Int. Agrophysics, 1994, 8, 93-101

MANURE CHARACTERIZATION

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A b s t r a c t. The results of the investigations showed that manure properties do affect the performance of manure spreaders. Different spreader types are influenced in different ways when the manure properties change. Dry matter content alone is not enough to completely describe the relevant physical properties of the manure. There are connection between at least some of the proposed characterization parameters and important spreading characteristics like, e.g., manure flow and working width. The relevance of other characterization parameters need to be further investigated in the future.

K e y w o r d s: manure, manure spreaders, physical properties

INTRODUCTION

A problem encountered when testing and developing manure spreaders is that the performance of the spreaders is affected by the physical properties of the manure used in the tests. Manure properties also affect the performance and reliability of the spreaders and other manure handling equipment in practical use on farms.

In order to ensure replicability when testing manure spreaders and facilitate the evaluation of new technical solutions, it is necessary to characterize the manure. At the Swedish Institute of Agricultural Engineering (JTI), some work has been done on the development of methods and equipment for this purpose.

MANURE - A HETEROGENEOUS PRODUCT

Manure is a very heterogeneous product containing everything from urine, faeces and straw material to bale strings, pieces of wood and stones.

The properties of the manure depend, among other things, on the type of animal, animal age, pregnancy status, production level and feed composition. After having left the animal, the manure is mixed with additives like litter, feed residues, urine and water. At the same time, microbial activity continuously changes the properties of the manure. Depending on the climate in the barn, there is also greater or lesser water evaporation.

Although there are clear connections between several of the factors mentioned and manure properties, the complexity of the problem makes it very hard to predict the properties of manure even when the factors are known. It is, however, important to remember that the farmer can affect the manure and its properties by changing one or more of the factors.

Another, more feasible way of getting information about the manure is to measure the properties directly. A survey of the literature revealed that scientists throughout the world have attempted to characterize manure by measuring numerous different properties. However, the study also revealed that there is a lack of overall knowledge about which properties are important and how they should be measured. Consequently, JTI has elaborated a proposal on this matter.

Important physical properties

In Sweden, organic manure is normally referred to as four types, namely solid manure, semi-solid manure, slurry and urine. Considering which physical properties are important, however, this depends mainly on whether the manure is going to be pumped or not. 'Pumpable manure' includes urine and slurry, 'non-pumpable' manure includes semi-solid and solid manure.

For manure which can be pumped, the following four properties were considered important:
- fluidity,
- separation tendency (short time),
- risk of clogging,
- dry matter (DM) content.

For manure which cannot be pumped, five properties were considered important:
- bulk density,
- stacking ability,
- comminution resistance,
- heterogeneity,
- dry matter (DM) content.

Measuring methods

Since the properties of interest are not the same for pumpable and non-pumpable manure, different measuring methods and equipment were developed for these two kinds of manure.

Pumpable manure

Fluidity can be measured either with the 'fluidimeter method' (Fig. 1) or with the 'ball method' (Fig. 2). Since the fluidimeter is much simpler to handle, this method should be recommended.

The principle of the fluidimeter is rather simple. The container is filled up with slurry.

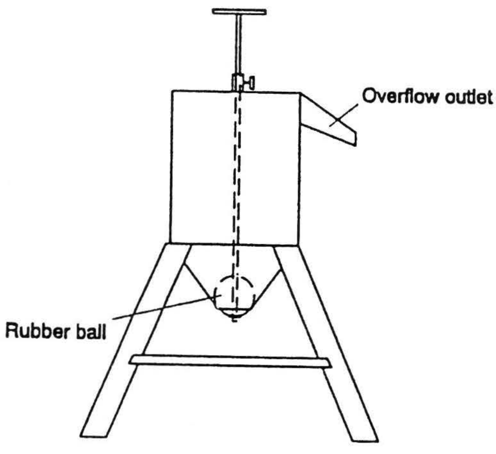

Fig. 1. The fluidimeter developed at JTI. The volume is 15.5 l and the outlet hole Ø50 mm. The hole can be easily changed to Ø40 mm using an additional cone.

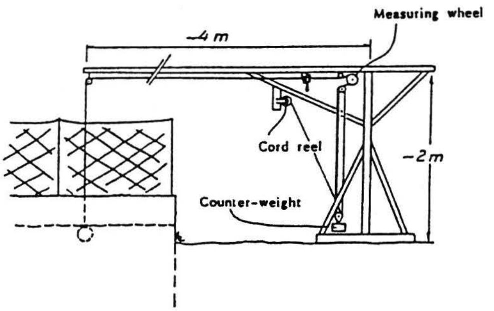

Fig. 2. The ball method. The hollow steel ball (Ø82 mm) is filled up with lead pellets to a bulk density of slightly more than 7 kg/dm^3. Using three different counter-weights, the ball can be counterbalanced to reach net weights corresponding to the bulk densities 3, 5 and 7 kg/dm^3.

When the rubber ball is removed, the slurry flows out through the outlet hole. The operator measures the emptying time with a stopwatch. The same principle is used for example when measuring viscosity of paints.

The ball method, which was originally proposed by Grimm and Langenegger [1], involves measurement of the time it takes for a steel ball with a certain diameter and weight to fall 1 m through the slurry. The principle is similar to the one used in the Höppler-viscosimeter although, here, the ball falls freely through the medium. With three counter-weights, the ball can be counterbalanced to reach different net bulk densities (Fig. 2). The falling time and the distance are registered by a PC using an optical speed sensor. The sensor gives 1 pulse/mm of cord passing over the measuring wheel. The sampling frequency of the computer is 200 Hz.

Measurements of the separation tendency have turned out to be a bit more complicated than they first seemed. For some types of slurry, the sedimentation process is greatly affected by the diameter of the sedimentation column. If the column is too narrow, the walls restrict the movements of the particles in the slurry and thus prevent or delay natural separation. This means that plexiglass or glass columns with 100 mm cannot be used. Instead, a sheet-metal column with ⌀ 400 mm and a plexiglass window on one side was manufactured at JTI (Fig. 3). However, it is very difficult to see the different layers in this column.

The risk of clogging is measured using a 'clogging meter' of the type shown in Fig. 4. The meter has a total volume of approx. 80 l and is divided into four sections. In the bottom of each section, there are holes with different diameters. The total hole area is, however, the same in all four sections.

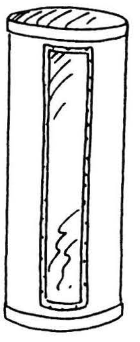

Fig. 3. The sedimentation column manufactured by JTI. The column is filled up to 1 m height with slurry. Then, the thickness and positions of any layers forming are noted after 1, 2, 4, 8, 16, 32 and 64 min.

After having filled the meter up with slurry, the bottom is opened and the slurry flows out through the holes. When the manure flow has ceased, which normally happens within half a minute, some holes are clogged with manure and some are not. Depending on the type of slurry, one or more of the sections might be clogged to 100 %. The operator notes the number of holes clogged in each section and, if all the holes in the section are clogged, the amount of slurry retained.

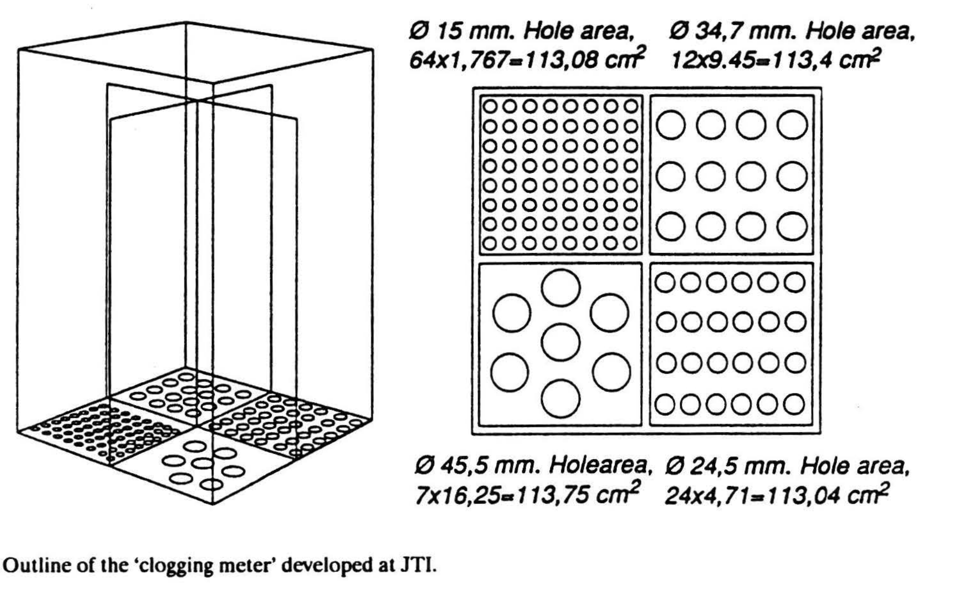

Fig. 4. Outline of the 'clogging meter' developed at JTI.

The percentages of the hole area clogged in all four sections are summarized with the percentages of liquid manure left in the sections where all the holes are clogged. The sum is here called 'clogging index'. The clogging index can vary between 0 and 200. When the clogging index is zero, no clogging occurs and the meter is totally emptied. At a clogging index of 200, no liquid manure leaves the meter when the bottom is opened. Other calculation methods may give a more relevant description of the risk of clogging better related to the performance of spreaders in practice. For example, the clogged hole area and the volume left can be weighted to an index in accordance with the proportions between hole diameters or hole areas in the different sections.

Dry matter content is determined using the conventional oven method. Six 50 g samples of slurry are dried at 105 °C until they reach constant weight (i.e., over- night). The slurry has to be well-mixed before the samples are taken out.

Non-pumpable manure

To measure the physical properties of manure that cannot be pumped, a special-made 'characterization box' (Fig. 5) is used. The box holds 1.3 m of manure and is moved with a front loader on a farm tractor.

The box is filled with manure using the front loader. When filling, the whole lifting stand with the desometer (shearing strength gauge) is removed. It is important not to compact the manure in the box with the loader, since this will give an error when measuring bulk density. Bulk density is measured weighing the whole box.

Measurements of comminution resistance are made with the desometer and repeated eight times in each box of manure; four times when the box is half filled and four times when it is completely filled. The spikes of the desometer plate are forced down into the manure. Then the plate is turned 90° at constant speed by an electric motor. Each turn takes 2 min. The torque is

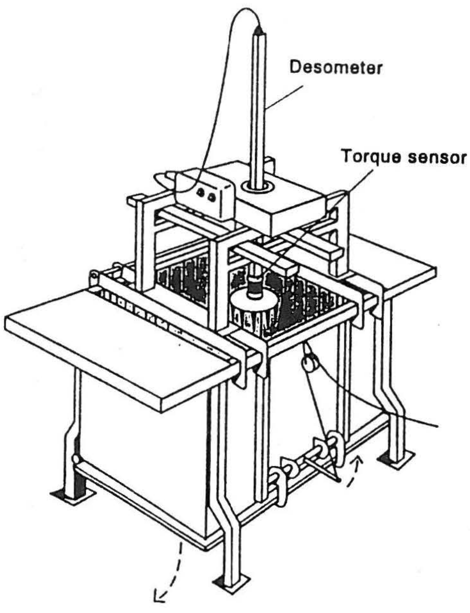

Fig. 5. The characterization box for non-pumpable manure. The box holds 1.3 m^3 of manure and weighs 480 kg with and 300 kg without the lifting stand. The desometer plate is 250 mm in diameter and has six 100 mm long spikes underneath.

measured with an electronic torque sensor mounted just above the plate.

For each type of manure, all characterization measurements are repeated three times (i.e., with three boxes of manure). This gives, as a total, 24 torque values from which the mean torque (M_{24}) is calculated.

Heterogeneity is calculated as the coefficient of variation for the torque values measured.

When measuring the stacking ability, the filled-up box is elevated 1.75 m from ground level with the loader. The bottom flap of the box is opened, causing the manure to fall down onto the ground. The operators then measure the length, breadth and height of the heap, from which the angle of repose can later be calculated.

The main problem when measuring the DM content of non-pumpable manure is to get a representative sample. It is important to get manure from different parts of the heap, but it is also important that the possibilities for the operator to subjectively choose where to take the samples are limited.

In order to achieve this, two samples are taken in the middle of each box of manure with a pitchfork, one when the box is half filled and one when it is completely filled. These samples (altogether 6) are then put together and thoroughly mixed with the pitchfork. From the small heap thus obtained, fifteen 100 g samples are taken and put into the drying oven. The same temperature and time is used as for slurry.

RESULTS

During 1990, practical experiments with several of the proposed characterization methods were conducted at JTI. As regards manure that can be pumped, the experiments were restricted to measurements of fluidity and determination of the dry matter content. For non-pumpable manure, all the proposed methods were studied.

The experimental work was resumed in the autumn of 1991 and continued during 1992. Among other things, equipment for measuring the risk of clogging and the separation tendency was developed and studied and the device for measuring the comminution resistance was reconstructed. In 1992, experiments were also carried out in order to investigate the relationship between characterization parameters and the spreading characteristics obtained when testing manure spreaders. These measurements were made by the Swedish National Machinery Testing Institute (SMP) in co-operation with JTI and are part of a project concerning the certification of manure spreaders.

Pumpable manure

The results show that it is time to reject the accepted approach where only certain dry matter concentrations are stated as limits between different types of slurry. There is, namely, no distinct relationship between fluidity and the dry matter content (Fig. 6). Neither is there any distinct relationship between the risk of clogging and the DM content (Table 1).

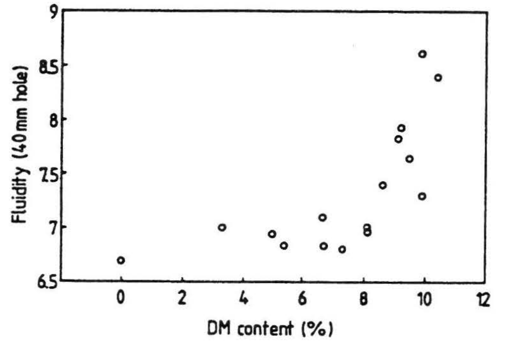

Fig. 6. The relationship between fluidity (measured with the 40 mm hole) and the DM content.

Fluidity can be measured at discretion either with the 40 mm or 50 mm hole, since there is a linear relationship between the emptying times obtained with these two hole sizes (Fig. 7). Which hole to use may be decided from time to time with regard to the thickness of the slurry.

Fluidity as measured with the ball method is clearly correlated with fluidity as measured with the fluidimeter. Figure 8 shows this relationship for the three different counterweights used. The weights give the ball a net bulk density of 3, 5 and 7 kg/dm^3, respectively.

The replicability of the measurements is generally very good, provided the slurry is

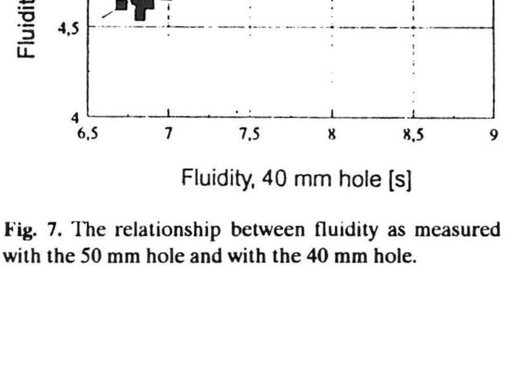

Fig. 7. The relationship between fluidity as measured with the 50 mm hole and with the 40 mm hole.

Table 1. Some results from characterization of pumpable manure

Pumpable manure	Fluidity*, s 50 mm hole	Clogging index	DM content (%)
Cattle slurry. Thin with some long straws	4.7	24	7.3
Cattle slurry. No visible lumps or straws	4.7	64	6.7
Pig slurry. Rich in chopped straws in a liquid phase	4.9	131	4.9

* water 4.64 s.

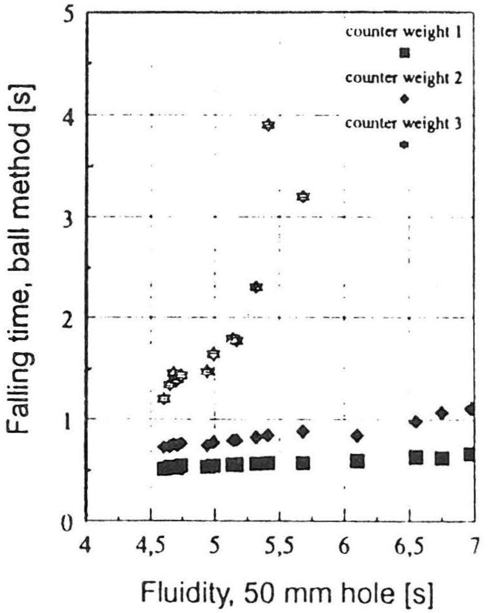

Fig. 8. The relationship between fluidity as measured with the fluidimeter (50 mm hole) and with the ball method. The three counter-weights give the ball a net bulk density of 3, 5 and 7 kg/dm^3, respectively.

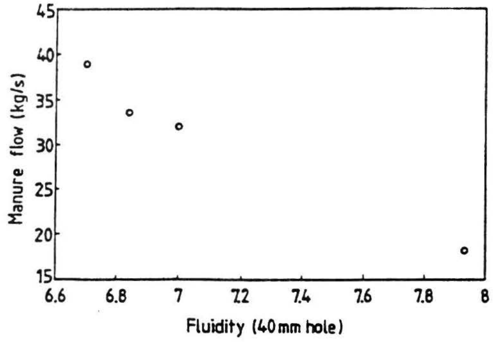

Fig. 9. The relationship between fluidity and the 'constant level manure flow' obtained when unloading an Omas vacuum tanker.

well mixed. Using the fluidimeter, there is no problem to get three measurements after each other with a time difference less than 0.1 s between the highest and lowest value. The clogging measurements also show a high replicability.

Figure 9 presents the relationship between fluidity and the manure flow obtained when unloading an Omas vacuum tanker. The tanker was equipped with a spreading boom with travelling hoses. Though there are just a few data points in the diagram, it can be seen that fluidity does affect the manure flow significantly. This, in turn, implies that fluidity gives a good picture of manure flow properties.

The clogging index appears to describe a combination of how much dry matter and what kind of dry matter the manure contains. We do not yet know whether the clogging index properly reflects the risk of clogging, but there are connections with other parameters like, e.g., the working width of an oscillating spout broadcaster attached to the Omas tanker (Fig. 10).

The equipment for measuring separation tendency has to be further developed. Perhaps the sediment layers would be more visible if the whole column were made out of transparent material. Illuminating the sedimentation column from the inside with a fluorescent tube was not successful since the light was not strong enough to penetrate the manure.

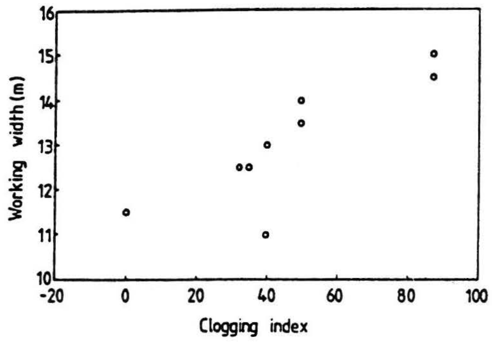

Fig. 10. The relationship between clogging index and the working width of an oscillating spout broadcaster attached to an Omas vacuum tanker.

Non-pumpable manure

The results for non-pumpable manure show the same as for manure which can be pumped: There is no distinct relationship between manure consistency and the DM content.

The active angle of repose, on the other hand, is in good agreement with the visual impression of manure consistency. Figure 11 is an attempt to 'translate' the angle of repose into a verbal description of the manure. The limits between the different types of manure are, of course, not very sharp.

The bulk density ranges from approximately 400 to slightly more than 1 000 kg/m^3. It might seem strange that the bulk density sometimes exceeds 1 000 kg/m^3, but this is probably caused by particles in the manure with a compact density higher than water.

In most cases, bulk density and the active angle of repose are closely related to each other (Fig. 12). This means that it would normally not be necessary to measure both these parameters. Manure consistency can be estimated from the bulk density value.

In order to determine if filling the characterization box three times is enough to provide sufficient accurracy, the manure on six farms was characterized, filling the box five times with each type of manure. The mean values were then calculated both for all five boxes and for every possible combination of three boxes (10 combinations per farm). These calculations were made for all four parameters measured with the characterization box.

Figure 13 shows the percentages of all 60 cases, in which the mean values obtained with three boxes deviate less than the interval stated for each parameter from the mean values for all five boxes. It also shows the interval required bo obtain agreement in 95 % of the cases.

The accuracy is very good when measuring torque, bulk density and angle of repose.

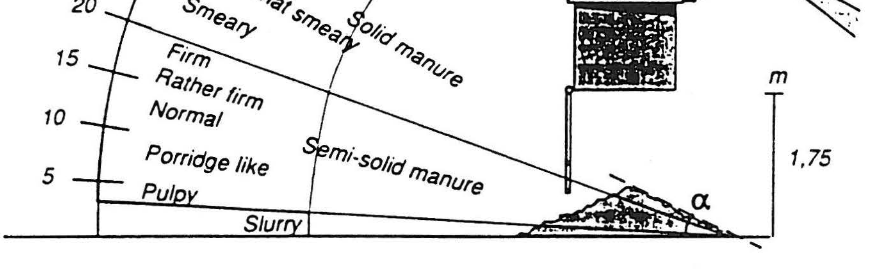

Fig. 11. The active angle of repose as measured with the characterization box for different types of manure.

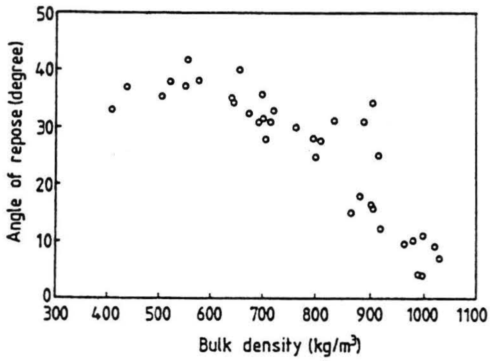

Fig. 12. The relationship between bulk density and the active angle of repose.

It is, however, not so good for the coefficient of variation. Since the coefficient of variation is based on the same measurements as the torque, it seems that it is the calculations rather than the measurements that should be changed.

Bulk density and/or manure consistency affect important spreading parameters like, e.g., manure flow and working width. Figures 14 and 15, respectively, show how the manure flow and the working width for a Kidd Tankaspread 1500 is influenced by the bulk density. The Kidd spreader distributes the manure laterally with a front-mounted fly-wheel. Other types of spreaders are influenced in other ways.

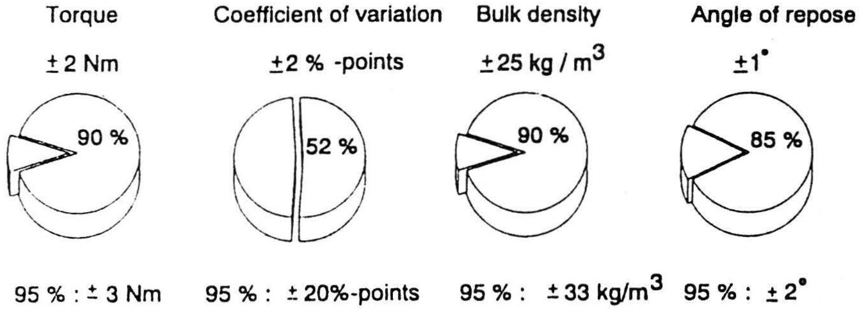

Fig. 13. Measuring accuracy when characterizing non-pumpable manure filling the box three times compared to five times. The calculations are based on data from six farms, giving rise to, as a total, 60 box combinations.

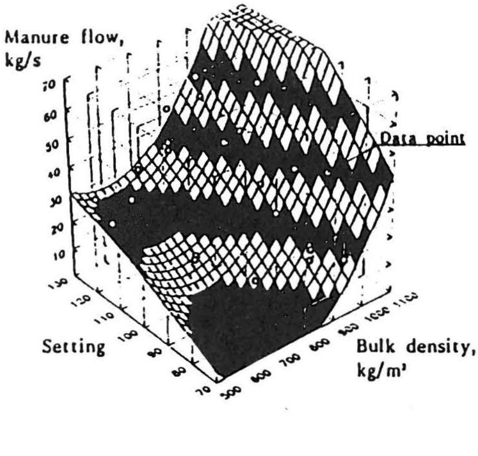

Fig. 14. The relationship between bulk density, setting and 'constant level manure flow' for a Kidd Tankaspread 1500.

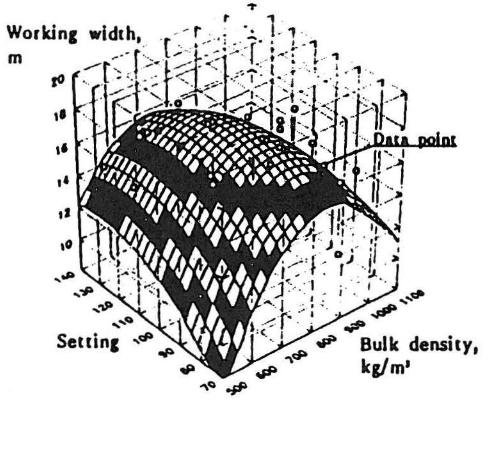

Fig. 15. The relationship between bulk density, setting and working width for a Kidd Tankaspread 1500.

When the data points in the diagrams deviate from the surface created by the computer, this is marked with dotted lines. The black and white zones indicate height curves.

The relevance of the torque and the coefficient of variation as measured with the characterization box is not yet entirely investigated. Trials are now being carried out by JTI in co-operation with SMP in order to investigate whether there is any connection between the comminution resistance of the manure and the P.T.O. power requirements per kg of manure spread. Another parameter that might be affected by the comminution resistance is the scattering of the manure. This should be further investigated in the future.

CONCLUSIONS

Though there are still a lot of questions to be answered some conclusions can be drawn from the material presented:

1. Manure properties do affect the performance of manure spreaders.
2. Different spreader types are influenced in different ways when the manure properties change.
3. Dry matter content alone is not enough to completely describe the relevant physical properties of the manure.
4. There are connections between at least some of the proposed characterization parameters and important spreading characteristics like, e.g., manure flow and working width.
5. The relevance of other characterization parameters need to be further investigated in the future.

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