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The Effects of some Constructive Properties and Operational Parameters of Rotary Fertilizer Spreaders on Fertilizer Flow Rate

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ABSTRACT : This study aims at investigating the flow rate of urea and ammonium sulfate through different orifices onto disc in the rotary fertilizer spreaders. For this reason, interchangeable orifices with different shapes (triangular, square, trapezous, square-like, and rectangular) in various sizes (150, 300, 450, 600, and 750 mm^2) at two positions (bottom and wall of hopper) were used in a hopper. Experiments were conducted according to three agitator rates of 300, 540, and 780 min^{-1}. As a result, all the factors investigated had significant effect on the flow rate.

Keywords: Rotary fertilizer spreader., fertilizer, orifice, flow rate

Diskli Gübre Dağıtma Makinalarında Bazı Yapısal Özelliklerin ve İşletme Parametrelerinin Gübre Debisine Etkisi

ÖZET : Bu çalışmada diskli gübre dağıtma makinalarında, amonyum sülfat ve üre gübrelerinin disk üzerine olan akışı incelenmiştir. Bu amaçla, değiştirilebilir farklı orifis şekilleri (üçgen, kare, trapez, uçları kavisli kare ve dikdörtgen) değişik alan büyüklüklerinde (150, 300, 450, 600, and 750 mm^2), depo tabanı ve depo yan yüzeyi olmak üzere iki orifis konumunda kullanılmıştır. Denemeler 300, 540 ve 780 min^{-1} karıştırıcı hızlarına göre yürütülmüştür. Sonuç olarak, incelenen tüm faktörlerin debi üzerine etkili oldukları belirlenmiştir.

Anahtar kelimeler: Diskli gübre dağıtıcısı, kimyasal gübre, orifis, debi

INTRODUCTION

From both agro-technical and economic point of view, the efficiency in spreading fertilizers is of great importance. Fertilizer broadcasters with spinning disc are widely used for the application of mineral fertilizers into soils, because of their high machine capacity, relatively low costs of purchase, maintenance and simple construction (Speelman, 1979; Fukuchi et al., 1982). The total number of spinning disc broadcaster produced in Turkey are 287 503 (Anonymous, 2000).

It is considered that, the evenness of distribution depends, first of all, on factors affecting the flow rate of fertilizers through orifices (Fukuchi et al., 1982; De, 1989).

The purpose of this study is to determine the effects of the shape, size and position of orifice and the revolution rate of agitator on the flow rates of fertilizers through orifices.

The influence of orifice diameter on the flow rate of granular material through various orifices has been studied by many researchers (Ketchum, 1911; Deming and Mehring, 1929; Franklin and Johanson, 1955; Fowler and Glastonbury, 1959; Brown and Richards, 1960; Beverloo et al., 1961; Fukuchi et al., 1982; Yoshida, 1987, 1988). De (1989) summarized in his comprehensive review of available literature on the subject that, according to the early studies flow rate was proportional to (orifices diameter)^n, the value of n varying but normally above 2.5.

In recent studies (Fukuchi, 1982; Yoshida, 1987, 1988), the effect of the diameter of orifices with various shapes on the flow rate was expressed as:

$$Q = k D^n$$

Where Q is the flow rate, D the hydraulic diameter and k and n are flow characterizing constants.

Beverloo et al. (1961) investigated the effect of the shape of orifice on the flow rate and reported that, with the same area the flow rate decreased through circle, square, rectangular, and triangular orifices, respectively.

Chang et al. (1991) compared the volume flow rates through vertical and horizontal orifices and reported that, the values of volume flow rate through vertical orifices were about 37 to 50% of the values for horizontal orifices.

Fukuchi et al. (1982) investigated the effect of agitator revolution rate on the flow rate and they found a linear relationship between agitator revolution rate and the flow rate: The higher the agitator revolution rate the higher the flow rate.

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MATERIALS AND METHODS

Interchangeable orifices with five different shapes (triangular, square, trapezous, square-like, and rectangular) in various size (150, 300, 450, 600, and 750 mm^2) at the bottom and at the wall of hopper positions were used in a standard hopper (Figure 1).

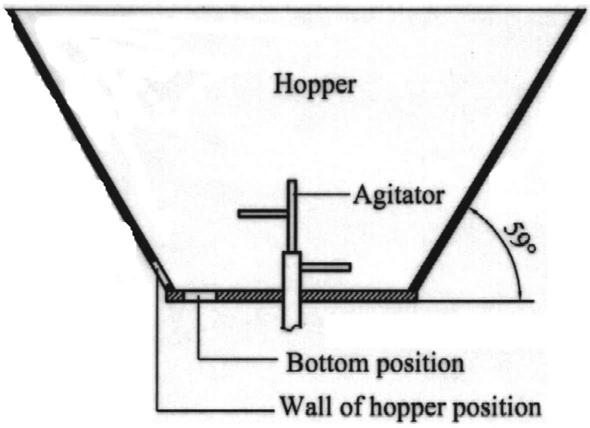


Figure 1. Orifice positions

The shapes, dimensions and hydraulic diameters of used in experiments are shown in Figure 2.

The hydraulic diameter values were calculated by using following equation (Wilcke et al., 1992):

$$D = \frac{4.A}{U}$$

Where

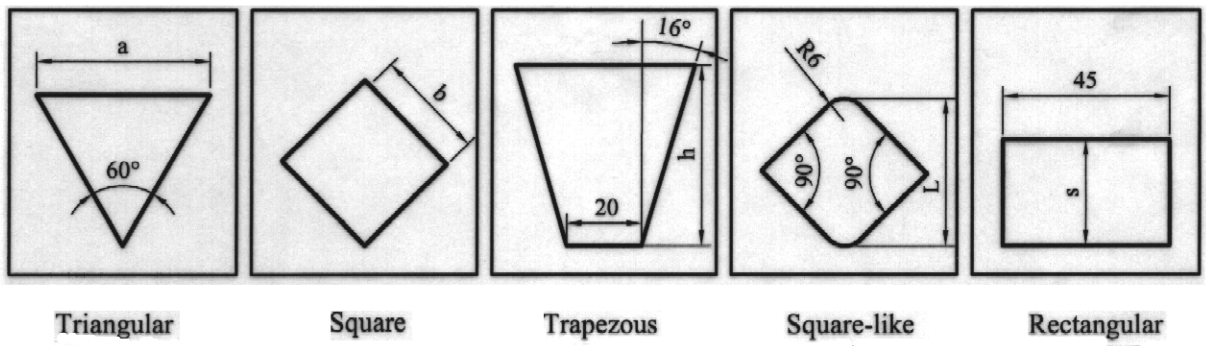
D : Hydraulic diameter of orifice (mm)

A : Orifice size (mm^2)

U : Orifice perimeter (mm)

The measurement setup used to measure the flow rate consists of five units: hopper, power supply, speed control unit with speed indicator, precision balance, and data acquisition system (Figure 3).

The diameter of the bottom of hopper was 160 mm and the conical angle of hopper was 59^0. Ammonium sulfate (21 %N) and urea (46 %N) were tested at three different agitator revolution rates of 300, 540, and 780 min^{-1}. Some properties of fertilizers used are shown in Table 1.



Orifice size (mm^2)	Orifice shape									
	Triangular		Square		Trapezous		Square-like		Rectangular	
	a (mm)	D* (mm)	b (mm)	D (mm)	h (mm)	D (mm)	L (mm)	D (mm)	s (mm)	D (mm)
150	18.61	10.75	12.25	12.25	6.83	10.33	13.22	13.11	3.33	6.21
300	26.32	15.20	17.32	17.32	12.69	16.28	20.13	18.31	6.66	11.61
450	32.24	18.61	21.21	21.21	17.90	20.56	25.53	22.19	10.00	16.36
600	37.22	21.50	24.49	24.49	22.65	23.96	30.12	25.58	13.33	20.57
750	41.61	24.03	27.38	27.38	27.03	26.83	34.16	28.53	16.66	24.33

*: Hydraulic diameter of orifice

Figure 2. The shapes, dimensions and hydraulic diameters of orifices used in experiments

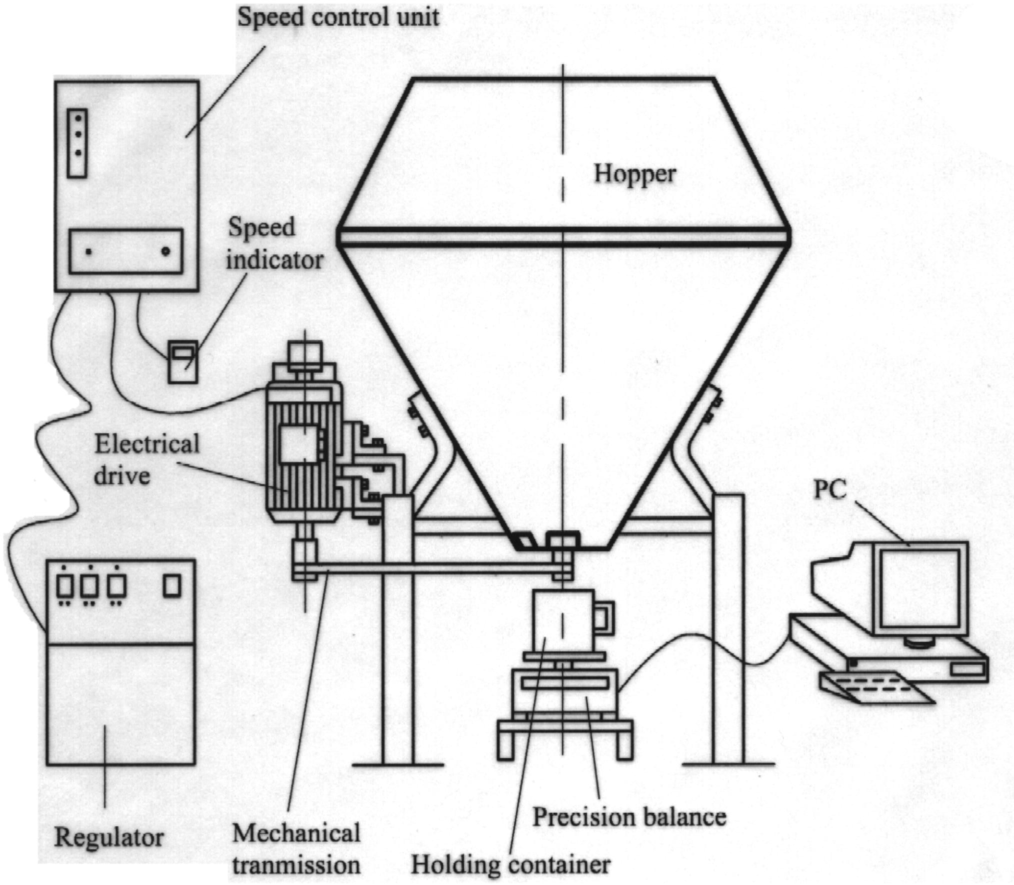


Figure 3. The measurement setup

Table 1. Some properties of fertilizers used

Fertilizer	Bulk density (kg/m^3)	Repose angle (degree)	Moisture content, d.b.+ (%)	Mass median diameter (mm)
Ammonium sulfate	975	34	0.08	1.2
Urea	780	30	0.59	1.7

+: dry based

During the experiments, the material that flowed through the orifice of hopper was weighed cumulatively at 1/10 second intervals by the precision balance. The data were transmitted to a PC in a continuous stream by the RS 232 C interface circuit. For each replication 35 values were taken, and each test was replicated three times.

RESULTS AND DISCUSSION

According to the regression analysis of the results, the relationship between the flow rate and orifice hydraulic diameter was found to be as

$$Q = k\,D^{n}$$

The values of n varied between 2.41 and 3.23, depending on the fertilizer type, orifice position and the revolution rate of agitator (Table 2). These values are in agreement with those of previous works.

On the other hand, the results have been analyzed by using the procedure GLM (General Linear Model) with respect to the fertilizer type, orifice position, orifice shape, and the revolution rate of agitator.

The variance analysis estimates of the mean values of the flow rates for each orifice size are shown in Table 3. This analysis showed that, the fertilizer type, orifice position, and orifice shape had a significant effect

(P<0.01) on the flow rate for all the orifice sizes. The effect of revolution rate of agitator on the flow rate is also significant for the orifice sizes of 450, 600, and 750 mm^2 at 1% level of probability and for the other orifice size at 5% level of probability.

On the other hand, Duncan's Multiple Range Test analysis is used to determine whether differences are significant or not (Table 4). This analysis showed that the flow rate values of urea were about 25 to 50% of values of ammonium sulfate for all the orifice sizes. This difference can be caused by the flowability and particle size distribution of fertilizers.

Similarly, the bottom orifices had higher values of flow rate than the values for wall of hopper orifices for all the orifice sizes, except for the smallest one. Without regarding the smallest orifice size, the mean values of flow rate of wall of hopper orifices were about 20 to 40% lower than the values for the bottom ones.

The square-like orifice resulted in the highest mean value of flow rate, followed by the square, triangular, trapezous, and rectangular one (Figure 4 and Figure 5). For the large orifice sizes, the flow rate increased as the revolution rate of agitator increased.

Table 2. The values of k and n in $Q = k\,D^n$

Revolution rate of agitator	Fertilizer	Orifice position	k	n
$300\ min^{-1}$	Ammonium sulfate	Wall of hopper	0.0019	2.80
		Bottom	0.0084	2.43
	Urea	Wall of hopper	0.0092	2.86
		Bottom	0.0062	2.41
$540\ min^{-1}$	Ammonium sulfate	Wall of hopper	0.0162	2.89
		Bottom	0.0853	2.43
	Urea	Wall of hopper	0.0123	2.98
		Bottom	0.0174	2.86
$780\ min^{-1}$	Ammonium sulfate	Wall of hopper	0.0009	3.12
		Bottom	0.0077	2.46
	Urea	Wall of hopper	0.0004	3.23
		Bottom	0.0057	2.47

Table 3. The variance analysis estimates of the values of the flow rate (Q)

Orifice size (mm^2)	150		300		450		600		750	
Variation sources	F.D.	F	F.D.	F	F.D.	F	F.D.	F	F.D.	F
Fertilizer (F)	1	337**	1	2334**	1	5626**	1	3758**	1	3261**
Orifice position (OP)	1	273**	1	2273**	1	5683**	1	3150**	1	2467**
Orifice shape (OS)	4	103**	4	754**	4	1177**	4	636**	4	382**
Revolution rate of agitator (RR)	2	3.14*	2	3.63*	2	140**	2	265**	2	504**
FxOP	1	0.31	1	10.2**	1	26**	1	72**	1	50**
FxOS	4	5.24**	4	11.6**	4	10**	4	5.43**	4	5.08**
FxRR	2	0.45	2	3.8*	2	3.71*	2	0.27	2	0.64
OPxOS	4	5**	4	14.4**	4	27**	4	13**	4	21**
OPxRR	2	0.25	2	12.1**	2	152**	2	106**	2	122**
OSxRR	8	1.57	8	1.2	8	7.32**	8	5.95**	8	6.56**
Error	127									
Total	156									

* Indicates significance at 5% level of probability

** Indicates significance at 1% level of probability

Table 4. The Duncan's Multiple Range Test estimates of the mean values of the flow rate (Q)

Orifice size (mm^2)	150	300	450	600	750
Orifice shape					
Triangular	1.71 a+	4.86 c	9.51 c	15.27 b	22.27 b
Square	1.76 a	5.08 b	10.01 b	15.35 b	22.41 b
Trapezous	1.24 b	4.07 d	8.58 d	14.55 c	21.04 c
Square-like	1.68 a	5.67 a	10.24 a	17.42 a	23.77 a
Rectangular	0.47 c	2.37 e	6.45 e	11.71 d	17.97 d
Revolution rate of agitator (min^{-1})					
300	1.43 a	4.36 b	8.56 c	13.85 c	19.67 c
540	1.40 a	4.49 a	8.95 b	14.82 b	21.25 b
780	1.28 b	4.39 b	9.37 a	15.91 a	23.56 a

+: Numbers in each column followed by the same letter are not significantly different

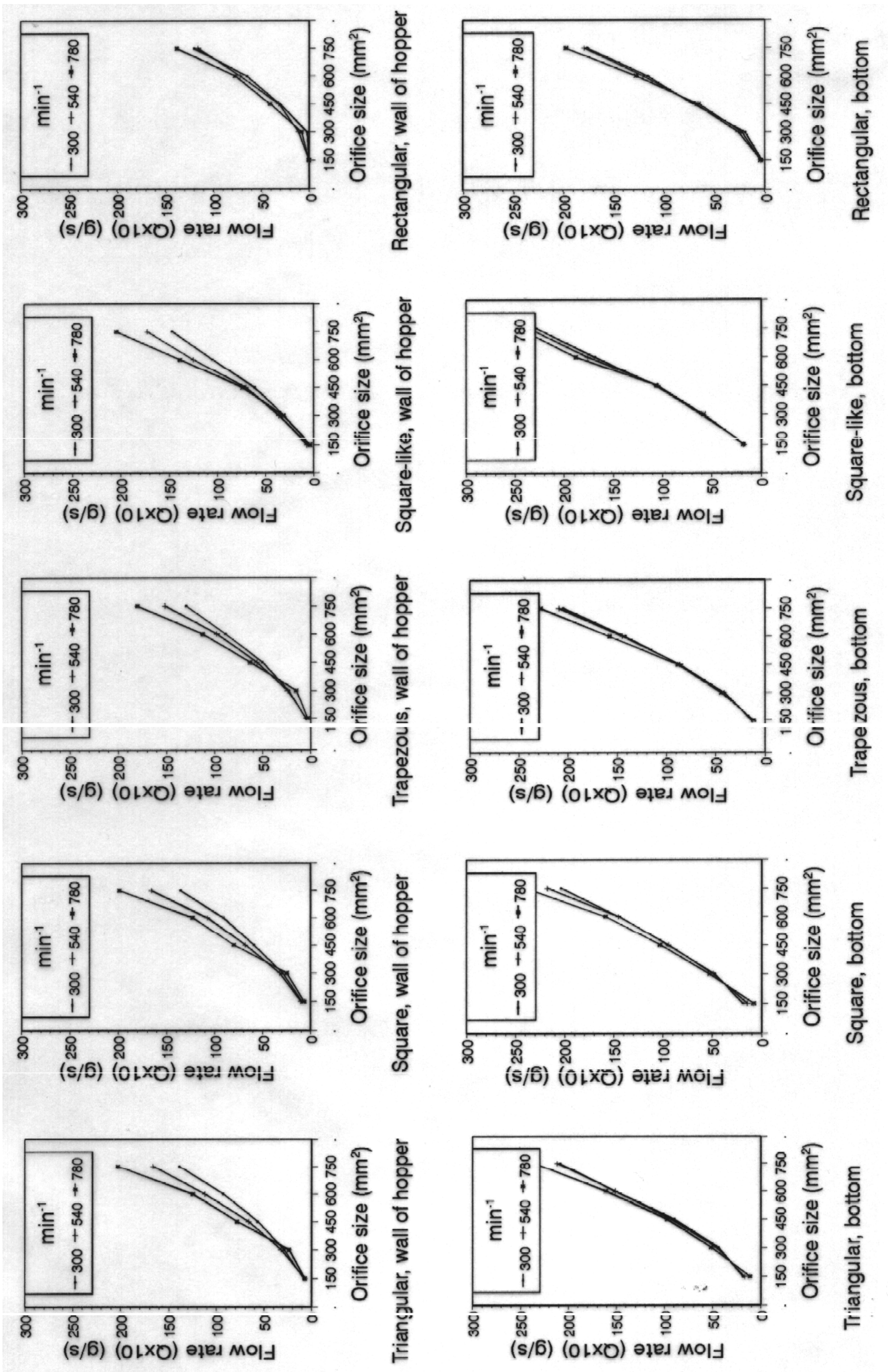


Figure 4. The values of the flow rate for urea

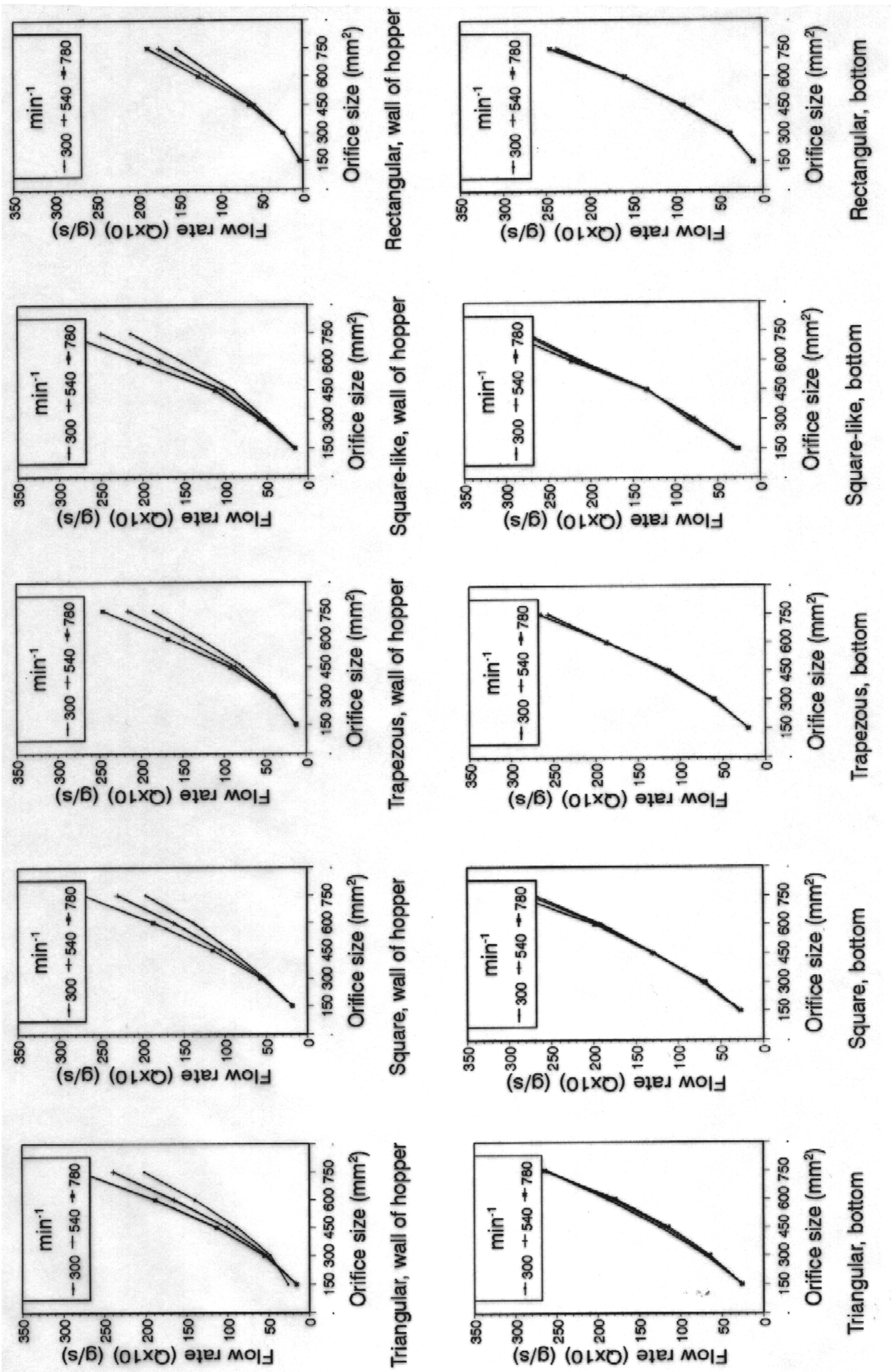


Figure 5. The values of the flow rate for ammonium sulfate

CONCLUSIONS

1. The influence of the orifice hydraulic diameter on the flow rate for urea and ammonium sulfate can be expressed as $Q = k D^n$, the values of n varied between 2.41 and 3.23.
2. The flow rate of ammonium sulfate has higher values than the values for urea.
3. The flow rate values for the bottom orifices are higher than values for the wall of hopper ones.
4. The highest value of the flow rate is obtained with square-like orifice, followed by the square, triangular, trapezous and rectangular orifices.
5. An increase of the revolution rate of agitator causes an increase of flow rate for the large orifice sizes, and a slight decrease in flow rate for the small ones.

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