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MAXIMIZING POTATO CROP YIELD USING A MODIFIED PLANTER-RIDGER

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ABSTRACT

This study was carried out at El-Gemmeiza Ag. Res. Station, El-Gharbia Governorate, during 2006 summer season. Potato seed tubers Sponta variety were planted using a modified potato planter-ridger at row spacing of 0.75 m, one tuber/0.25 m within row and 0.10 m planting depth. The modified machine was tested at forward speed levels of 3.35, 3.95, 4.55 and 5.15 km/h under ridge deformation depth levels of 0.10, 0.12 and 0.14 m. The higher potato crop yield of 12.15 ton/fed was achieved at 3.35 km/h forward speed and 0.10 m deformation depth. Moreover, the machine achieved an acceptable performance (0.89 fed/h field capacity and 135.55 MJ/fed specific energy requirements).

INTRODUCTION

Potato is considered as an one of the most important vegetable that may participate in solving the problems of food shortage. Also, it is widely used for industrial purposes.

Potato is a temperate or cool season crop which needs a low temperature, lower humidity, less windy and bright sunny days. The climatic conditions affect to great extent the soil temperature, which is very crucial for determining the potato yield. The optimum soil temperature for the normal potato seed tubers growth is 15-18 °C. When the potato seed tubers are planted at a higher soil temperature, the tubers formation is stopped completely, then, they are damaged. This is due to the increased rate of respiration which consumes the formed carbohydrate by the photosynthesis process rather than that stored in the tubers (Thompson and Kelly, 1957; Ware and McCollum, 1980 and Yamaguchi, 1983).

In Egypt, the total potato cultivated area is about 191,289 Fed. of 10.02 tons/Fed. mean productivity (Ministry of Agriculture and Land Reclamation, 2005). The manual planting method is still practiced in more than 85% of the potato cultivated area (Ismail, 1992). It is approved by the potato growers that the manual planting could be accomplished using a tractor ridge share to deform two ridges at lateral spacing of 0.70 m approximately. About 10 laborers.day/fed have to dig the deformed ridges and put the seed tubers at sequence longitudinal distances of about 0.20-0.25 m. At the next day, about 8 laborers.day/fed have to restore the deformation of the ridge sides. This acquisition is insufficient to maintain the soil from the erosion. Then, the tubers are exposed to the high temperature, the insect damage and the direct light; which causes tuber greening, resulting in dropping in potato yield.

It was reported by many researchers such as Ismail (1989), Ismail and Abou-Elmagd (1994), Abdou (1995), Abdou (1996), Khairy (1997), Moussa *et al.* (1998) and Ghonimy and Rostom (2005) that the potato mechanical

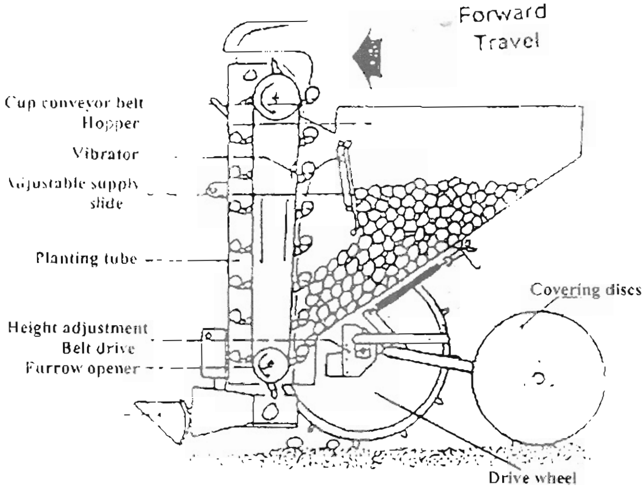

Fig. (1): Marathon (F) conventional potato planter.

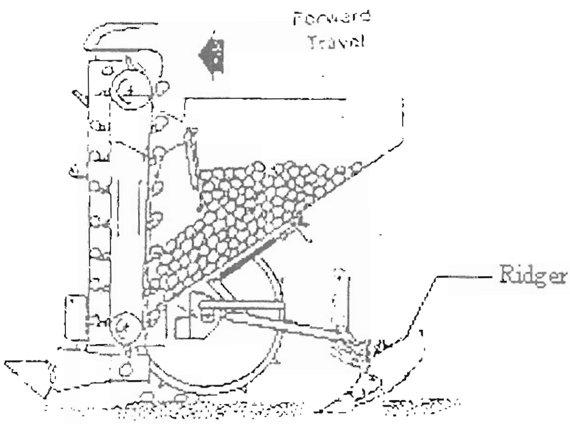

Fig. (2): S N-4 B modified potato planter ridger.

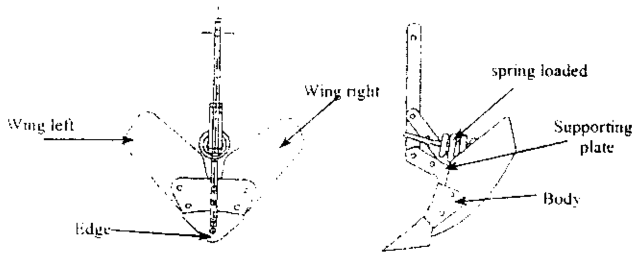

Fig. (3): Ridger components.

Seed bed preparation instructions

The seed bed was prepared using the chisel plough in two perpendicular directions at 0.20 m depth, followed by rotary plough. Then, the soil was leveled using a hydraulic land leveler.

Potato planting and ridging instructions

Potato developing and training Center (2001) recommended that the graded potato seed tubers Sponta variety of 50 mm in diameter are planted at 0.10 m planting depth, 0.75 m row spacing and 0.25 m hill spacing apart along the furrow. Both the conventional and the modifieu planters were adjusted and the feeding systems were calibrated to agree with these recommendations.

On the other hand, the lateral distance between the sequence ridgers is adjusted to be 0.75 m. The ridge profile may be altered by adjusting the wings of the ridger up and down according to the desired ridge height. As the planter is propelled, the tubers are buried in the furrow, then, the ridger covers the soil on the tuber in the row and constructs the ridge.

Treatments

At the duration of this study, the following treatments were tested:

a-Machine forward speed: the potato planter-ridger was operated and tested at forward speed levels of 3.35, 3.95, 4.55 and 5.15 km/h.

b-Ridge deformation depth: the potato planter-ridger was adjusted and tested at ridge deformation depth levels of 0.10, 0.12 and 0.14 m.

Experimental design

The experimental field was established as a split plots design in four replicates. The main plots involved the machine forward speed levels. While, the sub-plots involved the ridge deformation depth levels.

Measurements

The following parameters were measured to evaluate the modified potato planter-ridger, comparing with the conventional planter:

1- Potato planter-ridger performance

It was determined as cited by Kepner *et al.* (1982) as follows:

a- Actual field capacity (*AFC*)

$$AFC = \frac{1}{ATT} \quad \text{fed/h} \qquad (1)$$

Where:

ATT is the actual total time required per planting fed/h.

b- Planter field efficiency (ηf)

$$\eta f = \frac{AFC}{TFC} \times 100 \quad \% \qquad (2)$$

Where:

TFC is the theoretical field capacity, fed/h.

c- Tractor wheel slip (*S*)

$$S = \frac{v_1 - v_2}{v_1} \times 100 \quad \% \qquad (3)$$

Where:

v_1 is the machine forward speed without load, m/sec.

v_2 is the machine forward speed with load, m/sec.

d- Specific mechanical energy requirements (*SME*)

$$SME = \frac{11.41 \times FC}{AFC} \quad \text{MJ/fed} \qquad (4)$$

Where:

FC is the fuel consumption, Lit/h.

11.41 is the transformation coefficient from lit/h to MJ.

2- Potato planter-ridger accuracy

It was determined as cited by **Ismail (1992)** as follows:

a- Planter wheel skidding (*sk*)

$$sk = \frac{L - 3.14D}{L} \times 100 \quad \% \qquad (5)$$

where:

L is the actual distance per one planter's wheel revolution, m.

D is the diameter of the planter's wheel, m.

b- Feeding system efficiency (ηfs):

$$\eta fs = \frac{N1}{N2} \times 100 \quad \% \qquad (6)$$

Where:

N1 is the actual tuber number in **1 m** row length.

N2 is the theoretical tuber number in 1 m row length.

c- Seed tuber void percent (*TV%*):

$$TV = 1 - \eta fs \quad \% \qquad (7)$$

d- Coefficient of variation for seed tubers spacing (*cv%*):

$$cv = \frac{SD_s}{S_r} \times 100 \quad \% \qquad (8)$$

Where:

SD_s is standard deviation of tubers spacing, m.

S_r is recommended tuber spacing , m.

e- Seed tuber covering height

The seed tuber covering height was determined using a ruler to measure the depth from the top of the ridge to the seed tuber top in the hill.

3- Potato crop yield

For each treatment, an area of 1 m^2 was taken randomly to determine the potato tuber yield. This procedure was replicated three times, then, the mean value was recorded.

Statistical Analysis

1)**Standard deviation:** Data of the coefficient of variation for seed tubers spacing, the seed tuber void and the potato crop yield were analyzed statistically to determine the standard deviation.

2)**Analysis of variance:** Data of the potato crop yield were analyzed statistically as a split plots design in four replicates using Microsoft Office Excel 2007 computer program. The least significant difference test was carried out to compare the difference between the treatment means.

Regression and Correlation Analysis

Microsoft Graph 2007 computer program was used to carry out the simple regression and correlation analysis to represent the effect of the modified potato planter-ridger forward speed on potato crop yield under different ridge deformation depth levels.

RESULTS AND DISCUSSION

1- Potato Planter-Ridger Performance

a- Actual field capacity

Fig. (4) exhibits the positive relation between the machine forward speed and the field capacity. As the machine forward speed increased from 3.35 to 5.15 km/h, the potato planter-ridger field capacity increased by 40.44, 40.69 and 38.55% at ridge deformation depth levels of 0.10, 1.12 and 1.14 m, respectively. This trend could illustrate that the machine utilizes lower operating time per unit area with the increased forward speed. Whereas, the potato planter-ridger field capacity is inversely proportional with the ridge deformation depth. This might be due to the higher resistance of the deeper soil layer against the ridger, utilizing more time to accomplish the work. Meanwhile, the conventional planter achieved higher field capacity, than the planter-ridger at the previous range of the machine forward speed. This finding is due to the lower soil resistance against the covering discs, utilizing lower time to plant the unit area.

B- Field efficiency

As shown in Fig. (5), the machine field efficiency seemed to decrease slightly with the forward speed. As the potato planter-ridger forward speed increased from 3.35 to 5.15 km/h. the field efficiency decreased from 75, 73 and 71% to be 73, 71 and 69% at ridge deformation depth levels of 0.10, 0.12 and 0.14 m, respectively. While, the conventional planter field efficiency decreased from 76% to be 74% with the previous range of the machine forward speed. This trend is due to the positive relation between the machine forward speed and the lost time per unit area which is consumed for the frequency of refilling the planter hopper. On the other hand, the planter-ridger field efficiency tended to decrease with the ridge deformation depth. This tendency is attributed to the positive association between the ridging depth and the soil resistance against the ridger. So, the lost time per unit area increased with the ridging depth.

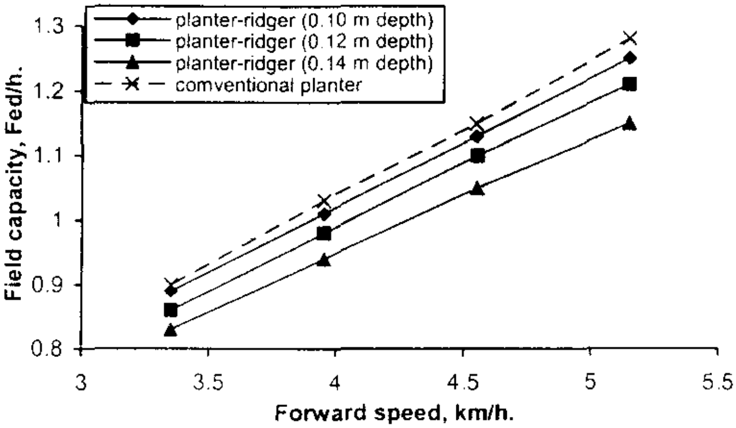

Fig.(4): Effect of potato planter-ridger forward speed on field capacity.

B- Field efficiency

As shown in Fig. (5), the machine field efficiency seemed to decrease slightly with the forward speed. As the potato planter-ridger forward speed increased from 3.35 to 5.15 km/h. the field efficiency decreased from 75, 73 and 71% to be 73, 71 and 69% at ridge deformation depth levels of 0.10, 0.12 and 0.14 m, respectively. While, the conventional planter field efficiency decreased from 76% to be 74% with the previous range of the machine forward speed. This trend is due to the positive relation between the machine forward speed and the lost time per unit area which is consumed for the frequency of refilling the planter hopper. On the other hand, the planter-ridger field efficiency tended to decrease with the ridge deformation depth. This tendency is attributed to the positive association between the ridging depth and the soil resistance against the ridger. So, the lost time per unit area increased with the ridging depth.

c- Tractor wheel slip:

Fig. (6) shows that the tractor wheel slip changed as a positive function with the machine forward speed. As the potato planter-ridger forward speed increased from 3.35 to 5.15 km/h, the tractor wheel slip increased from 9.00, 9.80 and 10.20% to be 17.00, 17.40 and 18.20% at ridge deformation depth levels of 0.10, 0.12 and 0.14 m, respectively. This trend is attributed to the insufficient traction power which makes the tractor wheels fail to overcome the tractive force at the higher forward speed, resulting in the increased wheel slip. Meanwhile, the increased ridge deformation depth caused higher impact action between the ridger and the soil, resulting in higher friction between the ridger and the soil that increased the wheel slip. Meanwhile as the conventional planter forward speed increased with the previous range, the tractor wheel slip increased from 7.80 to 16.00%. These lower wheel slip values are due to the lower friction force between covering discs and the soil which is accompanied with a sufficient traction power.

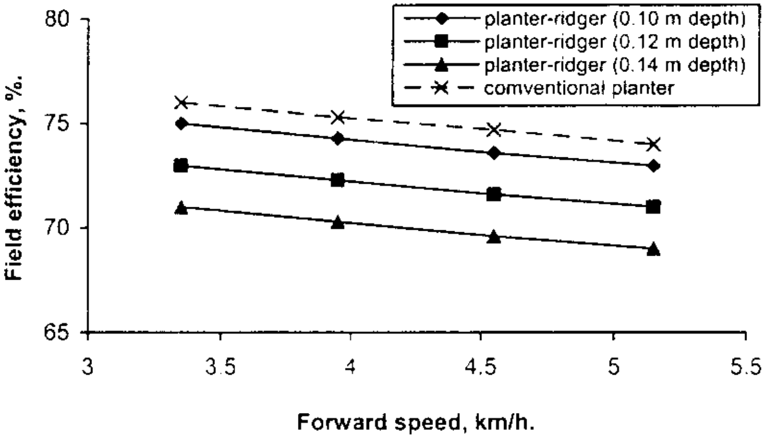

Fig. (5): Effect of potato planter-ridger forward speed on field efficiency.

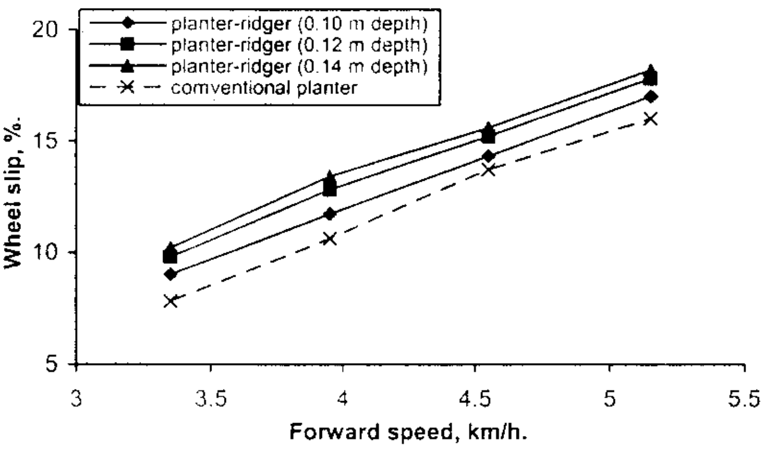

Fig. (6): Effect of potato planter-ridger forward speed on tractor wheel slip.

d- Specific mechanical energy

Fig. (7) reveals that there was a obvious drop in specific energy requirements with the machine forward speed. As the potato planter-ridger forward speed increased from 3.35 to 5.15 km/h, the specific energy requirements decreased from 135.55, 143.23 and 154.21 MJ/fed to be 118.81, 114.00 and 121.00 MJ/fed at ridge deformation depth levels of 0.10, 0.12 and 0.14 m, respectively. This trend is attributed to the reverse relation between the machine forward speed and the rolling resistance which is required to move the tractor and the machine. So, at the lower forward speed, there is an increase in the required force to deflect tractor wheels to push the disturbed soil and to overcome wheel and axle bearing friction, resulting in higher draft, consuming more fuel. Therefore, as the ridge deformation depth increased, the higher soil resistance magnified the draft, consequently, the draw-bar pull increased. Meanwhile, as the conventional planter forward speed increased with the previous range, the specific energy requirements decreased from 132.00 to 111.00 MJ/fed. The lower required energy of the conventional potato planter may illustrate that the covering discs requires lower draft, consuming lower fuel.

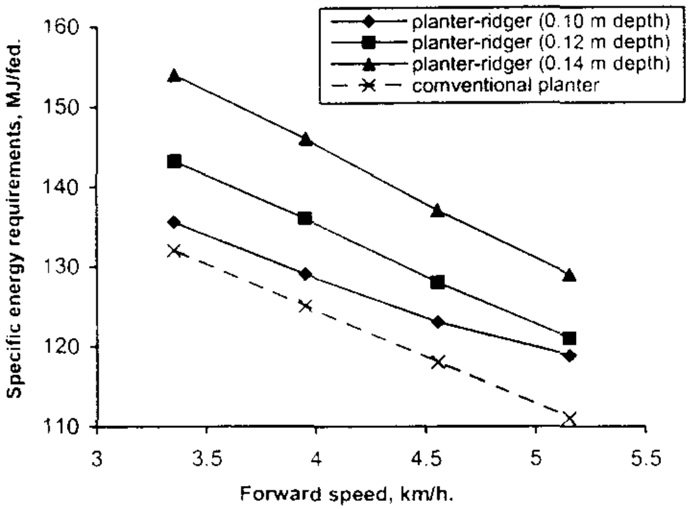

Fig. (7): Effect of potato planter-ridger forward speed on specific energy requirements.

2- Planter Accuracy

a- Planter wheel skidding

Fig. (8) demonstrates that the planter wheel skidding is directly proportional to the machine forward speed. As the potato planter-ridger forward speed increased from 3.35 to 5.15 km/h, the planter wheel skidding increased from 3.30, 3.90 and 4.60% to be 9.00, 10.10 and 11.25% at ridge deformation depth levels of 0.10, 0.12 and 0.14 m, respectively. Meanwhile, as the conventional planter forward speed increased with the previous range, the planter wheel skidding increased from 4.90 to 11.28%. The positive relation between the planter forward speed and the planter wheel skidding is attributed to the increased planter vibration at higher forward speed. Whilst, the planter wheel skidding is directly proportional to the ridge deformation depth. This trend is due to the loose structure of the deeper soil layer which increased the soil clods sweeping under the planter wheel, resulting in more rolling résistance, consequently, the planter wheel skidding increased. The lower values of the planter-ridger wheel skidding than that of the conventional planter illustrated that the planter-ridger is more stable during the ridger penetrates the soil, consequently the planter-ridger vibration decreased, resulting in increasing contact area between the planter wheel and the soil clods. Then, the lugged protrusions increased.

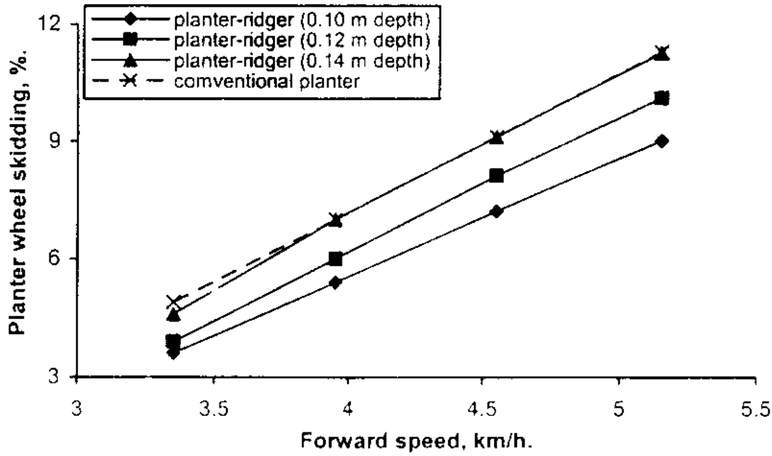

Fig. (8): Effect of potato planter-ridger forward speed on planter wheel skidding.

b- Feeding system efficiency

Fig. (9) showed that the maximum values of the feeding system efficiency of 100 and 96% were achieved at 3.35 km/h forward speed for the potato planter-ridger and the conventional planter, respectively. Meanwhile, the minimum feeding system efficiency of 87% was found at ridge deformation depth of 0.14 m. This means that the feeding system efficiency is inversely proportional to the machine forward speed and the ridge deformation depth. These observations would illustrate that the feeding system efficiency correlated negatively with the planter wheel skidding.

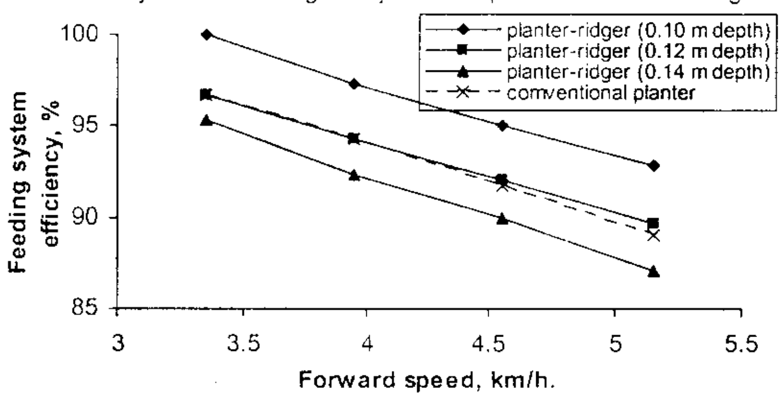

Fig. (9): Effect of potato planter-ridger forward speed on feeding system efficiency.

c- Seed tubers void

Fig. (10) demonstrates that the seed tubers void is a positive function of the feeding system efficiency. The lower seed tuber void values of 0 and 2.7% were found at 3.35 km/h forward speed for the potato planter-ridger and the conventional planter, respectively. Meanwhile, the maximum seed tuber void values of 6.10 and 2.75% were recorded at 5.15 km/h forward speed for the previous machines with the same respect. This means that the seed tuber discharge slightly decreases as the planter wheel skidding increased. It is due to the lower efficiency of filling feeding units as a result of the higher planter wheel skidding.

The statistical analysis showed that the planter-ridger recorded the standard deviation for the seed tubers void of 0.883%.

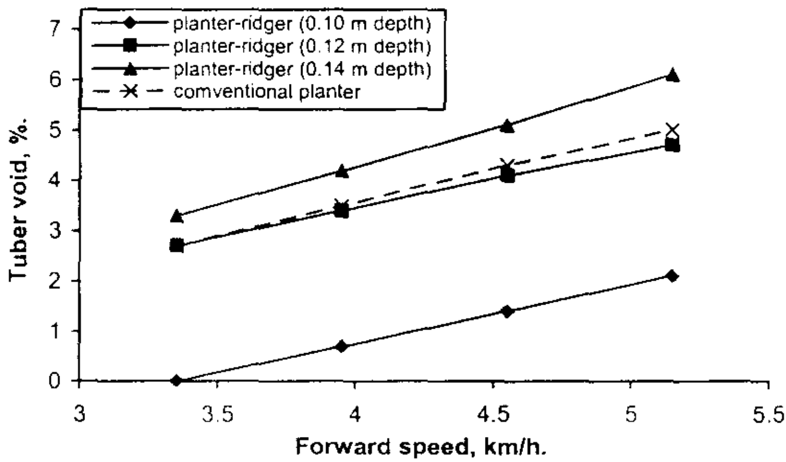

Fig. (10): Effect of potato planter-ridger forward speed on seed tubers void.

d- Coefficient of variation for seed tubers spacing:

Data in Fig. (11) clarify the positive relation between the machine forward speed and the coefficient of variation for the seed tubers spacing. This finding illustrated that the ratio of the machine forward speed to the speed of the released seed tuber from the feeding system is unified at the lower forward speed, resulting in a minimal effect on the accuracy of longitudinal seed tuber deposit. While, as the forward speed increased, this ratio tended to decrease, resulting in lower accuracy of longitudinal seed tuber deposit. Moreover, the lower forward speed reduces the machine vibration which decreases the kinetic energy of the released tubers from the feeding system, resulting in diminishing the seed tubers longitudinal deposit.

Meanwhile, Fig. (11) revealed that at ridge deformation depth of 0.14 m, the potato planter-ridger achieved the lower coefficient of variation for seed tubers spacing of 8.05%. The inversely relation between the ridge deformation depth and the coefficient of variation for the seed tubers spacing is illustrated that at the lower ridge deformation depth, the seed tuber is enclosed by a more amount of the soil clods, which decreases the tuber rolling motion, resulting in higher accuracy of seed tuber deposits.

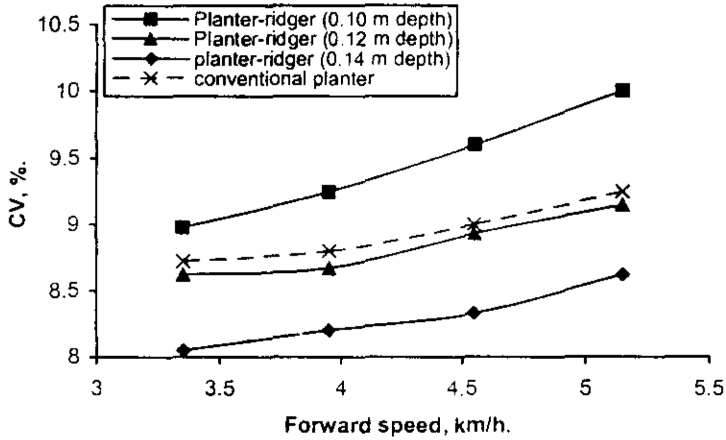

Fig. (11): Effect of potato planter-ridger forward speed on coefficient of variation for seed tubers spacing (cv).

The statistical analysis showed that the planter-ridger recorded the standard deviation for the coefficient of variation for the seed tubers spacing of 0.551%.

e- Seed tuber covering height:

Data in Fig. (12) indicated that the seed tuber covering height decreased slightly with the machine forward speed and the ridge deformation depth. The potato planter-ridger achieved the higher seed tuber covering height of 0.15 m at forward speed of 3.35 km/h and ridge deformation depth of 0.10 m. While, the lower seed tuber covering height of 0.10 m was recorded at forward speed of 5.15 km/h and ridge deformation depth of 0.14 m. This finding is attributed to the inversely relation between both the machine forward speed and the ridge deformation depth and the soil mechanical breaking up. So, using the planter-ridger at the lower forward speed and the shallower ridge deformation depth increases the disturbed soil, resulting in increasing the seed tuber covering height. On the other hand, the conventional planter recorded lower values of the seed tuber covering height than that of the planter-ridger at the same forward speed. It is due to the lower disturbed soil volume which is resulted using the covering discs.

3- Potato Crop Yield

Fig. (13) exhibited the reverse relation between the potato crop yield and both the machine forward speed and the ridge deformation depth. The planter-ridger achieved the higher potato crop yield of 12.15 ton/fed using 3.35 km/h forward speed at 0.10 m ridge deformation depth. As the machine forward speed increased from 3.35 to 5.15 km/h, potato crop yield decreased by about 6.75%, at the same ridge deformation depth. Whilst, as the ridge deformation depth increased from 0.10 to 0.14 m, potato crop yield decreased by 3.62% approximately, at the same forward speed. On the other hand, the conventional planter recorded the higher potato crop yield of 11.90 ton/fed. This means that the planter-ridger achieved higher potato crop yield than the conventional planter by about 2.08%. These results agree with the phenomena that potato crop yield is mainly affected by the regularity of the planted seed tubers in row and the higher seed tubers covering height.

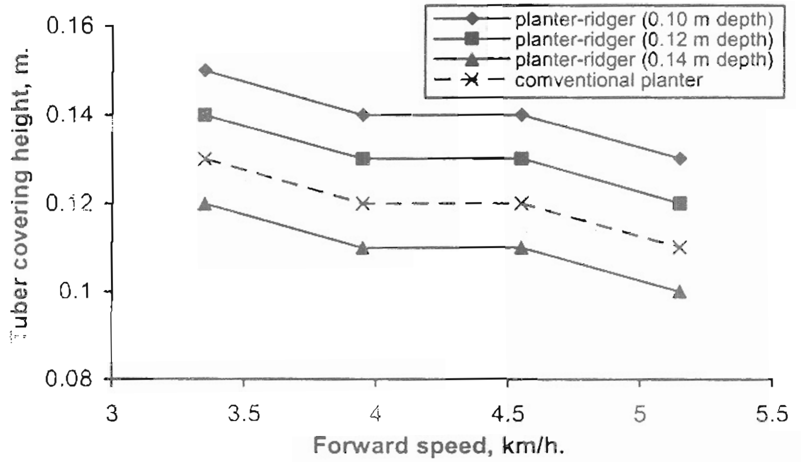

Fig. (12): **Effect of potato planter-ridger forward speed on seed tuber covering height.**

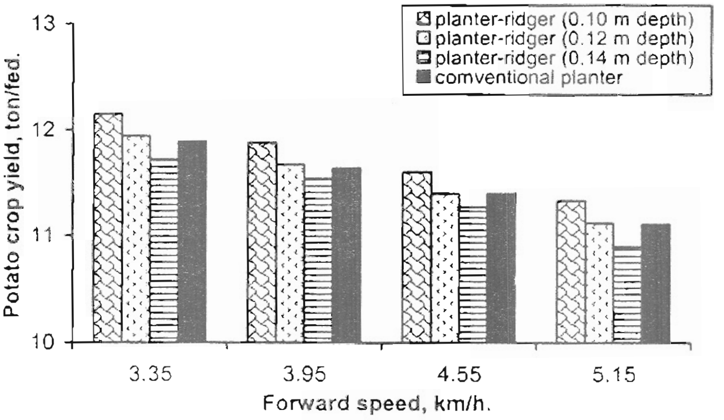

Fig. (13): **Effect of potato planter-ridger forward speed on potato crop yield.**

The statistical analysis showed that the planter-ridger recorded the standard deviation for the potato crop yield of 0.338 ton/fed.

The analysis of variance shows that there was a highly significant difference in the potato crop yield values due to the interaction of the planter-ridger forward speed and ridge deformation depth. The L.S.D. test at 1% level indicates that using the planter-ridger at forward speed of 3.35 km/h at ridge deformation depth of 0.10 m recorded the highest significant potato crop yield value among the other treatments.

The regression and correlation analysis indicated that the relation between the potato crop yield (y) and the planter-ridger forward speed (x) could be represented as follows:

1) 0.10 m ridge deformation depth: $y = -0.4556x + 13.709$ ($R^2 = -0.9806$)
2) 0.12 m ridge deformation depth: $y = -0.4556x + 13.499$ ($R^2 = -0.9806$)
3) 0.14 m ridge deformation depth: $y = -0.4556x + 13.279$ ($R^2 = -0.9806$)

From the regression and correlation analysis, it can be noticed that, there is a significant negative correlation between the machine forward speed and the potato crop yield. Also, it is noticed that, increasing the forward speed by 1 km/h the potato crop yield decreases by 0.46 ton/fed at any one of the tested ridge deformation depth.

CONCLUSION

The planter-ridger maximized the potato crop yield more than the conventional planter by 2.08%. This means that the planter-ridger created better conditions for potato tubers to grow and

correctly develop. The higher potato crop yield of 12.15 ton/fed was obtained at 3.35 km/h forward speed and 0.10 m ridge deformation depth. These operational factors achieved the lower coefficient of variation for the seed tubers spacing of 8.05% and the higher seed tuber covering height of 0.15 m. Moreover, these factors achieved an acceptable machine performance of 0.89 fed/h field capacity and 135.55 MJ/fed specific energy requirements. So, it is recommended to use the planter-ridger as an effective method to maximize the potato crop yield.

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تعظيم إنتاج محصول البطاطس باستخدام آلة معدلة للزراعة والتخطيط

جمال حسن السيد ، سامي السعيد بدر، أسامة طه بهنس و ناهد خيري إسماعيل
معهد بحوث الهندسة الزراعية – مركز البحوث الزراعية.

أجريت هذه الدراسة بمحطة البحوث الزراعية بالجميزة، محافظة الغربية خلال الموسم الصيفي ٢٠٠٦. وتم زراعة تقاوي البطاطس صنف Sponta باستخدام الة معدلة للزراعة والتخطيط على ان تكون المسافة بين الخطوط ٠,٧٥ متر والمسافة بين الدرنات في الخط ٠,٢٥ متر. وقد إختبرت الآلة عند ثلاثة مستويات للسرعة الامامية: ٣,٣٥، ٣,٩٥، ٤,٥٥، ٥,١٥ كم/ساعة وثلاثة مستويات لعمق تشكيل الخط: ٠,١٠، ٠,١٢، ٠,١٤ متر. وقد كان أعلى انتاج لمحصول البطاطس ١٢,١٥ طن/فدان عند السرعة الأمامية ٣,٣٥ كم/ساعة وعمق تشكيل الخط ٠,١٠ متر، وبالاضافة إلى ذلك فقد حققت الالة اداء مرضيا (السعة الحقلية حوالى ٠,٨٩ فدان/ساعة واحتياجات الطاقة النوعية حوالى ١٣٥,٥٥ ميجا جول/فدان).