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DEVELOPING A COMBINE MACHINE FOR HARVESTING AND COLLECTING OF ONION CROP

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ABESTRACT

The experiments were carried out at El-Maamoria village- El-Gamalia region, Dakhlia Governorate during onion harvesting season 2008-2009 to evaluate onion harvesting crop by a combine machine for harvesting and collecting onion crop and achieving the following factors: Decreasing harvesting costs of onion crop, Decreasing a partial and total damage caused in onion bulbs, Decreasing harvesting period and Easing of collecting onion crop. by using a developed combine machine to harvesting and collecting of onion crop. All treatments were carried out on onion crop at four different speed ratios K (ratio of elevator speed to machine forward speed) (K_1=1.8, K_2= 1.55, K_3= 1.05 and K_4= 0.8) and four different tilt angle of share (T_1=10, T_2=15, T_3=20 and T_4=25 degree) with different four depths of share (D_1=4, D_2= 5.5, D_3=7 and D_4=8.5 cm).The best results of harvesting efficiency, damage ratio and fuel consumption were at (K_3= 1.05, T_4=25 degree, D_3= 7 cm).

INTRODUCTION

Onion harvesting in Egypt still use traditional methods such as digging the bulbs out by hoes, manually either by hand pulling, or using the animal pulled ploughs. Collecting process of onion is also manually performed. Many of these traditional methods of harvesting and collecting onion crop have many problems such as the high cost of harvesting and collecting onion crop, the high percentage of partial and total damage caused in onion bulbs, high amounts of bulbs losses (remained bulbs), the long period of harvesting and collecting with the separating problem of onion bulbs from the soil clods during harvesting. Since this research is concerned with the combine machine development for harvesting operation and collecting operation of onion crop, which eventually decrease its costs. The machine under study in this research was originally used in potato harvesting operation.

As there are many factors affecting harvesting and collecting of onion crop such as speed ratio, tilt angle of share, depth of share, moisture content of soil, working width, ….etc; so in the coming study, some of the mentioned parameters were tested according to the most effective parameters i.e. speed ratio, tilt angle of share, depth of share.

Lepori and Hobgood (1970) found that speed of the lifting belts must be greater than forward speed of the machine. Ratio of belt speed to ground speed was found to be important, and ratio between 1.2 and 1.5 were found to provide satisfactory operation in average field conditions, Balls *et a*l (1981) indicated that decreasing the main digger web speed and increasing the forward speed of the harvester could reduce damage The ratio of web speed to forward speed is important to be as near to 1:1 as possible, Japanese Trade Policy Inst (1986) found that the operation width was 50 cm, the digging depth ranged from 20 to 25 cm, the mass of machine was 38 kg and power needed was 6 kw. In addition, this type of machine can work only in light soil conditions, Abdel-Galeil (1990) studied that a suitable potato harvester for Egyptian farms to replace the traditional methods in harvesting operations. He also indicated that the lifted tubers percent was affected by the digging depth and tilt angle. The optimum digging depth and tilt angle was 20cm and 18 degree respectively which achieved a highly lifted tubers percent. The damaged tubers percent decreased by increasing digging depth and tilt angle until 23cm and 21˚ respectively and Hammad et al (1991) indicated that increasing blade tilt angle increased the percentage of surfaced tuber and potatoes accumulated at the front of the blade but derides the percentage of bruised tubers. The percentages of surfaced tubers were (10.32, 20.27, 52.06 and 78.36), while the percentages of potatoes at the front of blade were (2.91, 6.16, 7.58 and 10.32) and the percentages of bruised tubers were (86.77, 73.57, 40.36 and 11.41) for tilt angle 8, 12, 16 and 20˚ respectively. Also the percentages of potato surfaced bruised and accumulated at front of the blade are mainly affected by the blade tilt angle. The most suitable tilt angle of the blade was 20˚.

Abd El-Galil (1992) reported that the highest percentage of damaged tubers was obtained at forward speed of 3.8 km/h and tilt angle of share 15. Also the lowest percentage of damaged tubers was obtained at forward speed of 1.8 km/h and tilt angle of share 21˚. He found that the best lifting tubers percentage over the soil surface was obtained at forward speed of 2.8 km/h, digging depth of share 20cm and the tilt angle of share 18˚, Vatsa *et a*l (1993) found that the tilt angle of shares could be adjusted between 10˚ and 45˚ to the horizontal, Youssif (1995) reported that the cutting angle of 17 degree is the most suitable for the performance of the harvest implement, while using cutting angle 24 degree gave the highest required draft and El-Sayed *et al* (1997) indicated that the least percent of buried tubers was obtained under levels of rake angles 8, 10 and 12 for separating red 15, 25 and 35cm respectively at the average levels of forward speed.

Emam (1999) found that increasing digging depth from 25 to 30cm, increasing share angles from 18 to 24 and lower forward speeds from 3.0 to 2.0 km/h by using chisel share increased the percentage lifted tubers from 84.73 to 93.81%, the undamaged tubers from 82.4 to 91.73% and harvester efficiency from 84.59 to 93.43%, on the other side decreased the percentage of the unlifted tubers from 15.27 to 5.19%, the bruised tubers from 9.10 to 4.57% and cut tubers from 8.50 to 3.70%,

Afify and Mechail (2000) studied that a potato harvester on the frame of a chisel ploughs to maximize exploitation. The equipment was tested under different operation conditions at three operation speeds (2.2, 3.12 and 4.49 km/h) and three levels of depths (13, 17 and 20 cm) and Abdel-Aal et al (2002) found that the optimum engineering parameters for the modified harvester which achieved the highest undamaged, lowest damaged and losses was obtained under operational conditions of forward speed of 2.3 km/h, digger tilt angle of 0.24rad (14 deg), distance between the blade and elevator chain of 5cm, chain speed of 100 r.p.m (2.41 m/s), riddle speed of 4.63 r.p.m (192.12 m/s), and riddle inclination of 0.12rad (7 deg).

The objectives of this study are:

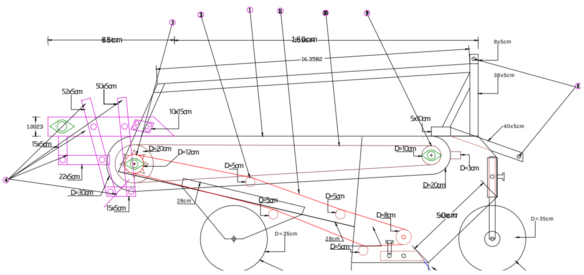
1- Decreasing harvesting costs of onion crop.
2- Decreasing a partial and total damage of onion crop.
3- Decreasing harvesting period.
4- Easing of collecting onion crop.

MATERIALS AND METHODS

1. The tractor: To make suitable harvesting onion, a tractor of Kubota 55 hp Model KUBOTA L.2402-M manufactured in Japan, 3 cylinders Diesel Engine, 55 hp (22.44 kW) at 2800 rpm

2 Specifications of the harvester before development:

The harvester before development consists of a frame, a shear, 3 hitch points, a vibrator, two wheels, two discs, a group of pulleys, separating unit (elevator), gear box, group of links, came and transmission system. Overall dimensions of harvester before development length 180 cm, width 140 cm and height 80 cm.



No	part
1	frame
2	Pulley of elevator
3	gear
4	Vibrator
5	wheel
6	share
7	disc
8	Hitch points
9	pulley
10	belt
11	elevator

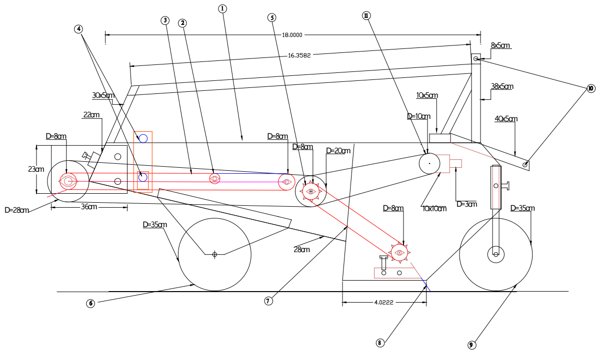
Fig (1): The harvester before development

a- The separation unit: The separation unit consists of a elevator. It is used to remove soil adhering to soil surface. It takes power from the tractor P.T.O. The elevator consists of a group of parallel steel stalks. Dimensions of elevator before modification were 150 cm length, 120cm width and 2 cm space between stalks.

b- The vibrator: The vibrator unit in rear of harvester was insufficient to separate soil particles from onion bulbs.

Fig (2): The vibrator before development

3 Specifications of the harvester after development: The harvester after development consists of the frame, shear (digging unit), 3 hitch points, the vibrator, two wheels, two discs, group of pulleys, separating unit (front elevator and ray separator), gear box, group of links, came and the transmission system. Overall dimensions of the harvester after development were 205 cm length, 140 cm width and 80 cm height.



No	part
1	frame
2	bare
3	Ray separator
4	vibrator
5	gear
6	wheel
7	elevator
8	Share
9	disc
10	Hitch points
11	pulley

Fig (3): The combine harvester after development

The separation unit consists of front elevator and ray separator. It is used to remove soil adhering to onion bulbs. It takes power from the tractor P.T.O. by a transmission system.

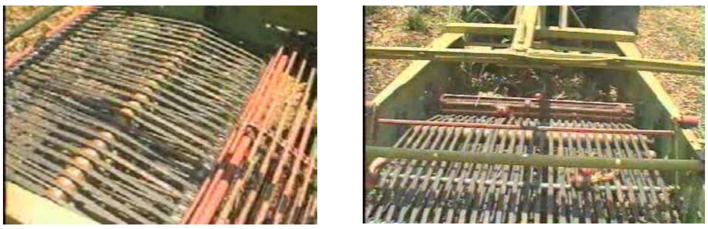


Fig (4): Front elevator and ray separator and vibrator after development

The front elevator consists of group of parallel steel stalks, two bars, six gears. The length of each stalks 120 cm. Dimensions of front elevator are 60 cm length, 120 cm width and 4 cm Space between parallel iron stalks.

The ray separator consists of two bars, each bar consist of group of pulleys, traveled with group of parallel belts. Dimensions of ray separator are 110 cm length, 120 cm width and 3 cm Space between parallel iron stalks.
The vibrator extended in the beginning of last of one-third of the rear elevator.

4- Physical properties of onion bulbs:

Two hundred samples of onion bulbs were taken randomly to determine the mentioned specifications. Each value in table (9) represents ten samples were taken randomly from the medium and asides of ridge.

Means of the physical properties of onion bulbs were 4.8 cm depth, 5.7 cm height, 6.1cm diameter, 145 gram weight and 78.8 cm3 volume.

Soil mechanical and chemical analysis was carried out at El-Serw Agricultural Research Station lab, Soil Department. The international method was used to determine the particle size distribution of soil. Soil samples were taken randomly in the medium and aside of the ridge. The results of analysis are shown Clay soil.

Methods

The moisture content of soil (d.b.) was measured using the oven methods at 105^0 C for 24 hours. Thirty samples of soil were taken randomly to determine the moisture content of soil before harvesting. Thirty samples of soil were carried out at El-Serw Agricultural Research Station Lab, Soil Department. By (equation 1) according to (*ASAE Standard Methods 1997).*

$$Mc = \frac{Ww - Wd}{Wd} X100 \quad \text{..............................} \quad (1)$$

Where: Mc = material moisture content, % W_w = wet soil mass, g.
W_d = soil mass, g

The harvesting (combine harvesting machine) efficiency was calculated according to the following (equation 2):

$$HE = \frac{Y - L}{Y} X100 \quad \text{..............................} \quad (2)$$

Where:
HE = harvesting efficiency (%). Y = total bulbs yield (ton/fed).
L = (U+N)=total bulbs losses, (ton/fed). U=unharvested onion bulbs, (ton/fed).
N = bulbs under harvester, (ton/fed).

The quality of the lifted onion bulbs was determined by counting the total damaged and undamaged bulbs collected from the same area.

The results of the total damaged bulbs were divided into two classes according to Amin, (1990).

1-Serious damaged bulbs (cut bulbs).
2-Weight of the slight damaged bulbs (skin broken and bruise damage).
3-The damage ratio (Dr)could be determined using the following (equation 3):

$$Dr = \frac{W}{Y} X100 \quad \text{..............................} \quad (3)$$

Where:
W = the weight of damaged bulbs (slight or serious).
Y = total bulbs yield (ton/fed).

Fuel consumption rate per unit time was determined by measuring the volume of fuel consumed during harvesting time. It was determined as follows:-

1- The tractor tank was filled to full capacity before and after all treatments.
2- The harvesting operations were then carried out and the time needed was recorded with a stopwatch.
3- Amount of refueling after the test represented the fuel consumption for treatment.

The fuel consumption per unit time is calculated by using the following (equation 4):-

$$F.C = \frac{F}{t} \, l/h \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Where:
F.C. = Fuel consumption rate, L/h. F = volume of fuel consumption.
t = time of harvesting

Test factors:

1- Speed ratio was adjusted at four levels of speed ratio between speed of elevator and forward speed 1.8, 1.55, 1.05 and 0.80 named K_1, K_2, K_3 and K_4 respectively.
2- Tilt angle of share (digging unit) was adjusted at four angles of share 10, 15, 20 and 25° named T_1, T_2, T_3 and T_4 respectively.
3- Depth of share (digging unit) was adjusted at four levels of depth of share (4, 5.5, 7 and 8.5 cm named D_1, D_2, D_3 and D_4 respectively.

RESULTS AND DISCUSSION

A. Harvesting efficiency, %:

1. Effect of tilt angle of share:

From data shown on fig (1) it was concluded a proportional relationship between tilt angles of shares and harvesting efficiency. Increasing tilt angle of share resulted in increasing the harvesting efficiency. With tilt angle of share of 10, 15, 20 and 25 degree the harvesting efficiency were 55.19, 63.71, 71.32 and 80.5 % respectively.

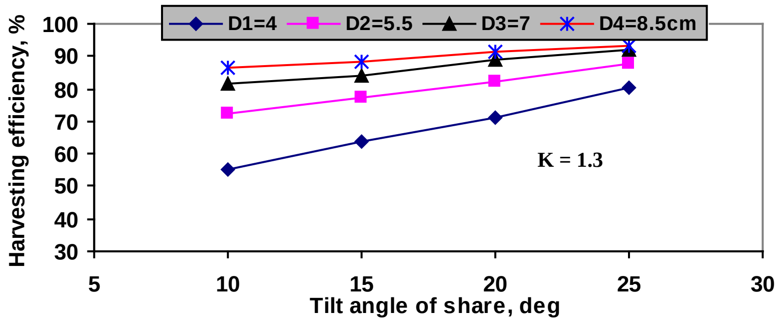


Fig. (1): Effect of tilt angle of share and depth of share on harvesting efficiency.

These results may be due to that the increase of tilt angle of share resulted in more penetration far from onion bulbs which led to the decrease of damaged bulbs that meant high harvesting efficiency and consequently more yield. The analysis of variance for data showed that the tilt angle of share had a significantly affect on the harvesting efficiency ($p < 0.01$).

2. Effect of depth of share:

From data shown in fig (2) it is easy to notice that increasing depth of share resulted in increasing the harvesting efficiency. From statistical analysis, harvesting efficiency was affected by depth of share, as there was a significant effect of share depth on harvesting efficiency. With depth of share of 4, 5.5, 7 and 8.5 cm the harvesting efficiency were 55.19, 72.17, 81.54 and 86.55% at tilt angle of share 10 degree and speed ratio of 1.3. These results may be due to increasing the depth of share due to the share the increase of tilt angle of share resulted in more penetration underneath from onion bulbs, which led to the decrease of damaged bulbs that meant high harvesting efficiency, and so more yield. The analysis of variance for data showed that the depth of share had a significantly affect on the harvesting efficiency ($p < 0.01$).

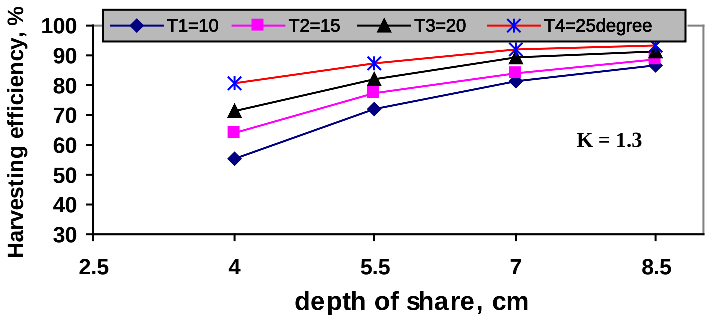


Fig. (2): Effect of depth of share and tilt angle of share on harvesting efficiency.

3. Effect of speed ratio:

From data shown in fig (3) it was found that, increasing speed ratio resulted in increasing the harvesting efficiency as a directly proportional relationship. With speed ratio of 0.80, 1.05, 1.55 and 1.8 the harvesting efficiencies were 63.87, 71.72, 78.54 and 81.32 %, respectively.

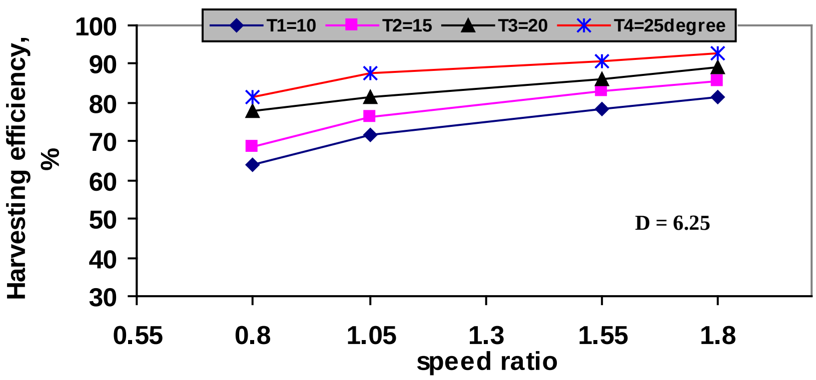


Fig. (3): Effect of speed ratio and tilt angle of share on harvesting efficiency.

These results were obtained under share depth of 4 cm and share tilt angle of 10 degree. These results may be due to the decrease of forward speed which caused an increase of speed ratio. This facilitates the control of share tilt angle to keep the adjusted digging depth at high-speed ratio. Statistically, the analysis of variance for data showed that the speed ratio had a significant effect on the harvesting efficiency ($p < 0.01$).

B. Damage ratio:

1. Effect of share tilt angle:

Fig (4) shows that Increasing share tilt angle resulted in decreasing the bulbs damage. Increasing the tilt angle of share from 10 to 15 degree resulted in decreasing the damage ratio from 19.47% to 16.36% under share depth of 4 cm at a speed ratio 1.8. While increasing share tilt angle of from 15 to 20 degree resulted in decreasing the bulbs damage from 16.36% to 12.75% under the same conditions. While increasing share tilt angle from 20 to 25 degree resulted in decreasing the bulbs damage from 12.75% to 10.26% under the same conditions. These results may be due to the insufficient suction associated with the 10 deg share angle, so that the share oscillates between partial and full depth. The analysis of variance for data showed that the tilt angle of share had a significantly affect on the damage ratio ($p < 0.01$).

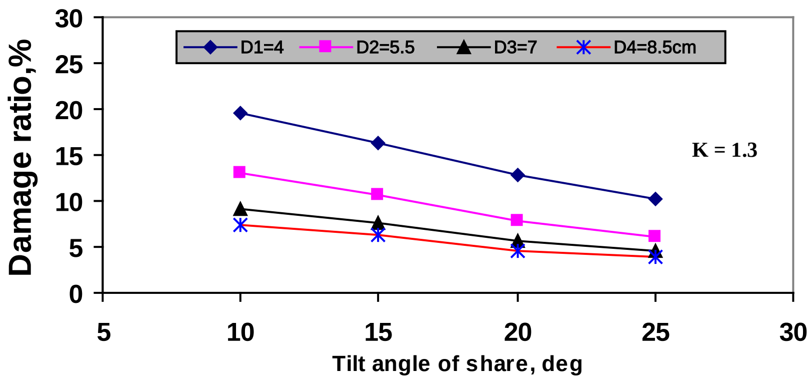


Fig. (4): Effect of tilt angle of share and depth of share on damage ratio.

2. Effect of share depth:

In fig (5) it could be concluded that under tilt angle of share 10 degree with speed ratio 1.3, increasing depth of share resulted in decreasing the bulbs damage. As increasing depth of share from 4 to 5.5 cm resulted in decreasing the damage ratio from 19.47% to 12.95% under While increasing depth of share from 5.5 to 7 cm resulted in decreasing damage ratio from 12.95% to 9.07% under the same conditions. While increasing the depth from 7 to 8.5 cm resulted in decreasing the damage from 9.07% to 7.30% under the same conditions. These results may be according to the increase of depth due to increasing the distance between the share and the bulbs downwards, which led to decreasing the damage. The analysis of variance for data showed that the depth of share had a significantly affect the damage ratio ($p < 0.01$).

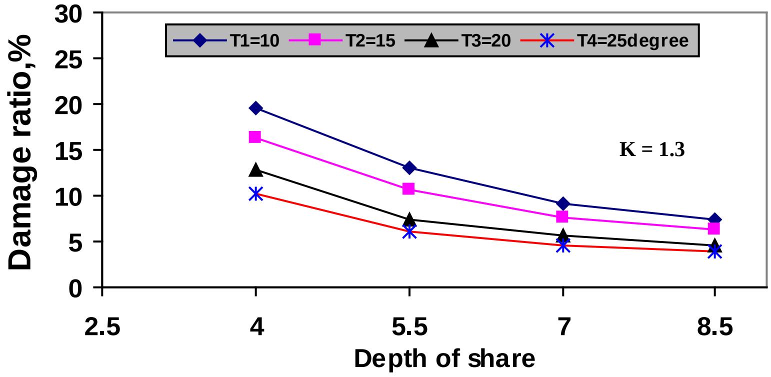


Fig. (5):Effect of depth of share and tilt angle of share on damage ratio.

3. Effect of share speed ratio:

From data shown in fig (6) it is easy to notice that increasing speed ratio resulted in decreasing the damage ratio. As increasing speed ratio from 0.80 to 1.05 at tilt angle of share 10 degree resulted in decreasing the damage ratio from 17.36% to 13.55% under depth of share 4 cm. On the other hand, the increase of speed ratio from 1.05 to 1.55 showed a decrease in damage ratio from 13.55% to 9.42% under the same conditions and the increase of speed ratio from 1.55 to 1.8 showed a decrease in damage ratio from 9.42% to 8.48% under the same conditions. These results may be due to the decrease of forward speed which caused an increase of speed ratio. This facilitates controlling of tilt angle of share to keep the adjusted digging depth at high-speed ratio. This case enhanced the stability and balance of the machine that led to decrease the damage ratio. The analysis of variance for data showed that the speed ratio had significantly affect the damage ratio ($p < 0.01$).

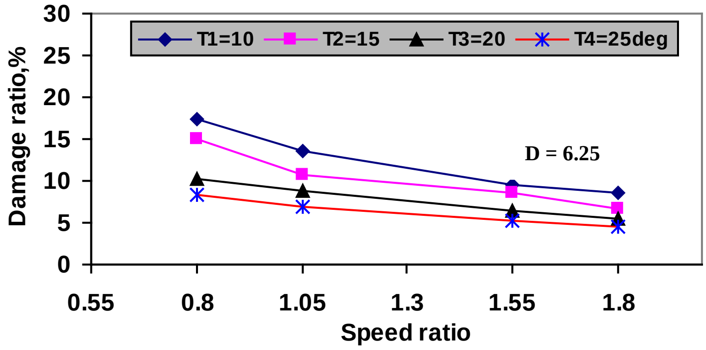


Fig. (6): Effect of speed ratio and tilt angle of share on damage ratio.

C. Fuel Consumption Rate:

1. Effect of share tilt angle:

From data shown in fig (7) it could be concluded that increasing tilt angle of share resulted in increasing the fuel consumption rate. As increasing tilt angle of share from 10 to 15 degree resulted in increasing the fuel consumption rate from 2.38 to 2.6 L/h under depth of share 4 cm with speed ratio 1.3. While increasing tilt angle of share from 15 to 20 degree resulted in increasing fuel consumption rate from 2.6 to 2.8 L/h under the same conditions. While increasing tilt angle of share from 20 to 25 degree resulted in increasing fuel consumption rate from 2.8 to 3.06 L/h under the same conditions. These results may be due to increasing the tilt angle of share due to the increase of tilt angle of share which resulted in more penetration away from onion bulbs underneath which led to the increase of soil resistance according to more depth which obliged machine to lift a higher soil mass that meant higher fuel consumption according to more load on tractor. The analysis of variance for data showed that the tilt angle of share had a significantly affect on the fuel consumption rate ($p < 0.01$).

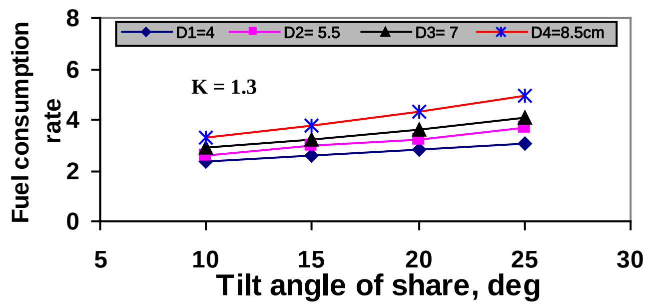


Fig. (7): Effect of tilt angle of share and depth of share on fuel consumption rate.

2- Effect of share depth:

From data shown in fig (8) it was concluded that a directly proportional relationship between depth of share and fuel consumption rate. As increasing depth of share from 4 to 5.5 cm resulted in increasing the fuel consumption rate from 2.38 to 2.67 L/h under tilt angle of share 10 degree with speed ratio 1.3. While increasing depth of share from 5.5 to 7 cm resulted in increasing fuel consumption rate from 2.67 to 2.91 L/h under the same conditions. While increasing depth of share from 7 to 8.5 cm resulted in increasing fuel consumption rate from 2.91 to 3.29 L/h under the same conditions. These results may be due to increasing the depth of share which leads to increasing resistance of soil and increasing the load on the tractor, which caused to increase the fuel consumption rate. The analysis of variance for data showed that the depth of share had a significantly affect on the fuel consumption rate ($p < 0.01$).

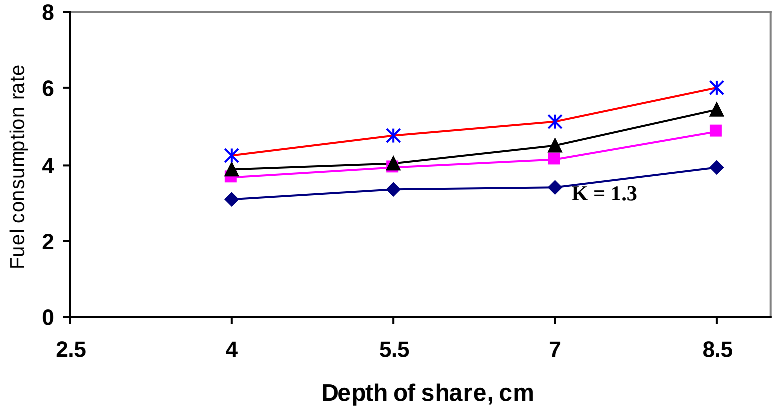


Fig. (8): Effect of depth of share and tilt angle of share on fuel consumption rate.

3. Effect of speed ratio:

From data shown in fig (9) it was found that, increasing speed ratio resulted in decreasing the fuel consumption rate. As increasing speed ratio from 0.80 to 1.05 at tilt angle of share 10 degree resulted in decreasing the fuel consumption rate from 3.44 to 3.02 L/fed under depth of share 6.25 cm. In addition, the increase of speed ratio from 1.05 to 1.55 showed a decrease in fuel consumption rate from 3.02 to 2.63 L/h under the same conditions and the increase of speed ratio from 1.55 to 1.8 showed a decrease in fuel consumption rate from 2.63 to 2.17 L/h under the same conditions. These results may be due to the decrease of forward speed that caused an increase of speed ratio which led to decrease the fuel consumption rate L/h. The analysis of variance for data showed that the speed ratio had a significantly affect on the fuel consumption rate ($p < 0.01$).

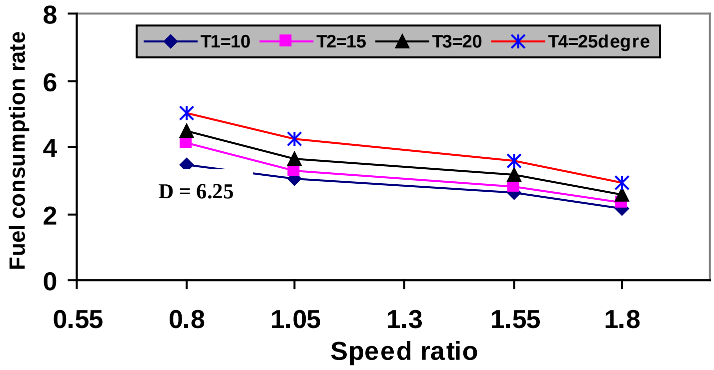


Fig. (9): Effect of speed ratio and tilt angle of share on fuel consumption rate.

Conclusion

The conclusion can be summarized as follows:

1- The results showed that increasing speed ratio resulted in increasing harvesting efficiency. Contrast increasing speed ratio resulted in decreasing damage ratio and fuel consumption.

2- Also, the obtained results showed that increasing tilt angle of share resulted in increasing harvesting efficiency and fuel consumption. Contrast increasing tilt angle of share resulted in decreasing damage ratio.

3- On the other hand, the results showed that increasing depth of share resulted in increasing harvesting efficiency and fuel consumption. Contrast increasing speed ratio resulted in decreasing damage ratio.

4- The standard working factors of harvester are speed ratio K3= 1.05, tilt angle of share T4=25 deg and depth of share 7 cm.

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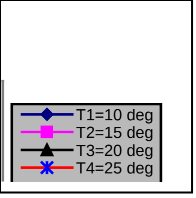

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تطوير آلة مجمعة لحصاد وتجميع محصول البصل

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يعتبر البصل من أهم محاصيل الخضر فى مصر نظرا لزراعته على نطاق واسع بالمقارنة بمحاصيل الخضر الأخرى وهو يحتل المركز الثاني من الناحية التصديرية بعد البطاطس. ويتم حصاد البصل في مصر يدوياً وهى طريقة لا تتناسب مع المساحات الكبيرة خاصة في الأراضي الجديدة ، كما أن استخدامها يؤدى إلى زيادة نسبة الفقد والتلف في المحصول وتحتاج إلى أيدي عاملة مدربة ووقتا أطول ، مما يؤدى إلى زيادة تكاليف الفدان الواحد. ولحل هذه المشكلة تم تطوير آلة مجمعة تقوم بحصاد وتجميع البصل وتتكون الآلة من السلاح: خاص بعملية الحصاد (التقليع) للأبصال من التربة.الحصائر: نوعين من الحصائر تقوم إحداهما بعملية رفع ونقل التربة والبصل غالى الحصيرة الأخرى والتي تقوم بفصل التربة عن الأبصال. مسيل: خاص بعملية تجميع الأبصال وهو عبارة عن مسيل لتوجيه نزول البصل خلف الآلة في صف فوق سطح التربة وهو مركب خلف حصيرة الفصل مباشرة.

ومن الدراسة تم الحصول على النتائج الآتية

١ - زيادة السرعة النسبية أدت إلى زيادة كلا من كفاءة الحصاد ونقص كلا من نسبة التلف ومعدل استهلاك الوقود في الساعة.

٢ - زيادة زاوية ميل السلاح مع الافقى نتج عنها زيادة كلا من كفاءة الحصاد ومعدل استهلاك الوقود في الساعة ونقص نسبة التلف.

٣ - زيادة عمق السلاح (الحصاد) أدى إلى زيادة كلا من كفاءة الحصاد ومعدل استهلاك الوقود في الساعة ونقص نسبة التلف.

٤ - أفضل ظروف تشغيل للآلة كانت عند سرعة نسبية 1.05 وزاوية الميل للسلاح مع الافقى 25 درجة وعمق السلاح 7 سم.

قام بتحكيم البحث

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