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MODIFYING THE AMOUNT OF FERTILIZERS USING VARIABLE RATE ADDING TECHNIQUE

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ABSTRACT

This research was carried out at Meet Aly village, Dakahlia governorate in summer season 2013 to determine the optimum parameter which can be used to control fertilizing with variable rate technique. To achieve the aim of this research at two fertilizer prototype on row was developed by adding an electronic gate on/off (developed unit) to that hand gate on/off system (traditional unit) on the same prototype. Four forward speeds were applied namely 3.38, 4.38, 4.79 and 6.70 km/h once at fixed fertilizer rate (150 kg/fed) by traditional unit, and another at variable fertilizing rate by developed unit. To evaluate the fertilizer units performance the amount of nitrogen in soil, fuel consumption, field capacity and cost estimation were determined. From the results it can concluded that using the developed fertilizer unit; a controlled by the electronic system on/off gate saved the amount of fertilizer to 56.8 kg/fed and total costs to 209.36 LE/fed at forward speed of 4.79 km/h. It can be recommended that the applied developed technique can be tested in a large scale to test its efficiency and suggest another methodology other than soil chemical analysis such as GIS maps.

INTRODICTION

In Egypt the farmers depends on the manual method of soil fertilization (Novak and ljublhana, 1990). This method has many disadvantages such as poor distribution, low field capacity, more time, excessive amount of fertilizer and more human efforts, then much money with less yields. Srivastava *et al.* (1993) reported that the fertilization was applied commonly with solid mineral fertilizers. Application of mineral fertilizers has certain advantages. Granular fertilizer may be spread uniformly over the entire field, called the broadcast application or it may be applied in narrow rows, called the banded application. The equipments for applying granular fertilizers include drop type (gravity), rotary (centrifugal), pendulum and air (pneumatic) spreader.

Virin *et al.* (2006) stated that the mineral fertilizers application is an agricultural task widely performed by centrifugal spreaders. These machines give satisfying results with regularly spaced parallel tractor trajectories but lead to over and under-applications when geometrical singularities occur (non-parallel paths, start and end of spreading,...). The application errors result then in water sources pollution and important yield losses. Cointault *et al.* (2000) reported that the most attempts to modify centrifugal techniques for variable rate fertilization have been based on controlling single parameters: (flow rate of granule). The various designs of sensors have been proposed, either based on measurement of the variation of fertilizer mass left in the hopper or by measurement of the power absorbed by the spinning disk during spreading.

Morgan *et al.* (2003) reported that the precision agriculture is an emerging technology for improving crop production inputs like fertilizer, herbicide, seed, etc. on a site-specific basis to optimize crop production based on in-field variability to reduce waste, increase profits and maintain the quality of the environment. Van Liedekerke *et al.* (2006) indicated that the precision techniques are still developing, but they will allow specific spreading doses that conform to environmental regulations. They said that this allows calculation of spreading patterns as a function of both particle and machine properties. In this way, expensive tests can be avoided. Finally, both methods are linked to GIS, such that an optimal fertilizer dose can be matched to specific soil needs. Grift *et al.* (2002) showed that the optical sensor is capable of automatically determining the spread pattern of a fertilizer spreader on the fly. The sensor could be a key component in the development of uniformity–controlled fertilizer application systems. Lawrence *et al.* (2007) showed that collecting accurate fertilizer distribution information from large field trials is difficult and very labor intensive. A computer analysis method was developed for analyzing field application variation of fertilizer distribution from any spreading vehicle. The tool used measured machine parameters, including geographical position and heading, and a series of static spread pattern tests from the spreading vehicle. A field distribution calculator and geographic mapping tool were created to first calculate the fertilizer material distributed in each 0.5 m quadrant of a field and then produce an application surface to show variation in the field application. Tola *et al.* (2008) indicated that the overall assessment of the developed control system indicated that the system could control and adjust granular fertilizer application rate effectively. Further experiments under field conditions are required and to ascertain if any essential modifications are required before the system can be used commercially.

The fertilizer distributors for a good fertilization have to meet the uniformity in distribution, the possibility of controlling the amount of fertilizer distribution, a relatively slight dependence of the amount of the application rate on shocks and inclination of the machine during its operation, insensibility of working elements of distributor to corrosive action of fertilizers ((Kepner et al., 1972). Yang (2001) showed that the variable rate applicator had very good dynamic response and high application accuracy. The methodologies and testing results presented in the article have practical implications for the development and testing of variable rate equipment in precision agriculture. Also, Fulton *et al.* (2001) mentioned that application accuracy is an important property to quantify when assessing variable-rate spinner spreaders. The coefficient of variation (CV) is typically used to characterize the quality of spread distribution. Lower CVs tend to be indicative of more uniform distribution patterns. Typically, the CV varies from 5 % to 10% for spinner spreader patterns. They added that, many factors affect fertilizer distribution and application accuracy, such as systematic errors associated with machine calibration and metering efficiency. They also added that many factors affect fertilizer distribution and application accuracy, such as systematic errors associated with machine calibration and metering efficiency. Marey (2004) indicated that increasing forward speed tends to increase the rate of fuel consumption and specific fuel consumption, while the fuel consumption in L/fed was decreased and the energy requirement in kW.h/fed decreased at all factor used. Also he found that when using granular fertilizer, the fuel consumption in L/fed was found to be 0.62 L/fed compared with 0.89 and 2.3 L/fed for coarse and powder fertilizer, respectively at forward speed of 2.9 km/h. Metwali (1995) mentioned that the obtained values of the total costs in LE/h were found to be 16.48 and 18.67 for the centrifugal fertilizer distributor and fertilizing drilling machine, respectively at implement forward speed of about 4.8 km/h. however, they were 1.74 and 7.33 LE/Feddan for the same pervious mentioned factors. He added that the total costs of the centrifugal fertilizer distributor is significantly less than the total costs of fertilizing drilling machine at all forward speeds.

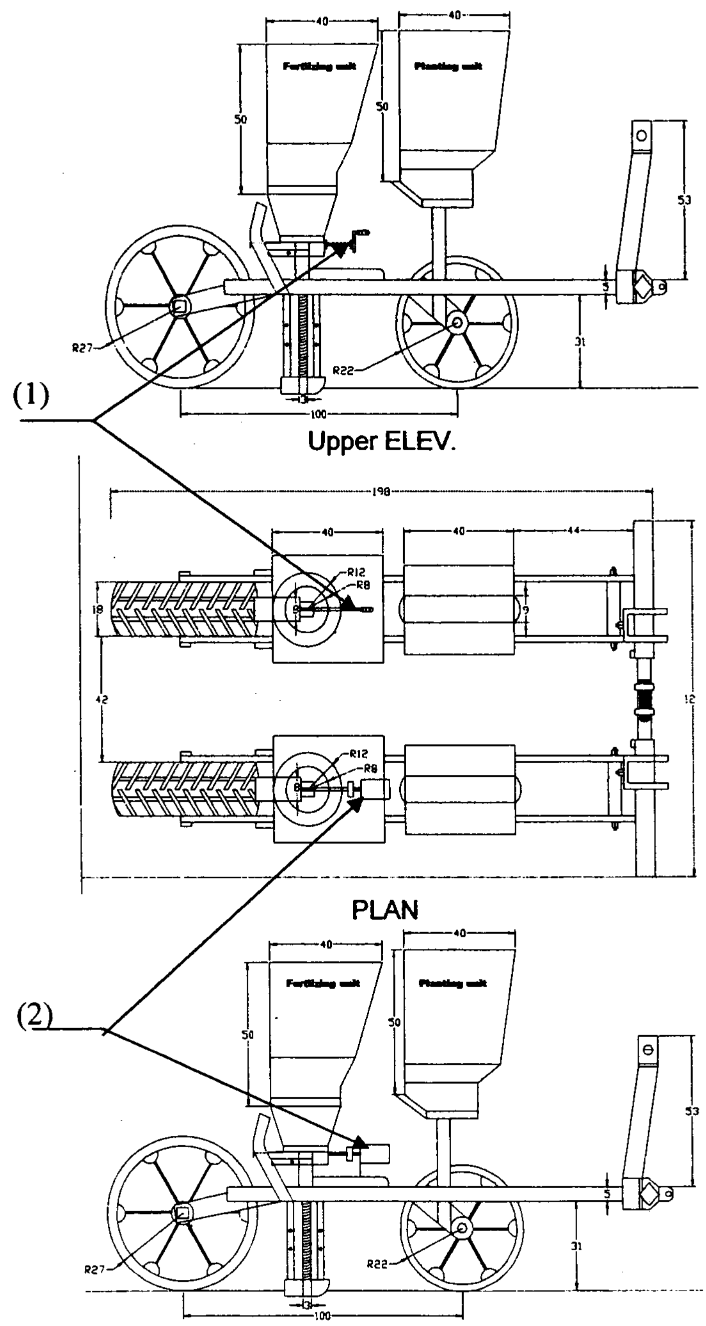
The research aimed to constructed a system to add the optimal fertilizer dose to the land through an electronic circuit and test its effectiveness.

MATERIALS AND METHODS

The research carried out at Meet Aly village, Dakahlia govemorate in summer season 2013 to developed fertilizer prototype suitable for variable rate application. The developed fertilizing prototype, used with maize crop a granular type fertilizer (Urea). The fertilizer has two units with the following dimensions, 1750, 1200 and 1200 mm length, width and height respectively. It consists of two units. Each one contains three main parts namely, hopper, gate, controller of gate area, furrow opener, covered wheel and fertilizing tube beside the secondary and main frame connecting to hitching tool as shown in Figs. (1 and 2). The differences between the traditional unit and the developed unit is the control system of the open / close gate (determine the gate opening). The traditional unit gate can be closed and opened by a wooden hand which connected to the screw bolt (Fig. 3). While the developed unit gate on/off was using the electronic circuit to control the wideness of fertilizer gate (Fig. 4 and 5).
The Romanian tractor (model Universal 650-M) was used as the power source. The tractor power is about 48.50 kW at crank speed 1250 rpm. The Urea fertilizer was selected as an example of the granular fertilizer as it is the most wide used fertilizer for many crop. The field experiments were done on clay soil texture form.

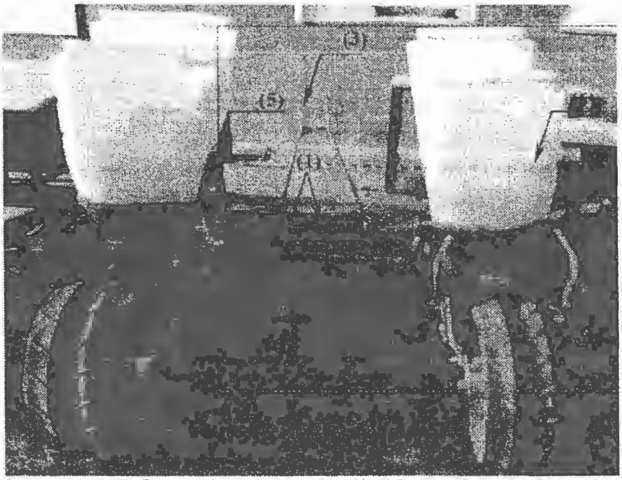
The field experimental test:

The maize was planted using a row crop planter fixed with planting and fertilizing units. Then two main experiments were conducted in the field at the same time. One of them using the traditional unit and the other using the devolved unit. The field experiments of the traditional and developed units were conducted at the following variables:



(1) Wooden hand (2) Motor

Fig. 1: A schematic drawing of the traditional and developed units.

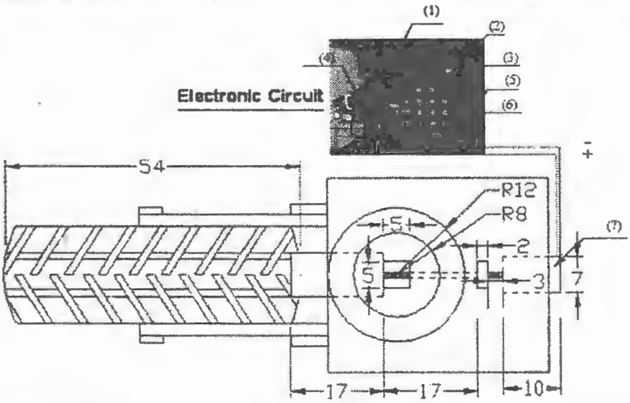


1- Main frame 2- Secondary frame 3- Hitching points 4- Covering wheels 5- Furrow opener 6- Hopper

Fig. 2: Developed and traditional fertilizers unit.

Fig. 3: The traditional fertilizer unit

Fig. 4: The developed fertilizer unit



(1) Digital screen (2) Conductor lamp (3) Timer keys (4) Cancel key
(5) Gate area keys (6) Close key (7) Motor

Fig. 5: A schematic diagram of feed gate and electronic elements.

a - Four forward speeds of 0.94, 1.21, 1.33 and 1.86 m/sec at the 2nd fast gear, 4th low gear, 3rd fast gear and 4th fast gear respectively with fuel throttle around 80%.

b – The gate area opening was adjusted according to the calibration experiments for both fertilizing units.

These experiments were replicated three times in strip plot design. The amount of N in the soil were determined by analysis (Caldhaal method, AOAC, 1970). The soil samples are taken at 5m² before and after each test using the traditional unit at the specified locations in row and the average of amount of Urea were recorded. The samples which has been taken before the tests, were identified and tabulated to be used as a control reference for the developed unit to adjust the gate area and the gate opening time (Table 1). Meanwhile, using the developed unit the three samples were taken slightly after the beginning, middle and slightly before the end of the change the gate area. The results of the amount of Urea samples for each test were recorded.

Table (1): The recorded data of the nitrogen content in the soil (kg)

Rows / Longitudinal distance, m	1	2	3	4
0	0.001	0.002	0.001	0.001
10	0.270	0.270	0.270	0.270
40	0.010	0.100	0.320	0.180
60	0.290	0.050	0.120	0.030
75	0.170	0.020	0.150	0.020
100	0.150	0.160	0.110	0.040
135	0.080	0.020	0.400	0.040
185	0.230	0.100	0.380	0.080
280	0.800	0.240	0.480	0.110
340	1.620	1.620	1.620	1.620
415	2.080	2.080	2.080	2.080
455	0.140	0.200	0.290	0.120
540	0.120	0.140	0.530	0.170
630	0.130	0.190	0.240	0.160
675	0.130	0.200	0.210	0.120
735	0.200	0.020	0.500	0.410
850	1.080	0.500	0.380	0.130
895	0.140	0.200	0.300	0.180
920	0.200	0.100	0.050	0.100
1000	0.130	0.100	0.110	0.190
Total in soil	7.971	6.312	8.541	6.051
Recommended	12.5	12.5	12.5	12.5

To evaluate the performance of fertilizer units the following calculations were done:

1- Amount of nitrogen in soil: the sample of soil analyzed by a Caldhaal method in the soil laboratory at El-Serw Research Station according to AOAC (1970).

2- **Fuel consumption:** was determined by measuring the volume of fuel consumed during the operation for each test and calculated in liter per hour. It was measured by completely filling the fuel tank then before the end of each it was refilled test using a scaled container.

3- **Field capacity:** The field capacity of the prototype has been used to calculate the energy and cost per feddan. The effective field capacity of the prototype is a function of the prototype width, the forward speed of travel and turning time lost during the operation. The required amount of the overlap is largely a function of speed,

ground condition and skill of the operator. The effective field capacity of prototype may be expressed as follows (**Kepner et al., 1986**)):

$$F_c = \frac{V_m . W}{10} \times \frac{F_e}{100} \qquad ....(1)$$

where: F_c: effective field capacity, Fed/h

V_m: speed of travel, km/h

W: rated width of the prototype, m

F_e: field efficiency, %.

4- **Field efficiency:** the prototype field efficiency (F_e) may be expressed as follows:

$$F_e = \frac{To}{Te + Tn + Ta} \times 100 \qquad ....(2)$$

where: To: theoretical time per hectares,

Te: the effective operating time, per hectare.

$$Te = \frac{To}{K} \times 100 \qquad ....(3)$$

K: prototype width actually utilized, %

Tn: time lost per hectares due to interruptions that are not proportional to area. At least part Tn usually tends to be proportional to Te,

Ta: time lost per hectares due to interruption that tend to be proportional to area.

5- The specific energy

The specific energy was calculated using the following equation by **Barger *et al.* (1963)**:

$$S_e = \left(\frac{F_u \times \rho_f \times C.V}{3600} \right) \times \left(\frac{427 \times \eta_{th} \times \eta_m}{75 \times 1.36 \times F_c} \right) \qquad ....(4)$$

where: S_e: specific energy, (kW.h/Fed);

F_u: fuel consumption rate, (L/h);

ρ_f: density of fuel, kg/L, (for diesel = 0.85 kg/L);

CV: calorific value of fuel, (Kcal/kg);

427: thermal-mechanical equivalent, (kg.m/Kcal);

η_{th}: thermal efficiency of the engine, assumed 40 % for diesel engine;

η_m: mechanical efficiency to engine, assumed 80 % for diesel engine;

F_c: actual field capacity, Fed/h.

6- Cost estimation:

Implements cost, which include fixed costs (depreciation, interest, housing, insurance and taxes) and variable costs (repair and maintenance, fuel, oil and labor) are a major capital input for most farmers. Finally determine the economic benefit of the fertilizer prototype units.

7- **Statistical analysis:**

The regression analysis and the analysis of variance of experimental factors were calculated during analyzing the laboratory and field collected data in this study. Analysis were executed using the aid of the computerized statistical procedures of Excel (2003).

RESULTS AND DISCUSION

1- Effect of forward speeds on amount of nitrogen fertilizer in soil

From the figure it can be also concluded that the developed unit saves amount of fertilizers reaches to 137.0, 123.4, 92.3 and 71.8 % compared to the traditional unit at forward speeds of 3.38, 4.38, 4.79 and 6.70 km. Moreover, the lowest differences between the adding fertilizer and the recommended value obtained using the developed unit at 6.70 km/h respectively forward speed.

The chart bars in Fig (6) indicates that the amount of fertilizers decreases as the forward speed increases. These results were obtained wither the prototype developed or undeveloped with the matching technique. This may be due to slippage of the prototype wheels due the high speed as this slippage would decrease the rotation of the feeding system in unit distance resulting in the decrement of fertilizers in specific area.

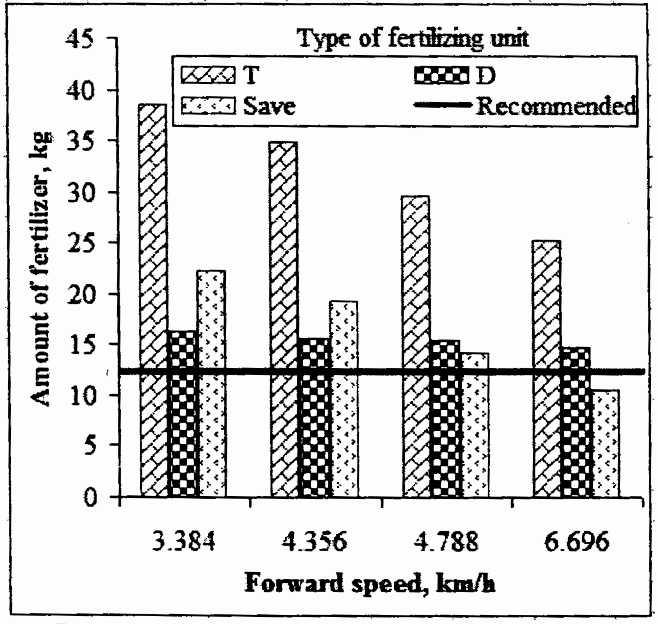


Fig. (6): Effect of forward speeds on amount of fertilizer in soil.

2-Effect of sampling position on amount of fertilizer in soil

Figs. (7a- 7d) illustrate distribution of fertilizers longitudinally on the row and the amount of the fertilizer at different sampling positions using the developed unit. From the figure it can be seen that at some distances in row of gate is approximately closed because the fertilizer amount in soil is enough to maize fertility. While the other points are opened to add the recorded amounts in Table (1).

The estimated coefficient of variance were 2.67, 2.81, 2.86 and 2.67% respectively at the forward speeds of 3.38, 4.38, 4.79 and 6.70 km/h. These results in agreement with the founding of (**Fulton et al., 2001**).

3- Effect of forward speed on fuel consumption

The relationship between fuel consumption (LE/Fed) and forward speeds of the prototype has an inversely proportional as shown in Fig. (8). The previous figure gives the value of fuel consumption 30.30, 18.63, 15.71 and 10.07 L/fed at the corresponding values of speeds of 3.38, 4.38, 4.79 and 6.70 km/h respectively.

From fig (7a), the amount of fertilizers saved as a result of using the developed matching approach were12.811, 12.644 and 12.166 kg and respectively, compared with the traditional or un calibrated method at a speed of 3.38km/h for the prototype. If the saving for one feddan is calculated one can conclude that the saved amount of fertilizer would be 56.8 kg/feddan.

4-Effect of forward speed on field efficiency

Fig. (8) shows the effect of forward speed on the field efficiency. As shown in figure, the field efficiency has an inversely proportional to the forward speeds for both types of fertilizer units. It is clear that using the traditional fertilizer unit at forward speeds of 3.38, 4.38, 4.79 and 6.70 km/h. At the same forward speed, the corresponding values for the developed fertilizer unit were 96.00, 94.72, 94.41 and 92.58 respectively.

The linear fit curve is the best to describe the relationship between field efficiency (ηf) and the forward speeds (S) for the traditional and developed unit. The linear equation can show as follow:

$$\eta ft = -1.2092\ S + 98.718 \qquad R^2 = 0.9889$$

$$\eta fd = -1.0114\ S + 0.9913 \qquad R^2 = 0.9913$$

Where: ηft = Field efficiency using traditional unit

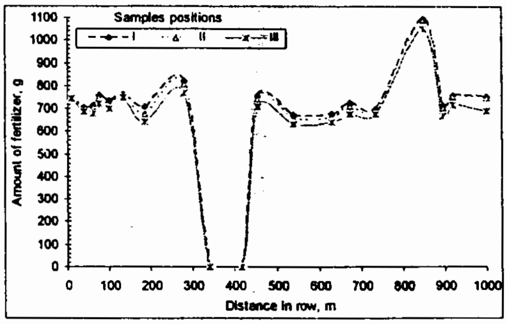
ηfd = Field efficiency using developed unit

S = Forward speed, km/h

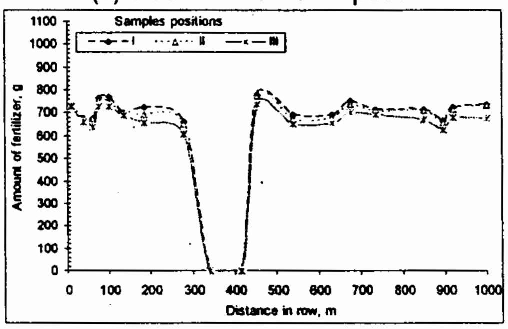
The reason for the high efficiency values of developed unit, is owing to the extra working time consumed in choosing the button corresponding to the appropriate opening of the on/off fertilizers gate.

5- Effect of forward speed on specific energy

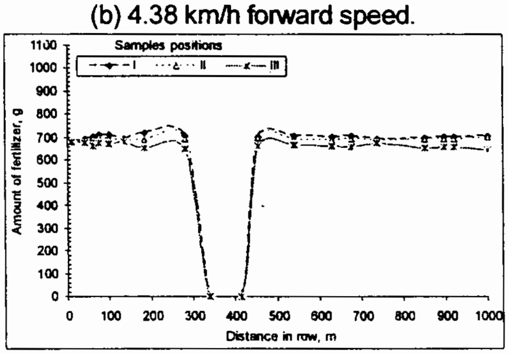
The relationship between specific energy and forward speeds of the prototype has an inversely proportional as shown in Fig. (9). From the figure it noted that at forward speeds increased of 3.38, 4.38, 4.79 and 6.70 km/h the s decrease of 0.165, 0.098, 0.084 and 0.046 kW.h/fed respectively for the fertilizer prototype.



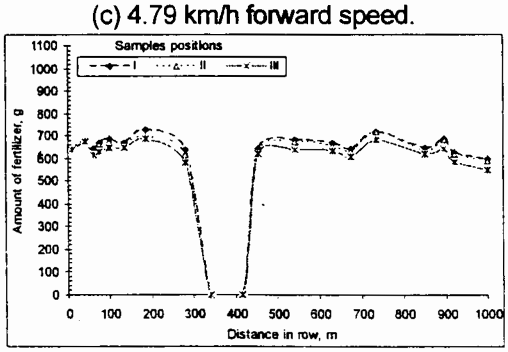
(a) 3.38 km/h forward speed.



(b) 4.38 km/h forward speed.



(c) 4.79 km/h forward speed.



(d) 6.70 km/h forward speed.

Fig. (7) Effect of forward speeds on adjusted amounts of fertilizers.

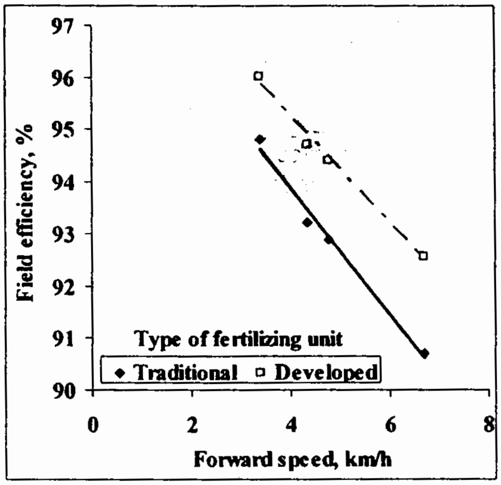


Fig. (8) Effect of forward speeds on field efficiency using fertilizing units.

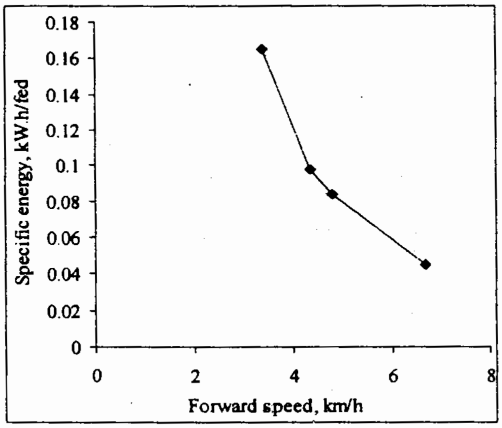


Fig. (9) Effect of forward speeds on field efficiency using fertilizing units.

6- Cost estimation

An economic comparison carried out between the traditional fertilizer unit and the developed fertilizer units. The capital cost of the developed unit is slightly higher than the undeveloped 149.22 LE/h and 209.36 LE/fed respectively, because the extra electronic and electric components responsible for opining and closing the fertilizers gate for the developed unit.

This increased the fixed cost of the developed unit by 71.18% over the undeveloped oné. The variable costs are about the same although it was noticed a significant save in the cost of developed unit owing to the less amount of fertilizers used for the same area. Matching and adding the precise dose of fertilizers lead to a decrement in the amount of fertilizers of about 56.8 kg /feddan. Fig. (10) shows that the brings about a change in the total cost from 149.22 LE/h to 209.36 LE/fed for developed and un developed units, respectively. The percentage of saving occurred is about 28.82 % in favor of the developed unit.

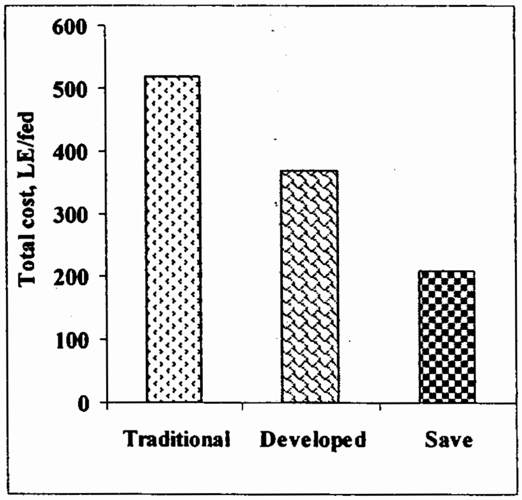


Fig. (10): The relationship between fertilizer prototype total cost via the traditional, developed unit and save cost.

CONCLUSIONS

The tool proved to be effective for calculating an accurate representation of field application variation and should have many uses in fertilizer application.

From the above results it can be concluded that using the developed fertilizer unit; which controlled the on/off gate by an electronic system as a variable rate technique; saved an amount of fertilizer of about 56.8 kg/fed and total costs about 209.36 LE/fed at forward speed of 4.79 km/h.

For future work on this point, the author suggest more modifications on the developed system to be used on a large scale.

These modifications are concerned with the introduction of GIS technique to be linked to the electronic system of the on/off gate which has seemed to be successful in this work.

REFERENCES

Cointault, F.; P. Sarrazin; and M. Paiindavoine (2000). Modulation of the centrifugal spreading of the granules fertilizers: Flow measure and determination of the particles trajectories by imagery. In: colloque AP2000 : Actes Du colloque Agriculture de Precision, edited by Educagri editions (Dijon France) , pp. 321 – 335.

Fulton, J. P.; S. A. Shearer; G. Chabra and S. F. Higgins (2001). Performance assessment and model development of a variable–rate, spinner–disc fertilizer applicator. Transactions of the ASAE, 44(5), 1071–1081.

Grift, T. E. and J. W. Hofstee (2002). Testing an online spread pattern determination sensor on a broadcast fertilizer spreader. Transactions of the ASABE. 45 (3): 561-567.

Kepner, R. A.; R. Bainer and E. L. Barger (1972). Principles of Farm Machinery. 2nd Edn., Westport, Connecticut, pp: 248-268.

Lawrence, H. G. and I. J. Yule (2007). Development of an image processing method to assess spreader performance. Transactions of the ASABE. 50 (2): 397 – 407.

Marey, S. A. E. (2004). Developing a Mechanism for Fertilizers Distribution in Small Holdings. Phd. thesis Agric., Eng., Dep., Mansoura Univ.

Metwali, M. A. A. (1995). Comparative study on crop fertilizing machines. M. Sc. Thesis, Kafer El-Sheikh, Tanta Univ., Egypt.

Morgan, M. and D. Ess (2003). The Precision-Farming Guide for Agriculturists. Deere & Company, Moline, Ill 61265. Paz, J. O., W. D. Batchelor, T. S. Colvin, S. D. Logsdon, T. C.

Novak, M. and R. G. Ljubljana (1990). 21. Mrhar M. Kmetijski stroji in naprave. CZD Kmecki glas (1997); 94. Brcic J. Mehanizacija u biljnoj proizvodnji. Zagreb (1981); 75-85.

Srivastava, A. K.; C. E. Goering and R. P. Rohrbach (1993). Engineering Principles of Agricultural Machines. 2950 Niles Road, St. Joseph, Michigan (ASAE), USA.

Tola, E.; T. Kataoka; M. Burce; H. Okamoto and S. Hata (2008). Granular fertilizer application rate control system with integrated output volume measurement. Biosystems Engineering 101 (4): 411-416.

Van Liedekerke, P.; J. De Baerdemaeker and H. Ramon. (2006). Fertilizer Application Control. American Society of Agricultural Section 5.5 Fertilizer Application Control, pp. 273-278 of Chapter 5 Precision Agriculture, in CIGR Handbook of Agricultural Engineering Volume VI Information Technology. Edited by CIGR--The International Commission of Agricultural Engineering; Volume Editor, Axel Munack. St. Joseph, Michigan, USA: ASABE.

Virin, T.; J. Koko; E. Piron; P. Martinet and Michel Berducat (2006). Application of optimization techniques for an optimal fertilization by centrifugal spreading. International Conference on Intelligent RObots and Systems - IROS - IROS , pp. 4399-4404.

Yang, C.; J. H. Everitt and J. M. Bradford (2001). Comparisons of uniform and variable rate nitrogen and phosphorus fertilizer applications for grain sorghum. Transactions of the ASAE. Vol. 44(2): 201–209.

تعديل كمية الاسمده باستخدام تقنية معدل الإضافة المتغير

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تعد عملية التسميد من أهم العمليات الزراعية والحيوية لنمو النباتات لذا يجب الاهتمام والعناية بالتسميد وإدخال أحدث التقنيات الحديثة لبرامج التسميد ومن أهم هذه التقنيات استخدام نظام التسميد الدقيق والذي يعتمد بدرجة أساسية على الاحتياجات التسميدية للنبات دون زيادة أو نقصان بهدف الحصول على أعلى إنتاجية للمحصول المنزرع. لذا يهدف هذا البحث إلى تحديد العوامل المثلى للتحكم والحصول على تقنية معدل إضافة متغير للسماد. وللوصول إلى هدف البحث تم استخدام وحدة تسميد على خطوط تتكون من وحدتين. حيث تم تطوير فتحة نزول السماد في إحدى الوحدات ليتم التحكم في فتحها وغلقها يدوياً والوحدة الأخرى يتم التحكم في فتح وغلق فتحة نزول السماد بها إليكترونياً. وقد تم تشغيل الآلة عند أربع سرعات تقدم للجرار ٣,٣٨، ٤,٣٧، ٤,٧٩، ٦,٧٠ كم/ساعة ومعدل تسميد يناسب محصول الذرة (١٥٠ كجم/فدان) للوحدة التقليدية ومعدل تسميد متغير حسب محتوى التربة من السماد للوحدة المطورة. ولتقييم أداء آلة التسميد تم تحديد كمية النيتروجين في التربة، الوقود المستهلك، السعة الحقلية، الكفاءة الحقلية، التكاليف. وقد نتج من التجارب أنه باستخدام الوحدة المطورة أمكن توفير حوالي ٥٦,٨ كجم/فدان وتكاليف كلية حوالي ٢٠٩,٣٦ جنيه/فدان عند سرعة تقدم ٤,٧٩ كم/ساعة. وعلى ذلك يمكن التوصية بإمكانية تطبيق النظام المطور على نطاق واسع واختباره مع إجراء عملية الزراعة لتقييم وضبط الكميات المناسبة التي يجب إضافتها من الأسمدة المختلفة.