Journal of Soil Sciences and Agricultural Engineering

Journal homepage & Available online at: www.jssae.journals.ekb.eg

Development a Unit for Onion Harvesting

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ABSTRACT

This study was mainly conducted to fabricate and evaluate a harvester unit for onion crop. So the experimental design was implemented with four different of blade types, tilt angle of shares and speed ratio under three different harvesting depths. These variables were tested according to Total losses concerning (Blade damage - Brushing damage - Conveying losses - Un-lifted bulbs ratio); Efficiencies concerning (Digging efficiency - Cleaning efficiency - Harvesting efficiency - Field efficiency); Effective field capacity; Specific energy and Total costs. All trials were preceded in El-Serw Agic. Res. Station, Damietta Governorate during the onion harvest season 2020-2021. The overall results were summarized into the modification in the onion harvester with blades changed to scoop shapes with tilt angle of shares of 25^0 and speed ratio of 2.11 under harvesting depth of 11 cm to achieve the lowest total damage and high efficiencies and specific energy with less overall costs in general. While some parameters showed the best results in partial variables as gator blades and 5 cm digging depth for effective field capacity and field efficiency; speed ratio of 1.7 for effective field capacity, cleaning efficiency and specific energy and blade angle of 20^0 for field efficiency.

Keywords: Onion harvester, blade angle, harvesting efficiency, losses, total costs, El-Serw Agricultural Research Center (EARC).

INTRODUCTION

Onion (Allium cepa L.) is one of the oldest bulb crops, known to mankind and consumed worldwide. It is one of the most important commercial vegetable crops grown in Egypt. It is valued for its distinct pungent flavor and is an essential ingredient for the cuisine of many regions. Onion is the queen of kitchen. In season 2014/2015, the total cultivated area of fully grown onion in Egypt was 196968 fed, which gave total production of 3040607 Mg, (Central Agency for Public Mobilization and Statistics, 2017). Egypt is one of the ten most productive countries of onions in the world. The exports of Egyptian onions at end of 2019 recorded 550,000 tons, compared to 310,000 tons in 2018. (FAO, 2020)

Many researchers have acted on the development of root harvester as Anon (2008) developed a tractor-mounted harvester- with an elevator for digging root crops. The field capacity of the machine was 0.28, 0.24, and 0.21 ha/h, whereas the damage was 1.98, 1.92 and less than 1.0%, respectively, when operated at speed of 2.78, 2.41 and 2.10 km/h, respectively. Savings in cost of harvesting and labour were 52.28, and 69.05%, respectively, in comparison to manual harvesting of onion. Meanwhile, Hossain *et al.* (2017) stated that the two-wheel tractor (power tiller) is a public tillage tool in agriculture for easy to fragments of land at an affordable price for small farmers.

Yousef (1995) developed an onion digger and evaluated its performance at different types of share, namely, straight, triangle, double triangle and Three-point share, Under the different cutting angles of 10°, 17°, 24° and other variables like as forward speed, spinner wheel speed and vibrating sieve frequency. He recommended the three-point share to a cutting angle of 17° and forward speed 2.64 km/h to have the lowest total damage percenof onion bulbs. After that**,** Refaey (2010) conducted a factorial experiment to vehicle with different speeds and blade angles based on a randomized complete design. The best performance of the harvester was found at vehicle speed of 1.8 km/h and the blade angle of 20 degree.

Tapan *et al.* (2011) clarified the importance of the harvester in reduction the percentage of the damaged bulbs than the manual methods. Later confirmed by Khurana *et al.* (2012) when tested a prototype harvester for digging different root crops instance onion, garlic and carrot. They finally concluded the importance of harvester in reduction the percentage of crop damage to total exposed crops for the same crop, in addition saving labor, time, and total cost of harvesting operation in comparing to manual method. On onion, Singh (2014) developed and evaluated the performance of a digger in compare with manual method and also confirmed the mechanical method have an optimum for minimum damage and high digger efficiency to the onion bulbs, savings in labour and total cost. On the other hand, Kawale and Ramappa (2019) reported that high field capacity of tractor drawn onion digger with low fuel consumption and the cost of the developed onion digger and operation cost and time saving than manual onion digging. Meanwhile,Nour *et al.* (2020) concluded that the developed harvesting machine have many advantages as a high field capacity and efficiency with low specific energy and total cost, the proper forward speed and soil moisture content at constant digging depth, pulling chain speed and penetration angle.

Concerning to the speed and blade angle, they have significantly affected bruised crop percentage which increase the percentage of bruised carrot and onion crop with increase in forward speed save 44% of cost. Meanwhile El-Fakhrany and Fathalla (2020) revealed the effect of blade shape and angle in manufacture a front-mounted digger especially to be

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DOI: 10.21608/jssae.2023.180174.1121

used with the two-wheel tractor for digging onion bulbs. The digger mainly consists of a frame, two detachable shanks and digging blade. They carried out two experiments to evaluate the performance of the developed digger during digging two cultivars of onion namely Giza 20 and Giza red; by testing two types of digging blade namely smooth sharpened edge blade (SSB) and triangular fingered blade (TFB) at three different blade angles. The results clarified that SSB represented less damaged bulbs of both onion cultivars than TFB. The results indicated also that; increasing the blade angle decreased the un-lifted and damaged bulbs; and increased the digging efficiency, onion bulbs storability, required power and consumed energy with the two onion cultivars. Therefore; the developed digger can be used with the two-wheel tractor with SSB at increasing the blade angle.

Jadhav *et al*. (1995) observed that the actual field capacity of the onion digger windrower varied from 0.16 to 0.19 ha h^{-1}. The percentage of damaged bulbs varied from 2.63 to 3.45. The machine gave a digging efficiency in the range of 89.66 to 93.23 %. The cost of prototype was Rs.16000 and cost of operation was Rs.126 to Rs. 149 ha^{-1}. The pull-type mounted onion digger intended for two stages harvesting of onion cultivars with field capacity 0.42–0.6 ha/hr, and digging efficiency is 98.0–98.9% (Laryushin and Laryushin, 2009).

Recently concerning to the interest of digging depth and speeds, Omar *et al*. (2018) developed and evaluated the performance of an onion harvester under four digging depths and four different forward speeds at constant soil moisture content in compare with manual method. The indicated the significant difference between both methods which onion harvester have maximum field capacity with lifting and field efficiency, and minimum total losses and power and energy consumed than manual one. It was recommended to operate the developed harvester for harvesting onion crop at a depth harvesting of 10 cm and a forward speed of 0.720 km/h where the lowest criterion cost was 674.33 LE/fed, the lowest losses was 1.9%, and the least energy consumed was 59.5 kW.h/fed. Meanwhile Khurana *et al*. (2013) modified an existing potato digger to be a root crop harvester with modification in mechanical digging related to width and spacing between different crops, digger blade related to width, thickness, and angle with the horizontal, an elevator conveyor attached behind a blade related to the spacing between the MS rods of the elevator conveyor and constant slope of the elevator conveyor. In comparison between the modifying harvester and manual method, the performance of the machine was found satisfactory for digging onion, carrot, garlic and potatoes which increases the field capacity of the machine, percent exposed bulbs/roots, and saves cost and labor of operation for the harvesting with less damage to four crops.

The overall objective of this study is to manufacture and evaluate onion harvester according to previous research recommendations appropriate to local conditions.. Specifically, it aimed to: 1) design and fabricate a mechanical onion harvester pulled by a tractor; 2) evaluate the performance of the harvester; and, 3) conduct a simple cost analysis.

MATERIALS AND METHODS

This study was mainly carried out during the onion harvesting season 2020-2021 in El-Serw Agic. Res. Station, Damietta Governorate to fabricate and evaluate a harvester unit for onion crop. The soil of the experiment was clayey with 13 % moisture content and 1.32 g/cm^3 bulk density at the beginning of the experiments. Soil mechanical and chemical analysis was carried out at El-Serw Agricultural Research Station lab, Soil Department. A tractor (KUBOTA L. 24M) of 55 hp (22.44 kW) per 2800 rpm was used during carried out the experiments.

Specifications of the developed harvester

The harvester after development consists of the frame, shear (digging unit), three hitch points, the vibrator, two wheels, group of pulleys, separating unit (front chain and rear elevator), gear box, group of links, cam and the transmission system as shown in Fig 1, and the overall dimensions are tabulated in Table 1.

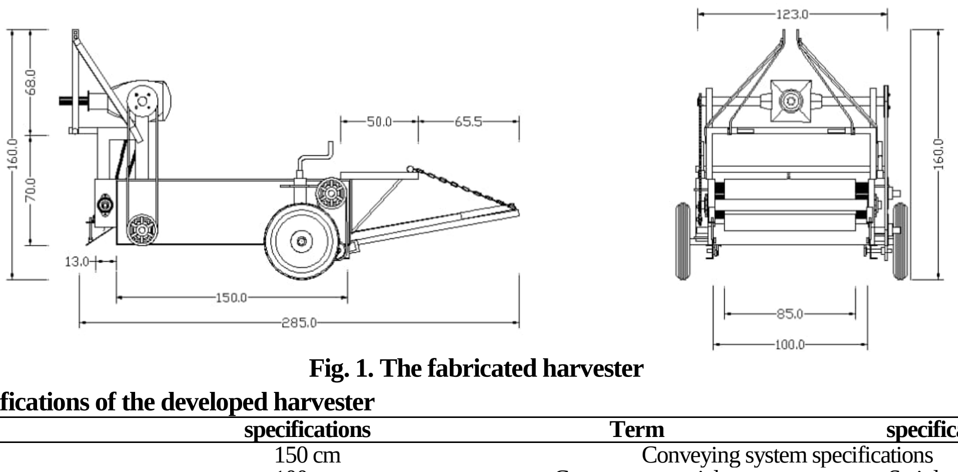

Fig. 1. The fabricated harvester

Table 1. Specifications of the developed harvester

Term	specifications	Term	specifications
Max. length	150 cm	Conveying system specifications	
Max width	100 cm	Conveyor material	Stainless steel
Max. height	66 cm	Shaft material	En8
Digging blade design parameters		Shaft diameter	30 mm
Blade geometry (cm)	100 x 25 x 1	Speed of conveyor	3.13 m/s
Draft force (N)	3256.8	Length of conveyor	553 mm
Shear blade rake angle	0-25^0	Width of conveyor	740 mm
Material	En42	Angle of conveyor	15^o
Dimension of one slat of share		Material handling capacity	0.0993 m^3/s
Length	100 cm	Power consumption	1.08 hp
Width	10 cm	Sprocket pitch	12.7 mm
Thickness	1.0 cm	No. of chain links	56

The chassis is rectangular in shape with dimensions of 150 cm in length, 100 cm in width and 66 cm in height. As the machine is a semi mounted type, two line idler wheels were assembled at the rear part of the machine. The cut system (Fig 2) consists of a slat flat blade with 100 cm length, 10 cm width and apex angle of 0 - 25^0. The blades cut the soil under the roots of onion bulbs at a desired depth, and carried them up and released them on the top of the soil surface.

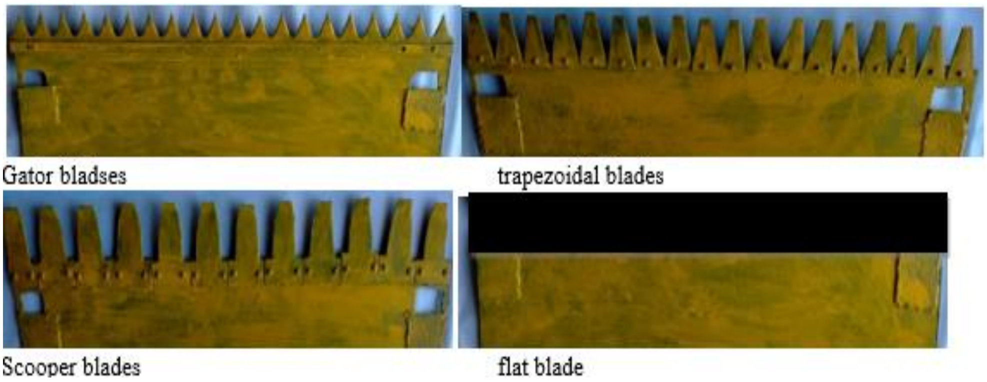

Fig. 2. Blade types

The conveying unit consists of a chain. It is used to remove soil stuck to onions surface and transfer the onions from the digger scoop to the rear outlet of the system. This system consists of 2 EN8 shafts that were designed by ASME standards. It takes power from the tractor PTO by transmission system, Fig 3. The chain consists of a group of parallel steel bars and each bar is 120 cm. The parallel steel bars spacing was about 3 cm to ensure that the onions didn't pass through them. The chain and sprockets were designed to sustain the maximum draft load of the soil and onions. The conveyor was designed to operate at the recommended 15-degree angle to ensure maximum efficiency and minimize the onion bulbs damage.

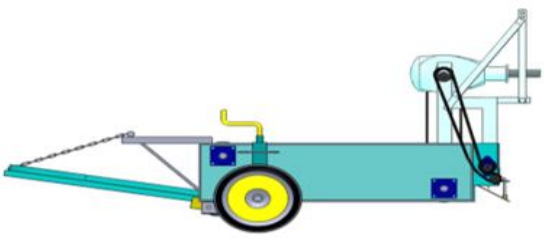

Fig. 3. The mechanism for adjusting depth and blade angle

Test factors:1- Blade type (shape): Flat blade, Gator blades, Trapezoidal blades, Scooper blades

2- Speed ratio was adjusted at four levels of speed ratio between speed of elevator and forward speed represent 2.11, 1.95, 1.85 and 1.7, respectively.3- Tilt angle of share (digging unit) was adjusted at four angles of share 13, 16, 20 and 25°, respectively.

4- Depth of share (harvesting depth) was adjusted at four levels of depth of share 5, 8 and 11 cm, respectively.

Experimental measurement:

- Total losses concerning (Blade damage - Brushing damage
- Conveying losses - Un-lifted bulbs ratio) were measured.
- Efficiencies concerning (Digging efficiency - Cleaning efficiency - Harvesting efficiency - Field efficiency) were measured.

Total harvesting losses is total onion bulbs losses percentage. It was calculated by the next equation:(1)

$$\text{T loss} = \frac{UL+Db}{Y} \times 100 \quad \text{.................(1)}$$

Where:

TLOSS= Total losses, [%]; UL= Mass of unlifted bulbs, [Mg.fed^{-1}]; DB = Mass of damaged bulbs, [Mg.fed^{-1}]; and Y = Total bulbs yield, [Mg.fed^{-1}].

Lifting efficiency was calculated according to the following equation: (2)

$$\eta L = LB \times Y \times 100 \quad \text{.................. (2)}$$

Where: **ηL= Lifting efficiency, [%]. LB = Mass of lifted bulbs, [Mg.fed^{-1}]. Y = Total bulbs yield, [Mg.fed^{-1}].**

Conveying losses:

Separation losses were determined by using the following equation : (3)

$$Sl = \frac{W_l}{W_t} \times 100, \% \quad \text{............................ (3)}$$

Where

Sl is the separation Losses, %; W_l is the weight of bulbs over the apiece of cloth, kg; and W_t is the total weight of bulbs (W_l + W_{nl}), kg; while W_{nl} is the Weighing of collecting bulbs over the soil at ten meters, kg ;

Cleaning efficiency was determined by using the following equation (4):

$$\eta_{cl} = \frac{W_{cl}}{W_t} \times 100, \% \quad \text{.......................... (4)}$$

Where:

η_{cl} is the cleaning efficiency, %; W_{cl} is the weight of cleaning bulbs in the sample, kg; and W_t is the weight of total sample, kg.

Harvesting efficiency (combine harvesting machine) was calculated according to the following equation :(5)

$$THE = \frac{Y-L}{Y} X 100 \quad \text{............(5)}$$

Where:

THE is harvesting efficiency (%); Y is total bulbs yield (ton/fed); and letter (L) refers to total bulbs losses (ton/fed) and equal the total sum of unharvested onion bulbs (ton/fed), U and total damage (ton/fed), D.

Field efficiency (F.E.) is ratio of actual field capacity to theoretical field capacity expressed in percent as follows equation (6):

Field efficiency (F.E.) = (A.F.C. / T.F.C.) x100 .... (6)

Where:

A.F.C. = actual field capacity, fed/h, and T.F.C. = theoretical field capacity, fed/h

The theoretical field capacity means number of feddans per hour estimated from the equation (7):

Theoretical field capacity= (W x S/ 4200),fed/h ... (7)

Where :

W is working width of share, m; and S is Average working forward speed, km/h

Effective field capacity= (1/Ta), fed/h..... (8)

Where

Ta is total time and equals the sum of T1+T2+T3; T1 is digging time, h; T2 is turning time, h; T3 is Adjustment time, h; and Ta= Actual time consumed to dig one feddans, h.

- Mathematical calculations concerning (Effective field capacity - Specific energy) were calculate .

Required power :

The following formula was used to estimate the engine power (Hunt,1995) :

$$Ep=[F.C(\frac{1}{3600})\times\rho E\times L.C.V\times427\times\eta THB\times\eta m\times\frac{1}{75}\times\frac{1}{1.36}].kw.................(9)$$

Where*;*

EP=engine power, kw; F.C=fuel consumption,(1/h); ρE=density of fuel,(kg/1),(for Gas oil =0.85), L.C.V=calorific value of fuel,(11.000k.cal/kg). ηTHB=Thermal efficiency of the engine,(35%for Diesel engine). 427= Thermo- mechanical equivalent, (kg.m/ k.cal).ηm=Mechanical efficiency of the engine,(80% for Diesel engine).

So, the energy can be calculated as following :

$$\textbf{Energy requirements}=\frac{power(kw)}{field\ capacity\ (fed/h)}\ldots\ldots\ldots\ldots..(10)$$

- Total costs determination

The variety of onion was Beheri (red) and the onion harvester head was pulled by a Goldoni tractor. The harvester was then operated at four forward speeds of 1.7, 2.4, 3.1 and 3.8 km/h and four blade angles of 13, 16, 20 and 25 degree in a split-split design with three replications. Each replication was a row with a length of 10 m. The effects of forward speed and blade angle on the quality performance of the machine was studied regarding to damages (light and heavy damages) and percentage of the harvested onions and comparing total costs with traditional harvesting method according to recent prices.

Nilsson (1972), Have (1991)and Hunt (1995),and expresses the total yearly fixed and variable costs as a function of machine capacity:

$$C=[\Psi\times\rho\times\theta+\frac{A\times U}{\theta\times FE}\times(r\times\rho\times\theta+L+\delta\times\theta)]/p\ldots\ldots..(11)$$

Where;

C: is the total yearly costs (LE/ton),Ψ:is a factor expressing depreciation and interest as a fraction of the purchase price,(1/year), ρ:is the purchase price per unit capacity (LE .h/ton), θ:is the machine capacity (ton/h), A: is the treated seasonal area (fed/year), U:is the expected crop yield (ton/fed), FE: is the field efficiency expressing the ratio between gross and theoretical capacity, r:is a factor expressing repair and maintenance costs as a fraction of purchase price,δ:is the fuel costs proportional to the capacity (LE/h),and pr: is process productivity (ton/year).

The hourly cost for harvesting operation was determined according to the local rental prices for machines in Agricultural Mechanization stations as follows:

$$\textbf{Operating cost}=\frac{harvesting\ cost,LE/h}{actual\ field\ capacity,fed/h}\ldots\ldots\ldots\ldots\ldots.(12)$$

The operating cost for the harvester was calculated as follows:

$$\textbf{Operating cost}=\frac{machine\ cost,LE/h}{feed\ rat,Mg/h}\ldots\ldots\ldots\ldots\ldots\ldots.(13)$$

The criterion cost=operating cost +bulbs losses cost, L.E./Mg (ton).

Principle of operation

The harvesting process begins at the end of the proposed onion beds. The harvester moves forward by a push force towards the onion bed. As it moves forward, the digger blade slices the soil at a depth below the onion bulbs and automatically lifting the soil mixing with onion bulbs to the conveyor directly. As the soil and onions passes through the conveyor, the soil drops to the ground in between the bars and the onion bulbs forward to the vibrator at back of the harvester leaving them exposed on top of the plots. The fabricated harvester was evaluated for digging of onion planted on the beds having 1.1 m width. Performance of the harvester was highly satisfactory for digging of the onion bulbs planted on beds of about 1.1 m width. The harvester was developed with an vibrator conveyor attached behind the harvester for cleaning, separation and easy collection of onion bulbs and a roller behind the harvester was provided for soil compaction for easy collection of bulbs.

The used measuring devices:

- **Speedometer:** A speedometer was used to measure the actual rotating speed.
- **A Digital balance: A** Digital balance (accuracy of 5g) was used to weigh the samples of onion bulb obtained from plots of replicates.
- **An electric oven:** A thermal oven was used for drying samples to estimate soil moisture content.
- **Supplementary tools:** Different workshop instruments were used to adjust, assemble and maintain the harvester components.
- **Cloth sheet:** A piece of cloth was used to collect the losses bulbs from the front chain and rear elevator.
- **Cores:** Apparatus consists of cores having sharp edge was used to measure soil moisture content and bulk density.

Data analysis: By split-split plot design, data collected from four replicates for all treatments were analyzed using a statistical computer program (CoStat) estimating ANOVA and determining regression analysis with the significance level at 0.05.

RESULTS AND DISCUSSION

Effect of the interaction between studied variables on the onion total losses

Figs. 4 show the effect of blade types, blade angles and digging depth under different speed ratios on onion total losses%. It is obvious that lowest results, of total losses 1.80 %, were obtained under blade angle 25^0 for scoopal blades and digging depth of 11 cm under speed ratio of 2.11. Meanwhile the highest result, of total losses of 16.91%, was obtained for flat blade and 13^0 blade angle with digging depth of 5 cm under speed ratio of 1.7.

The interaction between all studied parameters of blade angles, blade types, digging depth and speed ratios showed the lowest result of the total losses (1.8%) was obtained with blade angle of 250 for scoopal blades and digging depth of 11 cm under speed ratio of 2.11. While the highest result of total losses of 16.91 % was obtained for flat blade and 130 blade angle with digging depth of 5 cm under speed ratio of 1.7.

Statistical analysis of ANOVA for the obtained data showed a significant effect with the interaction between (depth x speed ratio) as $p<0.05$. However, there was a non-significant effect between (angle x speed ratio) and also, with the interaction between (angle x depth) on total losses throughout all treatments ($p>0.05$) where R2 = 0.75; Coefficient of Variation = 22.31% and the LSD 0.05 = 0.52, 0.45 and 0.52 for angle, depth and speed ratio, respectively.

Effect of the interaction between studied variables on the onion digging efficiency

Fig. (5) show the effect of blade angles, blade types and digging depth under different speed ratios on the onion digging efficiency. The best results, of digging efficiency 98.92 % was obtained under blade angle of 250 for scoopal blades and digging depth of 11 cm under speed ratio of 2.11 while the lowest result, of digging efficiency 88.16 was obtained for flat blade and 130 blade angle with digging depth of 5 cm under speed ratio of 1.7.

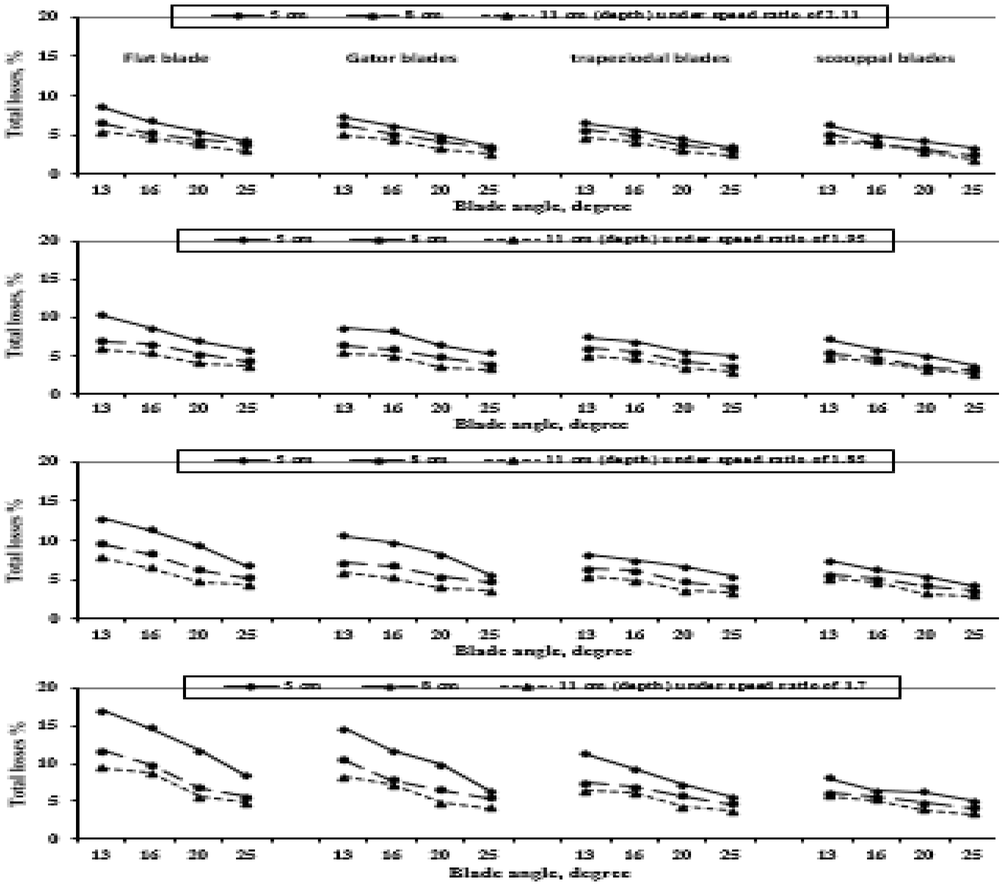

Fig. 4. Effect of type shape, blade angle and digging depth under different speed ratios on total losses, %

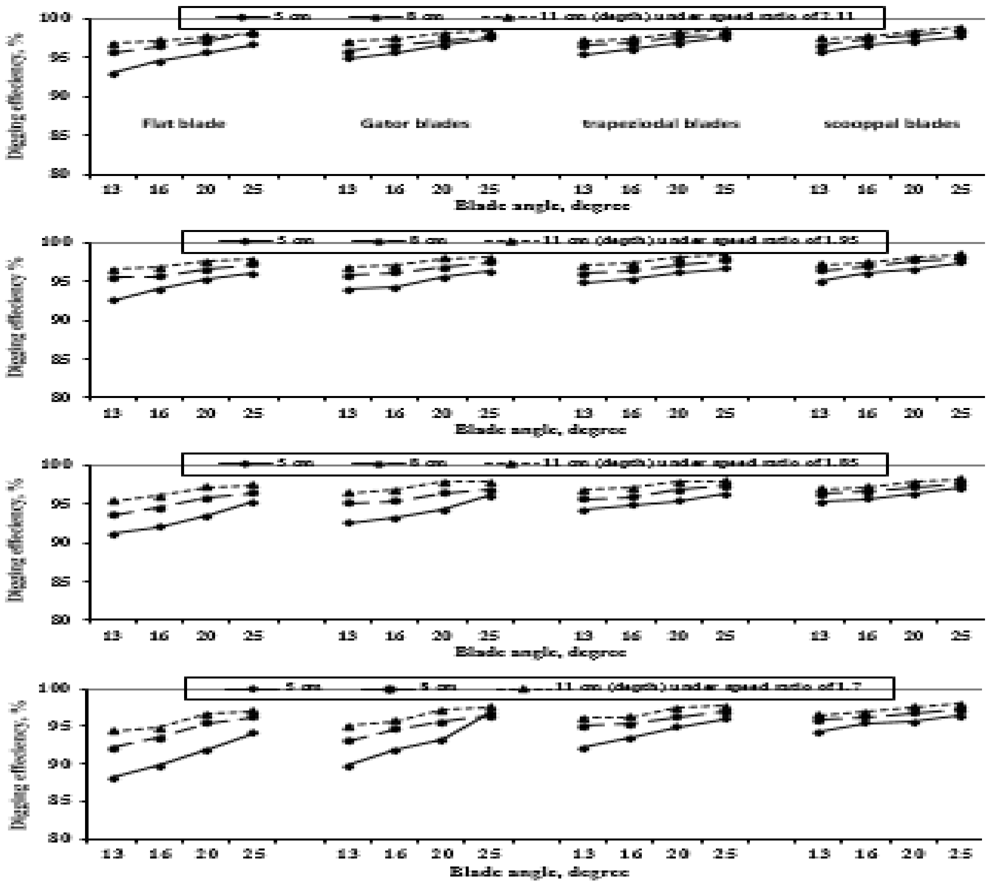

Fig. 5. Effect of blade type, blade angle and digging depth under different speed ratios on digging effeciency, %

The interaction between all studied parameters of blade angles, blade types, digging depth and speed ratios showed the best results of digging efficiency (98.92 %) was obtained under blade angle of 25^0 for scoopal blades and digging depth of 11 cm under speed ratio of 2.11. While the lowest result, of digging efficiency 88.16% was obtained for flat blade and 13^0 blade angle with digging depth of 5 cm under speed ratio of 1.7.

Statistical analysis of ANOVA for the obtained data showed a significant effect with the interaction between (angle x depth) as $p<0.05$, but there was a non-significant effect between (angle x speed ratio) and also, with the interaction between (depth x speed ratio) on digging efficiency throughout all treatments ($p>0.05$) where R^2 = 0.77; Coefficient of Variation = 0.95% and the LSD 0.05 = 0.36, 0.31 and 0.36 for angle, depth and speed ratio, respectively.

Effect of the interaction between studied variables on the onion cleaning efficiency

Fig. (6) show the effect of blade angles, blade types and digging depth under different speed ratios on the onion cleaning efficiency. It is clear that the best results of cleaning efficiency (96.95 %) was obtained under blade angle of 25^0 for scoopal blades and digging depth of 11 cm under speed ratio of 1.7. While, the lowest result of cleaning efficiency (82.30%) was obtained for flat blade and 13^0 blade angle with digging depth of 11 cm under speed ratio of 2.11.

The interaction between all studied parameters of blade angles, blade types, digging depth and speed ratios showed the best results, of cleaning efficiency of 96.95 %, was obtained for blade angle of 25^0 for scoopal blades and digging depth of 11 cm under speed ratio of 1.7. While the lowest result, of cleaning efficiency of 82.30, was obtained for flat blade and 13^0 blade angle with digging depth of 11 cm under speed ratio of 2.11.

Statistical analysis of ANOVA for the obtained data showed a high significant effect with the interaction between (angle x speed ratio) as $p<0.05$. However, there was a non-significant effect between (angle x depth) and also, with the interaction between (depth x speed ratio) on cleaning efficiency throughout all treatments ($p>0.05$) where R^2 = 0.89; Coefficient of Variation = 1.54% and the LSD 0.05 = 0.57, 0.49 and 0.57 for angle, depth and speed ratio, respectively.

Effect of the interaction between studied variables on the harvesting efficiency

Figs. 7 show the effect of blade angles, blade types and digging depth under different speed ratios on harvesting efficiency. The best result, of harvesting efficiency 98.20 %, was obtained for scoopal blades and angle of 25^0 and digging depth of 11 cm under speed ratio of 2.11. While the lowest result of harvesting efficiency of 83.09 was obtained with flat blade and 13^0 blade angles with digging depth of 5 cm under speed ratio of 1.7.

It could be concluded that the interaction between all studied parameters of blade angles, blade types, digging depth and speed ratios showed the best results of harvesting efficiency (98.20 %) was obtained for scoopal blades and angle of 25^0 and digging depth of 11 cm under speed ratio of 2.11. While the lowest result, of harvesting efficiency 83.09, was obtained for flat blade and 13^0 blade angle with digging depth of 5 cm under speed ratio of 1.7.

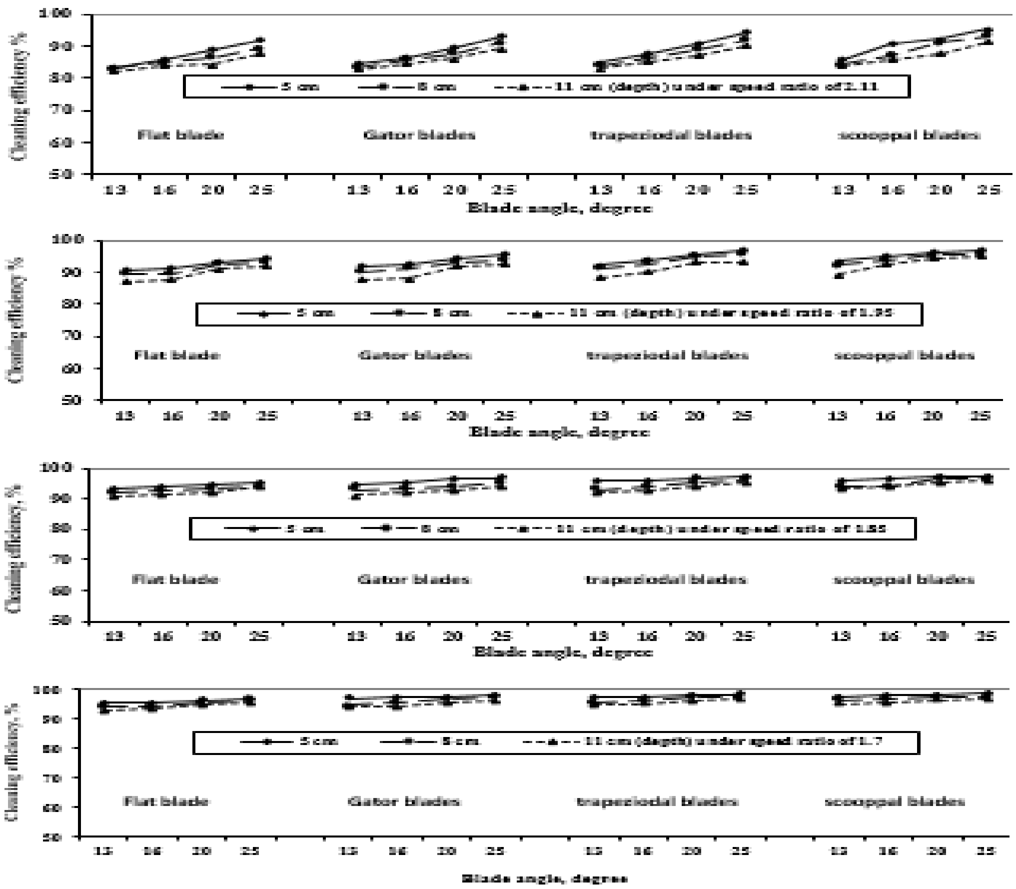

Fig. 6. Effect of blade type, blade angle and different digging depth under different speed ratios on cleaning efficiency

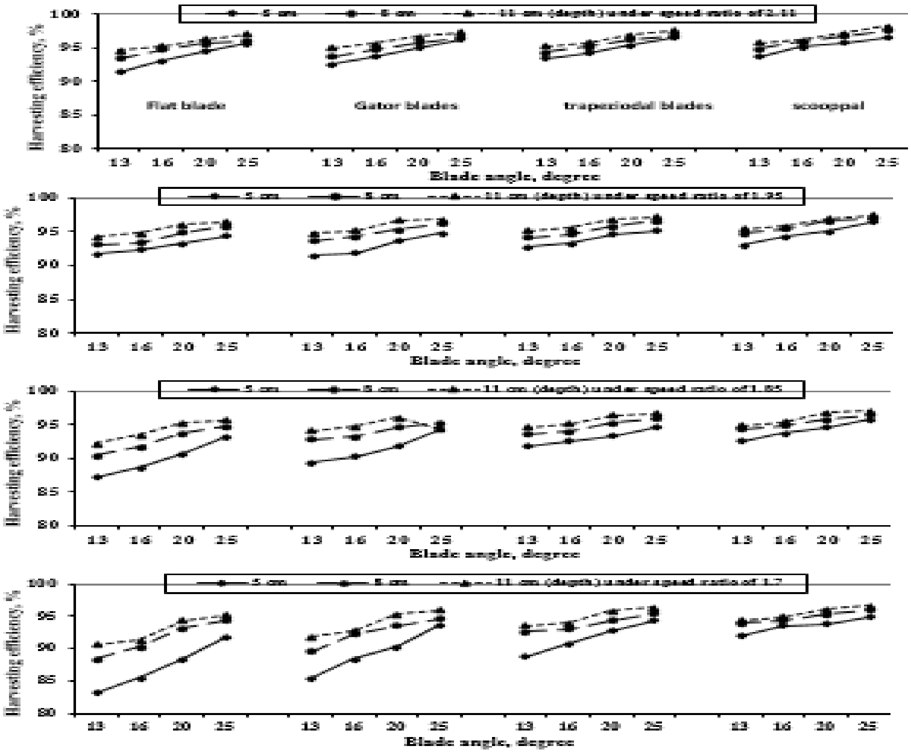

Fig. 7. Effect of blade type, blade angle and different digging depth under different speed ratios on harvesting efficiency, %

Statistical analysis of ANOVA of the obtained data showed a significant effect with the interaction between (depth x speed ratio) as $p<0.05$. However, there was a non-significant effect between (angle x depth) and also, with the interaction between (angle x speed ratio) on harvesting efficiency throughout all treatments ($p>0.05$) where $R^2 = 0.75$; Coefficient of Variation = 1.36% and the LSD 0.05 = 0.52, 0.45 and 0.52 for angle, depth and speed ratio, respectively.

Effect of the interaction between studied variables on the field efficiency

Figs. 8 show the effect of blade angles, blade types and digging depth under different speed ratios on onion field efficiency. Generally, the best result of field efficiency of 89.3 % was obtained under blade angle of 20^0 for gator blades and digging depth of 5 cm under speed ratio of 2.11.

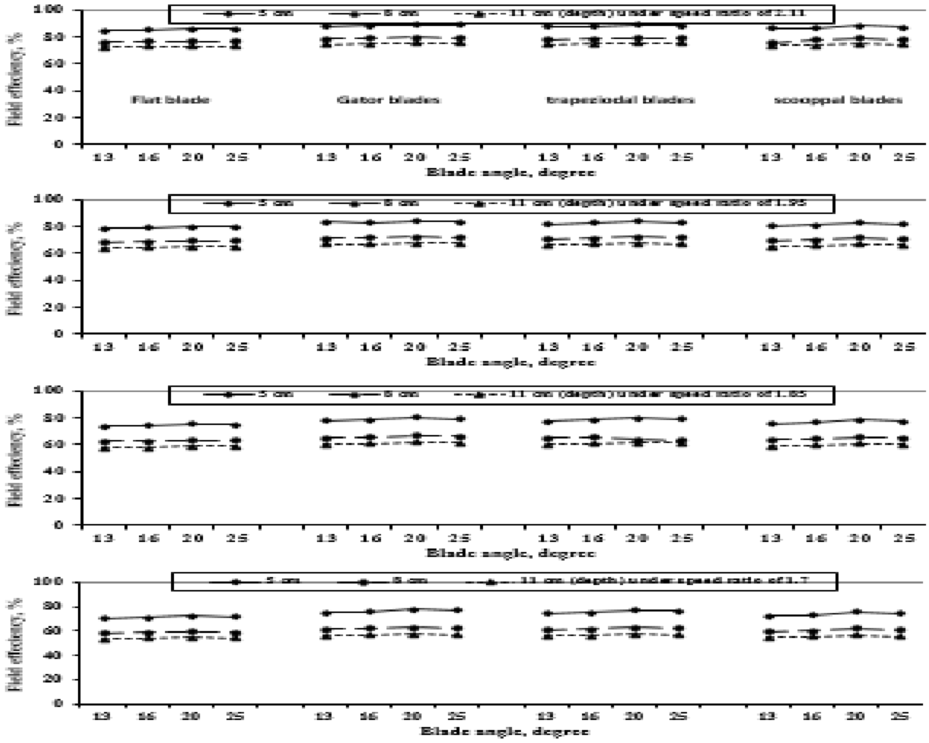

Fig. 8. Effect of blade type, blade angle and different digging depth under different speed ratios on field effeciency

While the lowest result of field efficiency (53.3) was obtained for flat blade and 13^0 blade angle with digging depth of 11 cm under speed ratio of 1.7.

The interaction between all studied parameters of blade angles, blade types, digging depth and speed ratios showed the best results of field efficiency (89.3 %) was obtained with blade angle of 20^0 for gator blades and digging depth of 5 cm under speed ratio of 2.11. However, the lowest result of field efficiency (53.3) was obtained for flat blade and 13^0 blade angle with digging depth of 11 cm under speed ratio of 1.7.

Statistical analysis of ANOVA of the obtained data showed a significant effect with the interaction between (depth x speed ratio) as $p<0.05$. However, there was a non-significant effect between (angle x depth) and also, with the interaction between (angle x speed ratio) on field efficiency throughout all treatments ($p>0.05$) where R^2 = 0.92; Coefficient of Variation = 3.97% and the LSD 0.05 = 0.011, 0.09 and 0.011 for angle, depth and speed ratio, respectively.

Effect of the interaction between studied variables on the effective field capacity, fed./h.

Figs 9 show the effect of blade angles, blade types and digging depth under different speed ratios on the effective field capacity. The best results, of field capacity 0.698 fed/h., was obtained under blade angle of 25^0 for gator blades and digging depth of 5 cm under speed ratio of 1.7. Meanwhile, the lowest result of field capacity (0.290 fed/h.) was obtained for flat blade and 13^0 blade angle with digging depth of 11 cm under speed ratio of 2.11.

Generally, the interaction between all studied parameters of blade angles, blade types, digging depth and speed ratios showed the best results of field capacity (0.698 fed/h.) was obtained under blade angle of 25^0 for gator blades and digging depth of 5 cm under speed ratio of 1.7. While the lowest result of field capacity (0.290 fed/h.) was obtained for flat blade and 13^0 blade angle with digging depth of 11 cm under speed ratio of 2.11.

Statistical analysis of ANOVA for the obtained data showed a non-significant effect between all variables under study on effective field capacity throughout all treatments ($p>0.05$) where R^2 = 0.27; Coefficient of Variation = 47.79% and the LSD 0.05 = 0.089, 0.077 and 0.089 for angle, depth and speed ratio, respectively.

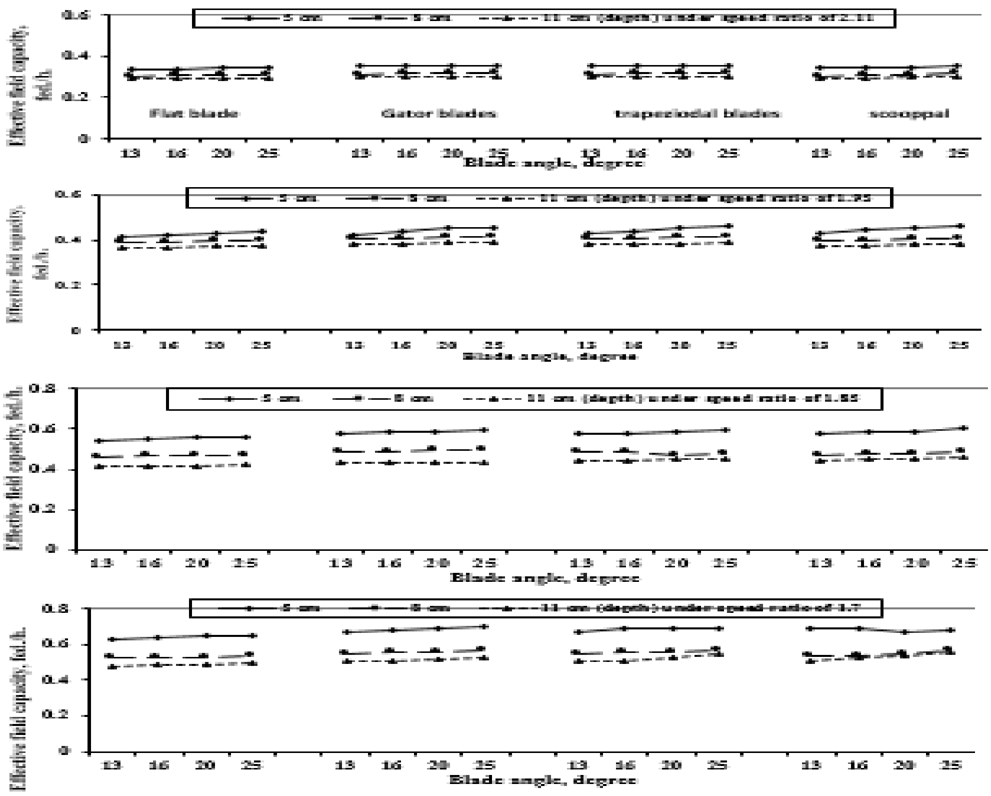

Fig. 9.Effect of blade type, blade angle and different digging depth under different speed ratios on effective field capacity, fed./h.

Effect of the interaction between studied variables on the specific energy, kW.h/fed.

Figs 10 show the effect of blade angles, blade types and digging depth under different speed ratios on specific energy. The lowest result of specific energy (14.67 kW.h/fed.) was obtained under blade angle of 13^0 for scoopal blades and digging depth of 5 cm under speed ratio of 1.7. Meanwhile, the highest result, of specific energy 34.60 kW.h/fed., was obtained for flat blade and 25^0 blade angle with digging depth of 11 cm under speed ratio of 1.7.

The interaction between all studied parameters of blade angles, blade types, digging depth and speed ratios showed the lowest result, of specific energy 14.67 kW.h/fed., was obtained under blade angle of 13^0 for scoopal blades and digging depth of 5 cm under speed ratio of 1.7 However, the highest result of specific energy (34.60 kW.h/fed.) was obtained for flat blade and 25^0 blade angle with digging depth of 11 cm under speed ratio of 1.7.

Statistical analysis of ANOVA for the obtained data showed a significant effect with the interaction between (depth x speed ratio) and a high significant effect with the interaction between (angle x depth) as $p<0.05$. However, there was a non-significant effect between (angle x speed ratio) on power requirements throughout all treatments ($p>0.05$) where R^2 = 0.92; Coefficient of Variation = 7.44% and the LSD 0.05 = 0.75, 0.65 and 0.75 for angle, depth and speed ratio, respectively.

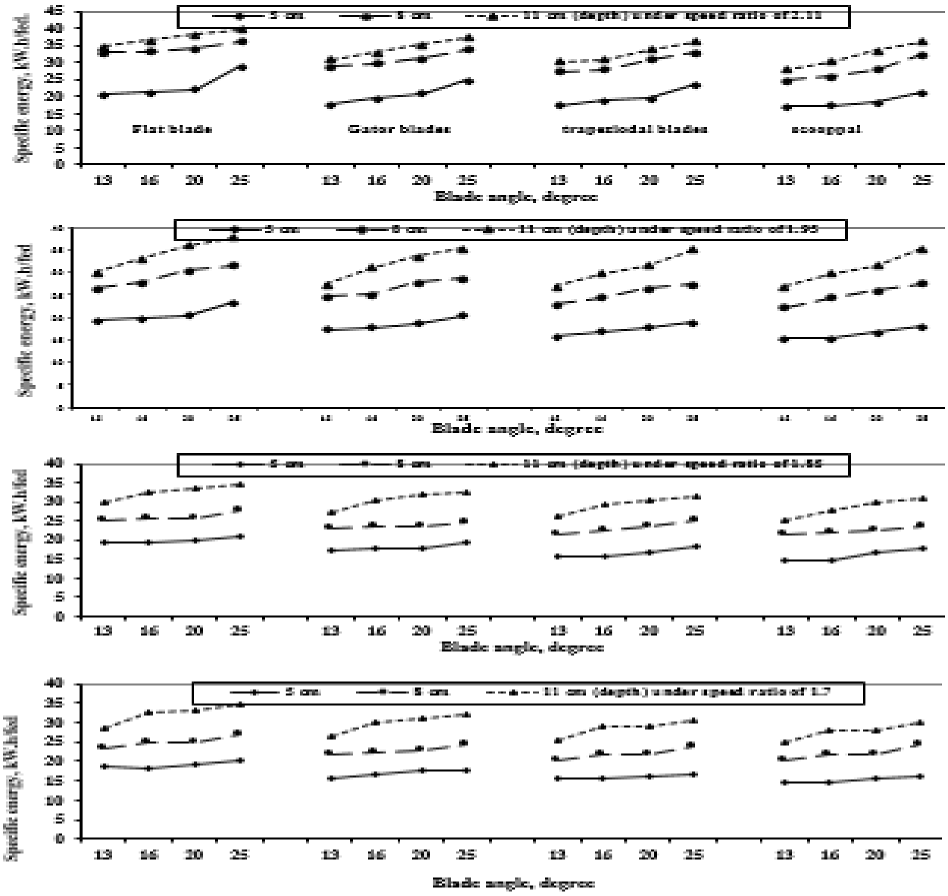

Fig. 10. Effect of blade type, blade angle and different digging depth under different speed ratios on specific energy.

Cost Analysis: The cost of harvesting onions using the machine was analyzed considering the actual costs of the tractor, onion harvester, fuel, and labor. Other values used in agricultural machinery cost determination according to Hunt (2001). The total costs was estimated according to the recent hiring prices and laborers wages and it was found that the total costs decreased by 62% comparing to traditional onion harvesting methods.

CONCLUSION

The results could be summarizes in the following points:

- Scoopal blades showed the lowest results for blade damage, brushing losses, conveying losses, un-lifted bulbs ratio, and consequently total losses. Also, it showed the best results for digging efficiency, cleaning efficiency, harvesting efficiency, and specific energy. While gator blades showed the best results for effective field capacity and field efficiency.
- A blade angle of 25^0 showed the best results for blade damage, brushing losses, conveying losses, un-lifted bulbs ratio, total damage, digging efficiency, cleaning efficiency, harvesting efficiency and effective field capacity. While, blade angle of 20^0 showed the best results for field efficiency.
- Harvesting depth (digging depth) of 11 cm showed the best results for total losses, digging efficiency, cleaning efficiency, harvesting efficiency while, digging depth of 5 cm showed the best results for field efficiency, effective field capacity.
- Speed ratio of 2.11 showed the best results for total losses, digging efficiency, harvesting efficiency and field efficiency. On the other hand speed ratio of 1.7 showed the best results for effective field capacity, cleaning efficiency and specific energy.

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تطوير وحدة لحصاد محصول البصل ذات جودة تصديرية عالية

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الملخص

اهتمت تلك الدراسة بتطوير وحدة آلية لحصاد محصول البصل ذات جودة تصديرية عالية، هذه الآلة تكون مجرورة خلف الجرار ، وتم اختبار أهم عوامل جودة أدوات وحدة الحصاد من خلال تشغيل أربعة أنواع مختلفة من سكاكين الحصاد تحت أربعة زوايا ميل بأعماق ثلاثة مختلفة أثناء الحصاد، كما تم اختيار أربعة نسب مختلفة في السرعة بين سرعة تقدم الجرار وسرعة حصيرة النقل وتأثيرهم على المحصول الكلى من خلال تقييم نسبة التالف الكلي، وتشمل (تالف بسبب كلا من السكاكين ، فرشاة الدفع والتنظيف، وحصيرة النقل ، وكذلك نسبة الأبصال الغير مرفوعة). كما تم حساب الكفاءات (كفاءة كلا من التقليع ، التنظيف ، والحصاد ، الكفاءة الحقلية). بالإضافة إلى تقدير السعة الحقلية الفعلية وحساب الطاقة النوعية وكذلك حساب التكاليف الكلية ، وقد أجريت تلك الدراسة بمحطة البحوث الزراعية بالسرو بمحافظة دمياط خلال موسم حصاد البصل 2020-2021. وقد أوضحت النتائج أن تشغيل السكاكين ذات شكل المغرفة تحت زوايا ميل 25^{5} بعمق 11 سم ونسبة سرعة 2.11 أفضل النتائج من حيث تقليل نسبة التالف الكلي ، وزيادة نسبة البصيلات المرفوعة ، وكفاءة كلا من التقليع ، الرفع ، التنظيف ، الحصاد ، استهلاك الوقود ، ومتطلبات الطاقة والطاقة النوعية. بالإضافة إلى أن بعض الأدوات كانت لها أفضل النتائج في تأثيرها على الناتج مثل الشفرات التمساحية وعمق الحفر البالغة 5 سم من حيث السعة الحقلية والكفاءة الحقلية ، كما أن نسبة السرعة البالغة 1.7أعطت أفضل النتائج فيما يتعلق بالسعة الحقلية وكفاءة التنظيف والطاقة النوعية وزاوية الميل البالغة 20^{5} للكفاءة الحقلية.