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THE ENGINEERING PARAMETERS AFFECTING THE AUGER-TYPE METERING DEVICES FOR FERTILIZING DISTRIBUTION

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ABSTRACT

This investigation carried out to study the engineering parameters of auger volume, cross sectional area of the orifice gate, fertilizers density and feeding shaft speed that effect on the discharge rate "g/min" and the volumetric efficiency "%" of the fertilizer applicator. The results indicated that the highest value of discharge rate is 2660 g/min that obtained at the orifice gate is adjusted at a cross section of area of 48 cm^2, on auger volume of 50.66 cm^3 and the rotational speed of feeding shaft was 11.6 m/s for a bulk density of 0.685 g/cm^3. While the lowest value was 190 g/min at the sequence condition of 2.7 m/s, auger volume of 24.27 cm^3 and gate area of 16 cm^2 for super Phosphate. Increasing the gate area from 16 to 48 cm^2 increases the volumetric efficiency from 64.8 % to 78.9 % at bulk density of 0.685 g/cm^3 and from 39.4 % to 51.1 % for bulk density of 0.995 g/cm^3.

INTRODUCTION

The physical properties of fertilizer are the majority factors effect on the volumetric flow rate of metering mechanism. **Klenin, et al. (1985)** indicated that the change in size of mineral fertilizers, hygroscopicity, dispersibility, density, tendency to scatter and cake and other properties influencing the functioning of machines designed. They added that the mineral size has a significant effect on machine operation, as granule size increases above 5mm; they become progressively weaker leading to poor spreading. Hygroscopicity of fertilizers, in most cases, determines their properties, which directly influence of the machines qualitative indices operation. Dispersibility of fertilizers is governed by their moisture content, which depends on their hygroscopicity. Scattering of fertilizer granules is defined as their ability to form an arch over orifices.

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This factor is characterized by the pressure in which must be applied to destroy the compact arch of fertilizer granules of 60mm height formed over the orifice. **Hofstee and Huisman (1990)** stated the particle motion in the fertilizer distributor device is discussed for both spinning disc and reciprocating spout fertilizer distributors. Five important properties which affect particle motion is reviewed, namely particle size distribution, coefficient of friction, coefficient of restitution, aerodynamic resistance and particle strength. The latter is indirectly related to particle motion. Methods for determining the properties and the results of different tests are discussed; relevant data for the 5 properties reviewed are presented. **Hofstee (1994)** used a new technique for measuring the velocity and direction of fertilizer particles discharged by a fertilizer distributor. The technique is based on the frequency shift of an ultrasonic beam. The instantaneous amplitude and frequency of the received Doppler signals are computed by digital signal processing. The velocity and the direction of each detected particle are calculated from the instantaneous frequency and the particle diameter is estimated from the instantaneous amplitude. The technique is used to quantify the influence of physical properties of fertilizer on the motion of fertilizer particles in the distributor device. A first series of experiments shows that this technique can measure the velocity and direction of fertilizer particles. The estimation of the particle diameter is more difficult because of the un-uniform frequency response to use the ultrasonic transducers in the frequency band. **Csizmazia and Andersson (2000)** indicated the majority of fertilizer spreading is solid state world-wide. Consequently, a technical development is to be performed to improve coefficient of variation of the fertilizer distribution and to increase the working width of the spreaders. The evenness of the spread pattern depends largely on the physical properties of the fertilizer. The influence of the physical properties on the particle motion through the air is very important. **Dutzi (2002)** discussed the measurement of the main physical characteristics of different types of dry fertilizers. These include the grain size distribution, the actual and bulk densities, grain strength, flow characteristics and friction on the spreading disc. The use of these data in assessing the various spreading characteristics of different fertilizer material is described, together with the practical measurement of actual performance in the test hall. Until now, many problems face the auger-type of fertilizer metering devices distributor.

Therefore, the objectives of this paper were to study the engineering parameters that control the proposed fertilizing applicator performance and to test the performance of the proposed fertilizer applicator.

MATERIALS AND METHODS

The fertilizer distributor unit consists of fertilizing hoppers, metering device, transmission system and agitator and fertilizer tubes. Fertilizer particles are usually different in shape from one type to another (powered–granular–crystallize), physicochemical properties, (bulk density–moisture content), mechanical properties, (friction angle - repose angle) and also in the amount of the application rate. Therefore, there are three hoppers, which have a rectangular shaped cross section at the top 350×360 mm, and trapezoidal at the bottom. In order to facilitate the flow of materials to slide down along the hopper walls, the latter must be inclined under a relevantly large angle 60^0, large than the friction angle of the fertilizers against the hopper walls. Controlled gates are fixed on hopper's sides, near the bottom. Each hopper has a capacity of 35kg of fertilizer (Fig. 1).

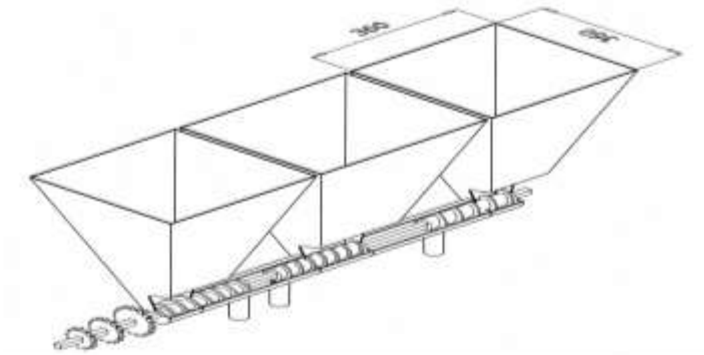

Fig. 1: Fertilizing hoppers

As shown in Fig. (2), the metering device consists of three augers are different in pitches length and screw diameter as indicated in table (1). The volumetric capacity of the three different augers are 24.27, 39.19, 50.66 cm^3 which there are located, one by one on the feeding shaft hoppers as shown in Fig. (1).The theoretical volumetric capacity of the auger by **Srivastava (1993)** is defined as:

$$Q_{th} = \frac{\pi}{4} \left[(d_{sf})^2 - (d_{ss})^2\right] I_p \, N \qquad \textbf{(1)}$$

where

Q_{th} : the theoretical volumetric capacity, cm^3/min

d_{sf} : screw flight diameter, cm

d_{ss} : screw shaft diameter, cm

I_p : pitch length, cm

N : screw rotational speed, rpm

Transmission system has two functions for driving metric device from land wheel, and for changing the auger shaft rotating speed to obtain different application fertilizer rates, kg/Fed. A vertical agitator is used to prevent dogging bridging in the hopper with the powered materials. It is located inside the right hopper only, Fig. 3. There are three slide control gates, which are fixed on the hopper sides to control the amount of flow from the hopper to auger chambers Fig. 4. The total cross section of the orifice gates is 150×80 mm. A rubber tube of 25mm diameter is mounted to the outlet of each tank. The ends of these tubes are collected in small collector, which poured go out from the point carrying fertilizers to the soil surface.

Table (1): The dimensions of the experimental augers

Types of auger	d_{sf}, cm	d_{ss}, cm	I_p, cm	Volume (V, cm^3)
1	5.3	3.9	2.4	24.27
2	6.0	3.9	2.4	39.19
3	5.8	3.9	3.5	50.66

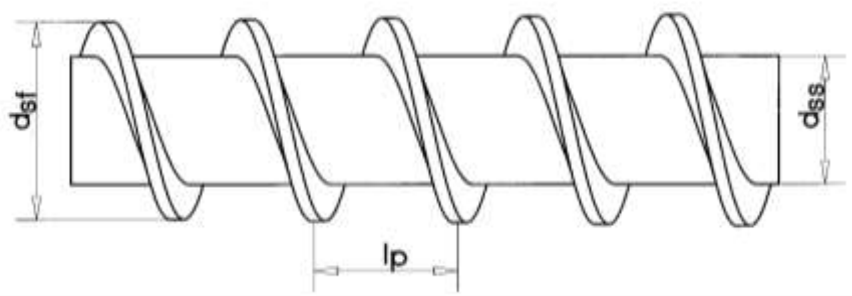

Fig. 2: A scheme of the auger

The strip-plot design used to evaluate the effect of experimental factors on the proposed design. The different parameters, such as twelve rotating speeds of auger shaft (N), three levels of augers volume (V), two different kinds of fertilizers (F_t) and three-orifice gate area (G_a) were replicated three replicates for each. The results number of plots was 216 plots in each replication.

Fig. 3: The vertical agitator

Fig. 4: The slide gate

The measurements were carried out to evaluate the fertilizer flow, two parameters were determined. Namely, is the discharge rate, g/min (*D*) and the volumetric efficiency percentage (η_v). Bulk density was measured by filling a known container volume with the different fertilizers, then the mass of different fertilizers was determined and the bulk density was calculated from principle equation. A digital measuring device was used to measure the friction angle, which was designed by (Matouk, et al., 2003).and angle of repose was measured using angle of repose apparatus designed by (Matouk, et al., 2006).

The discharge rate, (g/min) was measured three times in the laboratory by operating auger shaft for one minute for each treatment under different treatments. Generally, the discharge rate in terms of mass per unit time, for example, g/min, is expressed as:

$$Q_a = \frac{D}{\rho} \quad (2)$$

In reality, the actual capacity of an auger is consider less than the theoretical capacity. Then the volumetric efficiency is defined as:

$$\eta_v = \frac{Q_a}{Q_{th}} \times 100 \quad (3)$$

where

Q_a: actual volume capacity, cm^3/min

D : discharge rate, g/min

ρ : bulk density of the material, g/cm^3

η_{th} : volumetric efficiency, %

All data collected for all parameters of different treatments were statistically analyzed. The strip plot design (Gomezz and Arture, 1984) was adopted in these studies for statistical analysis of the data by SAS computer program. In order to ascertain whether the observed treatment effects were real and discernible from chance effects the "Null Hypothesis" was tested by "F" test at 5 % level of probability as well as L.S.D, at 1 % of probability (in case of highly significant differences) according to Sendecor and Cockran (1981).

RESULTS AND DISCUSSION

The discharge rate of the metering device

Fig. (5), shows the effect of the auger shaft speed on the discharge rate of different fertilizers at different auger volumes. In general, a linear relationship between the discharge rate "g/min" and auger shaft speed "m/s" was obtained. It was obvious that increasing the auger shaft speed increases the discharge rate for all levels of auger volumes. A gate area of 16 cm^2, the amount of discharge rate of fertilizer "g/min" were 480; 870 and 1060 g/min, obtained at 24.27; 39.19 and 50.66 cm^3 auger volume, respectively and at 7.21 m/s auger shaft speed for super Phosphate. The same result were 680; 1130 and 1520 g/min for Urea under the same previous condition.

At the gate area of 32 cm^2, the change in amount of discharge rate when increasing auger shaft speed from 2.77 to 11.66 m/s were 19.82 %; 22.55 % and 22.32 % at 24.27; 39.19 and 50.66 cm^3 auger volume, respectively for super Phosphate. While these were 28.7 %; 26.84 % and 26.98 % for Urea at the same previous conditions (Fig. 6).

As shown in Fig. 7 at gate area of 48 cm^2, the discharge rates of fertilizer amount were 650; 1115; 1420 g/min obtained at 24.27; 39.19 and 50.66 cm^3 of different auger volume, respectively and at 7.21 m/s auger shaft speed for super Phosphate. The same result were 1390 and 1830 g/min fore Urea under the same conditions.

The general trend of this relationship is that, as increasing auger shaft speed, auger volume and cross sectional area, the discharge rate increases. This trend may be attributed to the effect of increasing of auger shaft speed, auger volume and cross sectional area of the orifice gate on encourage more fertilizers easy to transform within different parts of the fertilizing unit.

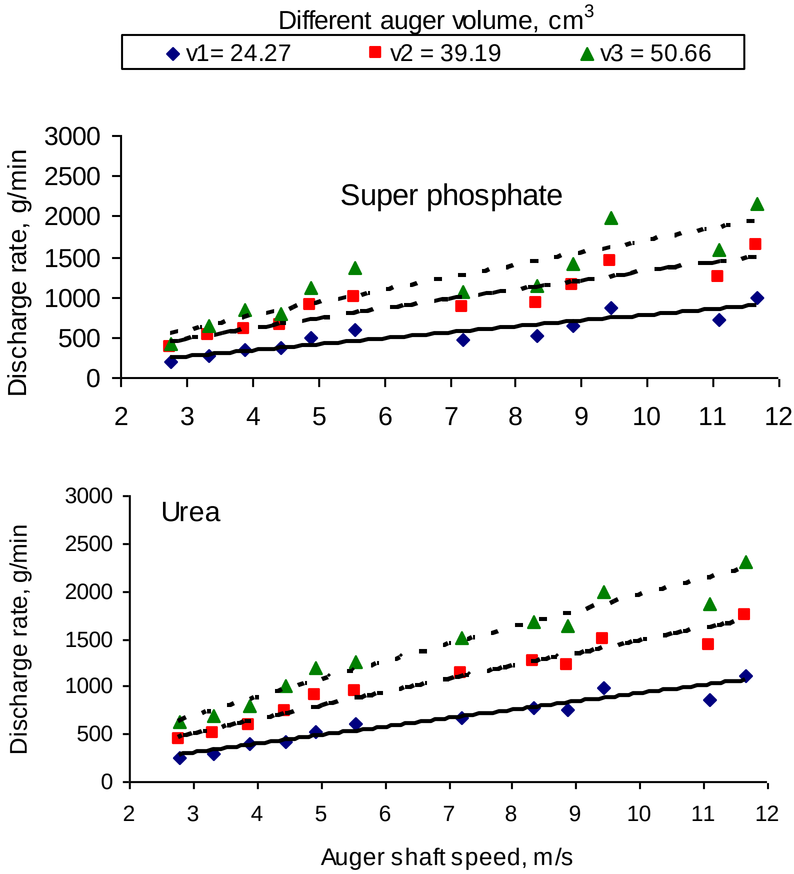

Fig. 5: The discharge rates of fertilizing metric device at the gate area of 16 cm^2.

A simple power regression analysis is applied to relate the change in discharge rate with the change in auger shaft speed for all treatment. The obtained regression equation was in the form of:

$$\mathbf{D = a\,N^{b}} \;\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\; \mathbf{(4)}$$

where:

D : the discharge rate, g/min;

N : the auger shaft speed, m/s;

a and b: coefficient constants

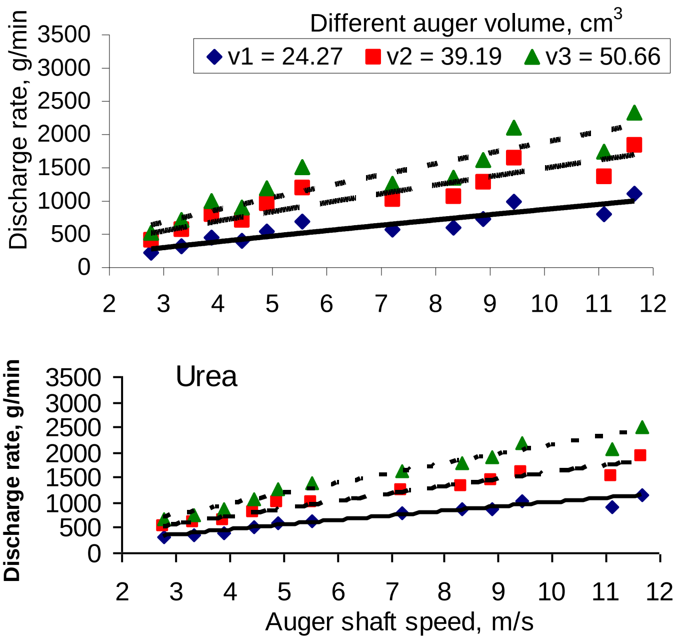

Fig. 6: The discharge rates of fertilizing metric device at the gate area of 32 cm^2.

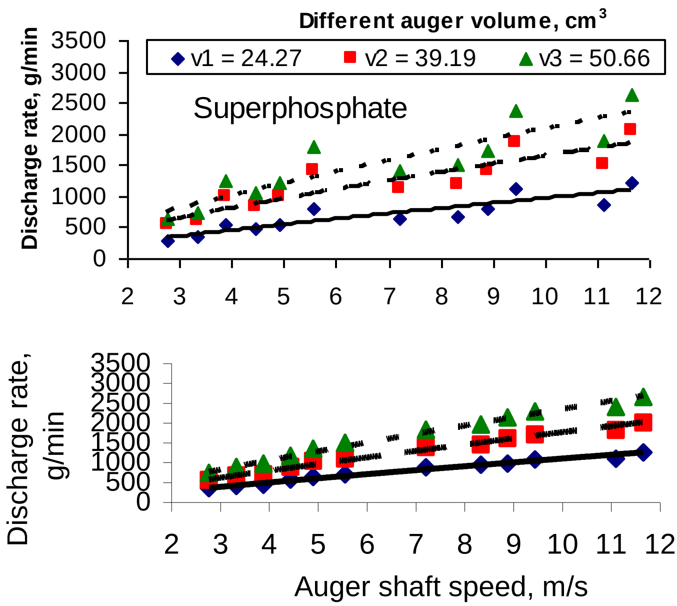

Fig. 7: The discharge rates of fertilizing metric device at the gate area of 48 cm^2.

The regression constants (a and b) for all obtained regression equation were tabulated in Table (2).

Table (2): Values of constants (a and b) of equation (4):

Fertilizer type	Auger volume, cm^3	Gate area, 16 cm^2			Gate area, 32cm^2			Gate area, 48cm^2		
		a	b	R^2	a	b	R^2	a	b	R^2
Phosphate	V_1=24.24	92.524	0.92	0.87	112.52	0.89	0.86	141.68	0.88	0.845
	V_2=39.19	184.54	0.85	0.88	220.26	0.83	0.86	275.8	0.78	0.835
	V_3=50.66	223.89	0.88	0.84	270.7	0.84	0.87	331.95	0.80	0.832
Urea	V_1=24.24	106.98	0.94	0.96	138.8	0.86	0.97	150.26	0.87	0.982
	V_2=39.19	185.17	0.90	0.97	214.18	0.87	0.97	237.06	0.87	0.985
	V_3=50.66	261.88	0.87	0.97	287.23	0.87	0.97	316.19	0.87	0.989

The SAS analysis indicated a highly significantly different for the treatments of auger shaft speed to the discharge rate. The values of gate area, auger volume and fertilizers bulk density recorded a highly significant efficiency. Also the total interaction between different treatments show a significant effect with (R^2 = 0.993) and (CV = 5.4 %), except the interactions of $V * F_t * G_a$ and $N * V * F_t * G_a$.

The general multiple regressions for the interaction between the operating parameters against the discharge rate are indicated the following equation:

$$D = 0.583\ (V\ N\ \rho) \qquad R^2 = 0.93$$

The metering device efficiency

The effects of auger shaft speed, auger volume, and orifice gate area for different fertilizer types on the volumetric efficiency illustrate in figures. (8) and (9). The general trend of this relationship is that the volumetric efficiency increases directly with increasing the auger speed up to 5.5 m/s for most treatments. Beyond this value, the volumetric efficiency decreased. This trend may be attributed to after this point; the centrifugal force restricts the flow of fertilizers.

The results indicate that the highest value of the volumetric efficiency was 86%. It was obtained when the orifice gate was adjusted at cross section area of 48 cm^2, auger volume capacity of 50.66 cm^3, and auger shaft speed of 4.44 and 4.99 m/s for spherical shaped particles (Urea). While, the lowest value is 28 % at the sequence conditions of gate area of 16 cm^2, auger volume of 24.27 cm^3 and speed of 8.33 m/s, for powdered shaped particles (super Phosphate).

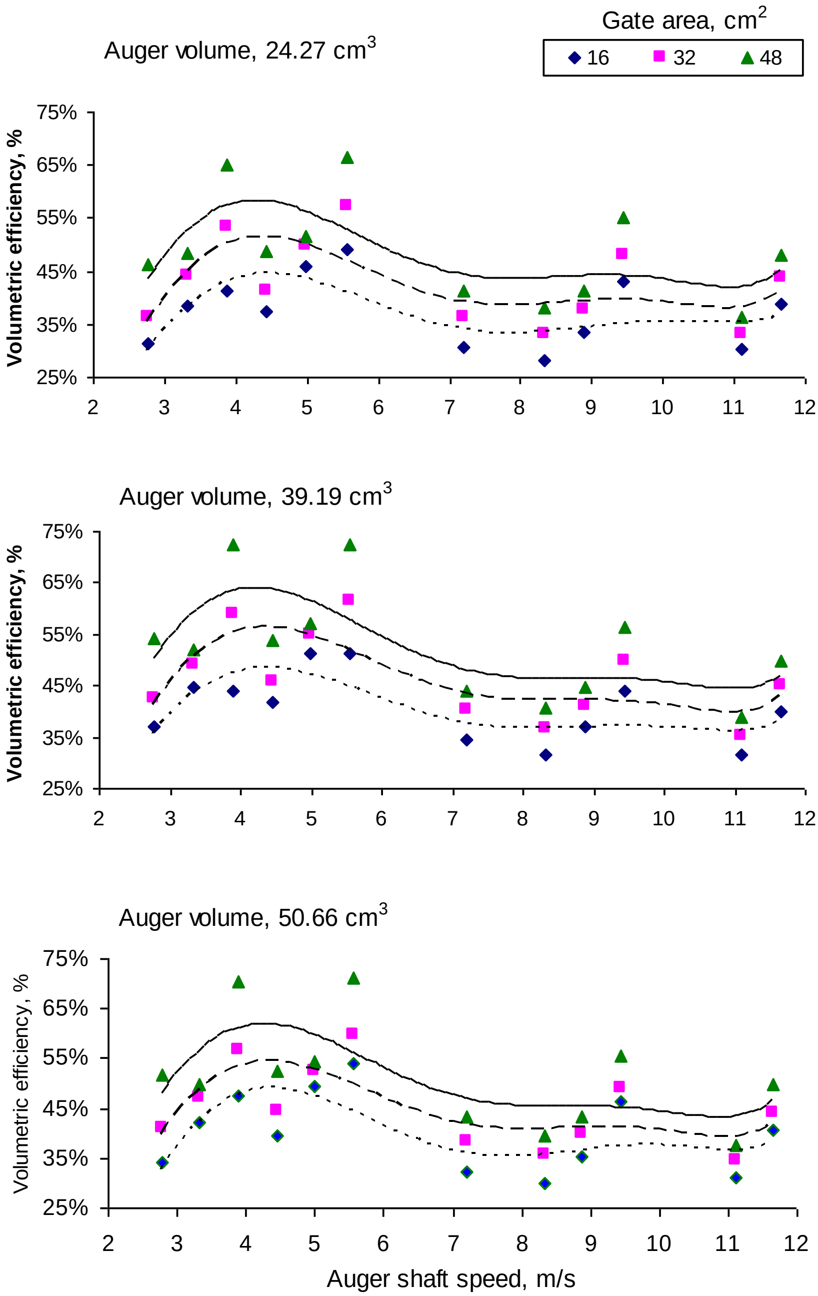

Fig. 8: Effect of auger shaft speed on volumetric efficiency using super Phosphate

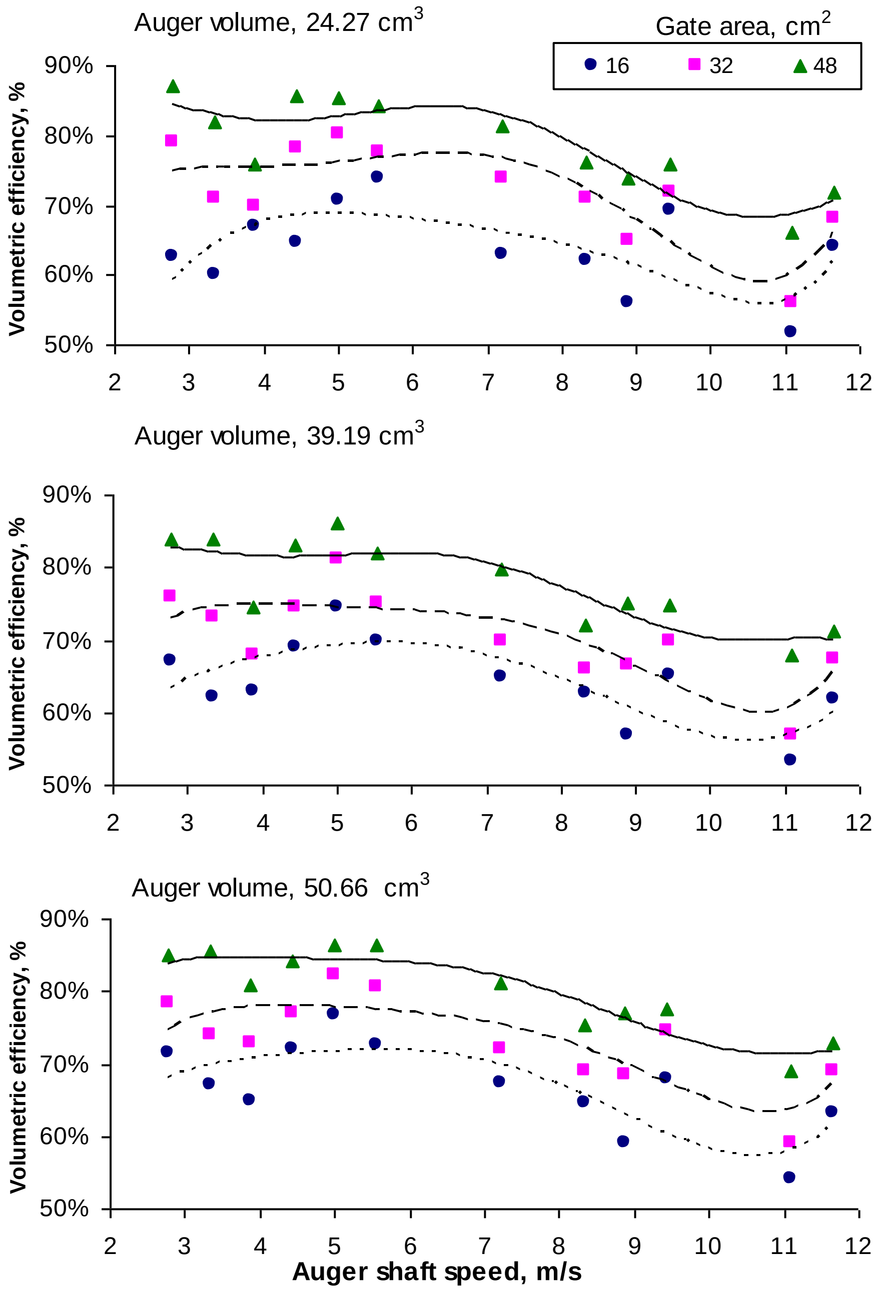

Fig. 9: Effect of auger shaft speed on volumetric efficiency for Urea.

Fig. 9 give a graphical presentation of the obtained results at different gate area "16; 32 and 48 cm^2" and different auger volume (V_1 = 24.27; V_2 = 39.19; V_3 = 50.66 cm^3) using Super phosphate. The volumetric efficiencies of fertilizer " η_v %" were 49%; 67% and 67%, at 16; 32 and 48 cm^2 gate area, respectively and at 5.55 m/s auger shaft speed for auger volume of 24.27 cm^3. The same results were 51%; 62% and 72% for auger volume of 39.19 cm^3 and were 54%; 60% and 71% for auger volume of 50.66 cm^3 under the same condition of gate area 16; 32 and 48 cm^2, respectively, auger shaft speed of 5.55 m/s for super Phosphate.

Meanwhile, at auger shaft speed of 4.99 m/s the volumetric efficiencies were 71%, 80% and 86%, obtained at 16, 32 and 48 cm^2 gate areas, respectively for auger volume of 24.27 cm^3 for Urea. The same results were 75%; 81% and 86% for auger volume of 39.19 cm^3 and were 77%; 82% and 86% for auger volume of 50.66 cm^3 under the same condition of gate areas 16; 32 and 48 cm^2, respectively and auger shaft speed of 4.99 m/s, for Urea as shown in Fig. 9.

The effect of auger shaft speed on volumetric efficiency at different fertilizers type of bulk density was analyzed using the regression type of power analysis. The results of analysis showed that, the relationship between the studied variables could be described as follows:

$$\eta_v = -k N^2 + l N + n \quad \text{……………….………….} \quad (5)$$

where

η_v : volumetric efficiency, (%);
N : auger shaft speed, (m/s);
K, l and n : coefficient constants.

The values of the constants k, l and n are presented in Table (3). The statistically analysis of SAS is not a significance difference between the levels of (2.77 and 9.44 m/s), (3.33 and 2.77 m/s), (3.88 and 4.44 m/s), (5.55 and 4.99 m/s) and (11.66, 8.33 and 8.88 m/s) on the volumetric efficiency.

Table 3: Values of constants (k, l and n) of equation (5):

Fertilizer name	**Bulk density, g/cm^3**	**k**	**l**	**n**	**R^2**
Urea	0.685	0.0019	0.0131	0.7341	0.611
Phosphate	0.995	0.0009	0.0012	0.4941	0.2032

CONCULUSION

The conclusions of this paper are summarized as follow:

1. The highest value of discharge rate is 2660 g/min., which is obtained when the orifice gate is adjusted at cross sectional area of 48 cm^2, auger volume of 50.66 cm^3 and the rotational speed of feeding shaft of 11.6 m/s for Urea. While the lowest value was 190 g/min at the same condition of 2.7 m/s, auger volume of 24.27 cm^3 and gate area of 16 cm^2 for super Phosphate.
2. Increasing the gate area from 16 to 48 cm^2, the volumetric efficiency increases from 64.8 % to 78.9 % at bulk density of 0.685 g/cm^3. It increases from 68.5 % to 80.7 % and from 39.4 % to 51.1 %, with bulk density of 0.995 g/cm^3.

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الملخص العربى

العوامل الهندسية المؤثرة على أجهزة التلقيم ذات البريمات المستخدمة في توزيع الأسمدة المعدنية

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تهدف هذه الدراسة إلي دراسة العوامل الهندسية المؤثرة كفاءة السريان لأجهزة التلقيم ذات البريمات المستخدمة في توزيع الأسمدة المعدنية. حيث اشتملت عوامل الدراسة علي:

١- السرعة المحيطية لعمود التغذية (N)
(2.7, 3.3, 3.8, 4.4, 4.9, 5.5, 7.2, 8.3, 8.8, 9.4, 11.1, 11.6 m/s)

2- حجم بريمة النقل (V)   (50.66, 39.16, 24.27 cm^3)

3- مساحة فتحة البوابة من الخزان إلى غرفة البريمة (Ga)   (16, 32, 48 cm^2)

4- الشكل البنائي للسماد (بودر- كروي)   (Ft_1, Ft_2,)

وأظهرت النتائج أنة:

بزيادة سرعة دوران عمود التغذية ازداد معدل السريان حيث سجلت سرعة محيطية مقدارها 11.6 م/ث أعلى معدل تصرف ومقداره 2660 جم/دقيقة حيث كان حجم بريمة النقل 50.66 سم٣ وفتحة بوابة مساحتها 48 سم٢ وذلك عند استخدام سماد اليوريا الكروى الشكل. بينما كانت ادني معدلات التصرف 190 جم/دقيقة وذلك عند سرعة محيطية 2.7 م/ث وبريمة حجمها 24.27 سم٣ وفتحة بوابة مساحتها 16 سم٢ وذلك عند استخدام سماد السوبر فوسفات البودر.

لتحقيق أعلى معدلات الكفاءة الحجمية لجهاز التسميد وهى 87% يجب أن يدور عمود التغذية بسرعة محيطية 2.77 م/ث وذلك عند استخدام بريمة نقل حجمها 24.27 سم٣ وفتحة بوابة مساحتها 48 سم٢.

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