FARM MACHINERY AND POWER

EFERTILIZER APPLICATOR EVALUATION USING THE RESPONSE SURFACE METHODOLOGY

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ABSTRACT

During the last decade, a great deal of attention gave to reclaim new lands (desert lands) and grow these lands by vegetable crops whereas these crops are considered to be high income in short rotation. Further, increase in vegetables production by increasing the yield per unit area is required by controlling the amount of fertilizer application. The fertilizer machine used in experiments is a banded type applicator consisting of a fertilizing hopper, metering device, agitator unit, fertilizer tubes, forming profile unit and transmission system. Response Surface Methodology (RSM) was employed to optimize the operating (peripheral speed of the auger, the gate area levels and auger volume) and constructional-related variables (fertilizer application rate). The design in this study is a Central Composite Design "CCD" by which it studied the influence of three factors in 15 runs at which three levels for each independent variable. These levels were coded "-1"; "0" and "+1" respectively. The design is to be run in a single block, to provide protection against the effects of turning variables, the order of experimental has been fully randomized. The optimum levels of the auger peripheral speed "A_s", auger volumetric capacity "A_v" and gate area "G_a" for three different fertilizer types are very close and they are in good agreement. For Super phosphate as example there were 5 m/s, 45 cm^3 and 40 cm^2 respectively. The highest value of discharge rate for Urea is 159.6 kg/h that obtained at orifice gate area of 48 cm^2, auger volume of 50 cm^3 and feeding shaft rotational speed of 10 m/s. Increasing the gate area from 16 to 48 cm^2 increases the volumetric efficiency from 64.9 % to 79.0 %; from 68.6 to 79.7, and from 39.4 % to 51.2 % for Urea, Nitrate and Super-phosphate respectively.

Keywords: Response Surface Methodology (RSM), band spreader, application rate, fertilizing hopper, metering device, agitator unit, forming profile unit, auger shaft speed, auger volume, gate area.

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INTRODUCTION

In Egypt, the agricultural land can be divided in to two wide types, namely: the old land (Delta land) around the Nile River and the New Land (desert land). To reclaiming New Lands and growing these lands by vegetable crops is the main goal, whereas, these crops are considered to be high income in short rotation. One of the major problems facing this aim in Egypt as well as other parts of world is the appropriate fertilization including program and system of addition. The mineral fertilizers are generally applied as broadcast. The drawbacks with broadcast application are, stimulate weed growth and fertilizer may come in contact with a large volume of soil and are likely to be fixed, there for, the crop does not derive full benefit of fertilizer, finally for application of phosphoric fertilizer as Super-phosphates are less mobile. Broadcast application will result in unavailability to roots. Consequently, as all the nutrients fertilizer are applied at the time of sowing or planting, it is a good practice to apply the fertilizer as placement, to decrease fertilizer looser by drainage water and increased the total nutrients in soil profile. The advantages of fertilizer placement are, stimulates early growth of seedlings, early root development will be rapid and extensive and plant growth will be stimulated. Kathleen (1998) and Neddermeijer et. al (2000) stated that Super-phosphate fertilizer in wheat is conventionally applied by broadcast method before sowing crop. This is a wasteful method of fertilizer application as only (15-25%) of the applied Super-phosphate is utilized by wheat crop. They also revealed that currently seed cum fertilizer drill place fertilizer either too far from the seed or in direct contact with it. In the former case, fertilizer use efficiency is hampered and in latter situation, relatively high rate of ammoniated Super-phosphate fertilizer affects the seed germination and crop yield. To solve mentioned problem the seed cum fertilizer is developed to place fertilizer 5cm away and 5cm deeper that the seed. Thus is saving 50% of Super-phosphate fertilizers and get benefit of 10% more grain yield.

Persson et al. (1999) investigated the technical solutions for variable rate fertilization. The aim of variable rate fertilizer application is to fulfill local requirements in the field to optimize the production for quantity or quality reasons. The choice of spreading technique and working width

influences the possibilities of performing variable rate fertilizer application. Based on two-dimensional measurement of distribution patterns from different fertilizer distributors at different working widths and application rates, the overall distribution pattern may be calculated for fields in which variable rate is intended. Calculations that have been carried out based on distribution patterns from common types of mineral fertilizer distributors show that the bigger the spatial variability in the field, the smaller the working width that should be used. While, Reumers et al. (2003) explained the experimental characterization of the tangential and cylindrical fertilizer distribution pattern from a spinning disc. Traditionally the performance of centrifugal spreaders is evaluated in spreading halls by measuring fertilizer distribution patterns in standardized tests. Alternative distribution patterns can be measured with compact devices that intercept the particle flow immediately after leaving the spinning disc. An experimental facility was built which allowed the measurement of the tangential, as well as the cylindrical distribution of the particle flow at the disc edge. A number of experiments were carried out, using one type of centrifugal spreader with a conical disc. The influences of vane length, mass flow rate, and particle size and fertilizer type on both the tangential and the cylindrical distribution patterns have been investigated. The results show that flows of particles with a larger mean diameter achieve a higher velocity on the disc, causing the distribution patterns to shift to lower angular positions. Furthermore, it is concluded that a smaller average particle size leads to a higher mass discharge flow rate from the hopper. In addition, a shift of the cylindrical distribution to a lower vertical position is observed when the mass flow rate increases.

William et al. (2004) indicated that granular fertilizer applications through variable-rate technology (VRT) for Florida citrus can be implemented through either real time sensing, GIS-map based control, or both. Evaluations were undertaken to establish the response of these techniques with two dry fertilizer units with different hydraulic configurations. A test program using ASAE S341.3 has been established for standardized conditions. Additionally, field trials were undertaken to ascertain fertilizer distribution under grove conditions. In these field

trials, both spinner disc and pneumatic discharge units were evaluated. Fertilizer distribution under grove conditions yielded distributions quite different from the Gaussian distributions found in open-field standardized tests. Coefficients of variation in tray distribution tests across the fertilizer swath were lower; 41.0% for grove condition versus 93.9% in open field results when comparing the same spreader unit. Grove application rates for three commercial spreaders were determined by under-tree tray collection of fertilizer and varied by 7.7% from the controller set point values. For both units, delay times (on-off) was 30% less than the off-on transition.

Kaplan et al. (1999) aimed to evaluate unevenness of fertilizer distribution and determination of the application rate. The relationship between the unevenness of the fertilizer distribution and the optimum application rate was studied using experimental data and different response function models. A universal formula derived from this study can be used to determine the relative loss of fertilizer for different models of the response function. It was shown that the loss of fertilizer for many cases can be accounted for the use the quadratic model. The formulae to correct the application rate for the given unevenness were obtained. Liu et al. (1998) developed a fertilizer distributor, which applies chemical fertilizers into the subsoil, where phosphorus and calcium, are mixed. In addition, based on root density distribution, a technique developed in which the fertilizer placed more densely in the upper layer than in the lower layer within the 200-600 mm depth of the subsoil. When both granular and powder fertilizers were applied at the rear of the first or second plow body, fertilizers reached the bottom layer with soil mixing by the plow bodies, and fertilizer distribution was greatest in the lower layer of the subsoil. When fertilizers applied at the side of the third plow body, an improved distribution obtained, but was not distributed over the entire operating width (300 mm), but concentrated more around the side of the third plough body. When fertilizer applied both at the rear and at the side of the third plough body, the desired distribution obtained, and the distribution density decreased linearly with tilled soil depth.

The conveying fertilizer in horizontal auger device faces many factors affecting the performance of application fertilizer rate (Ismail-2007). The lever control in the fertilizer tank bottom and the amount of feeding device parameters are considers as the main static factors influence of the fertilizer rate performance. While, the application rate of metering device, metering device efficiency and felid efficiency for Super-phosphate (15%), Nitrate (33.5%) and Urea (46.5%) are considers as the main dependent variables used in developing response surface functions.

Therefore, this investigation aimed to use the response surface methodology (RSM) that select and evaluate a suitable operation condition realizing the optimum fertilizer application rate and machine volumetric efficiency.

MATERIALS AND METHODS

In the experiments, the banded type fertilizer machine is consisting of a fertilizing hopper, metering device, agitator unit, fertilizer tubes and transmission system and forming profile unit (Fig. 1). The ground wheel of the proposed fertilizer unit driven the auger shaft that located inside the hopper near the bottom carries agitator to keep the flow of material constant (Fig. 2). A slide gate used to control the openings and to shut-off flow during turn around. In fertilizer prototype machine, three hoppers have a square cross section at the top of 360×360 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° larger than the friction angle of the fertilizers against the hopper walls. Each hopper has a capacity of 35kg of fertilizer (Fig. 3-A). The horizontal shaft located near the bottom of the fertilizer hopper. The shaft is operated by a transmission system that powered by the ground wheel. Transmission system as shown in Fig. (3-B) 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/feddan (one feddan= 0.42 hectare). The fertilizer is delivered through a rubber tube on soil surface and covered by soil that formed by the profile maker unit.

In lab, the plastic bags are provided on fertilizer application tubes to determine the machine performance. The measurement of fertilizer amount was carried out at a duration time of 15min approximately for each run. The machine land wheel was mounted above the lab surface as closely as possible to permit the fertilizer ingathering in plastic bags and it is driven by an electric motor.

One of the most important factors affecting the application fertilizers rate is the auger volumetric capacity. As a statistical and mathematical technique, Response Surface Methodology (RSM) was employed to optimize the operating (peripheral) speed of the auger and the gate area levels and constructional-related variables (auger volume). The RSM designs are not primarily used for understanding the mechanism of the underlying system and assessing treatment main effects and interactions, but to determine, within some limits, the optimum operating conditions of system (Kathleen, 2004). It is less laborious and time-consuming that other approaches and is an effective technique for optimizing complex processes since it reduces the number of experiments needed to evaluate multiple parameters and their interactions (lee et al., 2006).
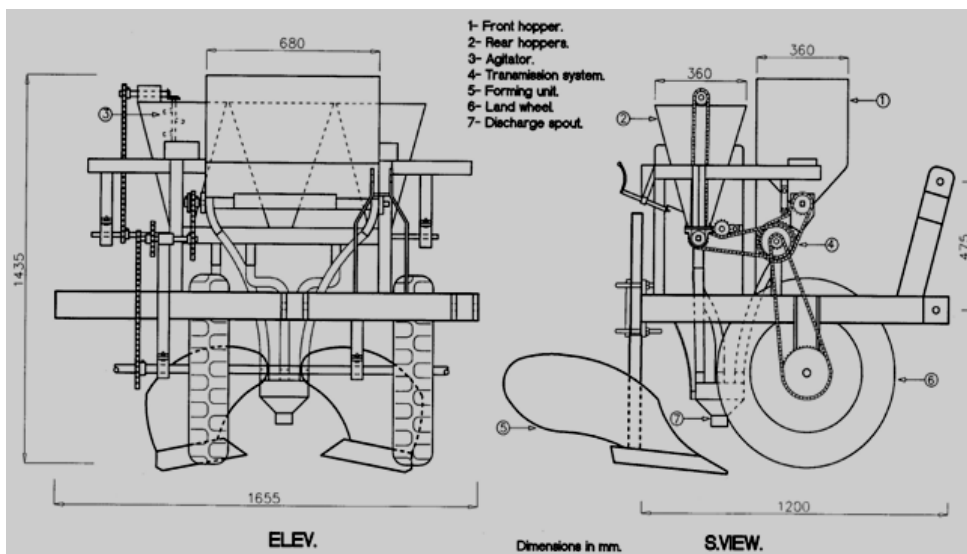

Fig.1-A: The layout of fertilizer

Fig. 1-B: The photograph of fertilizer prototype
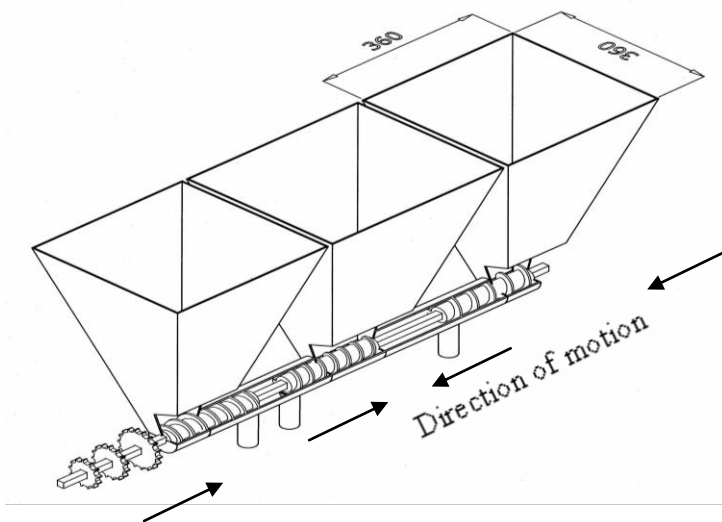Fig. 1: The prototype of Fertilizer

Fig. 2-A: The fertilizing hoppers

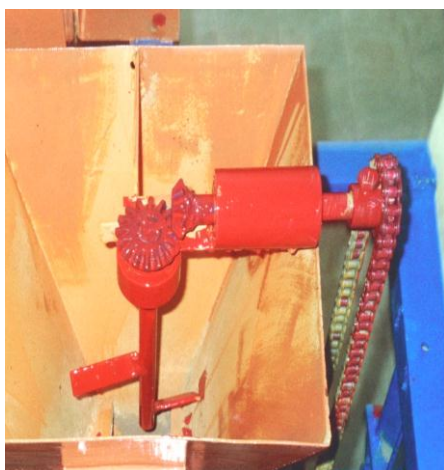Fig. 2-B: The fertilizing auger shaft
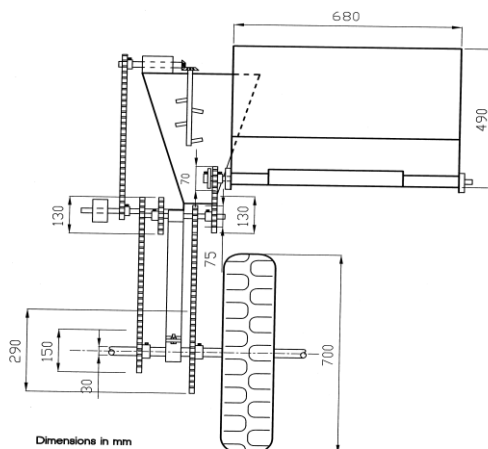
Fig. 3-A: The transmissions to vertical agitator

Fig. 3-B: The transmissions system

The response surface problem usually centers on an interest in some response "Y", which is a function of "Y" independent variables $\zeta_1, \zeta_2, \zeta_3, ..., \zeta_k$, that is,

$$Y = f\ (\zeta_1, \zeta_2, ...\zeta_k) + \varepsilon \qquad (1)$$

and response surface can take the different forms according to the function types of response and usually response function is defined in the quadratic polynomial form as follows:

$$Y = \beta_0 + \sum_{}^{k} \beta_i\ \chi_i + \sum_{}^{k} \beta_{ii}\ \chi_i^2 + \sum_{}^{k}\sum_{} \beta_{ii}\ \chi_i\ \chi_i + \varepsilon \qquad (2)$$

Where Y is the response; β_o is the intercept; β_i; β_{ii}; β_{ij} are the regression coefficients; χ_i; χ_i are the coded variables; and ε is the error. The coding of independent variables into χ_i is expressed by the following equation:

$$\chi_i = (\zeta - \zeta^*)\ /\ ds \qquad (3)$$

Where "ζ" is the actual value in original units; "ζ^*" is the mean value (center point); and "d_s" is the step value. The determination of center point for each independent variable was based on field conditions and the pre-experimental in lab on the three types of fertilizer used (Super-phosphate-15%, Nitrate-33.5% and Urea-46.5%). The special care has to be given for the selection of centre point as well as the minimum and maximum levels in order to construct polynomial functions form which the optimum levels of the independent variables are to be

calculated. The design in this study is a Central Composite Design "CCD" by which it studied the influence of three factors in 15 runs at which three levels for each independent variable. These levels were coded "-1"; "0" and "+1" respectively. The design is to be run in a single block, to provide protection against the effects of turning variables, the order of experimental has been fully randomized.

The centre point in this design is coded as zero and as the volumetric capacity of auger was chosen to be 36 cm^3. A step value of 14cm^3 was selected and as a result of this study, the selected auger volume dimension for the fertilizer auger becomes 22 cm^3 and 50 cm^3. To verify the above aim, the metering device is made of three augers are different in pitches length and screw diameter (screw flight diameter of 5.3, 6.0 and 5.8 cm, screw shaft diameters are 4.05; 4.11 and 3.93 cm and pitch length (P$_L$) of 2.4, 2.4 and 3.5 cm respectively). The three different augers are located, one by one on the feeding shaft hoppers as shown in Fig. (2-A), which there are provided from the local manufacturing company of the farm machinery.

The prototype of fertilizer had a ground-driven wheel that transfers the motion to the fertilizer auger with a combination of gears available (Fig.3-B). It was operated at three different peripheral speeds of 5.0, 7.5 and 10.0 ms^{-1}. The peripheral speed center point of 7.5 ms^{-1} for the fertilizer auger corresponds to 4.2 kmh^{-1} of machine traveling speed. The selection of the peripheral speed of the auger was achieved by considering the traveling speed of the fertilizer machine in the field. This relation can be found as the theoretical relative to the agronomy requirement and the types of planting crop (Ismail, 2009). The amount of fertilizer flow rates were regulated by controlling the gate area. There are three slide control gates, which are fixed on the hopper sides to control the amount of flow from the hopper and auger chambers, with the total cross section of the orifice gates is 150×80 mm. the gate orifice level was centered at 32 cm^2 while the other levels were calculated based on the CCD principles at a step value of 16 cm^2 of the projected orifice area. Table 1 gives a list of independent variables and the coded factor levels.

Each operating condition was established carefully and the rate of application flow (A_R) was measured in terms of kg/fed as:

$$A_R = \frac{4200 \times D}{2\,\pi\,r\,n\,w} \tag{4}$$

Where, "D" is the discharge rate (kg/min), "r" is a land wheel radius (meter), "n" is revolution number of land wheel per minute (rpm), "w" is operating width (m) and 4200 is the Egyptian feddan area. Each test was replicated three times.

Table 1: Coded level for independent variables used in developing response surface functions

Independent variables	code	Coded level		
		-1	0	+1
Auger shaft speed, m/s	A_s	5.0	7.5	10
Auger volume, cm^3	A_v	22	36	50
Gate area, cm^2	G_a	16	32	48

The performance of fertilizer application was evaluated using measures based on those adopted by Fouda (2007). Generally, the discharge rate in terms of volume per unit time ($m^3 \cdot min^{-1}$), It is expressed as $Q_a = \dfrac{D}{\rho}$. Where "Q_a" is the actual volume capacity ($cm^3 min^{-1}$); and "ρ" is the bulk density of the material (kg cm^{-3}). In reality, the actual capacity of an auger is consider less than the theoretical (Q_{th}). Then the volumetric efficiency "η_v" is defined as $\eta_v = \dfrac{Q_a}{Q_{th}} \times 100$.

The measured of the discharge rate were entered into an Excel spreadsheet where each data set was split into different groups of the actual volume capacity and theoretical capacity "Q_{th}" to determine the application flow rate for three types of fertilizer (Super phosphate, Nitrate and Urea). These types were selected as one of the famous varieties used in Egyptian farms and the physical properties of these varieties were shown in Table (2). The performance data were then transferred into a Minitab statistical package program for further analysis. All of the replications were used for the development of response surface function. The response surface functions were developed for each performance criteria. The functions developed were defined as full quadratic polynomials in Minitab, a statistical package program and stepwise procedure used for

the selection of the variables as they enter the model in liner, interaction and quadratic form.

Table 2: the physical properties of the different fertilizers

Name of fertilizer	Bulk density, g/cm^3	Angle of repose	Friction angle against steel	Form of fertilizer	Hygroscopic	Remarks
Super phosphate, 15%	0.995±0.025	44$^°$±1.35	30.5$^°$±2.01	Powder	Low	Medium distribution
Nitrate, 33.5%	0.913±0.013	33$^°$±1.65	28.5$^°$±1.82	Granulated	Medium	Easy distribution
Urea, 46.5%	0.685±0.054	28$^°$±0.98	19$^°$±0.95	Spherical	High	Easy distribution

RESULTS AND DISCUSSION

The application rate

The experimental results carried out in the laboratory based on Center Composite Design "CCD" are given in Table 3. As can be seen the auger operated at 7.5 ms^{-1} peripheral speed, average volumetric capacity 50 cm^3 and gate area of 48 cm^2 gives a satisfactory results in terms of application rate (A_R, kg/fed). This result could be explained as the good selection of the ranges for the independent variables and their step values.

Table 3: General (CCD) with coded and un-coded independent variables and performance values

	In depended variables			Depended variables (A_R, kg/fed)		
	X_1 (A_s, m/s)	X_2 (A, cm^3)	X_3 (G, cm^2)	Super-phosphate, 15%	Nitrate, 33.5%	Urea, 46.5%
1	7.5	50	48	115.32	166.74	120.18
2	7.5	22	48	32.38	60.94	40.16
3	5.0	22	32	120.16	168.16	114.84
4	5.5	36	48	61.42	84.19	53.84
5	7.5	22	16	73.14	110.14	80.18
6	10	36	48	102.14	145.9	105.6
7	5.0	50	32	53.14	77.94	71.16
8	10	22	32	99.36	142.13	100.27
9	10	36	16	42.42	72.46	58.94
10	10	50	32	86.15	126.84	83.14
11	5.5	36	16	73.14	110.14	80.18
12	7.5	36	32	62.84	124.36	98.17
13	7.5	36	32	84.16	150.3	18.37
14	7.5	36	32	85.38	118.96	88.94
15	7.5	50	16	73.14	11.14	80.18

The following Response Surface Regression functions with transformed-dependent variables for fertilizer application rates " A_R, kg/fed" were developed using three different types of fertilizers, namely, supper phosphate "15%", Nitrate "33.5%" and Urea "46.5%":-

A_R, of super phosphate = 73.14+ 2.08A_s + 24.14 A_v + 7.66 G_a + 26.08 A_s^2

$\qquad$ -11.71 A_v^2-5.97 G_a^2 -0.86 A_s. A_v +0.50 A_s . G_a +2.82 A_v . G_a

$\qquad$ R-Sq = 96.54% (5)

A_R, of Nitrate, 33.5% = 77.14+ 2.41A_s+ 39.25 A_v + 9.96 G_a + 39.28 A_s^2
$\quad$ +7.83 A_v^2 +17.04 G_a^2-1.21 A_s. A_v -1.03 A_s . G_a + 3.61 A_v .
$\quad$ G_a $\quad$ R-Sq=74.74% $\quad$ (6)

A_R, of Urea, 46.5% = 80.18- 2.88A_s+ 28.43 A_v + 9.10 G_a + 12.71 A_s^2 -
$\quad$ 2.88 A_v^2 +1.61 G_a^2+3.00 A_s. A_v +2.80 A_s . G_a + 0.36 A_v . G_a
$\quad$ R-Sq = 99.10% $\quad$ (7)

Where, "A_s" is the coded auger peripheral speed; A_v is auger volumetric capacity; and G_a is the gate area. The results from estimated regression coefficients for Super phosphate, Nitrate and Urea application rates function are given in table 4.

Equs. (5) to (7) with respect to each independent variable yields the optimum levels. The optimum level of the auger peripheral speed "A_s", auger volumetric capacity and gate area for three different fertilizer types are very close and they are in good agreement (table 5). From the equations (5, 6, and 7), the factor that more effect on the application rate performances is the " A_v" which recorded the height significant effect of "F" tests fouled by "G_a" and " A_s" parameters. From equations 5-7, the analysis of the response surface as the relationship between the equations factors residual and its percentage, the normal probability plots are plotted in Figs. 4-a, 4-b and 4-c for three types of fertilizer used (Super phosphate, 15%, Nitrate, 33.5%,and Urea, 46.5% respectively).

Table (4): Estimated Regression Coefficients of A_R "kg/fed" for Super phosphate, Nitrate and Urea.

Term	Coef.for Super-phosphate, 15%	Coef. for Nitrate, 33.5%	Coef. for Urea, 46.5%
Constant	133.792	425.588	140.992
Auger speed, m/s	-61.2969	-91.2420	-36.9731
Auger volume, cm^3	5.81056	-0.331492	2.39773
Gate area, cm^2	1.42452	-4.02352	-0.416038
Auger speed, m/s* Auger speed, m/s	4.17420	6.28480	2.03340
Auger volume,cm^3*Auger volume, cm^3	-0.0597895	0.0399872	-0.0147130
Gate area, cm^2*Gate area, cm^2	-0.0233252	0.0665527	0.00630371
Auger speed,m/s*Auger volume, cm^3	-0.0245714	-0.0345000	0.0855714
Auger speed,m/s*Gate area, cm^2	0.0125625	-0.0256875	0.0699375
Auger volume, cm^3*Gate area, cm^2	0.0125893	0.0160937	0.00158482

Table (5): The optimum level of the variable on the fertilizer application rates

Fertilizer types	Super phosphate, 15%	Nitrate, 33.5%	Urea, 46.5%
Auger volume	$A_v = 45cm^3$	$A_v = 50cm^3$	$A_v = 50cm^3$
Gate aria	$G_a = 40 cm^2$	$G_a = 50 cm^2$	$G_a = 50 cm^2$
Auger speed	$A_s = 5.0$ m/s	$A_s = 10.0$ m/s	$A_s = 5.0$ m/s

While the histogram in Figs, 5-a, 5-b and 5-c illustrate the frequency of equations residual. For the Figs. 4-a and 4-c, the percentage of equation residuals are distributed around the equation functions while they were concentrated about zero residual as shown in Fig. 4-b. Also, the frequency plots (Figs. 5-a, 5-b and 5-c) gave the same of the above trend.
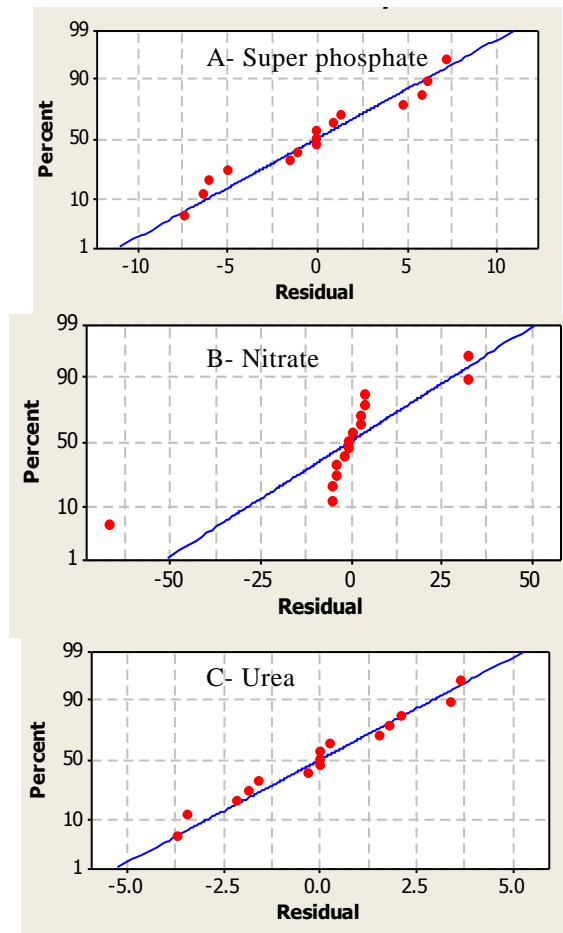
Fig. 4: The percentage of equations factors residual.
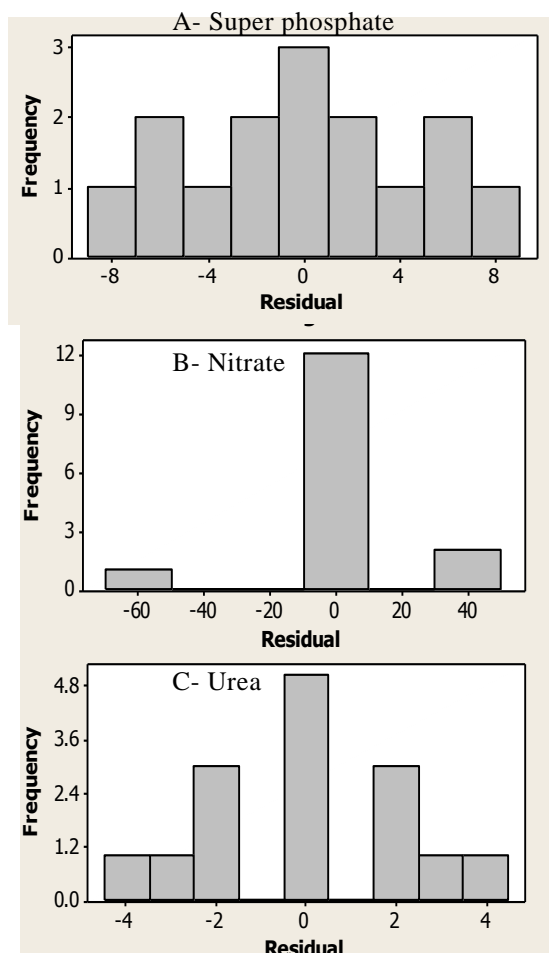
Fig. 5: The frequency of equations factors residual.

Graphical view of some response surfaces as drawn using surface plot are depicted in Figs. "6 and 7". A surface plot in Figs. "6-a, 6-b and 6-c" displays a three-dimensional view (application rate in "z" axis, auger speed in "x" axis and gate area in "y" axis) that may provide a clearer picture of the response surface based on a model equation.

Also, the response surface for relationship between auger speed in "x" axis and auger volume in "y" axis on the application rate are depicted in Figs. 7-a, 7-b and 7-c for Super phosphate, Nitrate and Urea respectively.
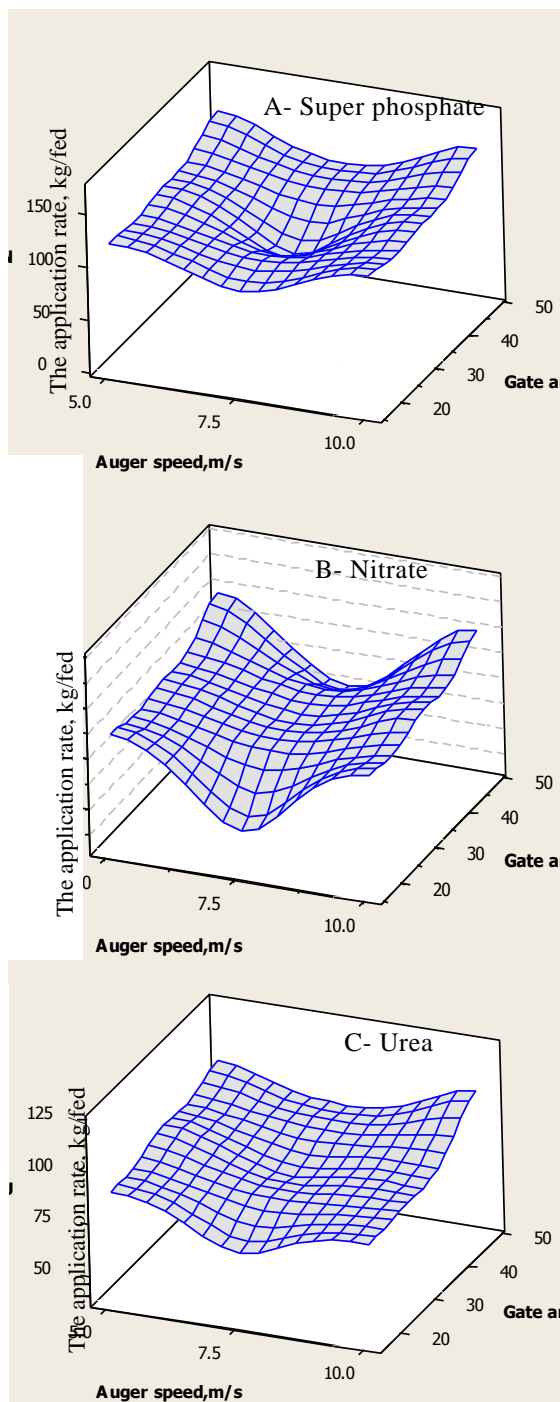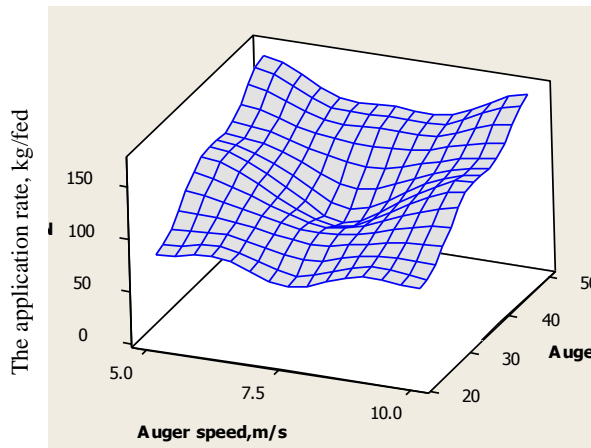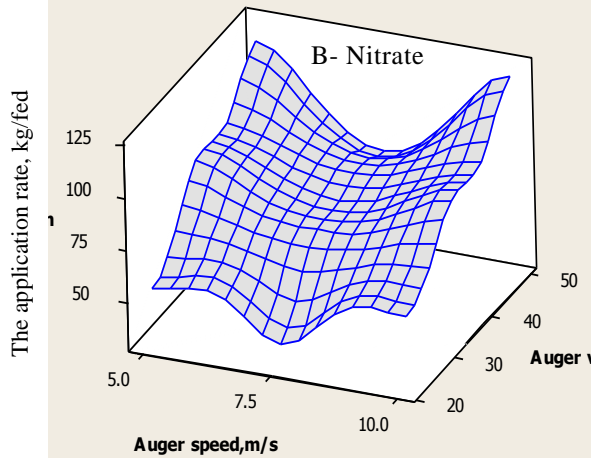
Fig. 6: the surface plot of application rate Vs gate area and auger speed
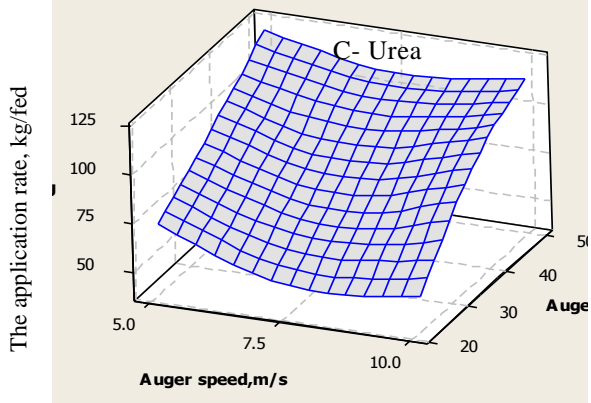
A- Super phosphate

Fig. 7: The surface plot of application rate Vs auger volume and auger speed.

2- The volumetric efficiency "η_v"

The effects of auger shaft speed, auger volume, and orifice gate area for different fertilizer types on the volumetric efficiency illustrate in figures (8), (9) and (10). 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.

Generally, 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 cm^3, and auger shaft speed of 4.44 m/s for spherical shaped particles (Urea) as shown in Fig (10). While, the lowest value is 28 % at the sequence conditions of gate area of 16 cm^2, auger volume of 22 cm^3 and auger speed of 8.33 m/s, for powdered shaped particles (Super phosphate) as shown in Fig.(8). Meanwhile, at sing Nitrate, the volumetric efficiency of fertilizer "η_v %" were 70%, 81% and 86%, at 16; 32 and 48 cm^2 gate areas, respectively for auger volume of 22 cm^3. While, the volumetric efficiency were 75%; 83% and 87% for auger volume of 36 cm^3 and were 73%; 80% and 85% for auger volume of 50 cm^3 under the same condition (Fig. 9).

The effect of auger shaft speed on volumetric efficiency 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:

$$\eta_v = -k\,N^2 + b\,N + n \dots\dots\dots\dots\dots\dots\dots\dots (8)$$

Where

η_v : volumetric efficiency, (%);

N : auger shaft speed, (m/s);

k, b and n : coefficient constants.

The values of the constants k, b 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.
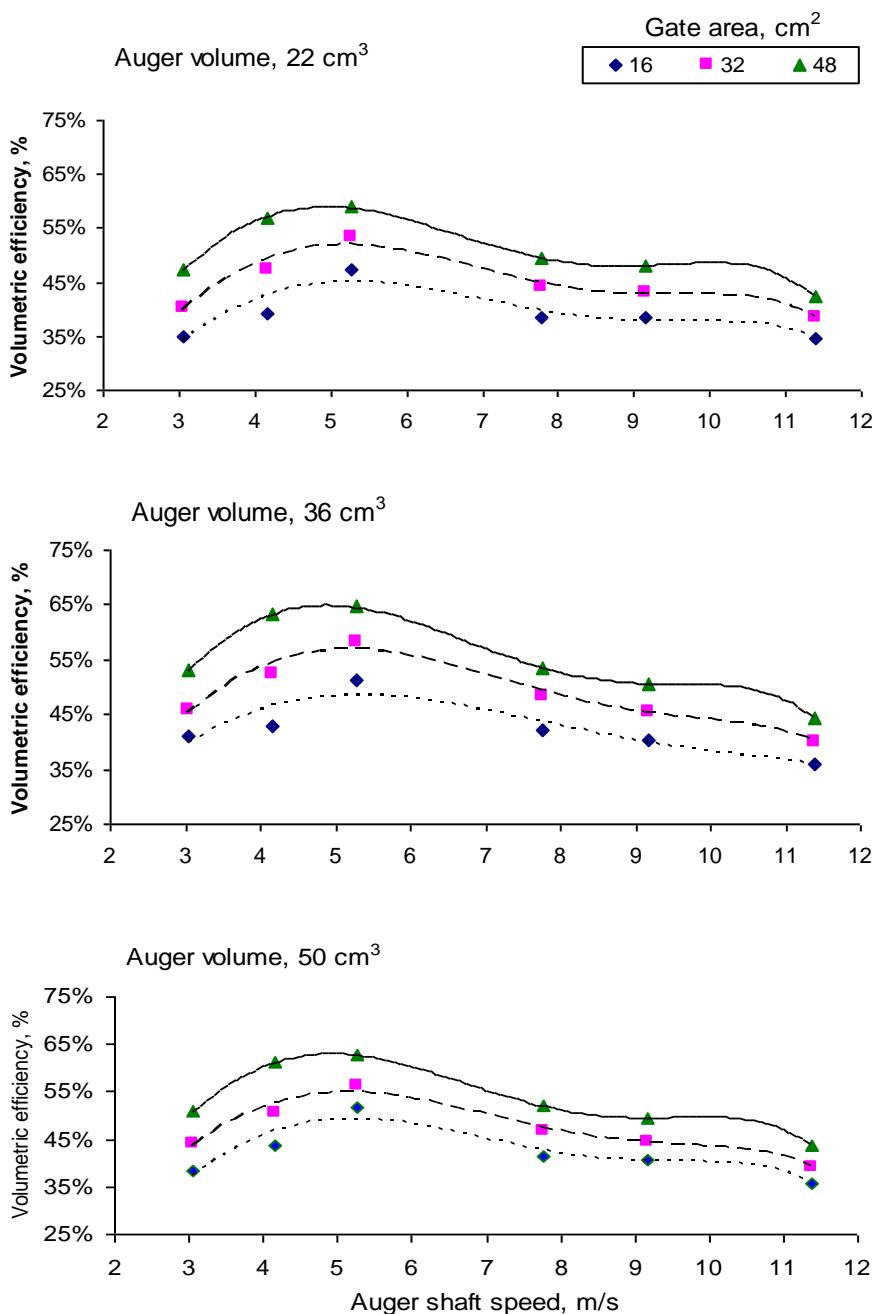
Fig. 8: Effect of auger shaft speed on volumetric efficiency at Super phosphate
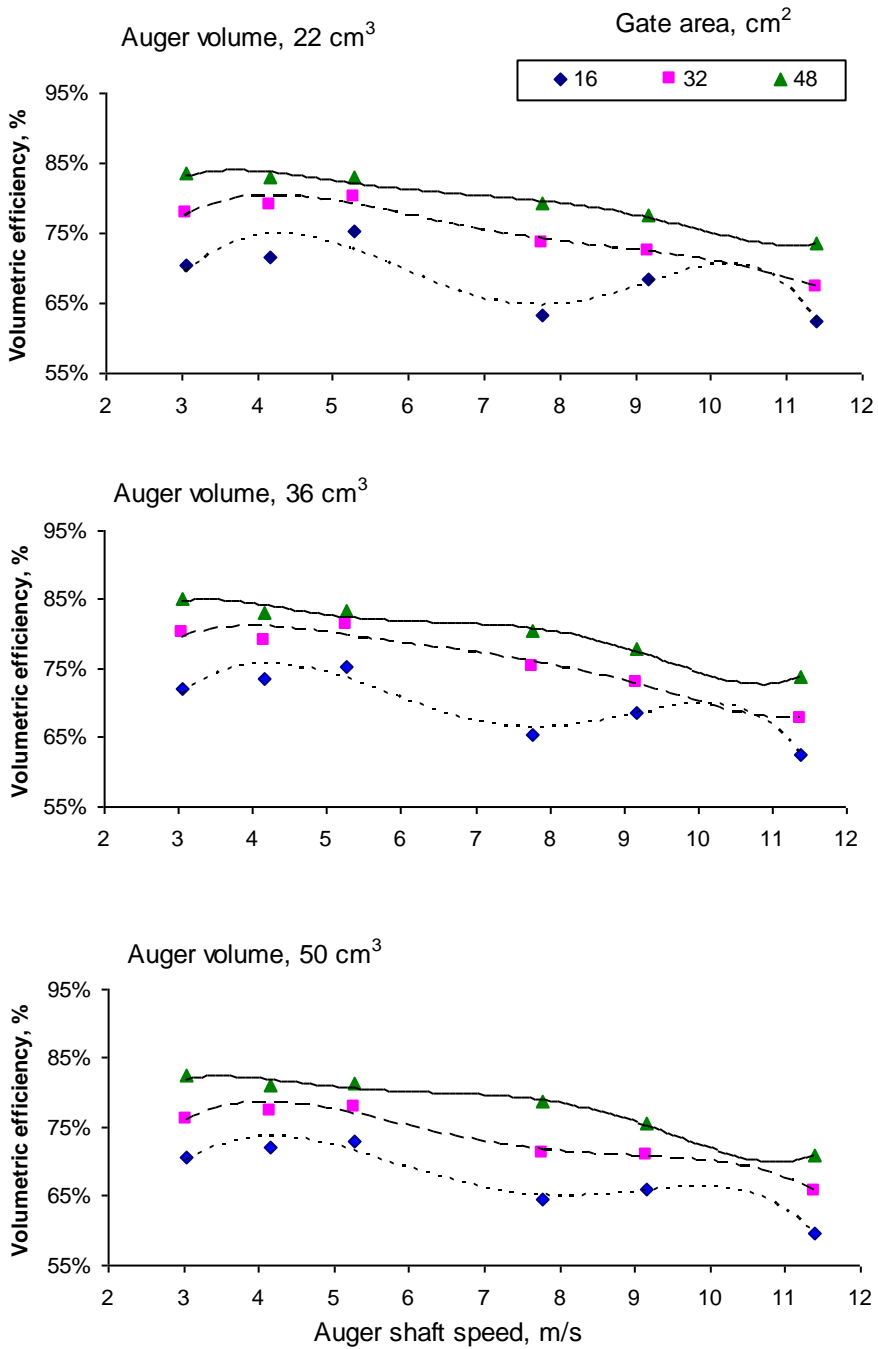
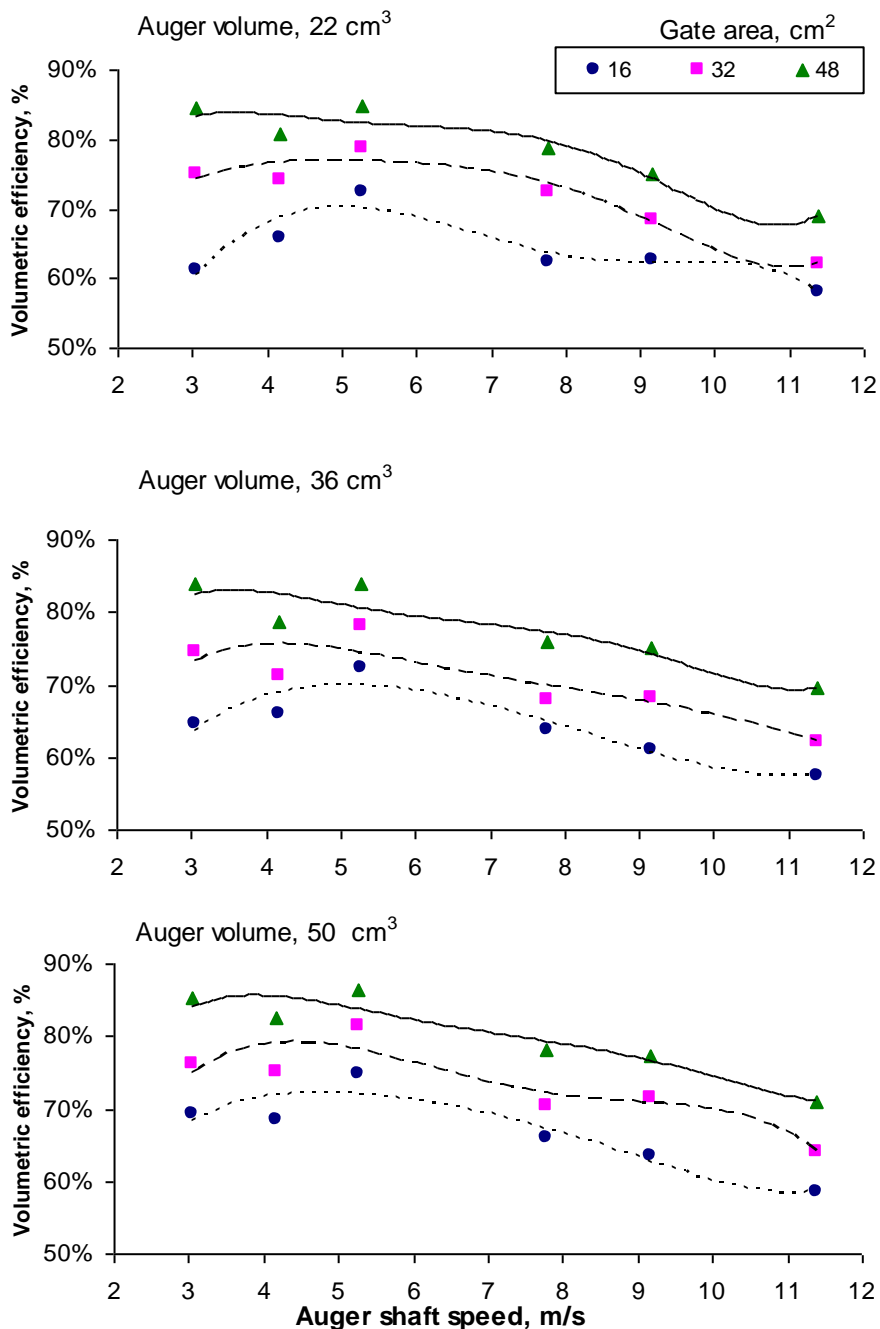Fig. 9: Effect of auger shaft speed on volumetric efficiency at Nitrate.

Fig. 10: Effect of auger shaft speed on volumetric efficiency at Urea.

Table 3: Values of constants (k, b and n) of equation (8):

Fertilizer name	Bulk density, g/cm^3	k	b	n	R^2
Urea	0.685	0.0019	0.0131	0.7341	0.611
Nitrate	0.913	0.0021	0.0179	0.7428	0.8919
Super-phosphate	0.995	0.0009	0.0012	0.4941	0.2032

CONCLUSIONS

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 64.9 % to 79.0 % at bulk density of 0.685 g/cm^3. Also, it increases from 68.6 % to 79.7 % and from 39.4 % to 51.2 %, with bulk density of 0.913 and 0.995 g/cm^3 respectively.

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<u>الملخص العربى</u>

تقييم موزع السماد بإستخدام طريقة إستجابة التأثير السطحى

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خلال العقد الماضى، أعطى قدرا كبيرا من الاهتمام لاستصلاح الأراضي الجديدة (الأراضي الصحراوية)، وتعد محاصيل الخضر من أهم المحاصيل التى تجود زراعتها فى مثل هذه الأراضى ويقبل المزارعون على زراعتها لإرتفاع العائد المادى وقصر دورة الحياة. وزيادة العائد المحصولى يتطلب التحكم الدقيق فى عملية التسميد. وتتكون آلة التسميد المستخدمة خلال التجارب من خزان تسميد، وجهاز تلقيم، ووحدة توزيع، وأنابيب التسميد، ووحدة تشكيل مصطبة، وجهاز لنقل القدرة. إستخدمت طريقة إستجابة التأثير السطحى (RSM) لتحديد أفضل مستويات لعوامل التشغيل (سرعة البريمة، مساحة البوابة، وسعة البريمة) وبالتالى تحديد معدل التسميد. إستخدم فى الدراسة تصميم التركيب المركزى "CCD" لدراسة تأثير ثلاث عوامل فى فى ثلاث مستويات لكل متغير مستقل، هذه المستويات أعطيت رمز ١-، صفر، ١+ على الترتيب. ولزيادة التحكم تم التحليل فى قطع عشوائية منفردة لإظهار التأثير الناتج عن العوامل. لوحظ التقارب والتوافق الجيد بين مستويات عوامل الدراسة (سرعة البريمة، مساحة البوابة، وسعة البريمة) عند أنواع الأسمدة الثلاث تحت الدراسة. حيث كانت مع السوبر فوسفات على سبيل المثال ٥ م/ث، ٤٥ سم٣، ٤٠ سم٢ على الترتيب. ولوحظ أن أعلى قيمة لمعدل التصرف كانت ١٥٩.٦ كجم/ساعة عند إستخدام سماد اليوريا مع سرعة البريمة ١٠ م/ث، مساحة البوابة ٤٨ سم٢، وسعة البريمة ٥٠ سم٣. كما تبين أنه بزيادة مساحة البوابة من ١٦ إلى ٤٨ سم٢ تزداد الكفاءة الحجمية من ٦٤.٩ إلى ٧٩.٠ % ومن ٦٨.٦ إلى ٧٩.٧ % ومن ٣٩.٤ إلى ٥١.٢ % لكل من سماد اليوريا والنترات والسوبر فوسفات على التوالى.

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