J. agric. Engng Res. (1987) **36**, 101–114

Performance Evaluation of an Oscillating Trough-type Fertilizer Applicator

R. K. BANSAL*; R. LEEUWESTEIN†

Results of a series of experiments conducted to study the factors influencing metering and the distribution pattern of fertilizer from an oscillating trough-type fertilizer applicator are reported in this paper. It was observed that the centrality of the raker strip and the trough, two principal components of the oscillating trough-type mechanism, and symmetry in the angle of oscillation of the latter with respect to the vertical centre line of the hopper are very important to minimize variations in the quantity and distribution of fertilizer. With the oscillatory-type mechanism, fertilizer falls from the front and rear edges of the trough, alternately. Thus the greater the rate of oscillation of the trough, the greater is the frequency with which fertilizer falls in a unit distance of travel resulting in more uniform distribution. The rate of application can be adjusted by varying the angle of oscillation.

1. Introduction

In the application of fertilizer by machine it is important to achieve uniformity because uneven application can result in unequal plant growth and maturity, and yields may thus be reduced even though the average rate of application is optimal.[1] The extent to which unequal distribution has an effect on the crop depends on factors related to soil type and the availability of moisture, agronomic practices, and the type of fertilizer used. As there is very little lateral movement of fertilizer in the soil, the aim is to apply it evenly in each row and over the whole field.[2]

To achieve such uniformity, the first step is to ensure proper metering and regular discharge by the mechanism employed in the applicator. Most of the commercially available fertilizer applicators in India use gravity feed through an adjustable opening, assisted by an agitator, because this mechanism is relatively easy to manufacture and simple to operate. However, such gravity feeding gives uneven application primarily because of the physical properties of fertilizer and bouncing of the machine in the field.[3] In India some designs of combined seed and fertilizer drill use fluted feed rollers, usually an aluminium casting. This type of mechanism occasionally seizes due to fertilizer dust lodging between the moving components. To overcome the problems of conventional methods of fertilizer metering, the possibility of designing an oscillating trough-type top-delivery system was explored. Subsequently, a four-row fertilizer applicator was developed[4] as a part of an animal-drawn planting system at ICRISAT (International Crops Research Institute for the Semi-Arid Tropics), Patancheru, Andhra Pradesh, India, for metering granular diammonium phosphate (18-46-0 NPK), ammonium phosphate (28-28-0 NPK), and prilled urea. Several units of this design were made by a small-scale manufacturer in India on a commercial basis.

Subsequent use of this fertilizer applicator in 1 to 4 ha plots at ICRISAT showed that there were variations, often very large, in the distribution pattern both along and between the rows. Application rates, at the same setting from different machines were also found to vary considerably. It was then decided to investigate the effects of variations in individual

* International Crops Research Institute for the Semi-Arid Tropics, P.O. Patancheru 502 324, A.P., India
† National College of Agriculture, Deventer, The Netherlands

Received 3 July 1985; accepted in revised form 5 April 1986

0021-8634/87/020101 + 14 $03.00/0

components of the oscillating trough-type metering mechanism on fertilizer discharge and distribution pattern. Results of a series of experiments conducted with a single row unit are presented in this paper. For the purpose of determining limits for the variation in the dimensions or position of critical components, a range of $\pm 12{\cdot}5\%$ from the mean application rate was considered to be acceptable in accordance with IS 6813–1973.[5]

2. Description of the fertilizer applicator

The fertilizer applicator (*Fig. 1*) consists of a hopper (A) which tapers towards the bottom. Along the length, at the bottom of the hopper, four rectangular openings (120 x 30 mm each) discharge fertilizer into four matching feeding chambers (B) located underneath. In the middle of the lower part of each chamber a raker strip (C) is welded in such a way that it protrudes by 10 mm from the lower edge of the feeding chamber. Each chamber opens into a semi-circular trough (D). Width of openings in the hopper, dimensions for the feeding chambers, and the trough diameter were determined from trial runs during the development stages of the design to ensure smooth flow and obtain commonly used fertilizer application rates for crops grown in the semi-arid regions. Troughs for four feeding chambers are made by removing the upper half of a 60 mm o.d. tube for 130 mm length at four places with 40 mm spacings and then blocking the tube between adjacent sections with circular plates. The tube, supported at both ends, is oscillated by a connecting rod (E) attached to a crank (F). The crank is a disc with eight holes drilled at different radii to vary the angle of

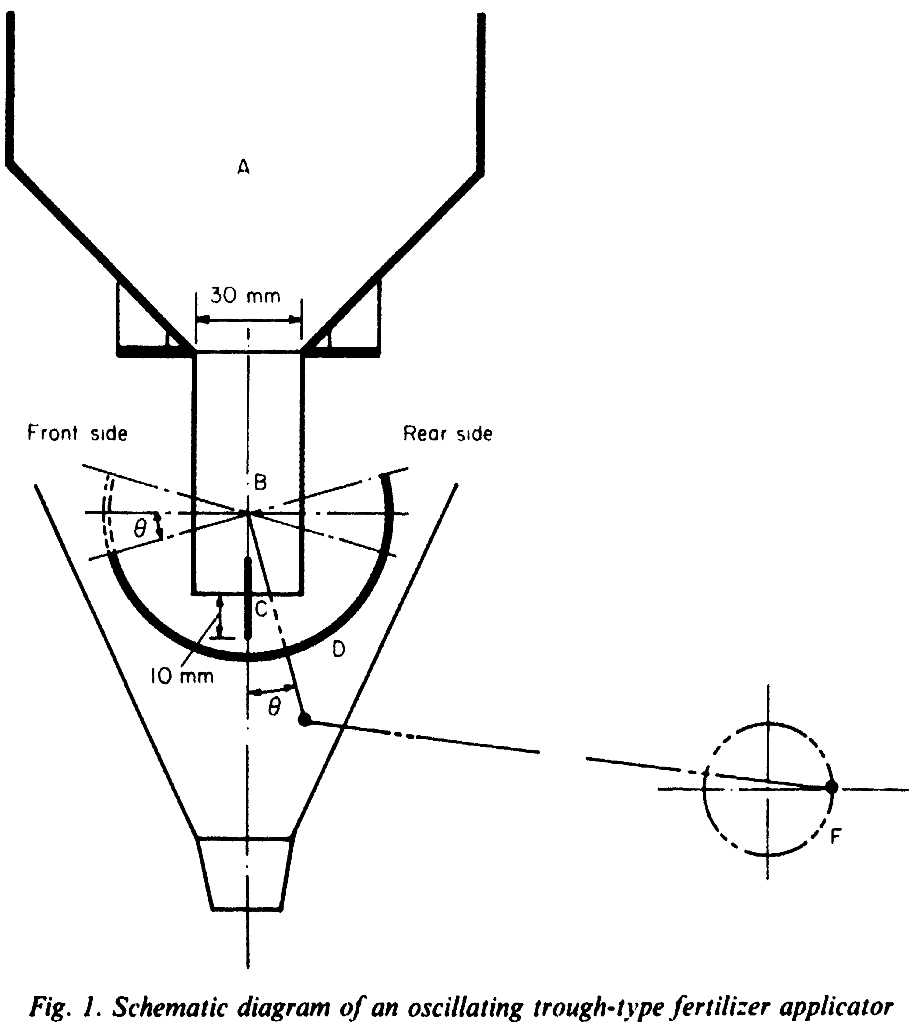

Fig. 1. Schematic diagram of an oscillating trough-type fertilizer applicator

oscillation of the trough to either side of its mean position (θ) from 17° to 35°, which permits adjustment of the fertilizer application rate. When the hopper is filled, fertilizer flows down through the feeding chambers into their respective troughs. When the trough oscillates, fertilizer spills over the left- and right-hand edges alternately, as a result of the raking action of the strip.

Measurements were taken on 10 commercially produced units to find out variations in the dimensions and relative positions of the raker strip, trough, and the connecting rod. Possible causes of variation in fertilizer application across the machine and along individual crop rows were identified as follows.

(1) Horizontal deviations in the positions of the raker strip (HS) and the trough (HT) with respect to the vertical centre line of the hopper (*Fig. 2*).
(2) Variations in the projection of the raker strip (VS) and in the height of the centre line of the trough (VT) from the lower edge of the feeding chamber (*Fig. 2*). These variations determine the actual gap (A) between the raker strip and the bottom of the trough.
(3) Interaction of HS, HT, VS, and VT.
(4) Length of the connecting rod (which affects the angle of oscillation of the trough).
(5) Crank to ground wheel speed ratio.

Experiments were conducted to find the effects of the above-mentioned factors.

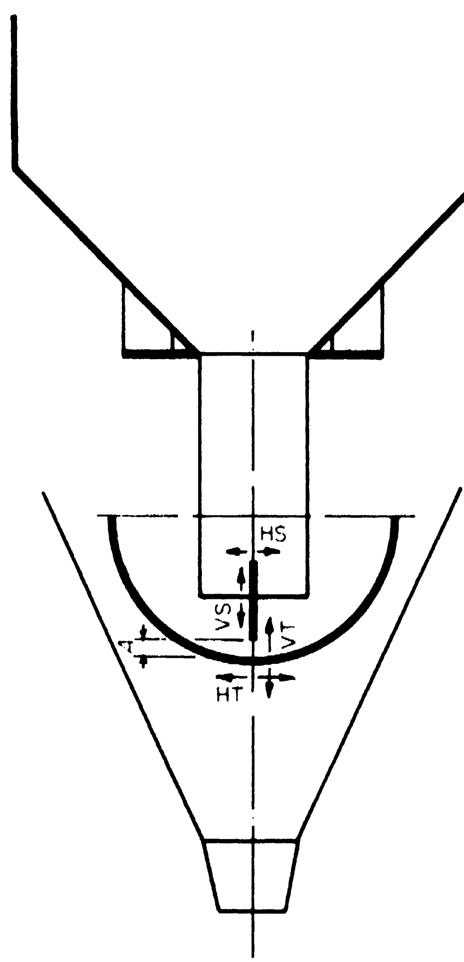

Fig. 2. Schematic view of the horizontal and vertical adjustments made in the positions of the raker strip (HS and VS) and the trough (HT and VT)

3. Materials and methods

To find out the effect of variations in the raker strip and trough positions, a single-row experimental hopper (*Fig. 3*) was made accurately to the drawing dimensions. The trough (A) was supported on two bushes such that its position could be shifted on either side from the central location in steps of 0·305 mm (0·012 in) which is equal to the thickness of the brass shims (B). The axis of the trough could also be moved up or down in steps of 0·305 mm from its designed location for a 5 mm gap between the lower edge of the raker strip and the bottom of the trough. Similarly, the feeding chamber (C) was modified to make adjustments in the position of the raker strip. The raker strip (D) was welded in a small frame (E) which slid freely inside the feeding chamber. On both sides of this frame small strips were welded, which projected through slots in the feeding chamber, to facilitate movement of the former horizontally (parallel to the axis of the trough), and vertically. On the feeding chamber also, strips were welded on either side just below the slot. Vertical adjustments in the position of the raker strip with respect to its designed location for a gap of 5 mm as mentioned above, were made by inserting the required number of the shims (F) of 0·305 mm thickness each, between the upper and lower strips. The raker strip could be shifted on either side of its central location by inserting 0·38 mm (0·015 in) thick shims (G) in the longitudinal direction in the space between the frame and feeding chamber. With this arrangement, the raker strip and the trough could be set in any position up to 1·52 mm in steps of 0·38 mm, and 3·00 mm in steps of 0·305 mm, respectively to either side of their central locations, and the gap under the raker strip could be varied from 1·85 mm to 7·64 mm, in 16 settings.

The experimental hopper was mounted on a rigid frame welded to a firm table (*Fig. 4*). An adjacent table supported a motor, a variable-speed drive gearbox, and a crank. An adjustable connecting rod transmitted motion from the crank to the trough. The speed of the crank was 85 rev/min corresponding to a designed gear ratio for a 650 mm diameter wheel of the planter and fertilizer applicator and a normal walking speed of the oxen of 1 m/s. To study the effect of relative positions of the raker strip and trough on fertilizer discharge, the

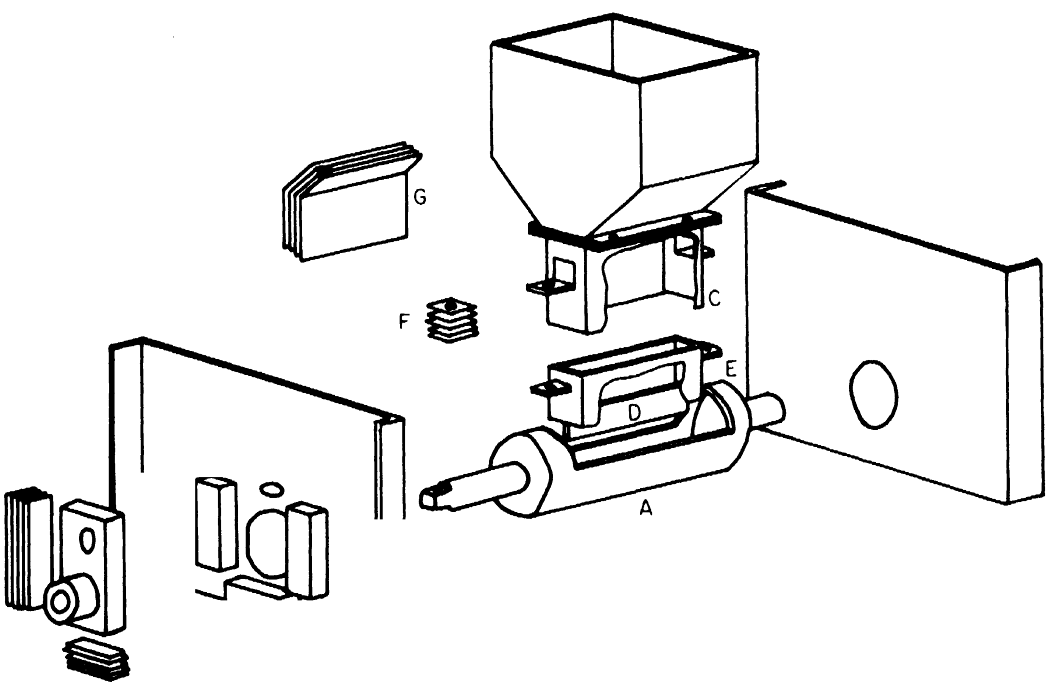

Fig. 3. Details of the experimental hopper

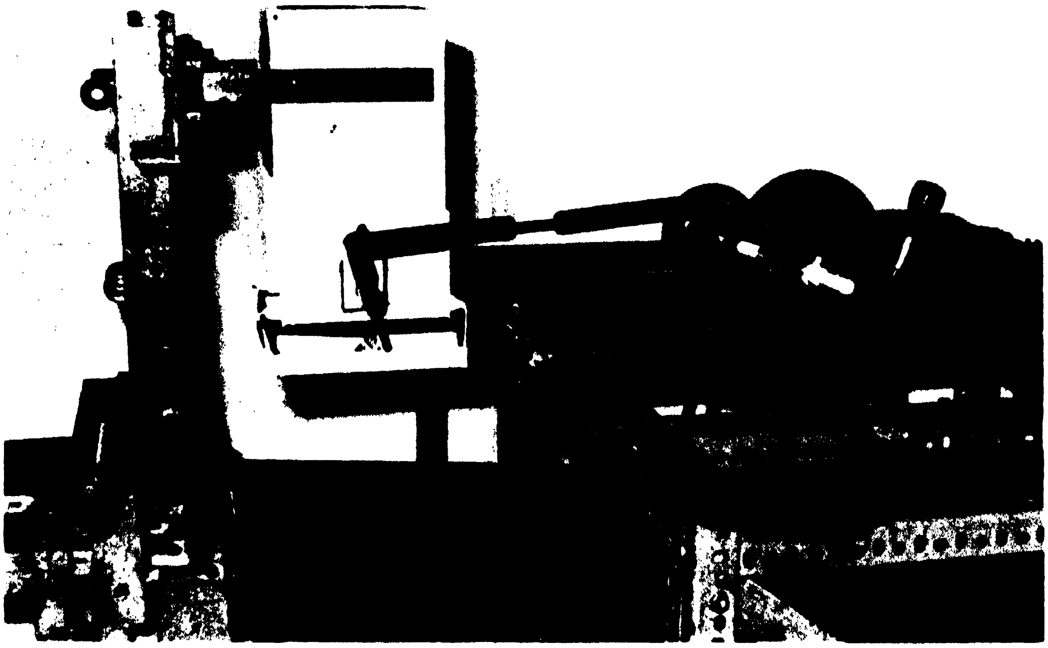

Fig. 4. Experimental set up for bench testing the fertilizer applicator

angle of oscillation of the trough was set at 26°30′ by fixing the connecting rod in the fourth hole of the crank (crank radius 36 mm).

During field evaluation of the oscillating trough-type fertilizer applicator with ammonium phosphate, diammonium phosphate, and urea it was observed that the difference in the discharge at any one setting for the above three fertilizers was generally within 5% of the mean.[4] Therefore, for a detailed study on this applicator only one fertilizer that is, ammonium phosphate with a particle density of 1·45 g/cc was used. During the initial trials it was observed that some times very coarse grains obstructed the flow of fertilizer blocking the space between the raker strip and the frame to which it is welded. To avoid this problem, fertilizer was screened through a 6 mesh (3·35 mm opening) sieve. The final particle size distribution is shown in *Fig. 5*.

In a crank and connecting rod mechanism as shown in *Fig. 1*, a connecting rod of finite length will always give a small difference in the angle of oscillation of the trough on front and rear sides. However, if the length of the connecting rod is equal to the distance between the centre of oscillation of the trough and the crank centre, this difference may be small enough not to cause a noticeable inequality in the fertilizer discharge from the front and rear edges. Any change in the connecting rod length from this setting will increase the difference in the angle of oscillation and so also the inequality in the fertilizer discharge. The first experiment, conducted on the test bench, was to study the effect of connecting rod length on fertilizer discharge from the front and rear edges of the trough by way of inequality in the angle of oscillation of the latter from its mean position. The length of the connecting rod was varied from 195·62 mm to 202·62 mm in steps of 0·87 mm (half turn of the screw thread) for a designed dimension of 200 mm. This variation caused the trough to tilt more on the front side when the connecting rod was too long and more to the rear side when it was shorter than the designed dimension. The angle of oscillation (θ), which was 26°30′, almost equal on both sides when a 200 mm long connecting rod was used at the fourth hole of the crank,

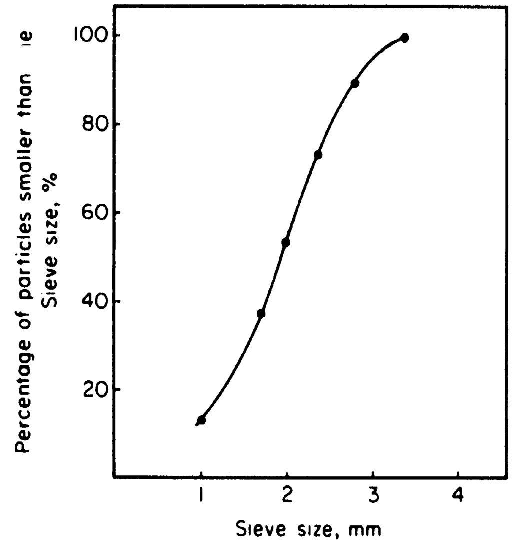

Fig. 5. Cumulative particle size distribution of ammonium phosphate fertilizer

became unequal by 7° and 4°10′ at extreme settings in the length of the connecting rod. The raker strip and the trough were positioned in the centre of the hopper and the projection of the former below the feeding chamber was made equal to the designed dimension of 10 mm by inserting or removing shims wherever needed. Similarly, the trough was moved up or down until a gap of 5 mm under the lower edge of the raker strip was achieved.

The second and third sets of observations, also taken on the test bench, were for detailed study of variations in the positions of the raker strip and the trough in horizontal (HS and HT) and vertical (VS and VT) planes, respectively. A fourth set of data was collected to determine the effect of interaction of the same four factors on the fertilizer discharge. Details of the factors and their levels used in these experiments are given in Table 1. For each setting

Table 1

Treatment details for three experiments conducted on the test bench

	Experiment 2		*Experiment 3*		*Experiment 4*	
Factor	*Levels*	*Actual settings*	*Levels*	*Actual settings*	*Levels*	*Actual settings*
Horizontal position of the trough with respect to the hopper centre line (HT)		Central, 0·61, 1·22, 2·135 and 3 mm to the front side				Central, and 3 mm to the front side
Horizontal position of the raker strip with respect to the hopper centre line (HS)		Central, 0·38 to 1·52 mm in steps of 0·38 mm on both sides				Central, and 1·14 mm to both sides
Vertical position of the trough with respect to its designed location for a 10 mm projection of the raker strip and 5 mm gap (VT)				Designed location, 0·305, 0·915, and 1·525 mm up and down		Designed location, 0·915, and 1·83 mm down and 0·915 mm up
Raker strip projection below lower edge of the feeding chamber (VS)				8·475 to 11·525 mm in steps of 0·61 mm		9·085, 10·00, 11·22 and 12·135 mm

Fig. 6. Experimental set up on the soil bin

three replications were made and fertilizer output from the front and rear edges for 50 revolutions of the crank was weighed separately.

To study variation along-the-row in fertilizer application the same experimental hopper was used. The hopper was mounted on a trolley that could move for 10 m on rails over a soil bin (*Fig. 6*). The crank was supported on the trolley frame and driven with a chain from one wheel. A series of 20 plastic trays of 28 cm length each were placed on the soil directly below the fertilizer hopper. The trays were connected with inverted V-shaped iron sheets to prevent fertilizer loss in the space between them. Although fertilizer could be collected over a distance of about 6 m, only the central 3 m section of the trays was used for taking observations. This was done to give the trolley enough distance to reach a constant speed before passing over the sampled area. To prevent fertilizer grains from bouncing out, a thin plastic mat was put inside each tray. Each tray was divided lengthwise into four equal sections by positioning pieces of cardboard vertically to collect fertilizer samples from 70 mm sections along the row.

During experiments, the speed of the trolley was kept constant at 1 m/s in keeping with oxen average walking speed. To study along-the-row variation in fertilizer application, observations were taken for a total of 16 settings corresponding to four levels each of the frequency of fertilizer falling on a unit distance and the angle of oscillation of the trough. The frequency of fertilizer falling on 1 m distance was set at 3, 4, 5, and 6 by adjusting the speed of the crank to 90, 120, 150, and 180 rev/min with the help of sprockets in the power transmission system. The angle of oscillation of the trough was set at 17°, 23°30′, 28°, and 31°30′ by making the crank radius 24, 32, 38, and 42 mm, respectively.

As is evident from the design (*Fig. 1*), fertilizer descends to the trough from the hopper by gravity; the height of the column of fertilizer in the hopper may have some effect on its rate of downward movement and filling of the trough. Thus, to quantify the effect of fertilizer level in the hopper another set of data was collected. After every passage of the trolley over the sampled area, the fertilizer fallen in each section was removed and weighed.

4. Results

4.1. *Effect of the connecting rod length*

As mentioned earlier, making the connecting rod too short or too long caused the trough to tilt more towards the rear and front sides, respectively. In *Fig.* 7, fertilizer discharge from the front and rear edges has been plotted against the difference in the angle of oscillation of the trough towards the front and rear sides at corresponding settings in the length of the connecting rod. It can be seen that a trough having greater tilt towards the rear side, as happened when the connecting rod was of smaller size than the designed length, gives more discharge from the front edge and less from the opposite edge. The discharge lines for these two edges converge as the difference in the angle of oscillation of the trough reduces, and finally join near a point where the latter becomes zero. That particular point signifies the correct length of the connecting rod to be used. Beyond this, when the connecting rod is too long, the angle of oscillation becomes greater towards the front side, indicated by negative values, giving more discharge from the rear edge.

The difference in the discharge from the front and rear edge is one of many causes of intrarow variation. Horizontal lines in *Fig.* 7 indicate upper and lower limits of fertilizer discharge from any edge corresponding to $\pm 12{\cdot}5\%$ range from a mean of 212 g where the difference is zero. Evidently, to remain within these limits symmetry in the angle of oscillation of the trough to both sides is important and the permissible deviations are 3° to the rear and 2° to the front side. These limits also suggest a tolerance of −2 mm and +1 mm for a connecting rod of 200 mm nominal size. In practice, it should not be difficult to maintain these dimensions and, therefore, the connecting rod is unlikely to be a source of too much variation in fertilizer application rate and intrarow distribution.

4.2. *Effect of horizontal deviation in the trough (HT) and raker strip (HS)*

Results of Experiment 2 (Table 1) showed that individual effects of horizontal deviation in the trough and raker strip positions on the total quantity of fertilizer discharged were statistically significant ($P < 0{\cdot}05$). As the trough was shifted away from its central position

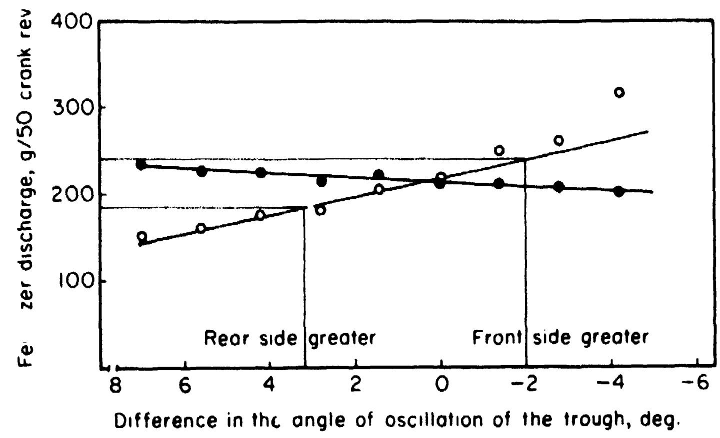

Fig. 7. Effect of the inequality in the angle of oscillation of the trough towards front and rear sides from its mean position on fertilizer discharge. —●—, Discharge from the front edge; —○—, discharge from the rear edge

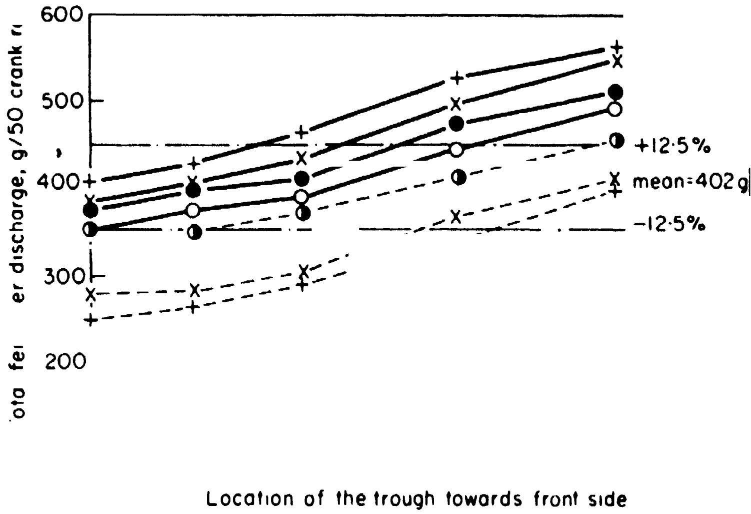

Fig. 8. Effect of horizontal positions of the trough (HT) and raker strip (HS) on total fertilizer output. Raker strip: —○—, in the central location; – –◐– –, 0·76 mm towards front side; – – × – –, 1·14 mm towards front side; – – + – –, 1·52 mm towards front side; —●—, 0·76 mm towards rear side; — × —, 1·14 mm towards rear side; — + —, 1·52 mm towards rear side

towards the front side, the total discharge tended to increase for all positions of the strip (*Fig. 8*). However, at a given position of the trough, the discharge was reduced significantly when the strip was moved towards the front side and increased when it was moved to the rear.

Interaction of HT and HS was also significant ($P < 0{\cdot}05$). Horizontal lines drawn at $\pm 12{\cdot}5\%$ of overall mean discharge indicate that permissible deviation in the strip depends somewhat upon the actual position of the trough itself. If we assume that in a commercial machine, the actual position of the trough will not deviate beyond $\pm 1{\cdot}5$ mm from the centre line of the hopper, then the raker strip can have a tolerance of $\pm 0{\cdot}75$ mm. If the trough can

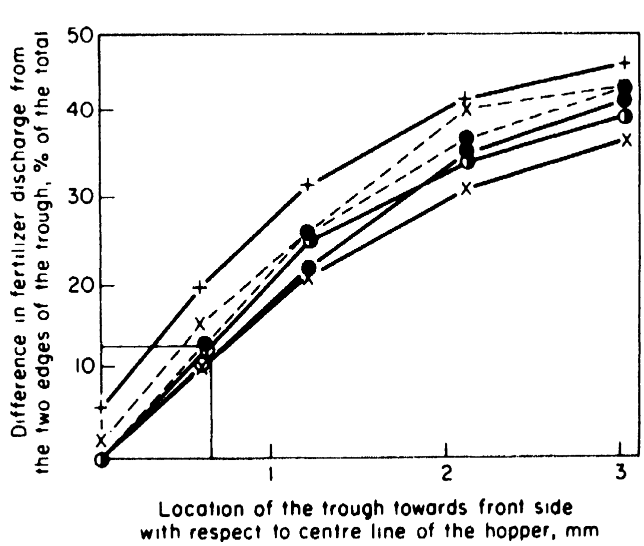

Fig. 9. Effect of horizontal positions of the trough (HT) and raker strip (HS) on fertilizer discharge from left and right edges. Raker strip: —◐—, in the central location; – –●– –, 0·38 mm towards front side; –●–, 0·76 mm towards front side; – × –, 1·52 mm towards front side; – – × – –, 0·38 mm towards rear side; – + –, 0·76 mm towards rear side

be located close to the centre line of the hopper, the permissible deviation in the raker strip may be more. As long as this kind of a combination is maintained, the total output for each row from a four-row machine can be expected to fall within ±12·5% of the mean.

However, the observations with respect to individual output from the front and rear edges present a different picture. In *Fig. 9*, the difference in output from the front and rear edges is expressed as a percentage of the total. It shows that when the strip and trough were in central positions, outputs from both edges were equal or very nearly equal. However, the differences increased sharply with a small deviation in the position of the trough. For a ±12·5% limit on this variation, the trough must be within ±0·70 mm of the centre line when the raker strip is in the centre. In practice, it is relatively easy to maintain a close tolerance for the raker strip by welding it in position using proper jigs. But, fitting tolerances in the trough can cause some intrarow variations.

4.3. *Effect of vertical deviations in the trough (VT) and raker strip (VS)*

As a consequence of change in the positions of the raker strip and the trough in the vertical plane (Experiment 3, Table 1), the gap under the raker strip varied from 1·85 mm to 7·95 mm. In *Fig. 10* fertilizer discharge for 50 revolutions of the crank is plotted against the gap between lower edge of the raker strip and bottom of the trough obtained from a step-by-step change in their positions in the vertical plane. Thus, curves along the X-axis represent the projection of the raker strip below the feeding chamber starting from 11·525 mm at the top to 8·475 mm at the bottom. Similarly, each dotted line corresponds to one position of the trough with respect to its designed location starting from 1·525 mm up on the right side to 1·525 mm down on the left. Obviously, the gap increased as the trough was lowered and/or the raker strip projection was reduced.

It is apparent from *Fig. 10* that a given position of the raker strip, moving the trough up

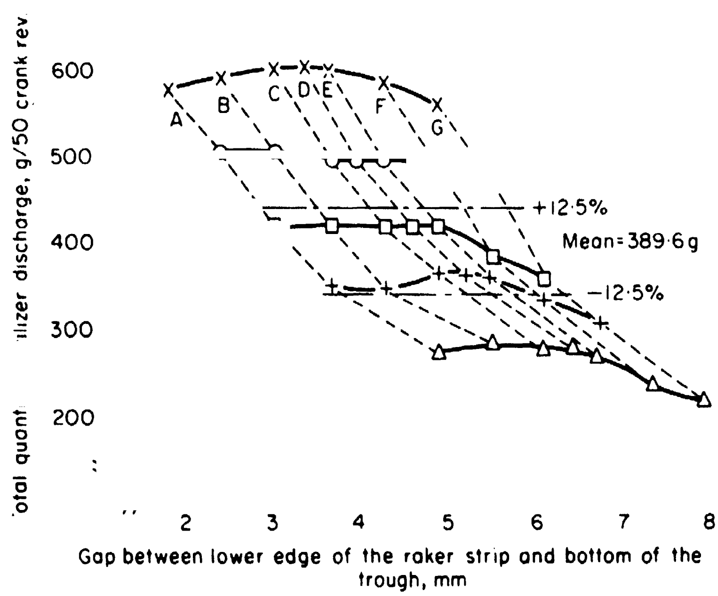

Fig. 10. Effect of the gap between the lower edge of the raker strip and bottom of the trough on the total quantity of fertilizer discharged. Raker strip projection below the feeding chamber: — × —, 11·525 mm; —○—, 10·915 mm; —□—, 10·305 mm; — + —, 9·695 mm; —△—, 8·475 mm. Trough position with respect to its designed location: A: 1·525 mm up; B: 0·915 mm up; C: 0·305 mm up; D: designed location; E: 0·305 mm down; F: 0·915 mm down; G: 1·525 mm down

or down has very little effect on the fertilizer discharge. The variation in the discharge due to lowering of the trough at a fixed setting for the raker strip was found to be within ±6% of the mean. This may be so because of a compensatory effect from the proportionate change in the level of fertilizer in the trough. At higher positions of the trough with respect to its designed location, the gap under the raker strip, and so also under the lower edge of the feeding chamber was reduced. A positive effect of the reduced gap under the raker strip on the fertilizer discharge was partly offset by the low level of filling of the trough.

In contrast to the effect of variation in the position of the trough alone, variation in the projection of the raker strip below feeding chamber keeping the trough fixed caused enormous change in the fertilizer discharge (*Fig. 10*). For example, as the projection of the raker strip reduced from 11·523 mm to 8·475 mm when the trough was fixed in its designed location (curve D) fertilizer discharge for 50 revolutions of the crank fell from 605 g to 278 g. It is because the gap under the raker strip increased from 3·38 mm to 6·43 mm.

From *Fig. 10* it can be seen that the mean fertilizer discharge could be obtained within an acceptable range of ±12·5% even when the gap varied from 3 mm to 6 mm provided the strip projection remained within 9·7 mm and 10·5 mm. From the experience of operating the fertilizer applicator in the field it is known that a gap of less than 4 mm is undesirable for maintaining a smooth flow. Thus it can be concluded that the strip projection in the range of 9·7 mm to 10·5 mm is most desirable to have a good control on fertilizer application rate as long as the trough is within 0·5 mm up and 1 mm down of the designed location.

4.4. *Interactions*

Table 2 shows that at a central position of the trough in the horizontal plane, its lowering with respect to the lower edge of the feeding chamber caused reduction in the total output from 369·7 to 244·2 g for 50 crank revolutions and had virtually no effect on the amounts from the front and rear edges. However, at an off-centre position towards front side, lowering of the trough caused more discharge from the front edge than the rear and the total output also increased from 511·6 to 550·6 g.

Table 3 points out a similar interaction between HT and VS at the central position of the trough. Although total discharge tended to reduce with raising of the raker strip, difference in the output from two edges remained fairly low. However, an off-centre location of the trough gave more discharge and large difference in the output from the two edges. It is therefore necessary to keep the trough close to the central position.

Table 2

Effect of variations in the horizontal and vertical positions of the trough on total quantity of fertilizer discharge and difference in the output from two edges

Horizontal position (HT)	*Vertical position (VT), mm*	*Fertilizer discharge, g/50 crank rev*	*Difference, % of the total*
Central	14·0	369·7	4·0
	14·9	339·1	2·7
	15·8	285·9	3·0
	16·7	244·2	3·9
3 mm towards front side	14·0	511·6	37·2
	14·9	535·4	33·0
	15·8	561·3	26·5
	16·7	550·5	20·6
SE±	—	2·5	0·34

Table 3

Effect of variation in the horizontal position of the trough and vertical position of the strip on total quantity of fertilizer discharge and difference in the output from two edges

Horizontal position (HT)	*Vertical position of the strip (VS), mm*	*Fertilizer discharge g/50 crank rev*	*Difference, % of the total*
Central	12·1	460·2	3·7
	11·2	337·7	2·5
	10·3	274·0	2·7
	9·1	166·9	4·6
3 mm towards front side	12·1	618·6	30·6
	11·2	533·2	30·2
	10·3	531·3	28·7
	9·1	475·7	28·0
SE ±	—	2·6	0·3

4.5. *Effect of frequency of fertilizer falling on a unit distance*

Table 4 shows that, as the frequency of fertilizer falling on a unit distance was increased, the average quantity of fertilizer collected from each section of the tray also increased, more or less in the same proportion. Standard deviation (SD) values tended to be low at higher frequencies, which suggests that the fertilizer distribution was more uniform at higher crank speeds. It appeared that the distribution at a frequency of three falls per metre was very poor because the SD values obtained are very high. Values for CV reduced drastically with the increase in frequency, primarily because of greater mean discharge.

Fig. 11 shows the actual distribution pattern of fertilizer application at a given angle of oscillation of the trough of 28° (crank radius 38 mm) for three and six falls per metre. At a frequency of three falls per metre some of the trays had very little (<0·5 g) fertilizer, whereas at six falls per metre each section received at least 1 g. In the latter case the average quantity for each section was 1·9 g as compared to 0·76 g at three falls per metre. It can be concluded that the effect of increasing the frequency on the total output was substantial and the distribution pattern was also influenced to some extent. Table 4 shows that sometimes nearly the same fertilizer application rate can be achieved at two angles of oscillation of the trough depending upon the frequency of falling. However, to apply a known quantity of fertilizer a setting at a low angle of oscillation and high frequency is better because it gives relatively more uniform distribution.

Table 4

Effect of frequency of fertilizer falling on 1 m distance and angle of oscillation of the trough on along the row fertilizer distribution

	Angle of oscillation of the trough											
	17°			*23°30′*			*28°*			*31°30′*		
Frequency	*Mean, g/7 cm*	*SD, g*	*CV, %*	*Mean, g/7 cm*	*SD, g*	*CV, %*	*Mean, g/7 cm*	*SD, g*	*CV, %*	*Mean, g/7 cm*	*SD, g*	*CV, %*
3	0·32	0·19	58·2	0·51	0·27	53·3	0·76	0·51	67·2	1·13	0·77	67·7
4	0·46	0·15	33·3	0·81	0·29	35·5	1·00	0·38	37·6	1·56	0·73	46·6
5	0·44	0·12	27·0	1·05	0·28	26·4	1·40	0·38	27·0	2·09	0·64	30·8
6	0·66	0·10	15·3	1·19	0·22	18·6	1·90	0·36	19·2	2·82	0·64	22·7

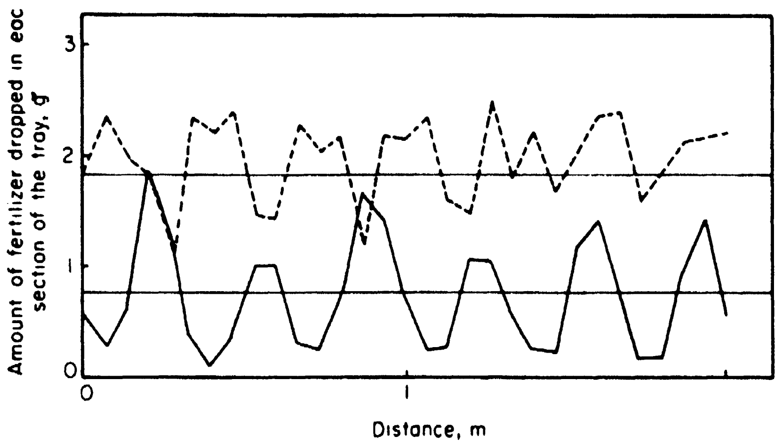

Fig. 11. Fertilizer distribution pattern along the row: ——, at a frequency of three falls per metre. Mean = 1·90 g; – – –, at a frequency of six falls per metre. Mean = 0·76 g

4.6. *Effect of fertilizer level in the hopper*

A test was carried out to see if the level of fertilizer in the hopper had an effect on the output. This was done by collecting the fertilizer dropped over a distance of 3 m. The fertilizer level in the 28 cm high hopper was kept at 4, 10·5, 17, and 23 cm from the top edge. The crank was kept in hole 7, and a gear ratio was used that gave 6 falls per metre. Results (Table 5) showed no significant differences between the mean outputs obtained at the four levels. The actual difference between the highest and the lowest output was only 2·8%.

5. Conclusions

The experiments have revealed that an oscillating trough-type fertilizer metering mechanism can give good control on the application rate and distribution provided certain components such as the connecting rod, raker strip, and the trough are accurately manufactured. To determine the acceptable limits for the variations in the dimensions or relative positions of these components a range of $\pm 12{\cdot}5\%$ from the mean quantity of fertilizer discharged for a fixed number of crank revolutions was used as datum. It was observed that variation in the designed length of the connecting rod causes inequality in the angle of oscillation of the trough from its mean position. The trough tilts more towards the front side when the connecting rod is too long and towards the rear side if it is shorter than the designed length. Permissible deviation in the angle of oscillation on front and rear sides were found to be 2° and 3°, respectively, which indicated +1 mm and +2 mm tolerance for a connecting rod of 200 mm nominal size.

A deviation in the trough on either side of its central location tends to increase the total quantity of fertilizer discharge because the output from one edge goes up sharply. But at a

Table 5
Fertilizer output at four levels in the hopper

	Fertilizer level from top edge of the hopper, mm					
	40	*105*	*170*	*230*	*Overall mean*	*CV, %*
Mean output, g/50 crank rev	129·9	130·4	126·8	127·4	128·6	1·5

known position of the trough away from the central location, a shift in the position of the raker strip to the same side as the trough reduces the total discharge. The discharge increases if the strip is positioned on the opposite side to the position of the trough from their central locations. For the experimental hopper, tolerance on the centrality of both the trough and the raker strip with respect to the vertical centre line of the hopper was found to be $\pm 0{\cdot}70$ mm to keep the variation in the fertilizer discharge within $\pm 12{\cdot}5\%$ of the mean.

In the vertical plane, the effect of the strip position on the total discharge was observed to be much more than that of the trough. Fertilizer discharge could be obtained within an acceptable range even when the gap between the strip and the trough varied from 3 mm to 6 mm, provided the strip projection below the feeding chamber remained between 9·7 mm and 10·5 mm and the trough did not exceed 0·5 mm up and 1 mm down from its designed location.

Ground wheel to crank speed ratio determines the frequency of fertilizer falling on a unit distance travelled by the machine. Experiments conducted with the frequency of fertilizer falling at three, four, five, and six times per metre revealed that the highest crank speed is desirable to obtain the best distribution along the row. A high crank speed also gives more discharge which can be changed by adjusting the angle of oscillation of the trough. The fertilizer level in the hopper was found to be of no consequence to the rate of application.

References

1. **Reed, W. B.; Wacker, E.** Determining distribution pattern of dry-fertilizer applicators. Transactions of the American Society of Agricultural Engineers 1970, **13**(1): 85–89
2. **Lee, J. H. A.; Karkanis, E. A.** Effect of ground speed and type of fertilizer on metering accuracy. Transaction of the American Society of Agricultural Engineers 1965, **8**(4): 491–496
3. **Chauhan, A. M.; Kumar, R.** Review of research developments in seed-cum-fertilizer drills in India and areas for further work. Journal of Agricultural Engineering. Indian Society of Agricultural Engineers 1972, **9**(3): 36–41
4. **Bansal, R. K.; Thierstein, G. E.** Metering granular fertilizer with an oscillatory mechanism. Journal of Agricultural Engineering. Indian Society of Agricultural Engineers 1984, **21**(1–2): 1–8
5. **ISI (Indian Standards Institute).** Test code for seed-cum-fertilizer drill. IS 6813–1973. ISI, New Delhi, India