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WINTER SCIENTIFIC MEETINGS – NOVEMBER 1994 & NOVEMBER 1995

Publication No. 35
FACTORS AFFECTING FERTILISER SPREAD PATTERNS

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Introduction

Traditionally, single-disc and spout-type spreaders have been the most widely used in Ireland, but in recent years there has been a trend towards twin-disc machines. For many years the standard bout width for cereals has been 12 metres and this is still the situation on many farms. However, on the more intensive cereal farms the operation has become more specialised and covers larger areas than in the past. The spraying operation dictates the machine capacity required and the tramline widths needed on these arms; it is desirable that the total cereal area can be covered in 2-3 days. On the larger holdings this means larger working widths and wider tramline spacings, which has led to the development of wide spreading fertiliser distributors—usually in the 15-24 metre range. Large areas and wide bouts have increased the need for greater hopper capacity.

The situation in grassland is somewhat different. Because of the difficulties in maintaining correct driving widths without the benefit of tramlines, the bout widths have generally not exceeded 12 metres, and 12-metre machines are the norm. The past few years have seen the introduction of large-capacity contractor-operated trailed machines using bulk fertiliser. Operating from a central location and working within a twenty-mile radius, this system depends on achieving very high work rates using fast forward speeds and wide bouts. Spot work rates of up to 60-70 acres/hour (24/28 ha/hr) have been achieved with these units, but difficulties have been achieved with these units, but difficulties have been encountered in maintaining even distribution at these work rates. A variety of machines is used for grassland spreading; on small dry stock and sheep farms, single-disc machines are still widely used because of their relative cheapness. The spout type is also popular in these situations but is also used on dairy farms. The larger and more intensive dairy farms tend to have more twin-disc machines and nearly all of the contract work is done with large twin-disc spreaders.

Irrespective of the spreader type, a common requirement of all spreaders is the need to achieve a sufficiently even distribution which will minimise crop yield reduction and financial loss. The efficiency with which this is achieved is affected by machine, fertiliser and operator characteristics which will be discussed below.

Methods of assessing distribution standard

Before going on to discuss factors affecting spread patterns and evenness of distribution, it is worth considering the methods of assessing distribution. All of the
methods of measuring the evenness of distribution from fertiliser distribution are based on spread patterns obtained by collecting material spread during the passage of the broadcaster over a set of trays. These are usually laid out in the form of a line at right angles to the direction of travel of the spreader. The material from the individual trays is weighed and a spread pattern produced. In farm practice, successive spread patterns must be overlapped to give the optimum spread. The calculated weights in the individual trays, after overlapping at a particular driving distance or bunt width, are used to estimate the degree of unevenness of the overlapped spread.

The ISO standard 5690 specifies collecting trays with either 1,000 mm x 250 mm or 500 mm x 500 mm, i.e. 0.25 m², with a minimum depth of 150 mm (Ref. 1). the degree of unevenness is shown by the Coefficient of Variation (CV) where

\[
CV = \frac{s}{\bar{x}}
\]

where \( s \), the standard deviation, is given by the equation

\[
s = \sqrt{\frac{1}{n-1} \sum (x_i - \bar{x})^2}
\]

in which

- \( n \) is the number of collecting trays
- \( x_i \) is the amount in each tray
- \( \bar{x} \) is the absolute mean, given by the equation

\[
\bar{x} = \frac{1}{n} \sum x_i
\]

CV is usually expressed as a percentage, so the equation would read

\[
CV(\%) = 100 \times \frac{s}{\bar{x}}
\]

An objection to the standard deviation or coefficient of variation as measures of unevenness is that insufficient importance is given to extreme values. In the Netherlands a different parameter for irregularity of distribution was developed which included the maximal deviation in addition to the average deviation from the mean. This characterised every distribution by a single figure (\( r \) giving due weight to the maximal deviation; it also made it possible to summarise the results of several tests in broadcast diagrams (Ref. 2).
The irregularity, \( r \), is defined as

\[
r = 100^8 \sqrt{\left(\frac{d}{20}\right)^8 + \left(\frac{d_n}{40}\right)^8}
\]

where \( d = \frac{100 \sum (x_i - \bar{x})}{n \cdot \bar{x}} \)

This Dutch method, while it has some merit was not adopted outside the Netherlands. A refinement of the ISO standard method, which utilises flow rates as well as transverse distribution, was introduced in the UK in the past few years, based on work carried out jointly by ICI Fertilisers and Silsoe Research Institute. The purpose of these tests is to evaluate fertilisers in terms of their performance in spreading equipment in the field and to-date the tests have been confined to nitrogen fertilisers only. In this two-dimensional spread pattern evaluation, the flow rate of the fertiliser through the feed orifices of different types of spreaders - spinning disc, oscillating spout and pneumatic spreaders - is measured while they are being driven over a special 'bumpy' track to simulate field operation. These flow rate measurements in the direction of travel of the spreader are combined with transverse spread pattern data for the same fertilisers, producing a two-dimensional distribution pattern for each machine/product combination over a 24 x 50 metre area. Overall CVs (OVCs) are calculated for each.

The overall CV values obtained are used to give a spread pattern rating (SP rating). The SP ratings are on a scale of 1 to 5 based on recorded OVCs in the two-dimensional protocol, SP5 being the highest rating. The scale has been set to reflect the latest information on acceptable accuracies and losses in arable fertilisation (Table 1).

### Table 1: The spread pattern rating system

<table>
<thead>
<tr>
<th>SP rating</th>
<th>Overall Variation Coefficient (OVC)%</th>
<th>Description and comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>&lt;8.0</td>
<td><strong>Good</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td>The best achievable in commercial practice.</td>
</tr>
<tr>
<td>4</td>
<td>8.0-10.0</td>
<td><strong>Average</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Financial losses may be within 'acceptable' norms in some crops.</td>
</tr>
<tr>
<td>3</td>
<td>10.0-12.0</td>
<td><strong>Poor</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Significant financial losses in most arable situations.</td>
</tr>
<tr>
<td>2</td>
<td>12.0-14.0</td>
<td><strong>Very poor</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Serious financial losses. Unacceptable in modern arable practice.</td>
</tr>
<tr>
<td>1</td>
<td>&gt;14.0</td>
<td><strong>Unusable</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Major financial losses and problems in all arable usage.</td>
</tr>
</tbody>
</table>
Silsoe Research Institute has calculated the effects of different degrees of unevenness of distribution of nitrogen on crop yield and financial return in elation to recorded OVCs and SP ratings for a range of cereal growing situations. In Table 2, predicted returns from specific examples of 'poor quality' fertilisers recorded in the Silsoe analysis are compared with that of an SP5 rated material.

**Table 2: Financial penalties of poor quality nitrogen**

<table>
<thead>
<tr>
<th>Fertiliser sample and rating</th>
<th>SP5 Nitram OVC = 6.18</th>
<th>SP3 Ammonium Nitrate OVC = 11.89</th>
<th>SP1 Granular urea OVC = 14.7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Return</td>
<td>Return</td>
<td>Penalty</td>
<td>Return</td>
</tr>
<tr>
<td>100 727.0</td>
<td>729.8</td>
<td>7.2</td>
<td>723.3</td>
</tr>
<tr>
<td>160 596.1</td>
<td>588.2</td>
<td>7.9</td>
<td>894.8</td>
</tr>
<tr>
<td>190 905.2</td>
<td>900.0</td>
<td>5.2</td>
<td></td>
</tr>
</tbody>
</table>

1. Each fertiliser rate is the economic optimum derived from a different nitrogen response equation - they do not represent a single site at different rates.

2. The financial return represents the margin over fertiliser costs, assuming a wheat price of £108/tonne, nitrogen cost of £0.32 kg N and additional fungicide cost of £0.30/kg N at higher input levels.

At the OVCs recorded, yield penalties of up to £16.60/ha were calculated.

However, these do not take quality factors into account and large financial penalties can be incurred in some situations due to the effect of uneven distribution on quality. For example, in milled wheat variations in specific weights, Hagberg readings and protein contents are influenced by nitrogen application. High nitrogen or screenings content can lower the value of a malting barley crop significantly.

**Spread pattern shape**

The shape of the basic spread pattern and the precision with which the overlapping of successive patterns is achieved plays a key role in determining the evenness of distribution achieved in the field. While there is a wide variety of patterns in the field, two basic types will be discussed here which behave quite differently when overlapped. These are: 1. the triangular or pyramid-shaped pattern; and, 2. the flat-topped or trapezium-shaped pattern.

A symmetrical triangular spread pattern (Fig. 1(a)) gives an even distribution when overlapped at all driving widths up to about half its overall spreading width, so variations in bout or driving width will have little effect on events of distribution, but will affect the application rate. In contrast, flat-topped patterns, while capable of producing a very even overlapped distribution, will only do so if overlapped correctly
and have a narrow bout width range within which distribution is acceptable (Fig. 1 (b)). This means that more rigorous and regular checking of the spread pattern using trays is required.

A disadvantage of the triangular pattern is that for a given overlapped bout width (working width) it requires a considerable wider overall spread (at least twice the bout width) than the flat-topped, which only needs an overall spreading width slightly greater than the bout width.

**Spreader developments**

As mentioned earlier, the main developments have been in twin-disc machines, with each major manufacturer having models capable of spreading up to 24 metres wide, and some claimed to be able to operate at 36-metre bout widths. The twin-disc spreaders can be divided into two groups: (1) those having very little adjustment of discs, or vane length and position, i.e. very little control over the shape of the spread pattern, for example, Bogballe EX, Bredal B2 and Lely Centerliner, (2) spreaders which have various adjustments which can be used to deal with different fertilisers, e.g. Amazone ZA-M, Rauch MDS, Betas and Alpha, Sulky DPX and Vicon Rotaflow. In theory, the spreaders on which the spread pattern can be adjusted to suit different fertilisers or rates should be the most efficient in getting a consistently good spread, particularly if the patterns can be checked using trays. In practice, it is not so simple, with some operators feeling that too much time can be spent setting up the spreader and checking patterns.

In our spreader testing work we have not been able to test wide-spreading machines because of limited size of the test area, but we have been able to get test results on many of these spreaders from European test stations. In looking at these results, many of the machines seem to be capable of giving an even spread at widths up to 24 metres when set properly. The difficulty or time involved in setting the spreaders correctly is not made clear, so it might be concluded that spreaders which gave good spread patterns with the minimum of adjustment would work out better in practice.

The modern spreader can usually work accurately over a range of bout widths, e.g. 12-18 metres with different fertilisers. In the past, increased width was usually achieved by increasing the tractor pat. speed or tilting the machine upwards at the rear. While some machines still use the tilting method, it is very unsatisfactory as it is difficult to set properly and also has a bad effect on the spread pattern. On modern spreaders, bout widths can be altered by varying the speed of the granules coming off the disc and/or the angle at which they are ejected. The methods vary. It may be done by fitting different discs (Amazone ZAM and Rauch), altering the angle or length of vanes on the discs (Amazone, Ruach), changing disc speed by using different gear ratios (Bredal B2, Lely Centerliner and Vicon Rotaflow) or changing the position where the fertiliser is fed onto the disc (Sulky DPX, Vicon Rotaflow, Rauch Alpha).

One task which has been made much easier on the modern spreader is application rate calibration. On the majority of machines, a simple method of collecting the fertiliser coming from the feed outlet over a given time is provided from which the rate
per acre can be calculated. This may be facilitated by removing one disc and collecting the fertiliser in a plastic bucket or other container or, where the discs cannot be removed easily, an attachment to collect the fertiliser coming off the discs can be used. There are also more ingenious solutions. For example, the Bredal B2 spreader, which has narrow belts feeding the fertiliser on the discs, uses a simple method of measuring the fertiliser bulk density, which is then used to select the correct feed opening from a chart. The Vicon Rotaflow uses a graduated cylinder which is placed over one of the feed outlets and filled with fertiliser in the cylinder, is used to calculate the rate per care. The most sophisticated system is that fitted on the Bogballe EXW spreader. This spreader has built-in load cells which actually weigh the fertiliser in the hopper. When this is used in conjunction with an electronic computing device called the ‘Calibrator’, rate calibration and checking of application rates can be done very easily while working.

Many manufacturers now have some kind of mini computer which in conjunction with a speed measuring device can be used to calculate area covered, work rate, and application rates, but calibration still has to be done manually.

In 1995, Sulky introduced the ‘Justax’ system which, they claim, allows the operator to set the spread width electronically from the tractor without the need for the disc or vane changes or overlap tests. The Justax consists of two sensors located behind the spreader connected to an electronic unit and an in-cab control for regulating the feed spout position. The two sensors monitor the spread profile of the fertiliser as it leaves the disc and the in-cab unit indicates whether it is correct or not. The spread can be adjusted by altering the position of the feed spouts until an ‘OK’ reading is indicated. If this system works satisfactorily it could be a very useful way of reducing the time spent measuring spreads and adjusting machines.

**Fertiliser characteristics**

The behaviour of a fertiliser during handling or spreading is affected by the physical characteristics of the individual particles. Flow rates, behaviour on spreading mechanisms and projection distance are all affected by factors such as size, density, shape and roughness of the fertiliser particles. Other factors which can affect the particle behaviour indirectly include hardness and resistance to breakdown, which can affect a particle size.

The most important characteristics in the field are granule size and shape. Particle size affects spreader performance in different ways:

1. It affects flow rate through feed outlets and, therefore, application rates. The degree to which flow rates are affected by variation in particle size depends on the extent to which the fertiliser is ‘force fed’, i.e. by agitators, feed rollers etc. (Ref. 3). Where there is little force-feed effect the application rates can be severely affected by variation in particle size-small particles having higher throughputs than larger. This creates major problems in setting broadcasters or drills if there is variation between different batches of the same material. Belt feed mechanisms are less affected by particle size variation as their feed rates are more dependent on bulk density than other characteristics.
2. Particle size affects projection distance and pattern shape. Small particles have a bad effect on spread patterns. Powder or dust in a fertiliser tends to influence the shape of a spread pattern out of proportion to the quantity because of the effect on particle movement on the spreading discs and limited projection distance. Results of published research would suggest that material less than 1mm in diameter should be excluded from fertilisers and the quantity less than 1.5mm reduced to a minimum; indeed, particles <2.0 mm may have a deleterious effect on spread patterns and increase C.V. values (Ref. 4). It would seem that a particle size range of 2–4+ mm is the most desirable. However, size range does not tell the whole story – two fertilisers could have the same size range and have quite different characteristics and performance. The mean particle diameter gives a better indication of the particle size distribution. This is expressed as the Mass Median Diameter or d₅₀; the d₅₀ is the particle size at which 50% by weight of the material exceeds that size (and of course 50% is smaller). There is some indication in the literature that fertilisers with relatively large d₅₀ values spread better.

3. Particle size is very important in the production of blends or mixtures of different fertilising materials (Ref. 5). The particle sizes of the individual constituent fertilisers must be matched. If they are not, then the individual constituent fertilisers must be matched. If they are not, then the individual components will segregate during spreading (and possible in bulk handling before spreading) and may be spread unevenly, even if the spread pattern of the fertiliser blend is quite good. The d₅₀ of each material should not deviate by more than 10% from each other, e.g. if the d₅₀ of one component is 3.0 mm the d₅₀ of the others should be within the range 2.7–3.3 mm.

Particle shape and surface roughness affect different aspects of the spreading process – they can influence the flow rate through feed outlets, movement on the discs and, therefore, throw-off point, and movement through the air. It has been our experience from spreader testing over the years that smooth round granules perform better than angular particles and give more desirable spread patterns.

Spreaders have to meter and spread a wide variety of materials ranging from small prilled urea (1.6 mm) to granular blends, with a wide variety of shapes and sizes. Generally, fertilisers having round granules with few grains less than 2 mm diameter and about 80% in the 2–4 mm range produce triangular-shaped spread patterns, with the largest quantity of fertiliser directly behind the tractor and tapering off gradually towards the sides when spread from twin-disc machines. This type of triangular pattern or pyramid-shaped pattern will give an even spread over a large range of driving widths (Fig. 1(a)). On the other hand, small-grained fertilisers such as prilled urea, or fertiliser with angular particles or a high proportion of dust or broken down granules tend to produce flat-topped patterns with a sharp cut-off at the edges, which can be overlapped to give an even spread but have much less margin for error (Fig. 1(b)). They need greater care in matching up bouts and adjustment of the spreader, and can be limited in the range of bout widths giving a good spread.

Some spreaders are more inclined to produce flat-topped spread patterns than others. Because flat-topped patterns can be used to produce wider overlapped patterns from any given pattern width, they are more likely to occur with machines
having relatively narrow actual spreading widths, and possibly, with any machine when approaching the limits of its width capacity. They are more likely to occur at 24 metres working widths than 18.

Other fertiliser characteristics which have an indirect effect on spreading performance include granule hardness and strength, and abrasion resistance, which affect the amount of fines in a batch of fertiliser.

The more progressive fertiliser distributor manufacturers have long realised the problems which arise in trying to produce machines capable of spreading a huge range of different fertilisers with a high degree of accuracy and have built or have access to first-class distribution testing facilities. In several cases they have obtained samples of fertiliser from the different countries and measured the spread patterns produced from these and recorded the settings which produced the optimum results. Measuring spread patterns for each individual fertiliser is a time-consuming and expensive business and one spreader manufacturer – Amazone in Germany – has developed a simpler, faster and cheaper way of achieving the same result, i.e. a suitable machine setting for a particular fertiliser. From a 3 kg sample of fertiliser three physical characteristics – particle size, ‘pure’ density and bulk density – are measured along with two performance parameters of the material – flow rate through an orifice and angle of throw from a rotating disc. The data from the test is compared with the information from a data band containing the results of hundreds of sample analyses and the corresponding evenness tests and settings, and the appropriate machine settling selected for the material in the sample.

Machinery operation

The operator controls the spreading operation and can optimise or nullify the potential of the spreader/fertiliser combination to produce an even distribution. Modern spreaders generally are capable of spreading fertiliser with a high degree of accuracy; machinery manufacturers have improved machine performance over the last decade. However, many operators are not sufficiently informed about the types of spread pattern produced, the factors which influence them and how they should set up their machines to optimise their performance.

The variability caused by different fertiliser types with varying granule characteristics makes it very difficult for the operator to produce a consistently good distribution. Improvement in this area will require more-co-operation between the spreader manufacturer and fertiliser producer to give better and more specific information to the farmer for setting the machine.
REFERENCES


Fig. 1(a): Triangular spread pattern (A) and overlapped spread (B) at 18 metres for twin-disc spreader with 'good' fertiliser. Graph (C) shows the effect of changes in driving width on events of spread (C.V. value) with machine set for 18 metres – spread is excellent up to 21 metres.

Figure 1(b): Flat-topped spread pattern (A) and overlapped spread (B) at 18 metres with angular granular fertiliser. Graph (C) shows low C.V. value at 18 metres but increasing rapidly at narrower or wider driving widths.