CHAPTER 27

Developing a Shallow Injection Tine for Slurry Application Into Grasslands

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A need for improved injection technology

In studies of existing shallow slurry injectors in Northern Europe, the injectors do not always work as desired. With hard soil conditions, the existing injectors cannot penetrate the soil, and the slurry is often left partly on the grass. Also, the existing shallow injectors place the slurry into open slots, where it is exposed to air, giving rise to ammonia emissions (Fig.1). The question was raised: Is it possible to design a tine which places the slurry into closed slots in the upper 5 cm soil level, thereby minimizing both ammonia emissions and fodder contamination by harmful bacteria? Not only is there a need to place slurry into closed slots, but also the additional tractor draft demand should be minimal and the tine should be suitable for different soil types. In grassland there is also the interaction between tine and crop; minimum impact of tine on plant growth is desired.

Note that ammonia loss is greatest when slurry is applied right after grass harvest because the slurry is fully exposed to sun and wind without the protection of the grass canopy.

In field experiments, two of the injectors used discs and one used pressurized injection (Fig. 2). Only the double disc openers managed to penetrate the soil and thereby

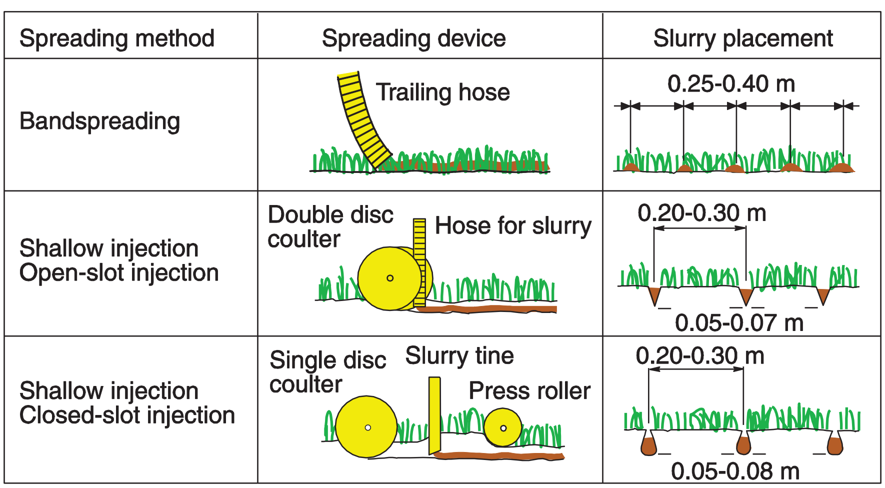


Figure 1. Principles of band spreading and shallow injection in open or closed slots. The definition of shallow is a working depth less than 0.1 m (4 in).

reduce the ammonia emissions by half compared to band spreading. The pressurized injection and the single disc tine opener did not manage to place the slurry below the soil surface.

Brainstorming the design

Development of a new shallow injection tine began with a brainstorming committee including a professor of agriculture engineering, a skilled fabricator, a soil scientist, a farm research technician and the author. After extensive discussions, the group decided on a principal design which resembled a smaller version of a 'tubulator' used in drainage (Fig. 3).

Design testing: function and draft demand on different soils

The tine was studied both in the laboratory (sand bin) and in the field in various soil types and timings. The interaction between soil conditions and tine design affected the draft demand and how well the tine penetrated the soil. A single tine was mounted either on a test rig for the sand bin or on a tractor-pulled trailer in the field. An open slot injector with two angled discs (DD) was used as the reference tine. Fortunately, the new tubulator design seemed to work under most soil conditions, although on low-density organic soils the soil did not come back together. Depth control proved to be important: injection that was too shallow could break loose clods of clay soil (brittle failure) in dry soils resulting in poor incorporation of the slurry into the soil; injection that was too deep results in unnecessarily high energy consumption, as working depth greatly affects

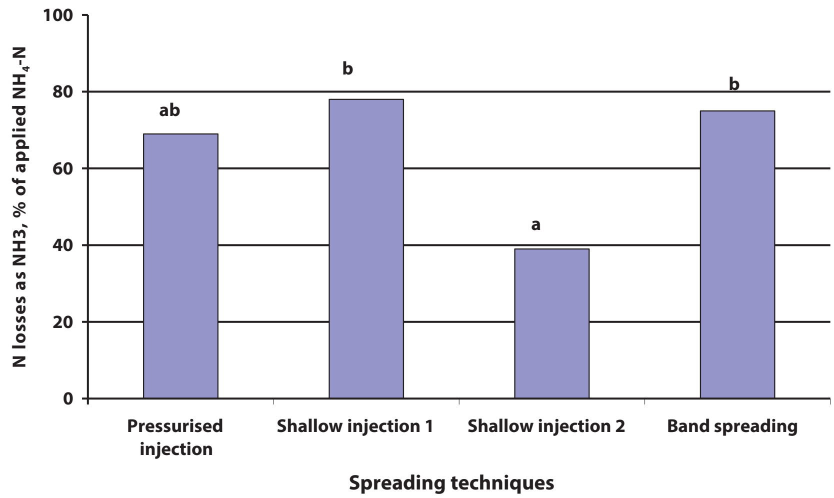
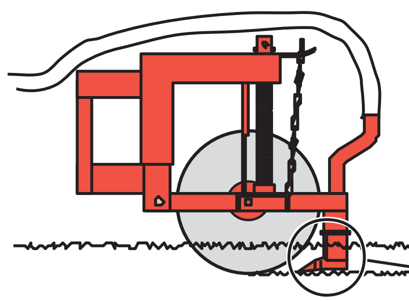


Figure 2. Loss of ammonia (% of applied) after spreading cattle slurry with four different techniques after the first cut in June, averaged over three years. Injector 1 is a single disc and injector 2 is a double disc. (Rodhe and Etana 2005).



Diameter ø, mm	Application rate tons/ha (~gal/ac)
32 (1.3in)	25 (2500)
37 (1.5 in)	35 (3500)
42 (1.7 in)	45 (4500)

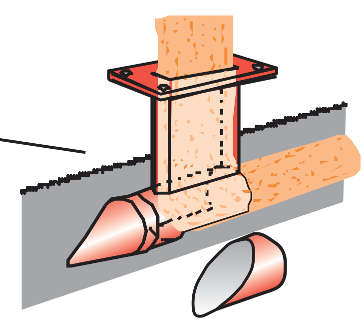


Figure 3. Principal design of the tubulator tine in three dimensions, with diameters of tube (ø) corresponding to three application rates at 0.25 m (10 in) spacing (prototype 1). Later, a press wheel closing furrow was added. (Rodhe et al. 2004).

Table 1. Horizontal and vertical forces (for lb force multiply by 224) for injectors used in two different soil conditions; for 25 t/ha (~2500 gal/ac) application rate the double disc and small tubulator were set at 5 cm (2 in) depth; for 35 t/ha (~3500 gal/ac) the double disc was set at 8 cm (3 in) depth and the medium tubulator with sharp tip (MT) at 5 cm (2 in) depth (Rodhe et al. 2004).

		Silty clay (soft)		Silty clay loam (hard)	
	Rate, tons /ha	Horizontal draft	Vertical draft	Horizontal draft	Vertical draft
			kN		
Double disc	*25*	0.48	0.95	0.88	1.86
Small tubulator	*25*	0.60	0.61	1.08	1.58
Double disc	*35*	1.03	1.53	2.22	3.10
Medium tubulator	*35*	0.62	0.61	1.19	1.49

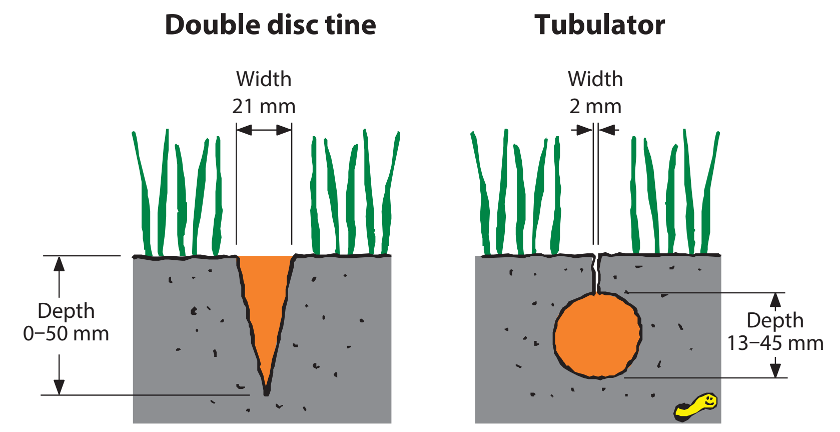


Figure 4. Placement into soil at the application rate of 25 t/ha (2500 gal/ac) with a double disc tine (open slot injection) and with the tubulator (closed slot injection).

draft demand. Of course, design parameters such as tine width, rake angle, shape and smoothness also influence the draft demand, so to minimize draft, the tine was made even more 'spool-shaped'.

The force needed for the tubulator and double disc was compared based on equivalent manure application rates. Table 1 presents the horizontal and vertical forces for the combinations of tine and depth at two different soil conditions, for the application rates 25 or 35 t/ha (~2675 or 3745 gal/ac). For applying 35 t/ha, the double disk was set at 8 cm (3 in) depth and was compared to the mid-sized tubulator tine (Fig. 3). The horizontal draft forces were similar for the two tines at 5 cm (2 in) depth, while the tubulator tine needed less vertical force to penetrate the soil.

The additional power requirement for a 6 m (20 ft) wide injector boom with 0.25 m (10 in) injector spacing, set at 5 cm (2 in) depth (speed: 6 km/h or 3.7 m/h) will be in the range of 18–44 kW (24–59 hp) depending on soil conditions. In practice, this means a need for double the tractor power.

Farm testing: slurry application

But will the tine also work with typical farm slurries? How will the slurry be placed into the soil? And, will the ammonia emissions be minimized as we hoped? The slurry was pumped through the hollow shaft to the tubulator and drained completely when the tine was lifted which prevented slurry from remaining in the plumbing. Figure 4 shows the placement of the slurry with an open slot injector and the tubulator; the tubulator-applied slurry was fully enclosed in the slot, allowing minimal ammonia emissions. The prerequisite that the tine created enough space for the slurry was fulfilled.

Commercial assessment: cooperation with industry

Working at the Research Institute and partly funded by agricultural industry, I contacted the slurry tanker manufacturer in our foundation. The company became interested in the design and a joint research application was developed to support further experiments on tubulator tines with a 4-m wide toolbar. The manufacturer minimized costs, for instance, by using a toolbar built for an open soil injector. With the additional funding, we were able to assess other performance aspects including crop yield and emissions of ammonia and greenhouse gases.

This study concluded that the tines needed to be smoother in order to minimize crop damage and 'brittle' failure. The importance of a depth regulation system was also highlighted. Ammonia emissions were not detectable, while nitrous oxide was higher from closed slot injected slurry compared with band spread (Fig. 5). However, taking into account the additional mineral fertilizers that would be needed with bandspreading (because of the ammonium loss), the greenhouse gas emissions were similar for the two methods, with ammonia reduction a clear benefit. Note that to ensure closure of the slots, an inflatable tire was mounted behind each tine.

In the second project with industry, the work continued to improve the smoothness of the tines and to test in different soil textures. The slot closing mechanism was also improved, in order to restore the sward as completely as possible thereby minimizing soil and crop damage. A newly

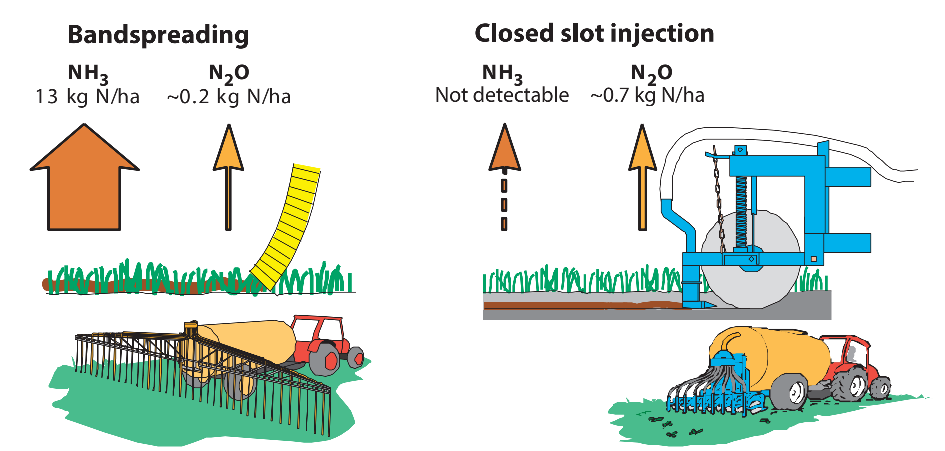


Figure 5. Ammonia and nitrous oxide emissions after application of cattle slurry to grassland either with bandspreading or with tubulator injection, application rate 25 t/ha (~2500 gal/ac) (Rodhe et al. 2006).

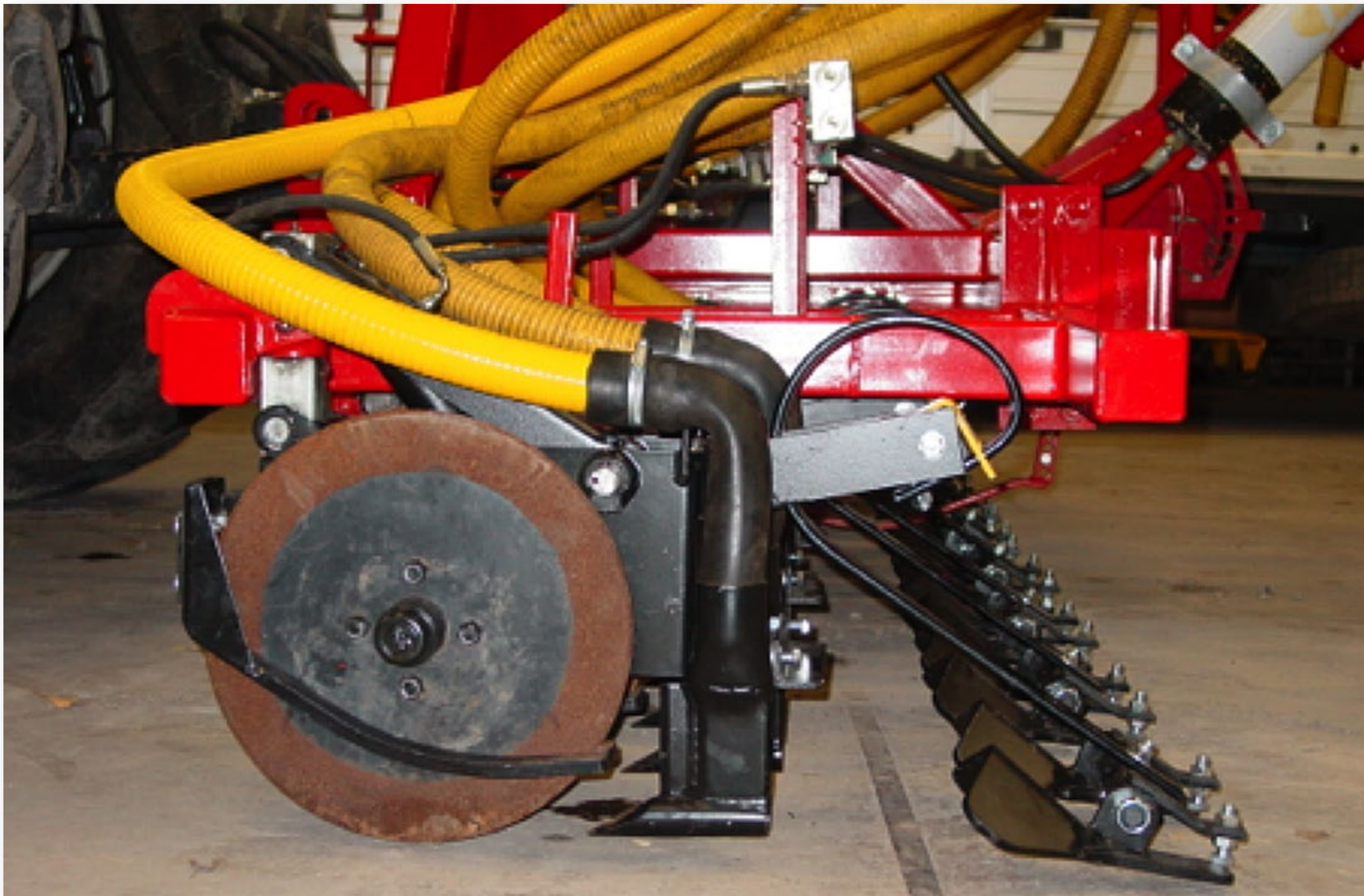


Figure 6. Prototype 4 — The closer, adapted to an existing tool bar from the manufacturer.

designed closing mechanism was placed behind the tine, mounted onto spring steel, to follow the soil surface, even when rough (Fig. 6). However, the manufacturer made some stipulations such as the use of a toolbar that was already in production. The fourth version of the tubulator works well although it requires some soil resistance; in soft soil with high organic matter content the tine acts more like a harrow tine than a cutter and injector.

Another design consideration was to enable sideways movement when meeting a big stone, so the tine was attached to spring steel. For added protection, the whole unit with disc, tine and closer was mounted with an overload protection system.

Crop damage

In another project we focused on damage to the grass stand: we examined different knife/injector tine equipment; spring and summer applications; three different grass stands; and addition of mineral nitrogen. The tubulator in Figure 6 was assessed as well as a double disc tine, vertical knife and a combination of vertical and horizontal knife. It could be concluded that both the timing and the design of the knife and injector equipment have significant influence on yield when used in grassland, with the highest yield decreases at spring use. The sum of yield over two years in average for the timings and grass stands with nitrogen added gave the relative yields of 94 (vertical knife), 92 (vertical and horizontal knife), 96 (double disc tine) and 94 (tubulator tine) compared to 100 for Control (no treatment).

Getting to market

How were we to get newly developed products onto the market? First, we needed a manufacturer interested in the product. But market demand is a key factor for the manufacturer. Today, only 4% of slurry is injected into grassland in Sweden and the interest in injection is rather low. The reasons for this are the strained farming economy together with a rather low price of nitrogen fertilizer. In analysis of low emission spreading technology, the price of nitrogen has the largest impact on profitability. In Sweden, the environmental tax on mineral fertilizers was removed to make conditions for Swedish farmers comparable to the rest of Europe. However, for organic farmers, the price of nitrogen in alternative products to manure could be rather high and therefore low emission technology could be more economically feasible. But on the whole, it is a very long process to develop new technology and to get it into the market.

References available online at www.farmwest.com

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