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A STUDY ON DEVELOPMENT OF TRANSPLANTER FOR TRANSPLANTING AND FERTILIZING OF SWEET POTATOES

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ABSTRACT

The main objective of the present study was to modify the vegetable transplanter to become suitable for transplanting and fertilizing sweet potatoes under Egyptian conditions. The performances of transplanting and fertilizing units were evaluated during transplanting operation of sweet potatoes. The performance of fertilizing units was evaluated and tested using four angle of metering device position of 0º, 15º, 30º and 45º (0, 0.262, 0.523 and 0.785 rad.) at four values of speed ratio (R) of fertilizing unit (0.92, 1.25, 1.57 and 2.14). On the other hand the performance of modified transplanter was also evaluated using four different values of transplanter speed ratio (λ) of 0.73, 1.0, 1.25 and 1.52.

Results indicated that the speed ratio range of fertilizing unit (R) from o.92 to 1.25 and position angle of metering device of 30º (0.523 rad.) below the horizontal position gave the best results of standard deviation, coefficient of variation and coefficient of uniformity. The results also showed that the best values of crop yield, void hills, field efficiency, fuel consumption and power requirements were 10.8 Mg/Fed., 3.5 %, 82.9 %, 3.93 l/h and 16.99 kW ,respectively, at the optimum transplanter speed ratio of 1.0.

The increase of modified transplanter speed ratio from 0.73 to 1.52 tends to increase the longitudinal and transverse scattering from 2.02 to 6.19 cm and from 0.98 to 2.95 cm, respectively. Also, the results revealed that the mechanical transplanting and fertilizing operation of sweet potatoes by using modified transplanter recorded the minimum value of cost (32.96 LE/fed.), compared with manual transplanting and fertilizing operation (140 LE/Fed.)

INTRODUCTION

Sweet potato is one of the most important vegetable crops in Egypt. The production of sweet potatoes roots in Egypt reaches up to 44.182Gg taken from 43965 feddans with an average yield of 10.05 Mg/Fed. (*Anon,* 2000).

Commercial product as the main factors in profitable production. Size, shape, smoothness, color and number of storage roots per plant are involved in the production of quality and quantity. Therefore, the efforts are focused on increasing productivity of sweet potato by growing high cultivars under the most favorable cultural treatments such as transplanting and fertilizing system.

Fertilizers are applied to the soil in order to increase the available supply of plant nutrients and thus promote greater yield or better crop quality. In Egypt, fertilizers are applied to the sweet potatoes crop manually by putting a hand of fertilizers beside every plant. The problem in transplanting and fertilizer application is to devise suitable methods that would reduce labor costs further, increase fertilizer use efficiency and minimize rate.

Pitt *et al.* (1982) mentioned that uniformity in the field application of fertilizer is an important factor in the efficiency of fertilizer up take. Also, they added that the important factors that determine uniformity are the design of the fertilizer application equipment, field and the environmental conditions at or near the time of application. Kepener *et al.* (1982) mentioned that the fertilizers applied as row- crop side dressing are the most immediate benefit when placed in moist soil within the root zone, but excessive mechanical destruction of the root system must be avoided. Side dressing is usually dropped in furrows opened by regular cultivator shovels but it can be placed at other locations or depth with separate narrow- shovel openers or chisels. Uniform distribution and proper placement in the soil have become increasingly important as factors in producing maximum crop response at minimum cost, carried out a study on manufacturing a combined machine for cultivating, fertilizing and spraying field crops. The results indicated that the metering device radial- feed wheel and the metering device placed 45^o (0.785 rad.) below horizontal gave the best distribution pattern of fertilizer with the speed ratio of 1.13. Klenin *et al.* (1985) explained that the principal methods for applying fertilizer over a field are: uniform application in row application and hill drop application. For most crops, the best results are obtained with row application of fertilizer, which is later worked in-to, the soil to a depth of 2 cm below the level of the seeds. The fertilizer is placed along side the seeds or seedlings the soil simultaneously.

El-Attar (1999) said that the increase of planting vegetable crops benefit depend on mechanical transplanting to transplant the seedlings quickly and efficiently with minimum labor requirements. The shortage of hand labors in Egyptian farms has become problem in the recent decade. ASAE (1989), Mansour (1997) and Hegazy *et al.* (2003) found that the field efficiency, plant density and total yield decreased by increasing the transplanter forward speed. Metwalli *et al.* (1998) and Helmy *et al.* (2003) revealed that increasing forward speed lead to increase the longitudinal, transverse scattering, missed seedlings and effective field capacity. Kasem (1999) modified a vegetable transplanting machine to transplant seedlings and build ridges or furrow in one operation. The results showed that both of longitudinal and transverse scattering values were highly affected by transplanting forward speed. The modified transplanter gave the best results of number of plants/m2, seedling depth, lowest values of void hills and highest crop yield. El-Khtib (1998) developed a manual feed transplanter Holland machine and Lannen machine types to be suitable for cotton transplanting under Egyptian conditions. He found that increasing forward speed from 0.75 to 1.50 km/h, cause a corresponding increase in the fuel consumption from 3.1 to 3.5 *l*/h, and from 3.5 to 3.9 *l*/h, and the drawbar power increased from 2.48 to 4.97 kW and from 3.01 to 6.01kW, respectively for previous modified transplanters. Amin *et al.* (1999) studied the kinematics index of hand feed transplanter and its effect on the machine performance. They concluded that transplanting with forward speed of 1.0 km/h reduced

the human (planting) error (4.7 %), damaged hills (0.4 %) and product a proper transplanting efficiency which was 91.9 %. Planting
costs reach to 88.82 LE/fed, comparing with 210 LE/fed. in tomato transplanting manually. **El-Sahrigi *et al.* (1991)** indicated that mechanical sowing and transplanting have lower cost than hand sowing or transplanting. The cost of manual transplanting of onion seedlings is 1.52 times higher than that when using 2-row transplanting machine. They concluded that using mechanical sowing or transplanting methods is recommended for obtain high yield and minimizing cost.

The aims of the present may be summarized as follows,

a- Modification the vegetable transplanter to be suitable for transplanting and fertilizing some vegetable crops under Egyptian conditions.
b- Evaluation and select the proper performance of fertilizing units under local conditions.
c- Evaluation the performance of modified transplanter during sweet potato transplanting and fertilizing and its effect on the field capacity and efficiency, void hills, deviation on row %, fuel consumption, total power requirements and the total costs.

MATERIALS AND METHODS

The experiments were carried out at the Agric. Res. Station at Sakha, Kafr El-Shiekh Governorate during the summer season of 2002/2003 in order to test and evaluate the performance of modified transplanter during sweet potato transplanting and fertilizing operation. For the duration of these experiments, the *Abes* variety of sweet potato and Urea 46 % fertilizer were used. The seedlings of sweet potato which used had some qualifications as shown in Table 1.

Table 1: Some qualifications of sweet potato seedlings:

Variety	Qualifications of sweet potato seedlings	
	average height, cm	average thickness, mm
Abes	22	5

The modified transplanter is an American made transplanter (Holland-1600) that designed to set the seedlings vertically mainly consists of two units of transplanting and fertilizing units and other secondary parts as shown in Fig. 1 and the specifications of each transplanting unit are illustrated inTable 2.

The seedlings are placed manually into the transplanting pockets consists of two rubber plates to hold the seedlings. The rubber plates are opened and closed with special spring mechanism.

Table 2: Some specifications of transplanting unit.

Specifications	Transplanting unit
wheel rim diameter, cm	60
radius of pocket arm, cm	32
gear ratio of pocket disc	11/8
number of pockets on disc	6

When the pockets pass from the guide plates, the spring pressure is released, loosing the rubber plates and releasing the seedling to slip from the pocket and remain it in the soil. The transplanter was mounted on the rear of Fiat 55-66 DT tractor (45 kW).

Two fertilization units were manufactured and fixed on the rear of the transplanting frame. Each fertilizing unit consists of hopper, metering devices, drive mechanisms and other secondary parts. The metering devices were placed in the bottom of fertilizer hoppers and took its motion from ground wheel by a group of wheels and chains transmission as shown in Fig. 1. The metering device radial – feed wheel for 14 fluted for dry fertilizer was used to obtain a constant and uniform metering action.

The metering devices of fertilization were applied as row-sweet potato seedling side dressing during transplanting operation. The first step of this study was to evaluate the performances of fertilizing unit were evaluated at four position angles of metering devices [horizontal(0^o), 15^o, 30^o, and 45^o] below horizontal and four values of speed ratio (0.92, 1.25, 1.57 and 2.14). The speed ratio (R) was adjusted by using the wheel shaft gear teeth of (11 and 15) and metering shaft gear teeth (7 and 12).

The following factors were determined to evaluate the distribution of the fertilizing unit: -

Standard deviation (S_d) = $\sqrt{\frac{\sum\left(X_i + X^-\right)^2}{n-1}}$ ……………………… **1**

where

X_i = the individual reading, g. and

X^-=mean reading = $\frac{\sum X_i}{n}$ ……………………………………… **2**

Coefficient of variation (C.V) = $\frac{S_d}{X^-}$ …**...** ………………………**3**

The coefficient of variation (C.V.) must to be in range of 10 – 15 % or less to produce a satisfactory uniformity (Walf and Smith, 1979)

The second step was carried out to evaluate the performance of modified transplanter during transplanting and fertilizing sweet potato at four different values of speed ratio (ë) of 0.73, 1.0, 1.25 and 1.52 which get out under peripheral speed of feeding mechanism (ù) and traveling speed of machine (V) whereas:-

ë=ù/V. ………………………………………**.4**

If the distance between seedlings in the row (S) measured, then the speed ratio (ë) will be determined according to **Klenin *et al.* (1985) and Bosoi *et al.* (1987)** as follow: -

ë = 2ὸr/ ZS ……………………………… …**.5**

where**:**

λ =the planter ratio;

r =the radius of the pocket arm measured up to end;

Z=number of the pockets and

S=the distance between plants in the row, (agronomic requirement).

The effective field capacity and efficiency were determined according to (ASAE, 1989).

The percentage of missing hills was calculating according to Hossary *et al.* (1980) by using the following formula;

$$\text{Missing hills} = \frac{\text{No. of missing hills}}{\text{No. of theortical hills}} \times 100,\ \% \quad ……………\mathbf{6}$$

Deflection on row (seedlings scattering) was measured in order to determine the distribution of seedlings. The deviation on row from average distance (%) was estimated according to (ASAE, 1992). The total crop yield was picked up along the harvesting period. The root was estimated in kg/m^2 and then calculated as Mg/fed.

Fuel consumption was determined during sweet potato transplanting and fertilizing treatments by using a graduate glass cylinder. Power consumption was calculated by measuring fuel consumption for each treatment using the following formula;

$$\text{Power} = \frac{F.C.}{60 \times 60} \times \rho_f \times L.C.V. \times 427 \times \eta_{th} \times \eta_m \times \frac{1}{75} \times \frac{1}{1.36}, \quad \text{kW} .... \mathbf{7}$$

where:

$F.C.$ = fuel consumption, lit. /h;

ρ_f = density of the fuel (0.85 kg/l for diesel fuel);

$L.C.V$ = lower calorific value of fuel, (10^4 Kcal/kg);

427 = thermo-mechanical equivalent, kg. m/Kcal.;

η_{th} = thermo efficiency of engine (40% for diesel engine) and

η_m = mechanical efficiency of engine (80% for diesel engine).

The cost analysis performed as fixed and variable costs according to Hunt (1983).

RESULTS AND DISCUSSION

Performance parameters by using fertilizing unit: -

The performance of fertilizer unit was evaluated by studying the effect of position angles of metering devices of horizontal (0^o), 15^o, 30^o and 45^o below horizontal and speed ratios (R) of 0.92, 1.25, 1.57 and 2.14 on the standard deviation, coefficient of variation and coefficient of uniformity of distribution pattern are shown in Figs. 2, 3 and 4.

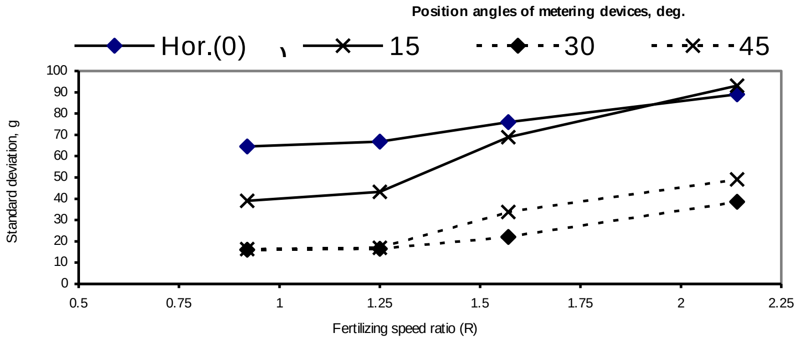

Fig. 2: Effect of position angles of metering devices and fertilizing speed ratios on the standard deviation of distribution pattern.

The results indicated that increasing fertilizing speed ratio tends to increase the standard deviation and coefficient of variation, whilst decrease the coefficient of uniformity of distribution pattern with all position angles of metering devices. On the other hand, the fertilizing speed ratio range from 0.92 to 1.52 gave the lowest value of standard deviation and coefficient of variation, while gave the highest value of percentage of coefficient of uniformity compared with fertilizing speed ratios 1.57 and 2.14 with all position angle values of metering device.

At the same time, the best performance was given at position angle of metering device thirty deg. below horizontal by using granular fertilizer comparing with the position angles of metering device horizontal (0^o), 15^o and 45^o below horizontal with all speed ratios.

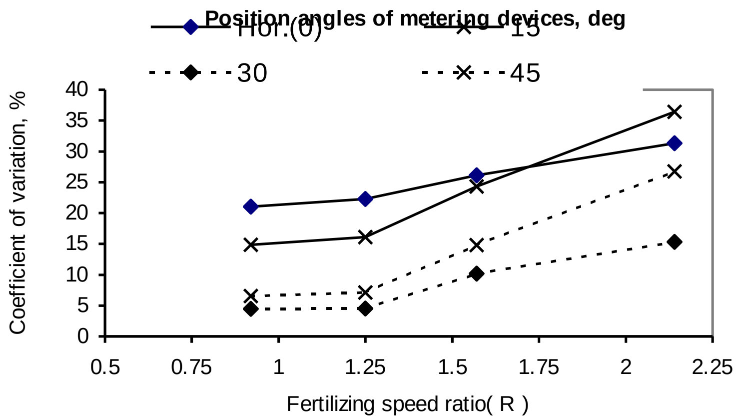

Fig. 3: Effect of position angles of metering devices and fertilizing speed ratios on the coefficient of variation of distribution pattern.

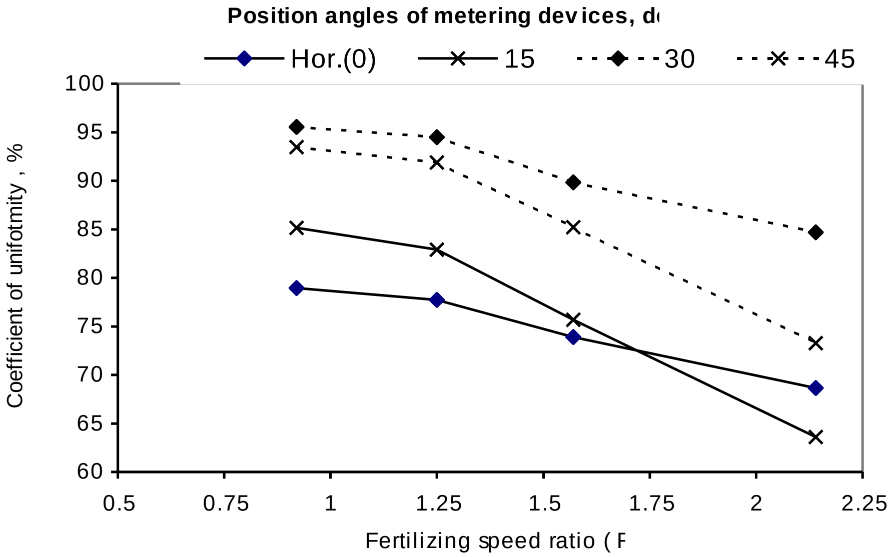

Fig. 4: Effect of position angles of metering devices and fertilizing speed ratios on the coefficient of uniformity of distribution pattern.

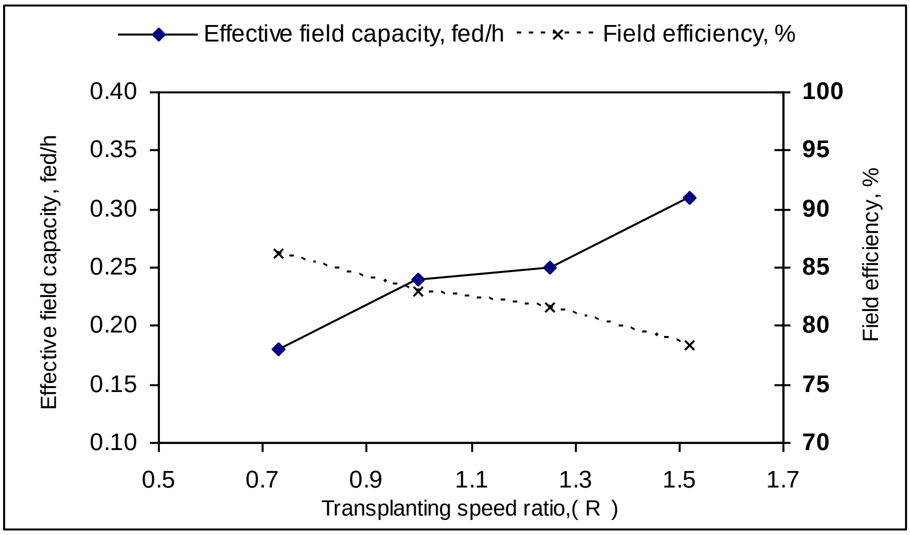

Fig. 5: Effect of transplanting speed ratio (ë) on the field capacity and efficiency.

Fig. 5 shows the effect of transplanting speed ratio on the transplanter field capacity and efficiency. The results indicated that increasing speed ratio from 0.73 to 1.52 lead to increase the effective field capacity from

0.18 to 0.31 fed. /h and decrease the transplanter efficiency from 86.2 to 78.0 %. At the same time, the increase of transplanter speed ratio from 0.73 to 1.52 was followed with an increase about 41.94 % in the field capacity.

Fig. 6 shows the effect of transplanting speed ratio on the missing hills percentage and total crop yield. It is clear that by increasing transplanting speed ratio, missing hill percentage increased and the total crop yield decreased. The results indicated that increasing speed ratio from 0.73 to 1.0 lead to decrease the total crop yield from 11.09 to 10.80 Mg/Fed and the missing hill percentage remained constant at 3.5 %. On the other hand, by increasing transplanting speed ratio from 1.0 to 1.52 the total crop yield decreased from 10.80 to 7.55 Mg/Fed and, the missing percentage increased from 3.5 to 6.29 %. This is due to the increase of transplanting speed ratio.

Fig. 7 shows the effect of transplanting speed ratios on the longitudinal and transverse scattering values.

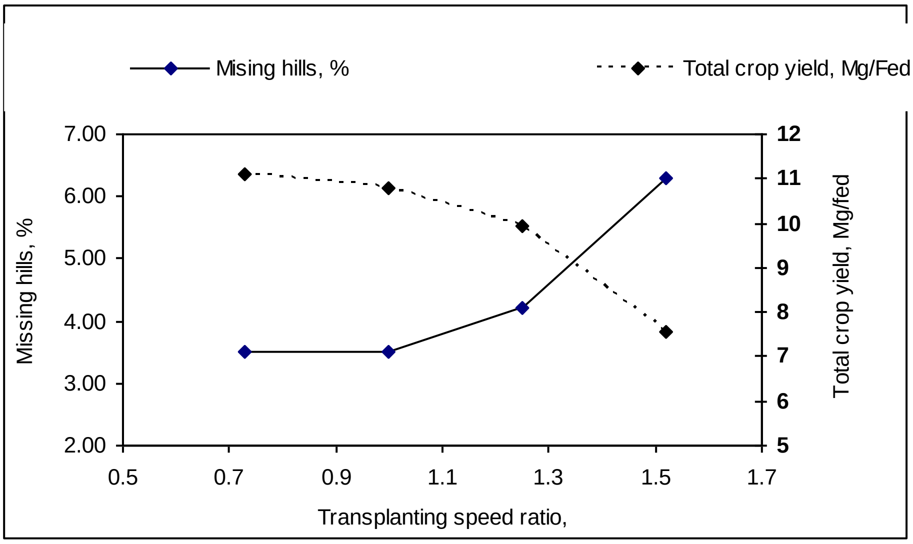

Fig. 6: Effect of transplanting speed ratio (ë) on the missing hills percentage and total crop yield Mg/Fed.

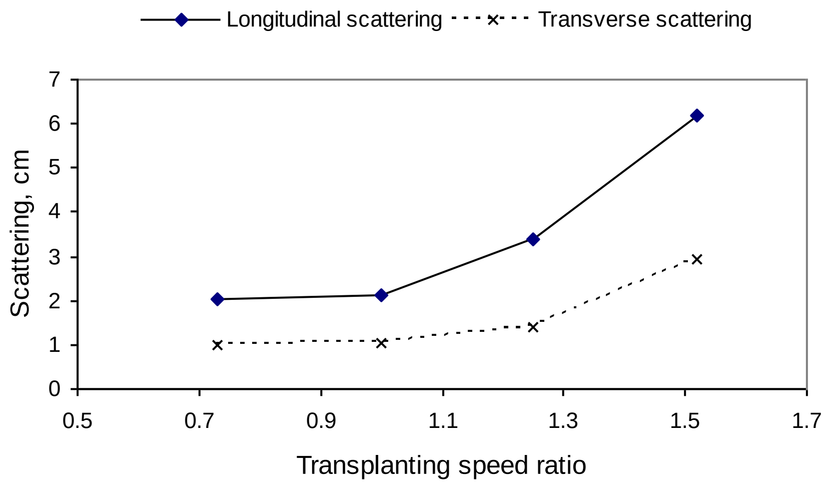

Fig. 7: Effect of transplanting speed ratio on the longitudinal and transverse scattering of sweet potato plants.

It is illustrated that increasing transplanting speed ratio from 0.73 to 1.0 tended to increase both longitudinal scattering values from 2.02 to 2.13 cm and transverse scattering values from 0.98 to 1.03 cm. Also, increasing transplanting speed ratio to 1.52 leaded to increase longitudinal scattering value to 6.19 cm and transverse scattering value to 2.95 cm. In general, the distribution uniformity of sweet potato seedlings in the unit area decreased by increasing both of the longitudinal and transverse scattering values. This is due to the increase of transplanting speed ratio.The results illustrated in Table 3 revealed that, the fuel consumption and power requirements increased with the increasing of transplanting speed ratio.

Table 3: Effect of transplanting speed ratio on fuel consumption and power requirements during sweet potato transplanting operation.

Transplanting speed ratio (ë)	Fuel consumption, l/h	Power requirement, kW
0.73	3.07	13.2
1.0	3.93	16.99
1.25	4.25	18.28
1.52	5.33	22.92

By increasing transplanting speed ratio from 0.73 to 1.52 fuel consumption and power requirements were increased from 3.07 to 5.33 l/h and from 13.2 to 22.92 kW, respectively.

On the other hand, the results indicated that using the modified transplanter decreased the operational costs of transplanting and fertilizing in comparison with manual methods. The operational cost decreased from 140 LE/fed under manual transplanting and fertilizing of sweet potato to 32.96 LE/fed by using the modified transplanter

CONCLUSION

Data obtained from field experiments under the conditions in the present study support the following conclusion: -

1-The speed ratio of fertilizer unit range of 0.92 to 1.25 gave the lowest value of standard deviation and coefficient of variation. However, it gave the lowest value of coefficient of uniformity.

2-Horizontal position gave the best results of standard deviation, coefficient of variation and coefficient of uniformity comparing with the other position angles of metering devices.

3-The modified transplanting speed ratio range of 0.73 to 1.0 gave the best results of crop yield, missing hills, field efficiency, and fuel consumption and power requirements.

4- Mechanical transplanting and fertilizing of sweet potato by using the modified transplanting recorded the minimum values of transplanting and fertilizing costs compared with manual transplanting and fertilizing operation.

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دراسة علي تطوير آلة لشتل وتسميد محصول البطاطا

إبراهيم صلاح الدين محمد يوسف
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يعتبر محصول البطاطا من محاصيل الخضر الهامة في مصر حيث يحتل المرتبة الثانية بعد البطاطس ورغم أهمية محاصيل الخضر في مصر الا أنها مازالت حتى الآن تشتل وتسمد يدويا وهذا يتطلب عمالة كثيرة وتكاليف عالية وتحتاج لوقت طويل مما يترتب عليه عدم انتظام لمسافات الزراعة وعمق الشتلات وكذالك توزيع السماد والتي تعتبر من أهم العوامل المؤثرة علي نمو وإنتاجية المحصول.

يهدف هذا البحث إلى تطوير شتالة الخضر(موديل هولاند - ١٦٠٠) وذلك بإضافة وحدتين للتسميد الكيماوي تم تصنيعها محليا لتصبح آلة مجمعة لشتل وتسميد بعض محاصيل الخضر في وقت واحد. وقد تم تقييم وحدتي التسميد الكيماوي أولا للوصول لأفضل أداء لهما ثم استخدامها مع الشتالة في التقييم الحقلي كآلة مجمعة لشتل وتسميد محصول البطاطا تحت الظروف المحلية وقد أظهرت النتائج الأتي:-

١- اقل قيم للانحراف القياسي ومعامل الاختلاف واعلي قيم لانتظام توزيع السماد لوحظت عند نسبة سرعة لوحدة التسميد بين ٠,٩٢ إلي ١,٢٥ .

٢- زاوية وضع قرص توزيع السماد ٣٠° علي الأفقي أعطت أفضل النتائج بالنسبة لنسب انتظام توزيع السماد والانحراف القياسي ومعامل الاختلاف.

٣- كما بينت نتائج التجارب الحقلية أن أقل نسب للشتلات الغائبة٣,٥% وأعلي قيميتين للمحصول ١١,٠٩، ١٠,٨ ميجا جرام/فدان واعلي نسبتين للكفاءة الحقلية ٨٦,٢، ٨٢,٩ % وذلك لنسبتي سرعة الشتالة المعدلة ٠,٧٣ ، ١,٠علي التوالي.

٤- بزيادة نسبة السرعة للشتالة المعدلة يزداد كلا من التشتتين الطولي والعرضي للنباتات وكذلك استهلاك الوقود والقدرة المستهلكة.

٥- كما أظهرت النتائج أن الشتل والتسميد الآلي بالشتالة المعدلة لمحصول البطاطا سجل أقل تكلفة ممكنة ٣٢,٩٦جنية/فدان بينما سجل الشتل والتسميد اليدويين اعلي تكلفة ١٤٠جنية/فدان.