Soil injection of animal slurry to growing cereals – effects on odour emission, draught requirement and yield

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Background

Livestock production causes environmental problems, such as odour nuisance, which damages the reputation of livestock producers both regionally and nationally, and may cause a reduction in the value of neighbouring properties (Hansen and Petersen, 2003). Reactions of neighbours of livestock farmers to odorants are increasingly affecting existing livestock operations and may constrain the further development of livestock production. Odour is caused by a large number of chemical components produced during animal growth and present in livestock manure (Spoelstra, 1980; Tanaka, 1988; O'Neill and Phillips, 1992; Schiffman et al., 2001). Many of these odorants have been identified in livestock manure by Hobbs et al. (1995) and the major odour components in pig slurry has been found by Hobbs et al. (1998) to belong to sulphides, volatile fatty acids (VFA), and phenolic and indolic groups. The odour components are released from the slurry surface. As a large surface area of the slurry and low diffusion resistance facilitate emission of these gases, a high emission of odorants takes place following land spreading of livestock slurry.

In Denmark most odour complaints relate to the land spreading of livestock slurry. In consequence an increasing amount of the livestock slurry is injected into soil to reduce odour emissions, and today approximately one third of the slurry produced in Denmark is injected. However, due to crop damage slurry injection to winter cereals does not yet take place. The crop damage is related to the fact that soil injection to growing cereals requires significant additional draught force compared to trailing-hose application, which implies that the working width of the slurry applicator has to be lower than the distance between existing tramlines. This results in additional tracks in the field and thereby risk of additional soil compaction and substantial yield reduction. Reduction of draught force per injection unit is therefore crucial for development of an injection system resulting in low crop damage. The design of the injection devise, on the other hand, has to ensure an efficient injection of applied slurry to reduce odour emission.

The aims of the present study are therefore to develop and evaluate injection technologies that allow efficient slurry injection to winter cereals regarding reduction of odour emission, additional draught requirement, and crop damage.

Materials and Methods

Pig slurry sampled from a pig finisher house was land applied to a growing cereal crop by trailing-hoses and two different types of injection devices developed for injection into cereal crops. The simple tine was a 10 mm wide rigid steel tine and the winged tine was identical to the simple tine except two 50 mm wide wings attached at the bottom of the tine. Both tines were operating with a rake angle of 80° and the rake angle of the wings was 10°. The simple tine was operating in approximately 120 mm depth and the winged tine in approximately 80 mm depth. Before evaluation eight units of identical application devises of each application system were attached to equal experimental slurry application systems (distance between bands = 0.30 m). The experimental slurry application system allowed a precise application rate equal to 30 t ha^{-1} to separate 2.0 × 30 m plots.

The concentration of odour above the differently applied slurries was quantified by means of a static flux chamber technique. The chamber, made of hardened PVC (height = 0.60 m, length = 2.40 m, width = 1.30 m), was equipped with two oscillating internal ventilators (Desk Fan, FT6, Zhongshan, China) fixed to the top of the chamber to allow for simulation of internal wind speed and for mixing of internal air. The external surface of the chamber was covered by aluminium foil to restrict unequal solar heating of the chamber during sampling period. The slurry-treated surface was covered by the static flux chamber immediately after slurry application. 20 min after covering, 20 L of air was sucked from the chamber into 20-L Tedlar air bags using vacuum boxes. The odour concentration in the Tedlar bags was determined by dynamic dilution olfactometry within 24 h (CEN, 1999).

Identifications and quantification of odorous components in the headspace air were obtained by the following procedure. Volatile odorants in 2 L of headspace air sampled in the tedlar bags were absorbed by absorbent thermal desorption (ATD) tubes. Absorbed volatile odorants were subsequently thermally desorbed and quantified by gas chromatography/ mass spectrometry (GC/MS) analyses. Concentrations of hydrogen sulphide (H_2S) and ammonia (NH^3) in headspace air were simultaneously determined by a portable hydrogen sulphide analyzer (Jerome 631-X, Arizona Instruments), and by ammonia gas detector tubes (Gastec tubes). All air samplings and odour analyses were triplicates.

The draught requirement of injection compared to trail hose application was determined using an instrumented carriage fitted with Extended Octagonal Ring Transducers (EORT) (Godwin 1975) to which the tines were mounted. The carriage was mounted on a conventional tractor and the experiment took place at two fields near Research Centre Bygholm, a sandy soil and a sandy loam (designated *clay soil*). The soil was planted with winter cereals and was cultivated one month before the experiment took place in October 2007. The growing crop did not affect the draught measurements. The soil density was 1.29 and 1.36 g cm^{-3} for the sandy soil and the clay soil respectively. Soil disturbance was measured with a profile meter for both tines.

Crop yield of winter wheat was measured in yield experiments carried out in the growing season of 2007. Slurry was applied in the beginning of April at crop development stage 5 in Feekes scale (Large 1954) by two application methods; surface application (trailing hose) or soil injection with the simple injection tine. The fertiliser value of the injected animal slurry is given as a Mineral Fertiliser Equivalent (MFE). MFE was calculated by an estimation of the N uptake from a linear N response curve made on the basis of the yield in kg N in grains ha^{-1} from treatment 1 to 4 in Table 1, MFE express the amount of N in mineral fertiliser 100 kg of total available N in slurry appears able to replace. This means that a MFE of e.g. 50 signify that 100 kg of total N in animal slurry can be replaced by 50 kg N in mineral fertiliser.

Results and discussion

Odour emission

The two injection systems evaluated were found to ensure a significant reduction of odour concentration in air sampled above injected slurry compared to slurry applied by trailing hoses (Fig 1a). Odour concentration in the air sampled above the slurry injected by the simple injection device was higher than the odour concentration sampled above the slurry applied by the winged injection device, but concentrations sampled above both injection devices were close to detection levels, which in this study was 100 OUE m^{-3} air.

The mean concentration of H_2S in air sampled above surface and injected slurry showed a pattern similar the odour analyses. The mean H_2S concentration in air sampled above surface applied slurry was found to be higher than the H_2S concentrations in air sampled above injected slurry, although differences were not found to be significant (Fig. 1b).

Figure 1. Odour concentration in odour units (OUE) per m^3 air (a), and concentration of hydrogen sulphide (H_2S) (b) in air sampled above surface applied slurry and slurry injected in 0.12 m depth by a simple injection devise and in 0.08 m depth by a simple injection devises attached wings. Bars illustrate standard deviation (n=3)

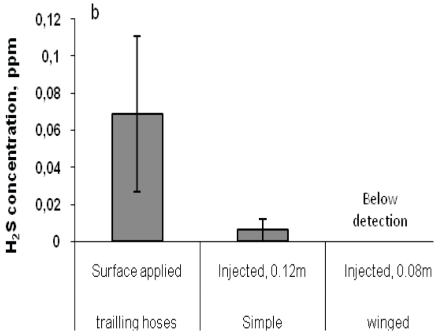
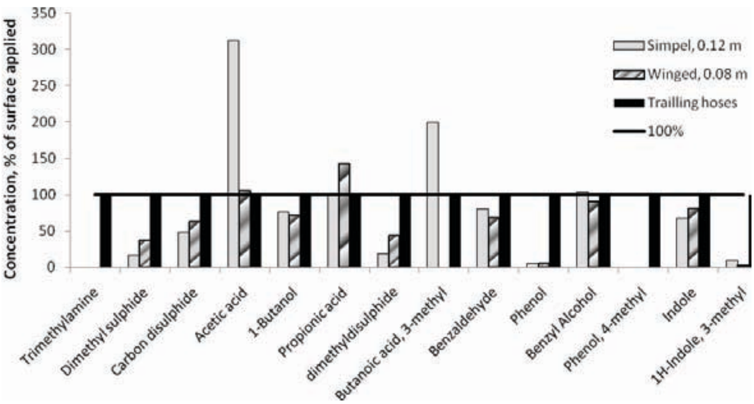


Figure 2. Mean relative concentration of odorants in air sampled above pig slurry injected by a simple injection devise in 0.12 m depth, by a winged injection devise in 0.08 m, and surface applied by trailing hoses. The concentrations of odorants in air sampled above injected slurry are shown as per cent of the mean concentration in air sampled above the slurry applied by trailing hoses

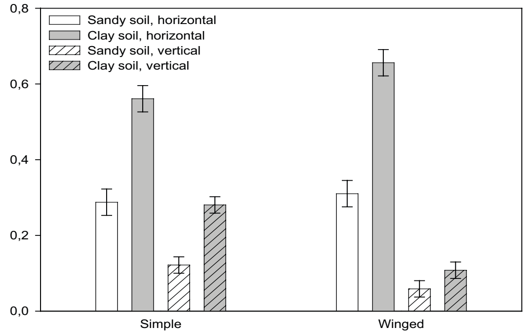


The concentrations of individual odorants in air sampled above the injected slurry were in general found to be reduced by injection (Fig. 2). The injection was found to have no or low effect on emission of odorants belonging to the group of carboxylic acids, (in particular acetic acid, propionic acid, and butanoic acid, 3-methyl), on odorants belonging to the group of alcohol (1-butanol and benzyl alcohol), and indole, while concentrations of odorants belonging to groups of amines, phenols and organic sulphides were in general reduced by more than 50% by injection.

Draught force

Both of the injection systems were found to result in a low additional draught requirement, which allows a high working width of the slurry applicator and thereby a low detrimental effect on crop yield. As shown in Figure 3 the horizontal force is almost equal for the two tines regardless of soil type. Both of the injection systems were found to result in a low draught requirement compared to other types of slurry injectors operating in cereal crops, reported (Pullen et al. 2004; Rodhe, Rydberg, & Gebresenbet 2004). This could potentially allow a high working width of a slurry applicator mounted with these tines.

Figure 3. Horizontal and vertical force measured for the simple and winged tine. The simple tine operates in 100 mm and the winged tine in 50 mm. Positive vertical force means an up trust movement of the tines. Error bars represent standard deviation (n=3).



The soil disturbance was almost the same for the two tines (data not shown) and therefore the specific resistance (N cm^{-3} loosened soil) was surprisingly equal. Ahmed & Godwin 1983 and Godwin & Spoor 1977 suggested that the specific resistance should be lower for winged tines compared to comparable simple tines, due to the extra soil disturbance created by the wings which should cost relatively less draught force because of the lower rake angle of the wings than the rake angle on the leg and tip of the simple tine. The shallow operating depth in this study could explain the missing effect of adding wings on the simple tine regarding specific resistance. The wings will simply not create very much extra soil disturbance due to the relatively wide soil disturbance profile in the upper soil layer.

Table 1. Yield response of winter wheat to different applications of mineral fertiliser and animal slurry (n = 5×4 = 20) (Knudsen 2007)

Treatment	Applied kg N NH_4-N ha^{-1}	Application method	Yield, kg N in grains ha^{-1}	Yield, tonnes grains ha^{-1}	Mineral fertiliser equivalent
1	0 mineral		59	4.81	-
2	100 mineral*	broad	100	7.52	-
3	150 mineral*	broad	124	7.91	-
4	200 mineral*	broad	142	7.93	-
5	50 mineral + 100 NH_4-N	trailing hose	113	7.66	63
6	50 mineral + 100 NH_4-N	soil injection	121	7.61	80
LSD	-	-	-	0.80	-

* rate of fertiliser applied split into two times, first application was around 1st of April and second time approximately 30 days later.

The vertical force was reduced by approximately 50 % for the winged tine compared to the simple tine, which can be explained by the low rake angle of the attached wings (Godwin & O'Dogherty 2007). This could be an important parameter if these tines should be mounted on a wide slurry injector, where little weight can be transferred to the tines by the boom construction.

Effect on yield

The yield experiment showed better utilisation of the nitrogen content of injected slurry compared to application by trailing hoses, see Table 1. The better utilisation occurred probably due to lower ammonia emission when slurry was injected and thereby more ammonium available for the crop, which resulted in higher protein content of the grains and thereby higher yield in N ha^{-1}. Yield in tonnes grains ha^{-1} was not affected by application method which can be explained by the relatively high yield response in general of the two treatments where animal slurry was used as fertiliser.

Conclusion

The two injection systems evaluated were found to ensure a significant reduction of odour emission from injected slurry compared to slurry applied by trailing hoses. Injection in 80 mm depth with a winged injector was just as effective as injection in 120 mm with a simple injector. Regarding draught force no significant difference between the two injection systems was measured. Both of the injection systems were found to result in a low additional draught requirement, which allows a high working width of the slurry applicator and thereby a low detrimental effect on crop yield. Nutrients from animal slurry was utilised better when slurry was injected than surface applied.

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