, a pulsing meter (Leafloor 2004; Chen and Leafloor 2006) had been designed to replace the current manure delivery nozzles. The pulsing meter delivers manure intermittently as pulses, while the nozzle system delivers manure continuously as bands. With the pulsing, each pulse of manure will be placed into a soil pocket. This method was named as pocket injection. As manure is placed only in pockets, pocket injection overcomes the drawback of placing manure on soil surface. The amount of manure placed in a pocket is defined as the pocket rate. Pocket rate (ml/pocket), together with the number of pockets per hectare, determines the manure application rate (L/ha). The question to answer is how much manure can be placed into a pocket without manure being over flow to the soil surface.

The maximum pocket rate can be considered to be equal to the volume of the pocket. Thus, studying the volume of pocket is important for the design of pocket injector. According to Knauf (2005), the AerWay DDS system created pockets with the volume varying from 130 to 300 ml, depending on the penetration depth and offset angle of the rolling tines. Typically, the penetration depth of AerWay rolling tine varies from 120 mm to 200 mm and the offset angle can be adjusted between 0 to 10°. A greater penetration depth and offset angle increase the pocket volume which favours a higher manure application rate, which is often desired in a pocket injection. Another question to answer is how easy manure can be facilitated into a pocket. A larger opening of a soil pocket would be easier for manure to flow in. It is obvious that the offset angle will affect the pocket opening dimensions. Turpin et al. (2007) reported offset angle can be adjusted to modify degree of soil disturbance and the size of the soil pocket; the greater the angle, the greater the pocket size and the soil disturbance. Also, altering the penetration depth may also change the dimensions of the pocket opening on the soil surface.

In addition to the tine penetration depth and offset angle, other factors, such as type of rolling tines and soil texture, may also have effects on the pocket volume and opening. Little information on the pocket characteristics and affecting factors is available in the literature. The objective of this study was to examine the soil pocket characteristics of AerWay rolling tines in forage fields as affected by the type of tine, offset angle, penetration depth, and soil texture.

MATERAL AND METHOD

Site description

Field experiments were conducted in two forage fields in October 2008. One field (Fig. 1A) had clay loam soil and was located in Piney, Manitoba. The other (Fig. 1B) had sandy soil and was located in Menisino, Manitoba. Both fields had a mix of alfalfa and timothy. Table 1 lists the soil composition in depths of 0-150 and 150-300 mm.

(A)

(B)

Fig. 1. Forage crop growing conditions of the test fields; (A) clay loam field; (B) sandy field.

Table 1. Summary of soil composition.

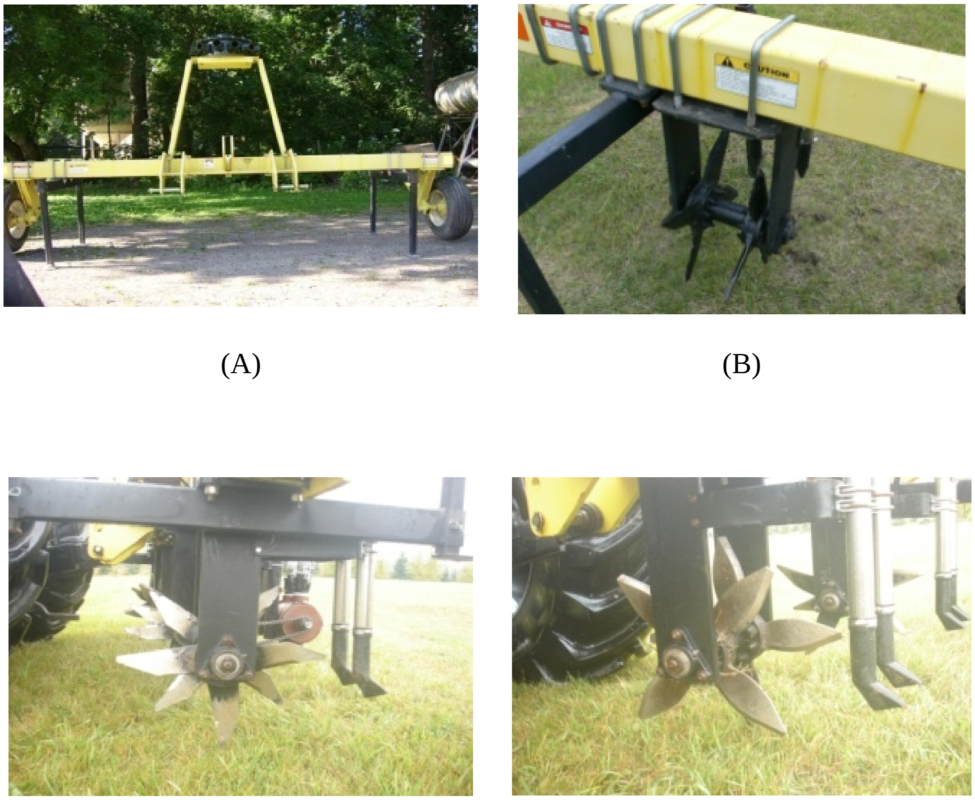
Particle (%)	Clay loam 0-150 mm	Clay loam 150-300 mm	Sandy soil 0-150 mm	Sandy soil 150-300 mm
Sand	50.89	62.91	67.28	82.49
Silt	24.31	20.72	24.07	12.47
Clay	24.8	16.38	8.65	5.04

Equipment description

A field scale tool-bar was used for the field experiments. The tool bar was 4.27 m long and had conventional three-point hitch arrangement and two support wheels (Fig. 2A). The rolling tines (Fig. 2B) used are AerWay box frame systems for row crops (Holland Hitch of Canada 2007). Only four box frames were mounted on the toolbar at 1.17 m box spacing. The large spacing was used to avoid interactions of soil disturbance between tines. Each box had two rolling wheels spaced 190.5 mm apart on the shaft (Fig. 2B). There were four rolling tines per rolling wheel. The offset angle could be adjusted between 0 and 5°. Both tines have a thickness of 12.5 mm and a length of 20 mm. Two types of rolling tines were used and they were Shatter tine (Fig. 2C) and Leaf tine (Fig. 2D).

Experimental design

The treatments were the combinations of two types of rolling tines (Shatter tine and Leaf tine), two penetration depths (125 and 150 mm), and two shafted angles (0 and 5°). These eight treatments were replicated four times. Therefore, the total number of test runs was 64. The travel speed was kept constant (5 km/h) for all plots. Shatter tines and Leaf tines were mounted on the tool bar side by side during the operation, i.e., the Shatter tine and Leaf tine treatments were performed in the same passage of the implement. This means that the experimental factor of tine type was not randomized. However, the factors of penetration depth and offset angle were randomized. The plot randomization actually used for each field is shown in Fig. 3.



(A) (B)

(C) (D)

Fig. 2. Field implement; (A) toolbar and support wheels; (B) AerWay rolling tines (box frame system); (C) AerWay Shatter tine; (D) AerWay Leaf tine.

125 mm, 5°, Leaf	125 mm, 5°, Shatter	150 mm, 5°, Leaf	150 mm, 5°, Shatter	150 mm, 5°, Leaf	150 mm, 5°, Shatter	150 mm, 5°, Leaf	150 mm, 5°, Shatter	150 mm, 0°, Leaf	150 mm, 0°, Shatter	150 mm, 0°, Leaf	150 mm, 0°, Shatter	125 mm, 0°, Leaf	125 mm, 0°, Shatter	125 mm, 0°, Leaf	125 mm, 0°, Shatter	150 mm, 5°, Leaf	150 mm, 5°, Shatter	150 mm, 0°, Leaf	150 mm, 0°, Shatter	150 mm, 0°, Leaf	150 mm, 0°, Shatter	125 mm, 5°, Leaf	125 mm, 5°, Shatter	125 mm, 5°, Leaf	125 mm, 5°, Shatter

Fig. 3. The plot layout for the field experiment in both fields; “125 mm, 5°, Leaf” stand for the treatment with the combination of 125 mm penetration depth, 5° offset angle and Leaf tine.

Measurements

Soil moisture content Initial soil moisture content was measured before the field operation. Soil cores were taken using a core sampler (diameter: 11.35 mm) at three random locations per plot to a depth of 300 mm at 50 mm intervals. Soil cores were oven-dried at 105 °C for 24 hours to determine the gravimetric soil moisture content (ASABE Standards 2006).

Soil bulk density Initial soil bulk density was measured also before the field operation. Copper core samplers (diameter: 50 mm) were used to take soil cores at three random locations per plot to a depth of 300 mm at 150 mm intervals. Soil cores were oven-dried at 105 °C for 24 hours to determine the dry soil bulk density (ASABE Standards 2006).

Pocket distribution on the soil surface Following the passes of the AerWay rolling tine, the number of soil pockets (Fig. 4A) in a 5-m distance along the travel direction was counted at five locations to determine the average longitudinal pocket spacing. Based on this spacing and rolling wheel spacing, the number of pockets per hectare was determined.

Pocket opening on the soil surface The pocket opening on soil surface was traced using a transparency (Fig. 4B) and a permanent marker. The transparency was bought back to the laboratory. The boundary of the traced pocket (Fig. 4C) was digitized to determine the area of the pocket opening. The length of pocket opening was taken as the maximum distance along the implement travel direction; the width was the average of three widths (W1, W2, and W3) equally distributed lengthwise.

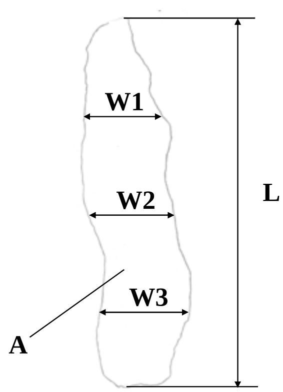
Pocket volume Pocket volume was measured by pouring sand into a pocket. First, sand was filled to the 1000-ml mark in a measuring cup, then it was poured slowly and carefully into the pocket until the pocket was full (Fig. 4D). The volume of the pocket was estimated as the different between 1000 ml and volume left in the cup.

Data analysis

ANOVA analysis was performed on the data of pocket characteristics. A mixed procedure was used since the factor of tine type was not randomised. Means between treatments were compared with Duncan’s multiple range tests. The statistical inferences were made at a 0.5 level of significant. When the interactions between the factors of penetration depth and tine angle were significant, simple effects were presented. Otherwise, main affects were presented.

(A)

(B)



(C)

(D)

Fig. 4. Top view of soil pockets; (A) pocket opening; (B) transparency used for tracing the pocket opening; (C) the definitions of the pocket width (W), length (L), and area (A); (D) sand in a pocket for measuring the pocket volume.

RESULTS AND DISCUSSION

Initial soil moisture content

Table 2 summarises the average values of soil moisture content for both soils. Both fields received some rain shortly before the field experiment. The clay loam soil had high moisture content through the entire soil profile measured. The moisture content at the 0-50 mm layer was as high as 56%. The top layer of the sandy soil site had a moisture content of 26% which was high for a sandy soil. Both fields were wet at the time of field operation. Due to the low clay content in both soils, the field operations were manageable.

Table 2. Initial soil moisture content.

Depth (mm)	Clay loam (%)	Sandy soil (%)
0-50	0.56	0.26
50-100	0.40	0.23
100-150	0.48	0.16
150-200	0.31	0.19
200-250	0.41	0.13
250-300	0.33	0.14

Soil bulk density

Table 3 showed the bulk density for the clay loam and sandy soil in two. The sandy soil had higher bulk density than the clay loam. Soil density was higher in the depth of 150-300 mm.

Table 3. Initial soil bulk density.

Depth (mm)	Clay loam (Mg/m^3)	Sandy soil (Mg/m^3)
0-150	1.06	1.37
150-300	1.14	1.68
Average	1.1	1.52

Number of pockets per hectare

In general, there were 14 pockets within the 5 m distance measured in the clay loam field and 12 pockets in the sandy field, giving the longitudinal pocket spacing of 0.36 and 0.42 m, respectively. If a rolling tine spacing of 0.19 was assumed, AerWay rolling tines would produce 146,199 pockets/ha in the clay loam field and 125,313 pockets/ha in the sandy field.

Pocket opening

The statistical analysis showed that the interaction effects of penetration depth and offset angle were significant for the clay loam field. Thus, simple effects of these two experimental factors are presented (Table 4A). For both Shatter and Leaf tines, pocket length increased with a greater penetration depth. Pocket width increased with a greater tine shaft angle. The greatest length, width, and area were demonstrated for the combination of 150 mm depth and 5° offset angle, regardless of the type of tine used.

Table 4A. Characteristics of pocket opening in the clay loam soil.

Treatment		Shatter tine			Leaf tine		
Penetration depth (mm)	Offset angle (°)	Length (mm)	Width (mm)	Area (mm^2)	Length (mm)	Width (mm)	Area (mm^2)
125	0	150b	25c	2413b	110c	17b	1216c
125	5	112c	30b	2396b	91c	27a	1703b
150	0	182a	18d	2093b	156b	20b	1088c
150	5	182a	44a	5555a	205a	27a	3212a

For the sandy soil, the interactions of penetration depth and offset angle were not significant. Thus, the main effects are presented (Table 4B). The pocket length was affected by penetration depth for shatter tines only, for which the 150 mm depth resulted a greater pocket length than the 125 mm. The larger offset angle produced wider pockets and larger opening area for both tines. No treatments differences were observed for other cases. With the same penetration depth and offset angle, pocket opening created by shatter tine was greater than that created by leaf tine.

Table 4B. Characteristics of pocket opening in the sandy soil.

Treatment	Shatter tine			Leaf tine		
	Length (mm)	Width (mm)	Area (mm^2)	Length (mm)	Width (mm)	Area (mm^2)
Penetration depth (mm)						
125	171b	19a	2570a	149a	12a	1200a
150	202a	18a	2570a	177a	11a	1382a
Offset angle (°)						
0	196a	15b	2253a	171a	9b	1216a
5	177a	22a	3107a	155a	13a	1367a

In summary, characteristics of pocket opening varied with penetration depth, offset angle, and soil texture. In most cases, the greater penetration depth and larger offset angle created greater pocket opening dimensions. In general, Shatter tine created greater pocket opening than leaf tine. Greater pocket opening may potentially favour liquid placement into the pocket. However, greater pocket opening also imply higher soil disturbance, and excessive soil disturbance in forage fields is not desirable.

Pocket volume

For the clay loam soil, the greater the penetration depth and offset angle affected the pocket volume for both tines (Fig. 5.). The mean of the pocket volume was between 69 and 303 ml. Shatter tine created larger pocket volume than Leaf tine.

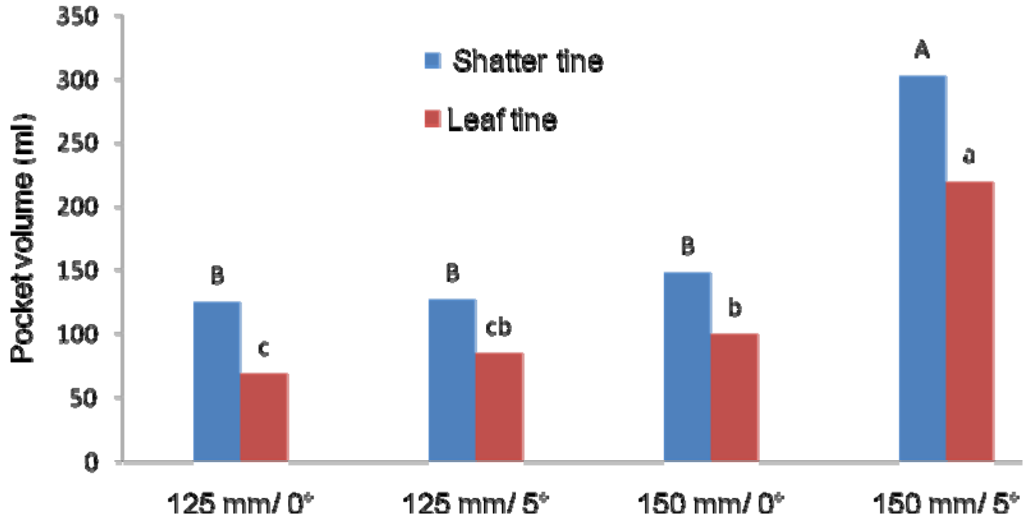


Fig. 5. Pocket volume in the clay loam soil for different combinations of penetration depth and offset angle (means followed by the same lower case or upper case letters are not significantly different).

For the sandy soil, the mean pocket volume varied between 88 and 197 ml. There were significantly increased with the greater penetration depth and offset angle for Shatter tine. However, differences between treatments were not statistically significant for Leaf tine, but still showed similar trends (Figs. 6A & 6B). With the same penetration depth and offset angle, shatter tine created greater pocket volume than leaf tine.

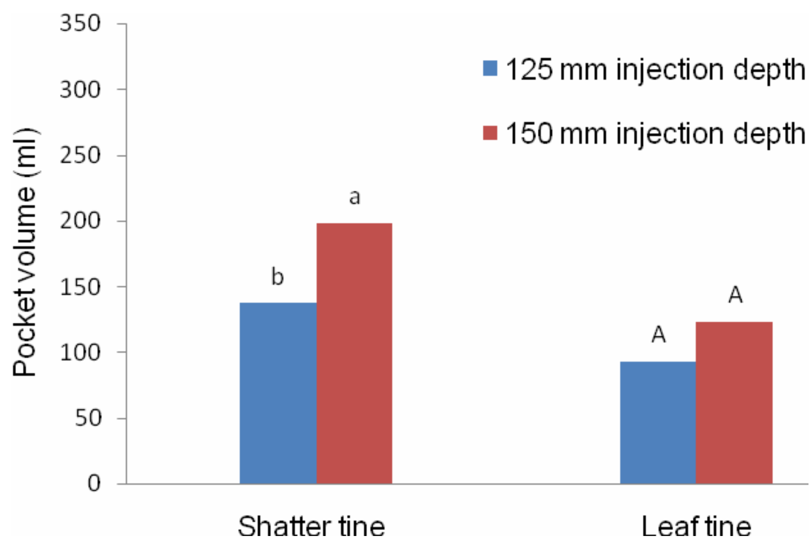


Fig. 6A. Pocket volume of AerWay rolling tines in the sandy soil with different penetration depths (means followed by the same lower case or upper case letters are not significantly different).

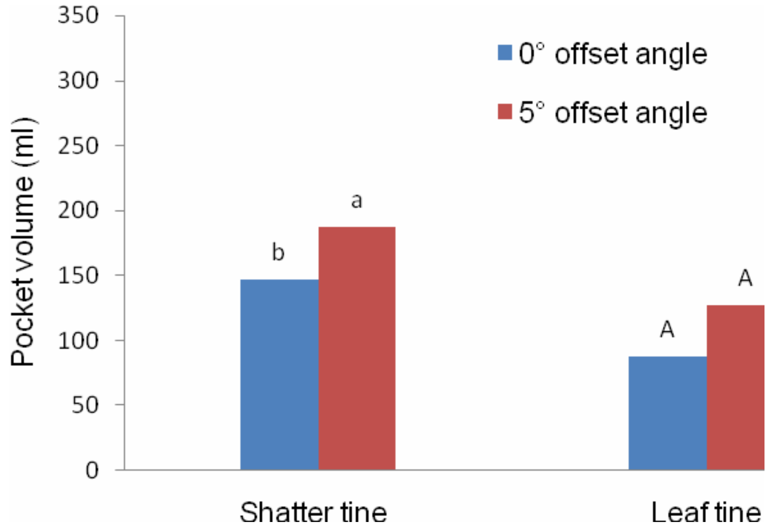


Fig. 6B. Pocket volume of AerWay rolling tines in the sandy soil with different offset angles (means followed by the same lower case or upper case letters are not significantly different).

In summary, pockets in the clay loam soil were bigger than those in the sandy soil. Shatter tine created bigger pockets than Leaf tine. Therefore, the clay loam soil and Shatter tine were better for higher manure application rates in pocket penetration. The results for pocket volume were matched with those from Knauf (2005), who reported that the pocket size from AerWay varied between 130 and 300 ml for penetration depths from 100 mm to 150 mm with 0° to 7.5° offset angles on a stony soil. Turpin et al. (2007) reported a greater range of pocket volume (361-565 ml) for the AerWay rolling tines in clay loam soil with a maximum offset angle setting and 130 mm penetration depth.

CONCLUSIONS

According to the field test, the characteristics of the soil pockets created by AerWay rolling tines varied with type of soil, type of tine, penetration depth, and offset angle. Shatter tines created larger pocket opeings than Leaf tines. Pockets openings were shorter and wider in the clay loam soil, and longer and narrower in the sandy soil. The greater penetration depth resulted in a bigger pocket opening length. The larger offset angle increased pocket volume. Pocket volumes in the clay loam soil (between 69 and 303 ml) were larger than those in the sandy soil (between 88 and 197 ml). Shatter tines created bigger pockets than Leaf tines. In general, greater penetration depth, larger offset angle, heavier soil, and Shatter tines produced greater opening and volume of pocket, which would favour higher manure application rates and easier manure placement.

ACKNOWLEGEMENT

This project was funded by the ACAAF Program of Agriculture Agri-Food Canada and SDIF program of Manitoba Conservation, Canada. Thanks are given to SAF-Holland Equipment in Norwich, Ontario for their technical and in-kind supports.

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