NEW ZEALAND AGRICULTURAL
ENGINEERING INSTITUTE

THE SPINNING DISC DISTRIBUTOR

Part 1

DESCRIPTION OF EXPERIMENTAL LAYOUT AND TEST METHOD

INFLUENCE OF FEED POINT, FERTILISER TYPE, AND VANE LENGTH ON EVENNESS OF DISTRIBUTION

PROJECT REPORT

P/8

THE SPINNING DISC DISTRIBUTOR

THE SPINNING DISC DISTRIBUTOR

Part 1

Description of Experimental Layout and Test Method

Influence of Feed Point, Fertiliser Type, and Vane Length on Evenness of Distribution

G. R. DAVIES

February 1972

A Project Report of the New Zealand Agricultural Engineering Institute, Lincoln College, University of Canterbury, New Zealand.

P/8

OTHER N.Z.A.E.I. PROJECT REPORTS

P/1 The Effect of Fire on Standard 8 S.W.G. and High Tensile 12½ S.W.G. Plain Fencing Wire: G.M. Garden (August 1967)

P/2 The Hydraulic Performance of Trough Valves: T.D. Heiler (July 1968) (2nd Edition May 1971)

P/3 Procedures for testing trench laid plastic drain pipes up to 4" in diameter: T.D. Heiler (July 1968)

P/4 A Provisional Test Procedure for Crawler Tractor Safety Frames: E.M. Watson and G.M. Garden (July 1971)

P/5 Procedure for testing Broadcast type Distributors used for the application of granular insecticide: J.E. Hager and K.R. Humphries (August 1969)

P/6 Procedures for Testing Broadcast-type Fertiliser Distributors: K.R. Humphried (February 1971)

P/7 Tractor Safety Frame Noise Levels: G.M. Garden with Medical Assessment by J.F. Copplestone (March 1971)

PREFACE

We hope that this report will be of interest to the makers and users of spinning disc distributors and to fertiliser manufacturers. Our object has been to make the project of practical help in fertiliser application and where it does not meet this requirement we should like to receive criticisms and suggestions. We shall also be glad to hear of any points which are not made clear in the report. We would like to incorporate any suggestions for additional work in the next part of the programme but the present plan is to terminate the project after the second series of tests.

Work at N. Z. A. E. I. done by:
G. R. Davies, R. F. Horrell, K. R. Humphries.

Report written by:
G. R. Davies.

CONTENTS

INTRODUCTION

The spinning disc distributor is basically a simple machine and especially suitable for broadcasting granular fertiliser over a large area. Properly designed and operated it can give a wide bout width and a uniform spread.

Even spreading is important with some fertilisers and trace elements and essential with most herbicides and pesticides but it is difficult to assess its importance when applying superphosphate to pasture. Very uneven distribution will reduce crop yield; very accurate distribution will be expensive; somewhere between the two extremes is a sensible, practical compromise.

After careful study of the whole subject of superphosphate application it was decided, in 1968, that a testing and experimental programme was justified at Lincoln. The project was visualised in three stages. First, the design and installation of test equipment; second, the testing of existing machines and fertilisers; third, but only if warranted by the findings of the second stage, an attempt to help improve design and operation of machines and of fertiliser properties. This last stage would be tackled by a study of published information from this country and overseas, and by a limited experimental programme.

Stage one of the project was completed in 1969 and a report has been published describing the test equipment and procedure adopted. About twenty distributors and numerous types of fertilisers and insecticides have been tested since 1969; the machines have ranged from the largest bulk spreaders to small insecticide distributors mounted on a tractor three point linkage. Individual reports have been published for each of these machines.

Results of tests showed that, although many machines were not set to give good patterns as received at Lincoln, most were capable of giving reasonable performance after some adjustment.

It was found, also, that the superphosphate varied in physical composition from batch to batch, the proportion of powder or 'fines' was especially inconsistent.

For these reasons it seemed justified to start stage three of the programme. Extra weight was added to this decision by the present need to use fertiliser as efficiently as possible, by the increasing use of herbicides and pesticides, and finally by the potential of the spinning disc for seeding as well as for its present purpose.

This report describes work carried out during 1971. We hope to complete the project with a final report later in 1972.

OBJECT

The aim of this project was to decide on the most suitable spreading pattern from a spinning disc distributor and then to find out how this pattern could be achieved.

Published information, and our own experience, show that there are two good spreading patterns. The first is rectangular, or nearly so, thus:

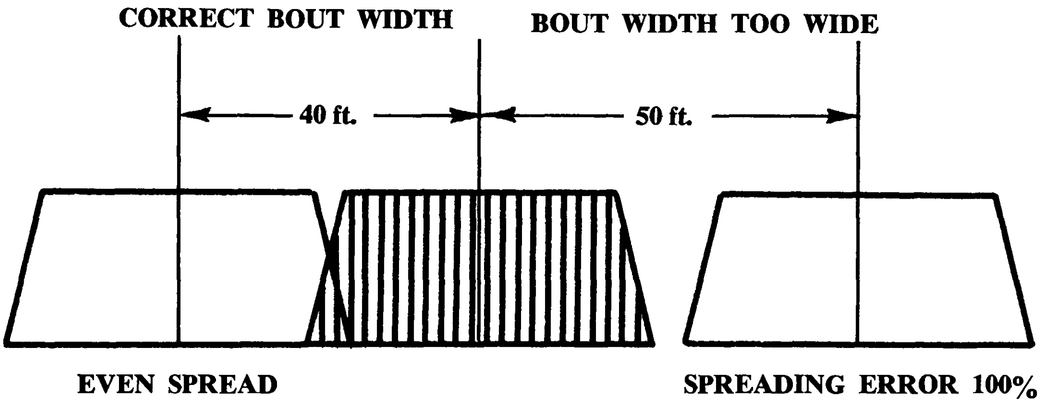

Fig. 1. 'Rectangular' discharge pattern.

This pattern is preferable where it is possible to maintain bout width accurately. It is the pattern which should be obtained from a 'full width' or box type spreader, but it is also suitable for the smaller 'lateral spread' broadcaster. However if bout widths are not precise the application rate will either be doubled or reduced to zero; the pattern is therefore unsuitable for machines which have a wide throw, unless bout markers are used.

The second pattern is triangular, or triangular slightly truncated, thus:

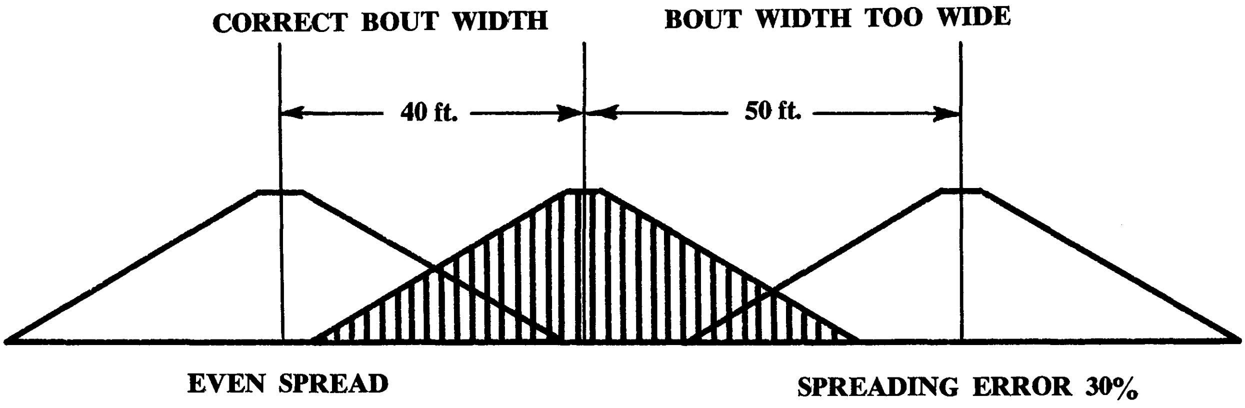

Fig. 2. 'Triangular' discharge pattern.

This pattern is preferable where it is difficult to maintain bout width accurately since the evenness of distribution is less influenced by small driving errors. This is the best pattern to aim for when spreading superphosphate on pasture, and is the one sought in this project.

EXPERIMENTAL EQUIPMENT AND PROCEDURES

The experimental equipment was made in the Institute workshops and consisted of a hopper unit, the spinning disc rig, and the catching trays with their plastic covers. The suspended hopper fed fertiliser onto the spinning disc. The disc distributed the fertiliser into about three hundred trays over which a plastic 'honeycomb' was spread to prevent the particles bouncing. The amount in each tray was weighed and the spread pattern determined from these weights.

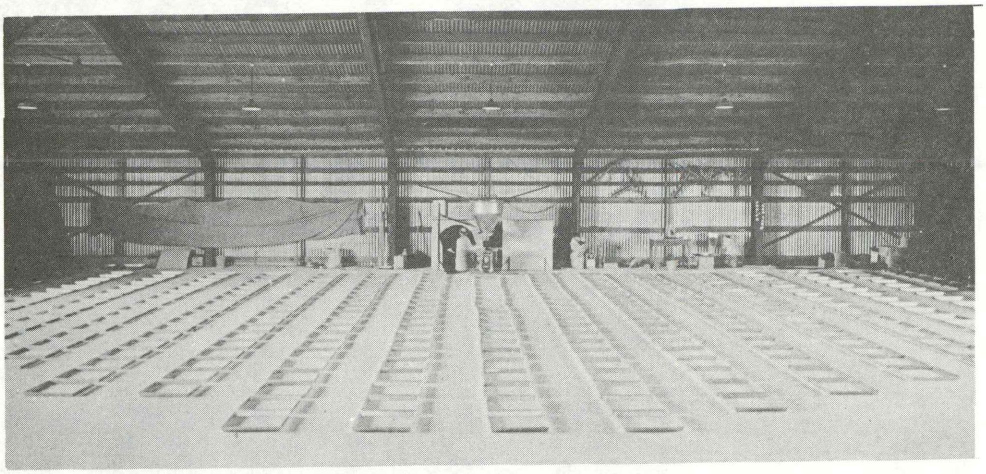

Fig. 3. General arrangement of the test equipment. Trays are laid out in parallel lines and have not yet been covered with the plastic honeycomb.

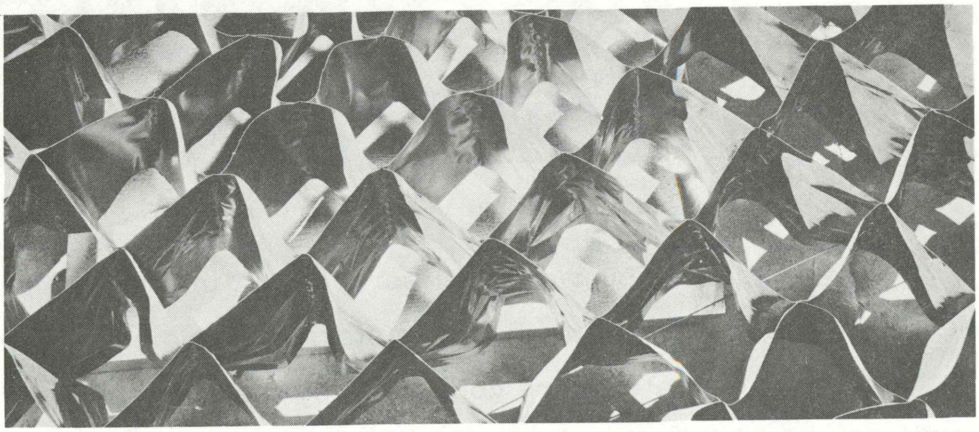

Fig. 4. Close-up of plastic honeycomb matrix used to cover the catching trays.

The Hopper

The hopper capacity was eight cubic feet and it could carry 650lb of superphosphate. The cone angle of the lower part was 60° and since this is well above the angle of repose of the fertiliser it should ensure free, even flow through the outlet, with no 'bridging' of the material in the hopper.

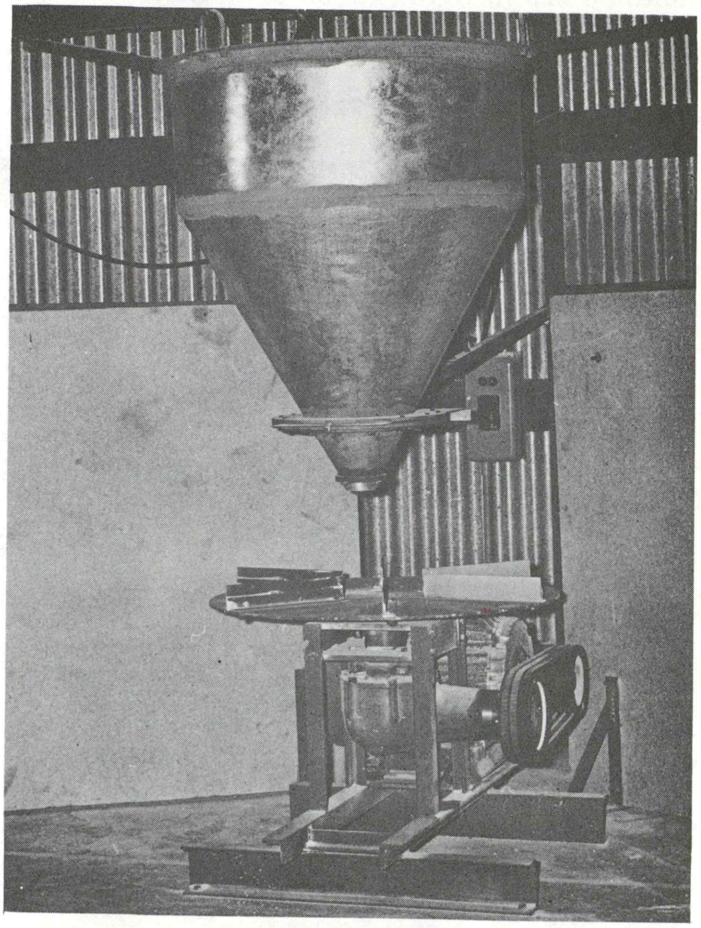

Fig. 5. Hopper suspended above the spinning disc.

A weighed amount of fertiliser was put into the hopper for each test, and flow onto the rotating disc was started by moving a rapid action cut-off slide. Flow rates were controlled by the size and shape of the outlet orifice; round, sharp-edged orifices were used for this series of tests. The hopper outlet could be positioned over any part of the disc by adjusting three tie bars.

Many different shaped feeds are used in practice but it is far easier to show the influence of small changes in the feed position with a round orifice and that is why this type was used initially. Later in the programme, when we know more about the distribution patterns from round orifices, we shall look at other types of feed.

Other workers claim that the rate of flow of granular material through a hole in the bottom of a hopper, such as this one, is independant of the height or 'head' of the material in the container. We thought this needed checking with superphosphate because the granules are not all the same size. This was done by suspending the hopper and its contents from a load cell, which measures the weight continuously during discharge, and then records it on the strip paper of a pen recorder.

It was found from these measurements that the discharge rates were indeed steady and uniform for orifice sizes from 1 in. diameter to 3¼ in. diameter. Five hundred pounds of superphosphate was allowed to flow through each of six orifices and the discharge rates ranged from 18 lb/minute to 470 lb/minute. Results are plotted in the next graph, Figure 6.

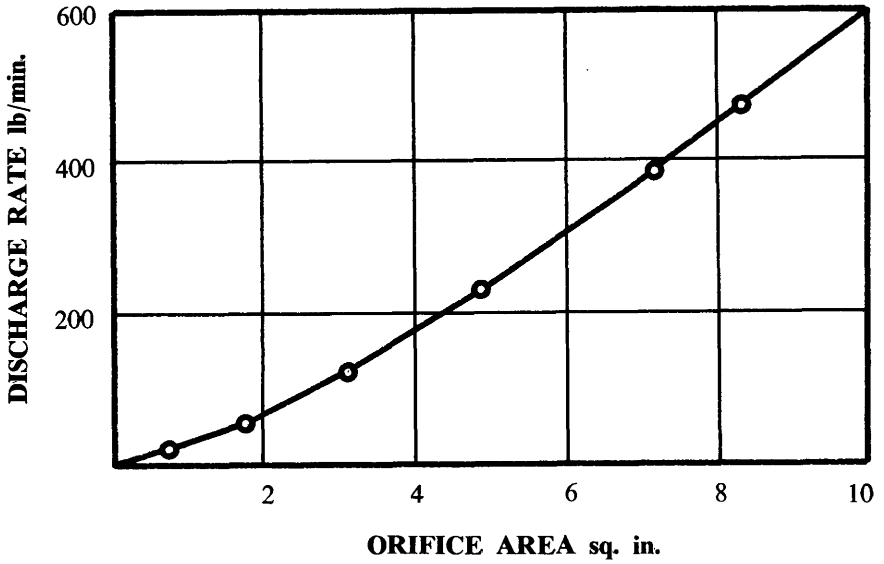

Fig. 6. Discharge rates of superphosphate through round orifices.

The Spinning Disc and the Catching Trays

The support for the spinning disc was a 12 in. diameter steel plate, 3/8 in. thick. This plate rotated on a thrust bearing and was driven by a constant speed electric motor through 'V' belts and an angle drive. By using different pulley sizes it was possible to obtain disc speeds between 400 rpm and 1400 rpm which span the range used in modern practice. All these components were held in a sturdy angle iron frame which was bolted to the floor. The height of the disc above ground could be varied by raising or lowering the frame. It can be seen from Figure 3 that the rig is located close to the wall of the test building. This, and the arrangement of the catching trays needs some explanation.

The discharge from spinners mounted on tractors or trucks should be limited to an approximate semi-circle behind the machine. If the arc is much less then 180° the distributor will only give a narrow bout width; if it is much greater than 180° the fertiliser may strike the vehicle before falling to the ground and this distorts the distribution patterns. For this reason it was only necessary to measure the fertiliser discharged over a semi-circle and the rig could be fixed mid-way along, and quite close to, one of the walls of the test building. This building is 75 ft by 75 ft and so it was possible to lay out the catching trays over a semi-circle of 35 ft radius. The trays can either be set out radially from the rig or in parallel lines, as shown in Figure 3. By setting the trays out in parallel rows, and then measuring the amount of fertiliser in each <u>row,</u> rather than in each tray, it is possible to determine the pattern of spread, as if the spinner was travelling across a paddock, instead of being stationary.

Square trays with a surface area of 3.11 square feet were used and were covered by an open mesh matrix during a test, as shown in Figure 4. This matrix was made of lightweight polythylene sheet welded into a honeycomb and then supported in a wire frame. From earlier development work we have found that the soft, pliable plastic stops ricochet of the fertiliser granules. At the end of a test run the matrix was removed and the amount in each tray weighed to give the distribution pattern.

TEST PROGRAMME

The spread pattern from a disc distributor may be influenced by any of the following:

> The physical properties of the material being spread, especially the size range of the granules.
>
> The rate and uniformity of feed onto the disc and especially the location of the feed point relative to the centre of the disc.
>
> The diameter, height and speed of the disc, whether it is flat or dished, and the number and shape of the vanes.

In an investigation like this one it is necessary to change only one variable at a time if this is at all possible. Since we suspected that the point of feed and the granule size distribution were most important we decided to look at these first.

The composition of the superphosphate received from the manufacturers varied too much in granule size to be used for comparative tests. A 'standard' blend had already been prepared and used for the general testing programme of proprietary machines and it was decided to continue using this blend, which is typical of modern production. This 'standard' blend is prepared by first sieving the superphosphate into five particle sizes and then remixing these five batches in set proportions, the sizes of the particles and their proportions in the blend are given in the next table.

Size Range of Granules	**Percent Weight in Blend**
>4 mm	22
2 - 4 mm	31
1 - 2 mm	27
0.5 - 1 mm	12
<0.5 mm	8

Table 1. Composition of 'standard' blend of superphosphate.

Since this series of tests was intended to be strictly practical the remaining conditions were chosen to be typical of modern practice in New Zealand.

Disc diameter	30 in.
Disc height above ground	17 in.
Disc speed	675 rpm
Number of radial vanes	6
Feed rate	160 lb/minute

(The feed rate was obtained by using a $2\frac{1}{4}$ in. diameter orifice, and would, in fact, give a distribution of about 2 cwt/acre at a bout width of 35 ft and a forward speed of 10 mph if used on a normal distributor on a paddock.)

Before commencing the main tests two short preliminary runs were necessary.

The first was to ensure that the bulk of the discharge was coming off the disc in such a direction that it would be caught in the trays. Eleven trays were arranged in a semi circle around the disc and runs were made at two feed points. Both were at 180° from the disc centre line but one was at a radius of 3.75 in. and the other at a radius of 7.5 in. The amounts caught in each of the trays are shown in the next diagram.

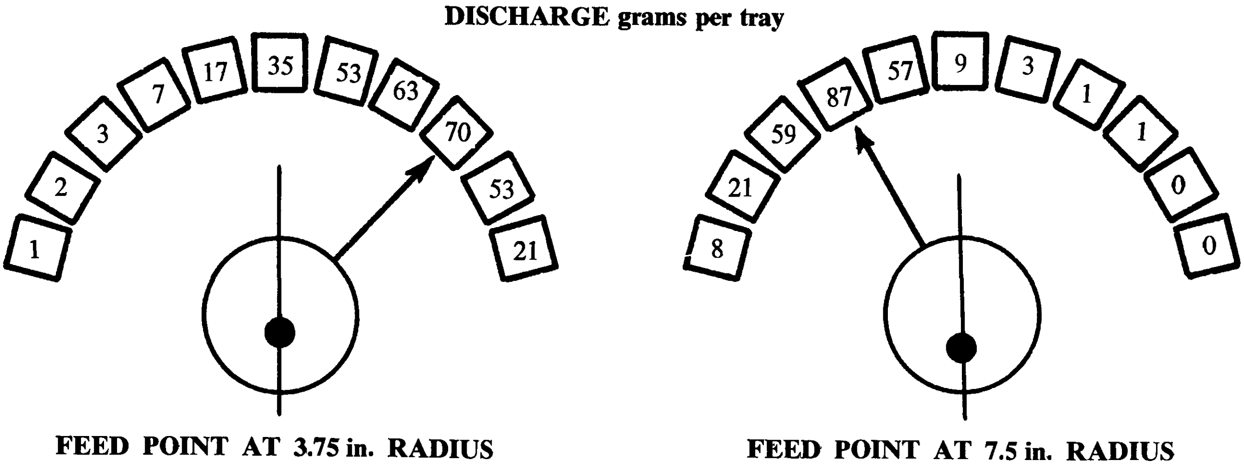

Fig. 7. Preliminary tests to find the centre line of discharge from a disc.

These two short tests showed that we could get an even discharge about the centre line by feeding on the disc at a radius of 3.75 in. but that the fertiliser would have to be put on earlier, in fact at 140° and not at 180°.

The second preliminary test was to find out if much fertiliser would be thrown outside the 35 ft measuring circle. It has already been mentioned that the trays were only set out to a radius of 35 ft from the disc so that if the fertiliser was thrown much further than this it would not be caught and measured. Also there would be a possibility of it hitting the walls of the building which are only 37 feet from the disc at the shortest distance in the measuring area.

Using the feed point found in the previous test, that is a radius of 3.75 in. on the disc at an angle of 140°, trays were laid out on the centre line from the disc to a maximum distance of 50 feet. The amounts caught in each tray were weighed and they have been plotted in the next diagram as a percent of the total discharge against the distance thrown.

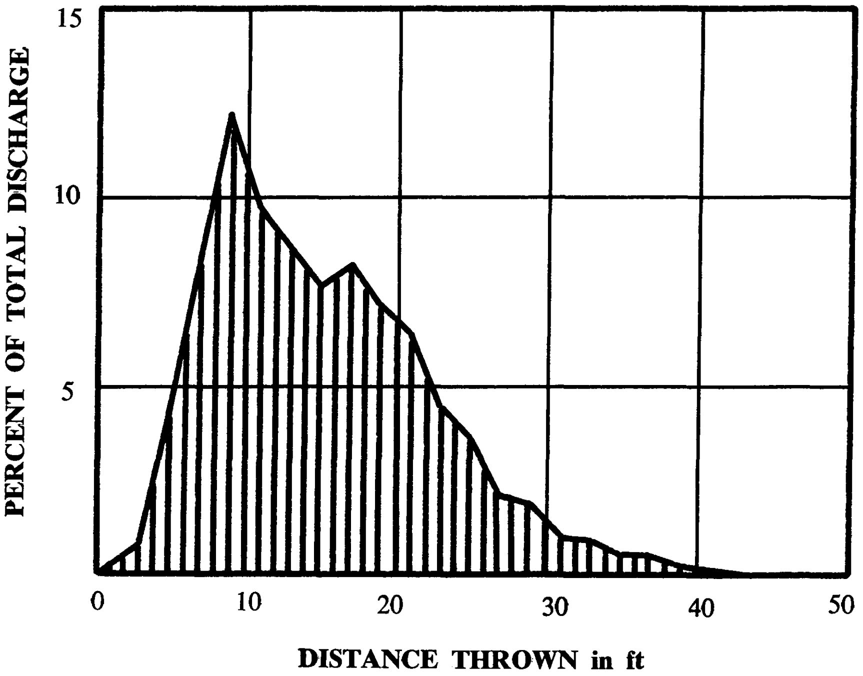

Fig. 8. Test to find the distance granules are thrown from the disc.

This test confirmed that less than 1.5% of the total put on the disc was thrown outside a radius of 35 ft.

The main part of the programme could now be started and in it we have looked at the influence of three variables, as described in the next three sections.

Influence of Location of Feed in Discharge

When fertiliser is dropped onto a spinning disc it is carried round on the disc itself for a short time and then flung off. If the disc is visualised as a compass card and the fertiliser is put on at, say, 210°, it could be carried round and flung off along the 360° line. The angle through which the fertiliser turns on the disc, in this case 150°, is called the 'Angle of Turn'. However in practice fertiliser would not be flung off at precisely 360° but over an arc, say between 320° and 40°. The angle of the arc, in this case 80°, is called the 'Angle of Spread'.

A diagram will, perhaps, help to make this clearer.

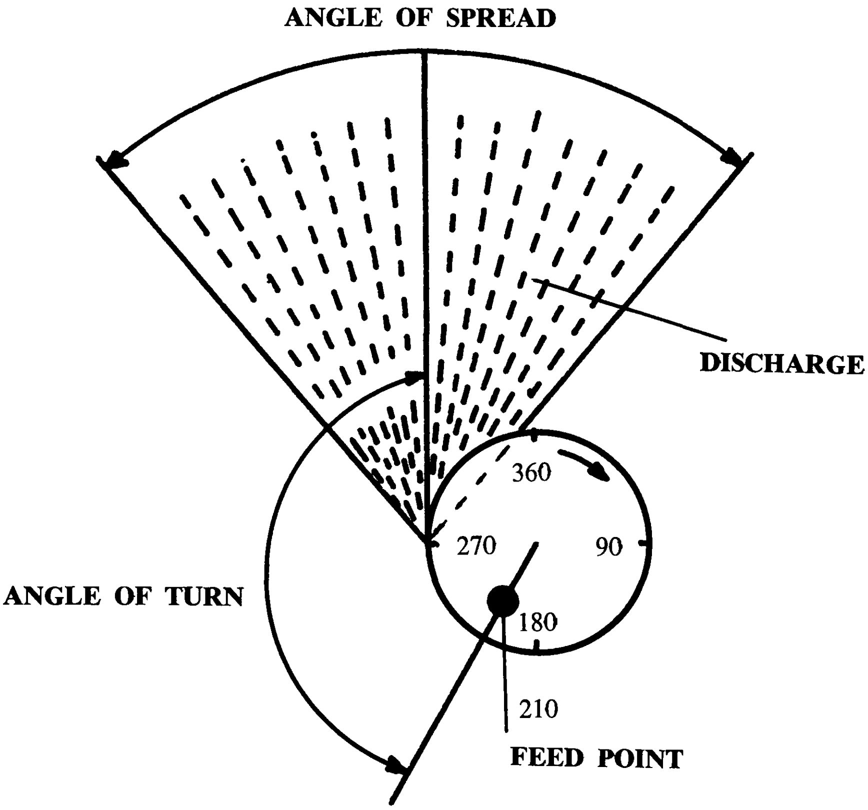

Fig. 9. Method of finding 'angle of turn' and 'angle of spread'.

Six tests were then run with the feed set at different distances from the centre of the disc. The angle of turn and angle of spread were found for each feed position and are plotted in the two graphs of Figure 10. It can be seen from these graphs that, as the feed point moves from the centre of the disc towards the circumference two things happen to the discharge. First it comes off the disc earlier, that is the angle of turn decreases and second that the spread decreases.

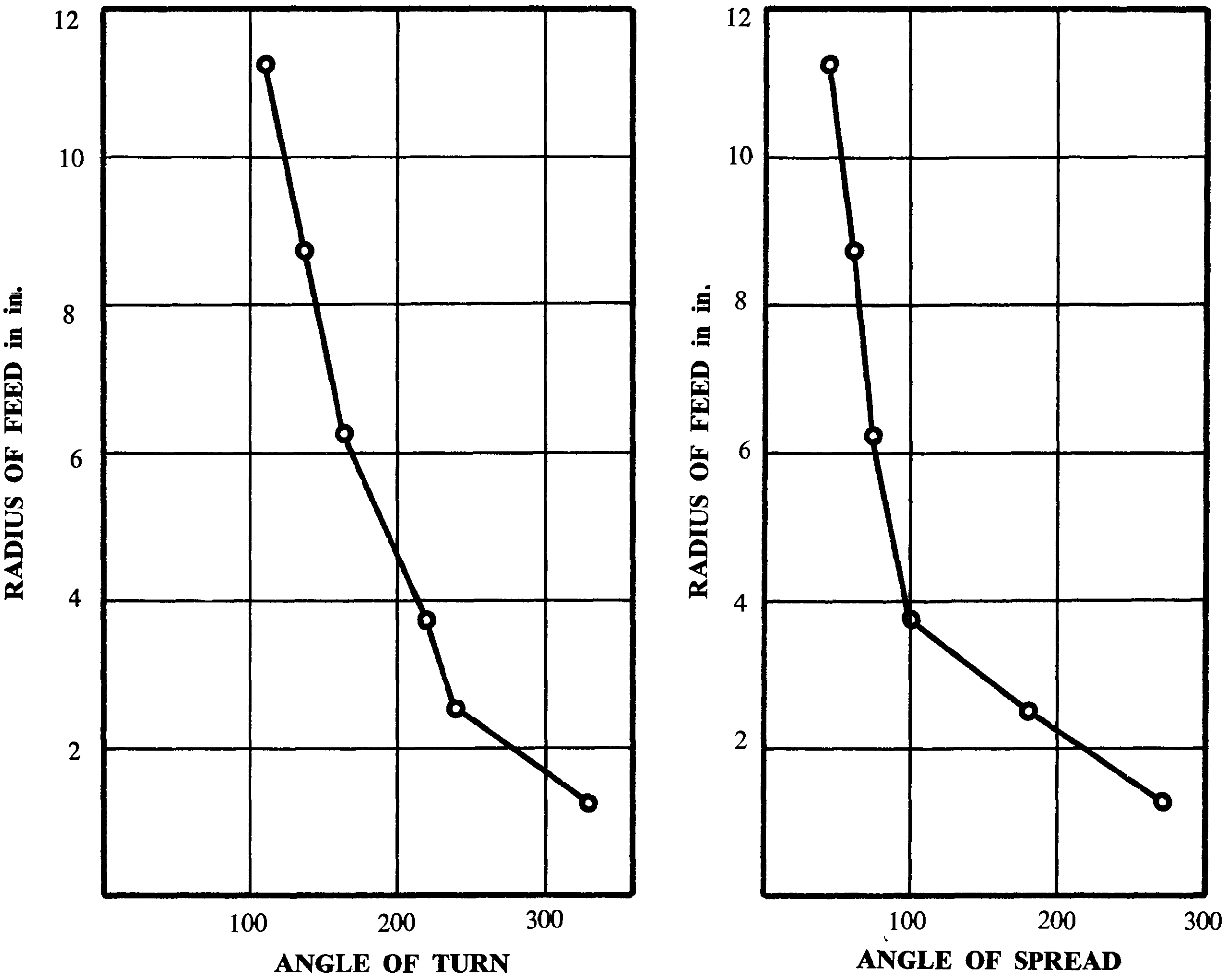

Fig. 10. Influence of feed position on direction and speed of discharge from a 30 in. diameter disc rotating at 675 rpm.

It has already been mentioned that the fertiliser should be discharged over a semi-circle, that is the angle of spread should be 180°. For this particular disc the fertiliser must be fed on at $2\frac{1}{4}$ in. radius to give this spread. At $2\frac{1}{4}$ in. radius the angle of turn is 240° so the exact position of the feed point must be at 120° and at $2\frac{1}{4}$ in. radius. All the remaining tests of this series were done with this feed position.

Influence of Granule Size Distribution on Spread Pattern

The next objective was to find out how the distribution pattern was influenced by a change from the standard blend of fertiliser, first to one consisting mainly of large granules and then to one of a more powdery type, that is mainly fines. Two new blends were made up, a 'Coarse' mix with the composition given in Table 2 and a 'Fine' mix with the composition given in Table 3.

Size Range of Granules	Percent Weight in Blend
>4 mm	28
2 - 4 mm	28
1 - 2 mm	34

Table 2. Composition of 'Coarse' blend of superphosphate.

Size Range of Granules	Percent Weight in Blend
1 - 2 mm	57
0.5 - 1 mm	26
<0.5 mm	17

Table 3. Composition of 'fine' blend of superphosphate.

The patterns obtained from these two blends are compared with that from the standard blend in the next diagram, Figure 11.

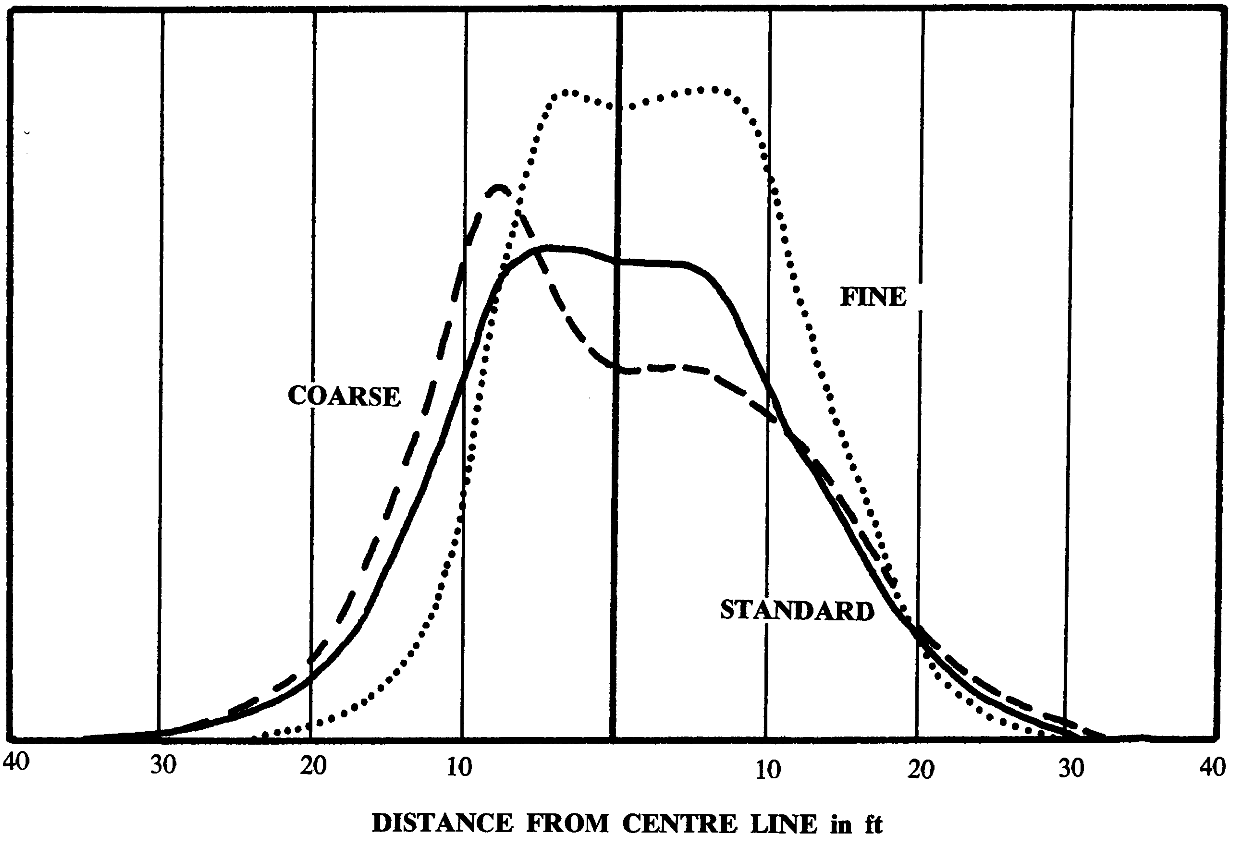

Fig. 11. Spread patterns obtained with different blends of superphosphate.

Although these results were obtained with the rig stationary the shape of the pattern will be the same as if the rig was fitted to a normal machine moving across a paddock. It is therefore possible to use the pattern to find out what is the uniformity of spread when successive bouts are overlapped. Patterns can be overlapped manually and figures obtained to show how evenly the fertiliser has been applied; however the arithmetic is time consuming and tedious and a computer programme has been written to find the maximum and minimum application rates and the 'Coefficient of Variation' over a range of bout widths.

'Coefficient of Variation' is a standard statistical term and is used as a measure of the evenness of spreading. The term is defined in the Appendix and, although it has some limitations in practice, it does give a fairly satisfactory assessment of performance. Coefficient of Variation is plotted against Bout Width for the three blends of fertiliser in the following graph, Figure 12.

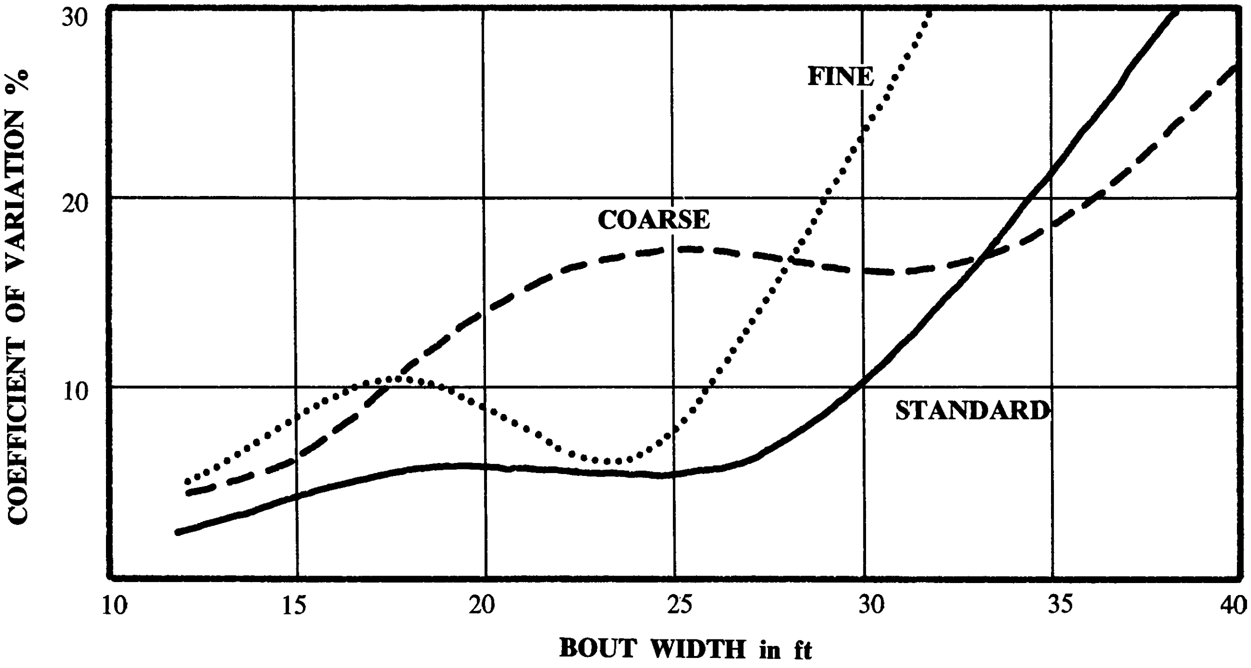

Fig. 12. Influence of superphosphate grade on coefficient of variation.

A maximum coefficient of variation of 10% is considered satisfactory for spreading superphosphate on pasture, but the figure is arbitrary. At 10% the maximum bout width for the coarse blend is 18 ft, for the fine blend is 26 ft and for the standard blend is 30 ft. At least under these test conditions the 'best' blend is the full range superphosphate containing a fairly even distribution of all granules from dust up to a maximum, in this case, of about 5 mm.

It has been generally assumed in the past that the most uniform application will be obtained when using a fertiliser whose particles are all the same size. This is probably true when using a box type or full width spreader, but when using a spinning disc broadcaster the normal pattern, if all the particles are the same size is like the one shown in Figure 13. This is not a good pattern to overlap.

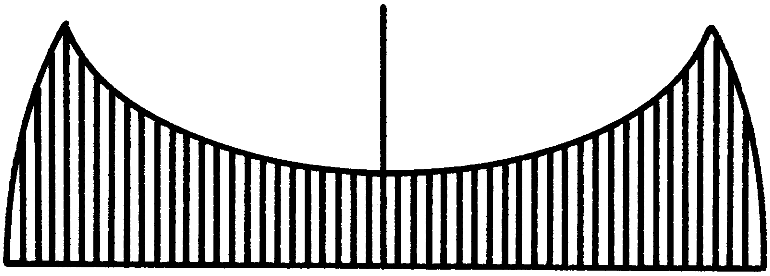

Fig. 13. Spread pattern using fertiliser with granules of uniform size.

From this it seems that a uniform granule size fertiliser is probably not the best for the spinning disc machine, but we should be more sure about this at the end of the project when other tests are completed.

Influence of Vane Length on Spreading Pattern

Up to now all tests had been done with the six radial vanes extending to the centre of the disc. This was necessary when finding the effect of feed position for the sake of uniformity since it would not have been logical to have fertiliser falling in line with a vane during one test and onto the bare disc in another. However during all the preceding tests it was noticed that, while most of the fertiliser was flung from the vane tips, as required, a small but significant part was 'knocked off' by the vanes and deposited in a small area near the disc, as illustrated in Figure 14.

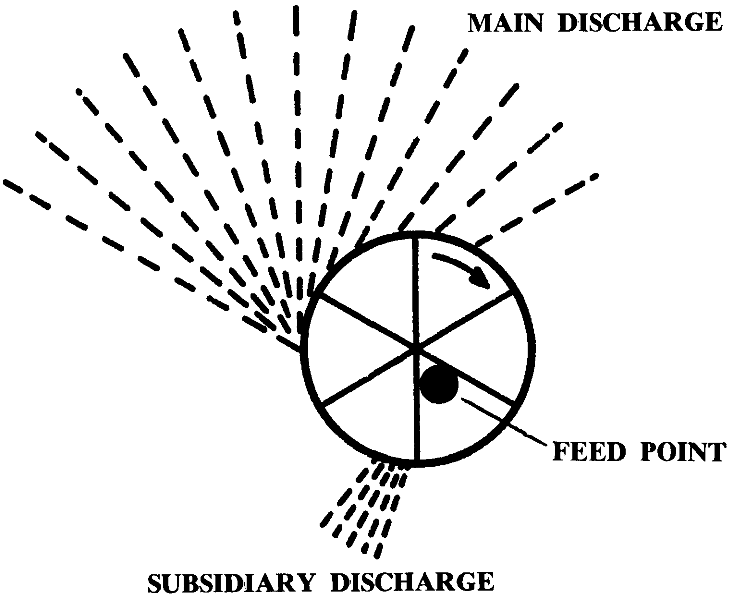

Fig. 14. Subsidiary discharge noticed with full radial vanes.

It is undesirable to have this uncontrolled discharge superimposed on the main pattern and this is what caused the hump in the pattern with the coarse superphosphate; the effect was naturally accentuated with the larger particles. Now that the optimum feed position was known the centre portion of the vanes could be cut away to leave a clear space, 8 in. diameter, at the centre of the disc, as shown in Figure 15.

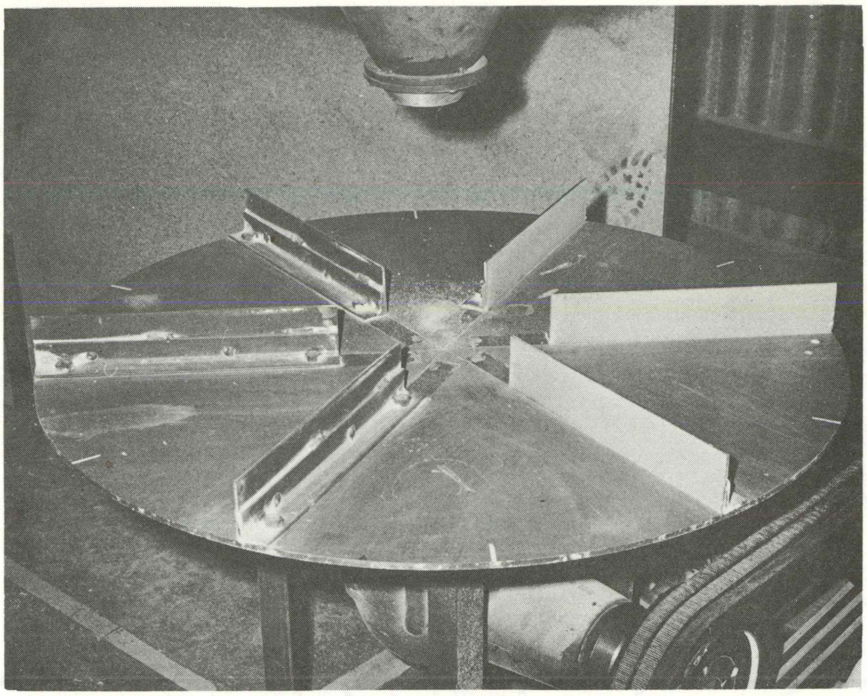

Fig. 15. Disc with shortened vanes.

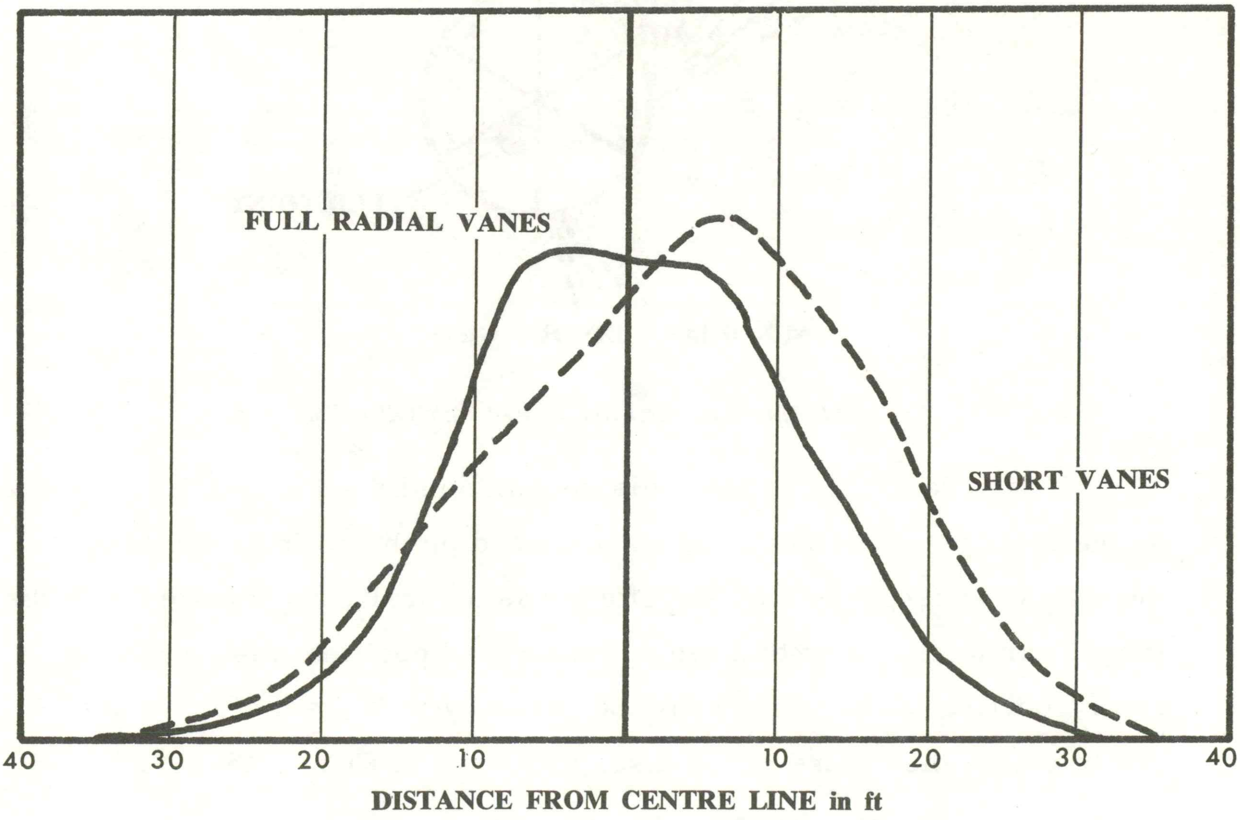

Fig. 16. Spread patterns with different vane lengths.

Shortening the vanes had a marked effect on the pattern and completely removed the subsidiary discharge. At a coefficient of variation of 10% it also increased the bout width to 35 ft as can be seen from the graph in Figure 17.

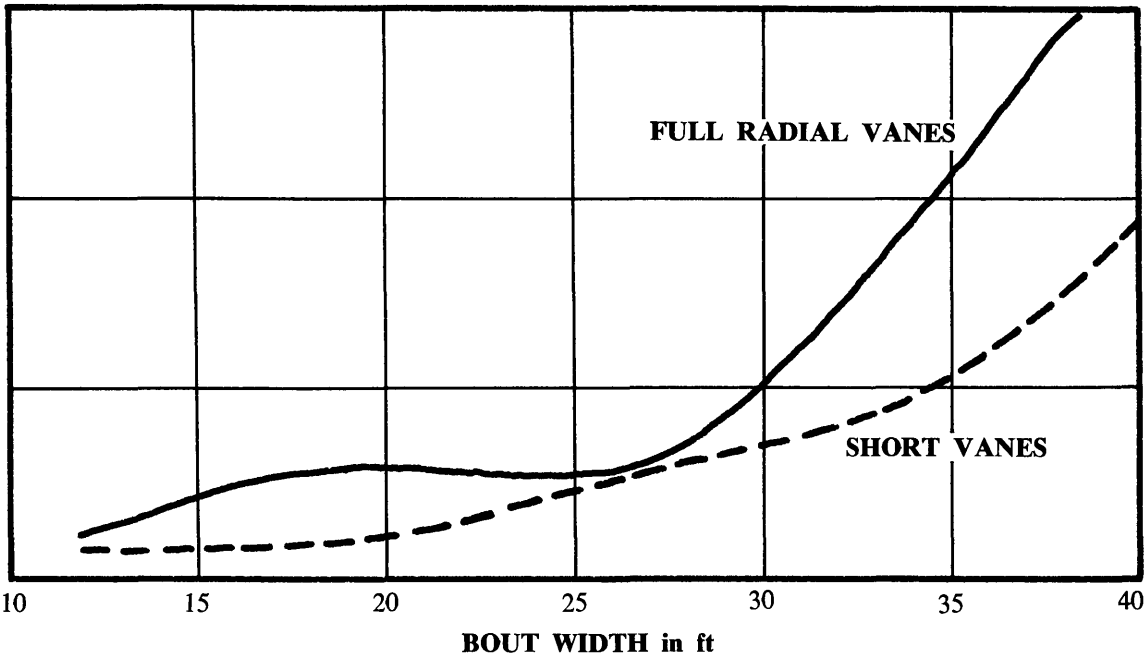

Fig. 17. Influence of vane length on coefficient of variation.

More by chance than design the pattern now obtained is the triangular one originally sought, the pattern is slightly offset from the centre line but this would be easily rectified by moving the feed about **20**$^{\circ}$ around the disc at the same radius. Eighty one percent of the fertiliser put on the disc was recovered in the 35 ft radius semicircle and this should be improved still further when the discharge is centralised.

This completed the first part of the project.

FUTURE PROGRAMME

In the next series of tests we shall look at:

The effect of varying the rate of feed of fertiliser onto the disc.

The effect of vane angle, swinging the vanes back and forward 10° from the radial position.

The influence of disc speed, running tests at 550 rpm and 800 rpm in addition to the present 675 rpm.

The influence of different shapes of feed orifice.

The important remaining variables are the influence of disc height and the use of a dished disc instead of a flat plate. It is possible that the effect of these variables can be calculated from the theory of particle trajectories and this is being examined. Theory has so far proved of little help in the project mainly because the irregular shape of the granules has made mathematical analysis of their trajectories almost impossible.

COMMENTS

It would be premature to draw firm conclusions until the remaining tests have been carried out and the project is complete. However we think a few comments can usefully be made at this stage; they may also help to clarify understanding of the project.

The information given in Figure 10 is perhaps the most important part of the report and it shows the significance of accurate feed onto the disc. The precise feed position to give best performance will, of course, vary from one design of disc to another, and also with operating conditions, for example disc speed and the amount of fertiliser put on it. What does seem important to us is that manufacturers of spinning disc machines should appreciate the sensitivity of discharge pattern to feed point. Our routine testing of standard machines has confirmed this; quite small adjustments to feed have made big improvements in distribution performance.

We have not seen any references in the literature to distortion of the distribution pattern by fertiliser being 'knocked off' the disc by the vanes as illustrated in Figure 14. This could be a quite significant source of error with some machines and may help to explain some unusual patterns.

Turning to fertiliser properties; we would not like to over emphasise, at this stage, the finding that a product containing a range of particle sizes could be the best material for the spinning disc type of distribution. However in view of the trend towards fertilisers of uniform particle size, especially in some overseas countries, it does seem important to confirm or refute this finding as soon as possible. What is undoubtedly important is that fertiliser manufacturers should seek to make their products as consistent as possible from batch to batch, especially in the proportion of fines in the total. Quite obviously a cost factor must be considered but it is asking a great deal of spinning disc distributor manufacturers that their machines should give consistently good performance with fertilisers of varying physical composition.

APPENDIX

Definition of Coefficient of Variation.

$$\text{C of V} \quad = \quad \frac{100\sqrt{\frac{\sum(A - B)^2}{N}}}{B}$$

where A = Weight of fertiliser in one row of trays

B = Arithmetic mean of weight in all rows

N = Number of rows of trays

REFERENCES

1. Procedure for testing broadcast type fertiliser distributors
   by K.R. Humphries
   N.Z.A.E.I. Project Report P/6. February 1971.

2. Design of the spreading mechanism of rotating disc fertiliser spreaders for obtaining an optimum distribution pattern.
   by K. Dobler and J. Flatow
   Grundlagen der Landtechnik. Vol. 19 No. 2 pp 55-60. 1969
   Translation No. 10216 by C.S.I.R.O. Melbourne.

3. Investigations on spinning disc fertiliser distributors.
   by W. Hollman and A. Mathes
   Lantechnische Forschung. Vol. 12 (6) pp 179 - 186. 1962
   Vol. 13 (1) pp 17 - 24. 1963
   Translation No. 144 by N.I.A.E. Silsoe, England.