THE MECHANICAL PERFORMANCE OF SUGAR BEET TOPPER

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Abstract

The objective of this study was to evaluate a sugar beet topping machine. Field experiments were conducted at Sakha Agricultural Research Station, Sugar Beet Crop Res. Dept., Kafr EL-Sheikh Governorate during the two winter seasons of 2004 and 2005 using sugar beet variety (Farida). Experiments were carried out using sugar beet topping machine to determine the effect of forward speed, flail speed and topping height on topper performance (over topping, under topping, untopped, broken beet and topping performance), power, energy requirements and topping cost.

The results showed that by increasing the forward speed from (1.8 to 5.0 Km/h) tends to increase the over topping from (2.50 to 3.0%), under topping (2.40 to 4.20%), untopped (2.60 to 4.0%), broken beet (6.50 to 9.90%), effective filed capacity (2..40 to 3.80 fed/h) and power requirements (14.5 to 18.0 kW).The results also showed that by increasing the forward speed from (1.8 to 5.0 km/h) leads to decrease the topping efficiency (95.0 to 92.0%), energy requirements(6.04 to 4.74 kW.h/fed.) and topping cost (20.8 to 13.3 L.E/fed.) at topping height of 5 cm. Also, the flail speeds and topping height of 3 cm take the same above-mentioned trend.

INTRODUCTION

Sugar beet is one of the most important crops in Egypt as a source of sugar, also for fodder and organic matter for the soil. The Egyptian government is planning to expand the grown area of sugar beet, because the sugar beet grows under a wide variety of soil and climatic conditions, especially in newly reclaimed lands. The total area of sugar beet during 1982 - 2002 has increased from 17.0 to 190 thousand feddan. The annual consumption of population from sugar is about 1.70 million tons. Therefore, only 72.94% self sufficiency is achieved and about 27.06 % has to be imported *(Ag. Extension Issue, 2002).* However, the problems of harvest mechanization for sugar beet crop start with the topping of beet crowns since it is a very difficult operation. Therefore, the nature of cutting process, the energy requirements of sugar beet topping and the cutting losses should be evaluated and studied.

Moore, et al. (1979) reported that the mean cutting force per unit blade length in topping sugar beet varies for knives of different edge profile. For asymmetric wedge knives, the cutting force increases as the wedge angle increases. For wires and semi-cylindrical edge knives the cutting force increases as the diameter of the edge increases.

Kepner, et al. (1982) mentioned that the basic operations performed in mechanical harvesting of sugar beet are: a) rotary flailing to remove top growth or cutting off the unwanted top portion of the beets at the desired height, b) appropriate disposition of tops to prevent interference with other steps in the harvesting operation, d) elevating the beets and separating them from clods and other foreign materials, and e) deposition the cleaned beets in a truck or trailer or in a tank on the harvester.

Tayel, et al. (1988) mentioned that the cutting force was directly proportional to the diameter of the root. On the other hand, the shearing force was greatly affected by the thickness of the sheared cut layer. The roots were not completely cut at thick layers especially at lower knife speed. Therefore, a reasonably random measurement of the root diameter before mechanical harvesting of sugar beet is highly recommended in order to get a right estimate of knife speed for root topping and reduce the mechanical damage of root. The knife speed should be greater than 2.8 m/s.

O,Dogherty (1986_a) indicated that data obtained from field experiments showed large variations in under and overtopping with the total of two sources of error ranging from 6 to 14% or more. Also, the effect of increasing the harvester speed up to 9.7km/h was studied. The result showed an increasing in overtopping with speed, together with an increase in under topping for smaller root spacing.

O,Dogherty (1986_b) stated that greater precision is necessary for small beet, for example, an error of only 2.5mm can result 4% overtopping and 3.5 % under topping.

Mohamed (1998) mentioned that the percentage of topping efficiency is related to the percentage of untopped beet, which the percentage of untopped beet decreased by increasing the forward speed. The percentage of topping efficiency increased from (97.04, 99.16,100.0 to 100.2 %) by increasing forward speed from (3,4, 5 and 5.2km/h) respectively at hg-value of 2cm and feeler speed 90 r.p.m. similar speed were obtained at different test conditions.

El-Sahar and El-Salam (1998) stated that the angle of cutting blade penetration, alow angle of zero consumed lower energy (35 joule) with low cutting losses of 6%. A high angle of 14^{O}, on the other hand, consumed high energy (69 joule) with high cutting losses of 12.5%.

Abou-Shieshaa (2001) reported that the increment in forward and flail rotational speeds increases both broken beet and overtopping. The minimum value of overtopping and broken beet were 3.42 and 1.15%, respectively at forward speed of 1.83 km/h and flail speed of 8.36 m/s for mechanical planting and field chopper. Meanwhile, the percentage of under topped was 6.35 under the same conditions.

Khodeir (2002) illustrated the effect of forward speed, knife speed and planting methods on topping accuracy. He indicate that the forward speed increases from 1.6 to 3.2 km/h tends to decrease topping accuracy from 95.91 to 93.30, 95.04 to 92.52 and 93.75 to 92.38% for knife speed of 9.42,11.52 and 15.71 m/s (450,550and 750 r.p.m.), respectively.

Fathy (2004) manufactured combined machine to do all the harvesting operations of sugar beet roots (Lifting, topping and collecting). By increasing forward speed from 0.55, 0.69, 0.86 and 1.06 m/s, decreasing the topping efficiency from 97.20, 96.56, 95.77 and 94.50 %, respectively, at soil moisture content of 22.93 %. Also, increasing forward speed tends to increase the total damaged roots from 4.51,4.80,5.10 and 5.40 %, respectively.

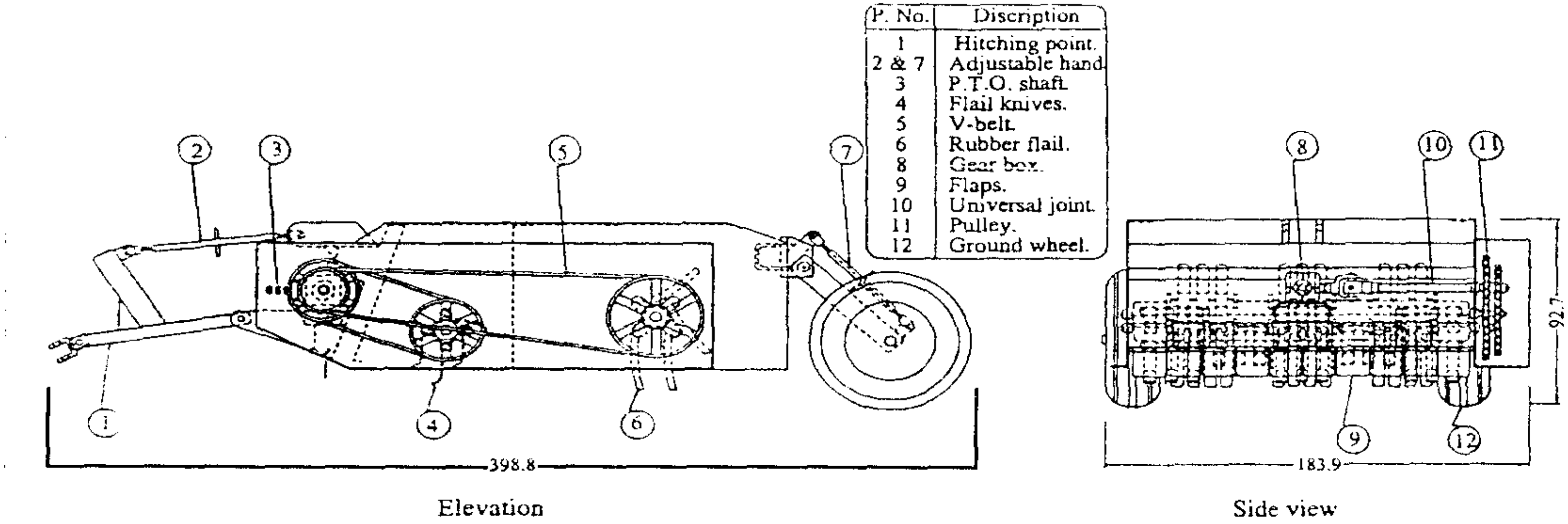
Hussein *et al.* (2004) reported that the optimum parameters for chopping sugar beet tops into silage, were cutting speed 23.55 m/s and knife clearance 1.5 mm at moisture content 60% which gave less power required 8.85 kW, less specific energy 3.54 kW.h/Mg and highest values of output 2.50 Mg/h, for flywheel cutter heads.The objective of this study was to evaluate the performance of asugar beet topping machine.

MATERIALS AND METHODS

Field experiments were conducted at Sakha Agricultural Research Station, Sugar Beet Crop Res. Dept., Kafer El-Sheikh Governorate during two winter seasons of 2004 and 2005 in area of about 2 feddans. An American made planter type Powell (12 MX muttiflex model), mounted used with seed rate of about 2.5 kg/fed. The planting speed with about 5km/h, number of row 6, empty mass 790 kg and width 430cm. Spacing between seeds, 20cm number of seeds/ cell 2to3, capacity of seed hopper 4 liters. The variety of sugar beet seeds were used in the present study (Farida).

Material

The topper machine USA made, was used in the present study namely: flail shredder number of knives rotating 6 in vertical planes parallel with the direction of travel. The knives are attached through a pivot axis in machine Fig.1. A tractor model Nasr 60 hp (44.77kw) was used to operate the topping machine, 6 cylinders and Diesel engine.



P. No.	Discription
1	Hitching point.
2 & 7	Adjustable hand.
3	P.T.O. shaft.
4	Flail knives.
5	V-belt.
6	Rubber flail.
8	Gear box.
9	Flaps.
10	Universal joint.
11	Pulley.
12	Ground wheel.

Fig. 1 : Main parts of flail shredder machine.

Miscellaneous equipment.

a) Stop watches for measuring the time for each travel distance

b) Sighting poles.

c) Measuring tap (30m long) for measuring the travel distance.

d) Tachometer for measuring the rotation speed, rpm.

e) Digital venire for measuring diameter of root and leafs.

f) Balance (used to weigh the beet tubers)

g) Calibrated cylinder for measuring fuel consumption.

Measurements:

The physical properties of sugar beet plants were root length 24.0cm, root diameter 12.0 cm, root width 6.2 cm, root volume 1700 cm^3, root mass 1600g, leaves mass 650g and height of leaf 41.2 cm.

Field experiments were carried out to evaluate the following:

Correct topped beet, %, under topped, overtopped, untopped, broken beet, %, topping efficiency, %, effective field capacity, fed/h, power requirements, kW, energy requirements, kW.h/fed and cost of topping operation.

Field experiments were carried out by using four forward speed 1.8,2.9,3.6 and 5.0 km/h, three flail speed of 8.51,12.0 and 15.5m/s and two topping heights 3 and 5cm.

Determination of fuel consumption rate:

Fuel consumption per unit time Fc was determined by measuring the volume of fuel consumed during topping operation.

Power requirement:

The fuel consumption was converted to power by using the following equation (Embaby, 1985):

$$P_{fe} = \frac{H_g \times M_f}{3600} \times \zeta_{th} \times \zeta_m \quad ,\text{kw} \;\ldots\ldots\; H_{q = G\,\delta\,/\,3600} \ldots\ldots \quad (1)$$

$$M_f = Q_r \times \delta_r \quad \ldots\ldots \quad (2)$$

$$P_{fe} = 3.32 \times Q_r \quad \ldots\ldots 3)$$

Where:

P_{fe} = Fuel equivalent power, kW;

H_g = Gross heating value of fuel, kJ/Kg = 45430kJ/kg, (Gearing,1992);

M_f = Fuel consumption rate Kg/h;

Q_r = Fuel consumption rate L/h;

δ_r = Fuel density, kg/L, (=0.823kg/L);

ζ_{th} = Thermal efficiency of engine, 40%, and

ζ_m = Mechanical efficiency of engine, 80%.

Energy requirement:

Energy required for operating the topping machine was calculated according to the following equation: -

$$\text{Energy requirements} = \frac{\textit{Power requirement,}}{\textit{Actual field capacity, fed/h}} \textit{ kw.h/ fed} \quad \text{.................(4)}$$

Determination of field efficiency:

a) The effective field capacity was calculated as follows:

$$\text{E.F.C.} = (T_l)^{-1}, \text{ fed/h.} \quad \text{.......... (5)}$$

T_l = effective total time of topping operation in hour per feddan.

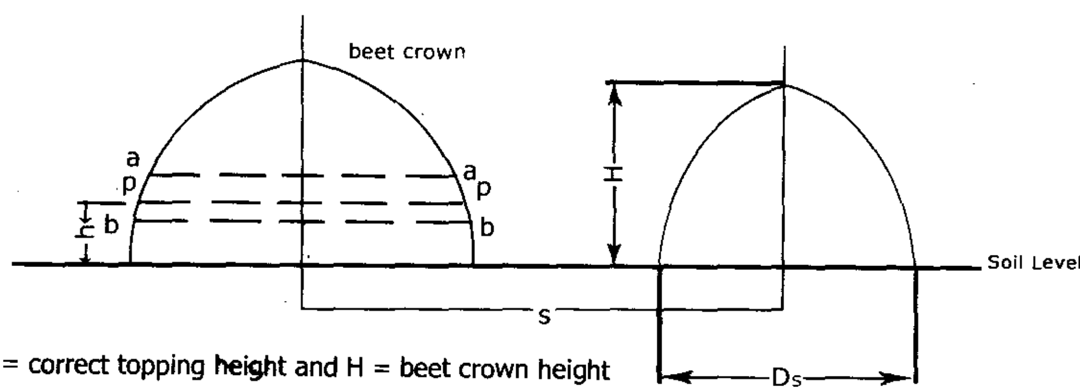
b) The field efficiency was calculated by using the following formula:

$$S_f = \frac{\textit{E.F.C.}}{\textit{Theoretical field capacity}} \times 100,\% \quad \text{.......... (6)}$$

Topper performance:

In field experiments with sugar beet topper, correct topped beet, under topped beet, overtopped beet, untopped beet, broken beet and topping efficiency were assessed as percent to be indicator for the topper performance.

A beet is shown at Fig.2 with the correct topping plane drawn on the assumption that the beet is horizontal and just below the lowest leaf scar. If the cut was made in the plane (p-p), the beet will be correctly topped, if the beet was cut in the plane (a-a), the beet will be under topped and if it was cut at the plane (b-b), it will be overtopped. During the experimental work, the performance of topper assessed by taking randomly selected 30m of work length, lifting the beet and collecting the tops. So under or overtopped can be estimated easily.



h = correct topping height and H = beet crown height

Fig. 2. Critical parameters of a beet crown stand showing correct topping plane (p-p), the plane for an undertopped crown (a-a) and an overtopped crown (b-b).

The percentage of the items which are used to control topper performance, can be calculated as following:

Correct topped beet (%) = $\frac{No.of\ correct\quad topped\,beet}{total\ No.of\ topped\,beet}\times 100$ .... (7)

Over topped beet (%) = $\frac{No.of\ over\quad topped\,beet}{total\ No.of\ topped\,beet}\times 100$ .... (8)

Under topped beet (%) = $\frac{No.of\ under\quad topped\,beet}{total\ No.of\ topped\,beet}\times 100$ .... (9)

Untopped beet (%) = $\frac{No.of\ untopped\,beet}{total\,No.of\ topped\,beet}\times 100$ .... (10)

Broken beet (%) = $\frac{No.of\ broken\,beet}{total\,No.of\ beet}\times 100$ .... (11)

Topping efficiency (%) = 100 – (untopped beet,(%) ....(12)

Topping cost:

Cost of topping per unit area (C), L.E/fed was calculated is based on the following formula by **EL-Awady (1987).**

C = $\frac{P}{h}\left(\frac{1}{a}+\frac{i}{z}+t+r\right)+\left(0.9\,w\times f\times u\right)+b,\quad L.E/h$ .... (13)

Where:

P = estimation price of machine, L.E;

h = estimation yearly hours of operation, h ;

a = life expectancy of the machine in years ;

i = annual interest rate, % ;

t = annual taxes and over heads, % ;

r = annual repairs and maintenance rate, % ;

0.9 = a correction factor for rated load ratio and lubrication;

w = engine power, kW ;

f = specific fuel consumption, L/kW.h ;

u = fuel price, L.E/L and

b = hourly labour wage, L.E/h.

RESULTS AND DISCUSSION

Topper performance:

a) Effect of forward speed and flail speed on overtopping beet percentage at topping heights of 3 and 5cm (Fig. 3).

It can be noticed that forward speed increase from 1.8 to 5.0 km/h leads to increasing over topping percentage from 2.50 to 3.00,2.60 to 3.20 and 2.80 to 3.40%, for flail speed of 8.51,12.00and 15.50m/s at topping height of 3cm, respectively for season 2004. Also, increase over topping percentage from 2.65 to 3.15, 2.76 to 3.36 and 2.97 to 3.57% at topping height of 3cm for season 2005, respectively. In the same manner, the same increase in forward speeds increases the percentage of overtopping from 2.30 to 2.80,2.50to 3.00 and 2.80 to 3.20%, at the same above mentioned flail speeds at topping height of 5cm, respectively for season 2004. Also, increase over topping percentage from 2.45 to 2.95, 2.66 to 3.16 and 2.97 to 3.37 % at topping height of 5cm for season 2005, respectively. Meanwhile, the flail speed increase tends to increase overtopping percentage. These tends may be due to the difficulty of keeping the topping machine adjusted at a constant height during high speeds (khodeir 2002).

b) Effect of forward speed and flail speed on under topping at topping percentage height of 3 and 5cm (Fig.4).

It can be said that by increasing the forward speed from 1.8 to 5.0 km/h tends to increase the percentage of under topping beet from 1.90 to 4.0, 2.70 to 4.50 and 3.60 to 4.90% for flail speed of 8.51, 12.00 and 15.50 m/s at topping height of 3cm, respectively for season 2004. Also, increase over topping percentage from 2.0 to 4.1, 2.8 to 4.6 and 3.7 to 5.0 % at topping height 3cm for season 2005, respectively. However, the same tendency was obtained whereas, the same increase in forward speed increases the percentage of under topping from 1.70 to 3.60, 2.40 to 4.20 and 3.40 to 4.80% at the same above mentioned flail speeds at topping height of 5cm, respectively for season 2004. Also, 1.8 to 3.7, 2.5 to 4.3 and 3.5 to 4.9 % at topping height of 5cm for season 2005, respectively. Meanwhile, the flail speed increase tends to increase overtopping percentage.

c) Effect of forward speed and flail speed on untopping beet at topping percentage heights of 3 and 5cm (Fig.5).

They indicate that by increasing the forward speed from 1.8 to 5.0 km/h tends to increase untopped beet from 3.00 to 4.60, 2.80 to 4.40 and 2.70 to 4.00% for fail speed of 8.51, 12.00 and 15.50 m/s at topping height of 3 cm, respectively for season2004. Also, increase over topping percentage from 3.2 to 4.8, 3.0 to 4.6 and 2.9 to 4.2 % at topping height of 3 cm for season 2005, respectively. On the other hand, the same increment of the forward speeds tends to increase untopped beet from 2.80 tom4.40, 2.60 to 4.00 and 2.50 to 3.80% at the same above mentioned flail speeds at topping height of 5cm, respectively for season 2004. Also, increase over topping percentage from 3.0 to 4.6, 2.8 to 4.2 and 2.7 to 4.0 % at topping height of 5cm for season 2005, respectively. In the same manner, the same increment of the flail speeds from 8.51, 12.00 and 15.50 m/s due to decrease untopped beet from 3.00 to 2.70, 3.90 to 3.20, 4.30 to 3.70 and 4.60 to 4.00% at the forward speeds of 1.8, 3.6 and 5.0 km/h at topping height 3 cm, respectively.

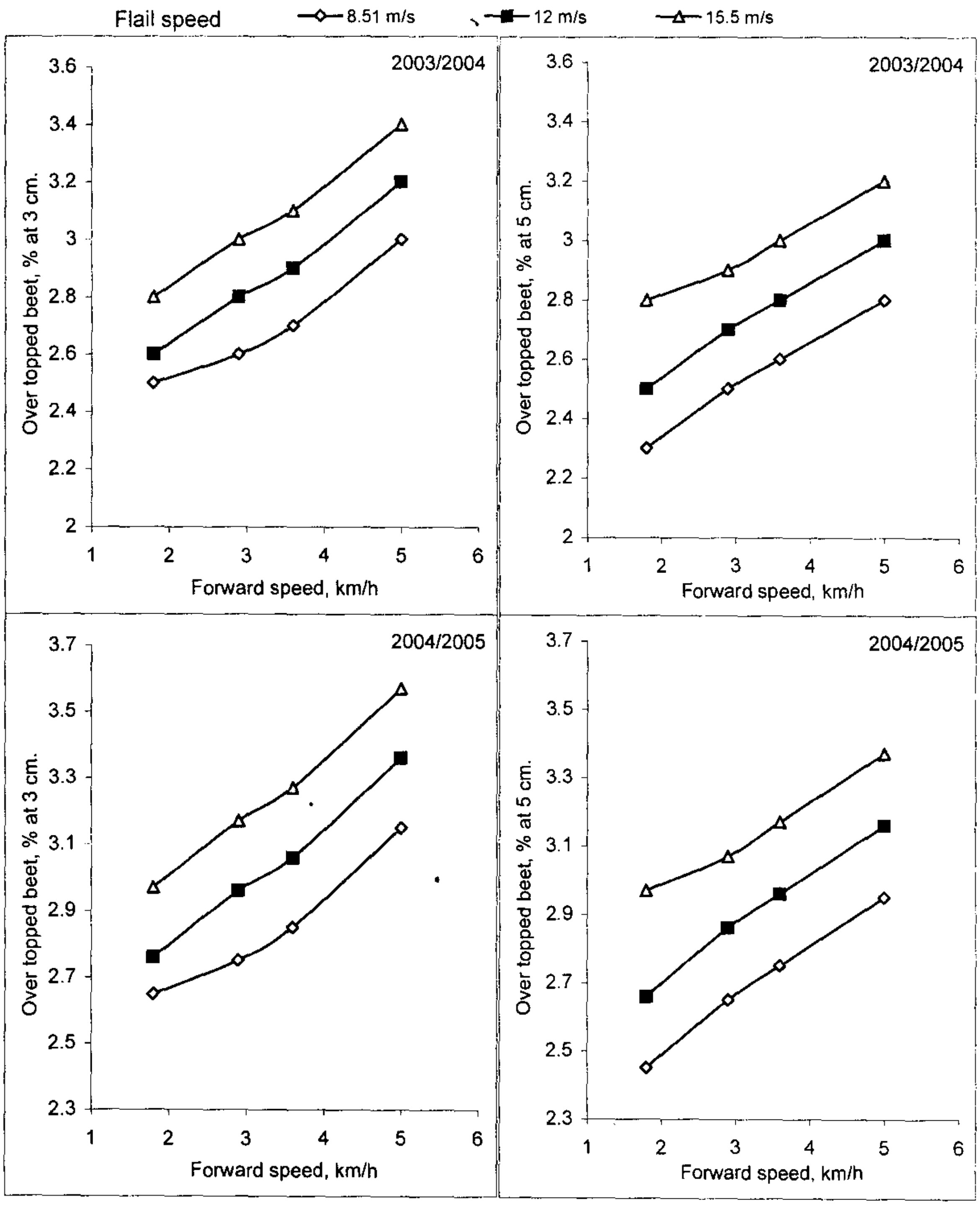


Fig. 3: Effect of forward speed and flail speed on over topped beet at topping height 3 and 5 cm for two seasons.

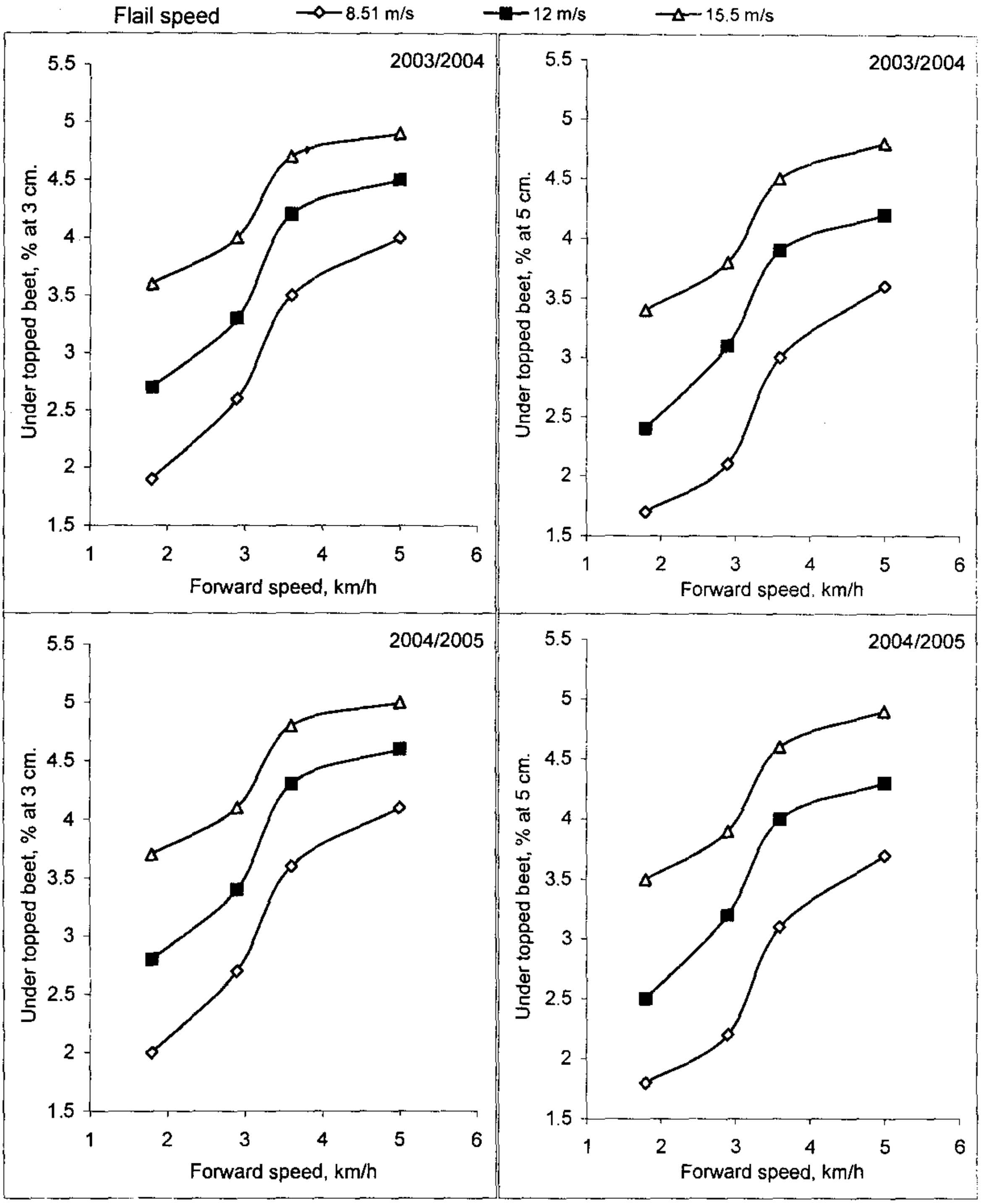


Fig. 4: Effect of forward speed and flail speed on under topped beet at topping height 3 and 5 cm for two seasons.

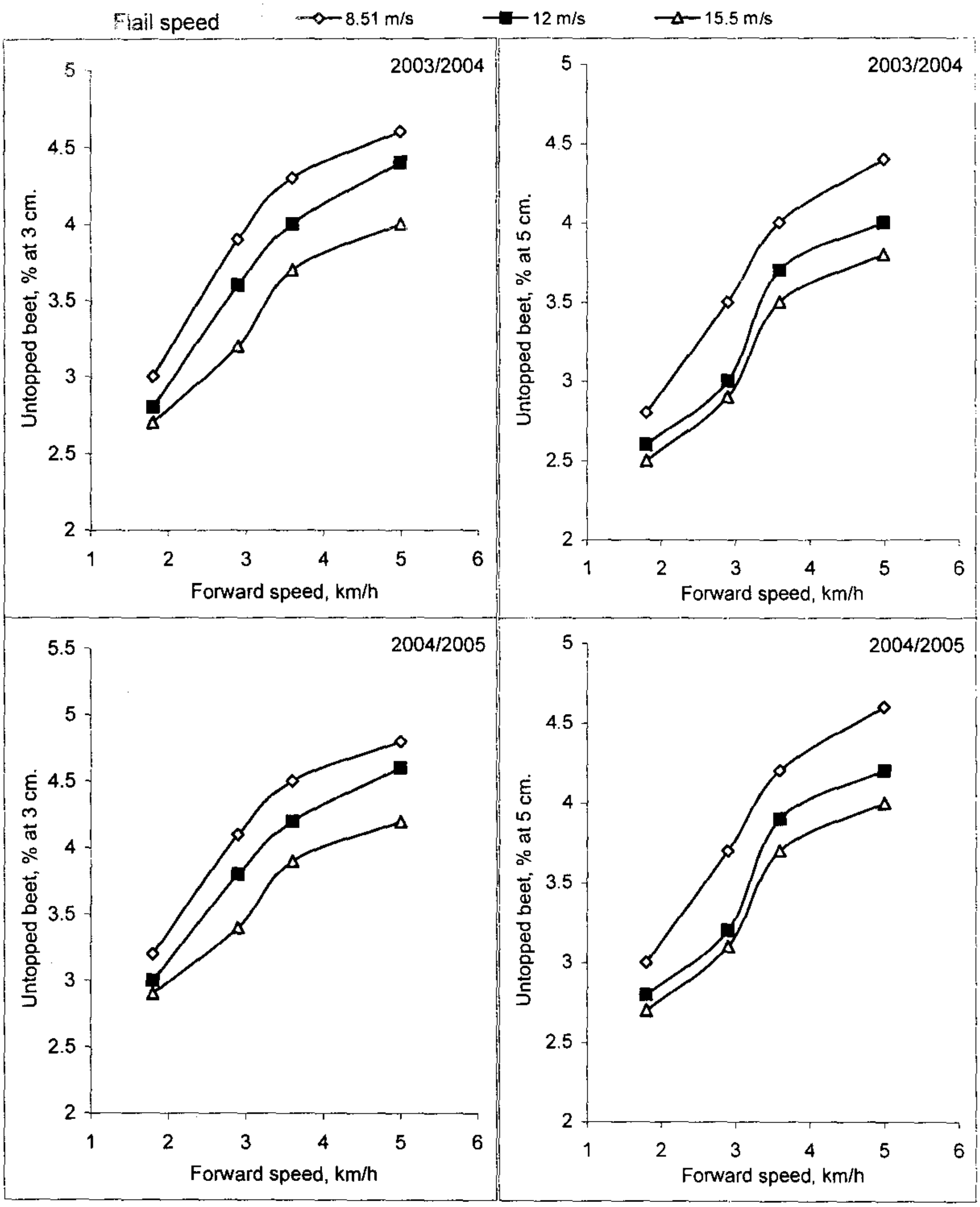


Fig. 5: Effect of forward speed and flail speed on untopped beet at topping height 3 and 5 cm for two seasons.

d) Effect of forward speed and flail speed on broken beet at topping percentage height of 3 and 5 cm (Fig.6).

Increasing the forward speed from 1.8 to 5.0 km/h increases the percentage of broken beet from 7.0 to 10.5, 8.5 to 11.3 and 9.3 to 12.0% for flail speed of 8.51, 12.00 and 15.50 m/s at topping height of 3 cm respectively for season 2004. Also, 8.0 to 11.5, 9.5 to 12.3 and 10.3 to 13.0 % at topping height of 3cm for season 2005, respectively. The forward speed increase from 1.8 to 5.0 km/h led to increase the percentage of broken beet percentage from 5.0 to 8.5, 6.5 to 9.9 and 7.5 to 11.3% at the same above mentioned flail speeds at topping height of 5cm, respectively for season 2004. Also, increase over topping percentage from 6.0 to 9.5, 7.5 to 10.9 and 8.5 to 12.3 % at topping height of 5cm for season 2005, respectively. On the other hand, the flail speed increase tends to increase broken beet percentage.

e) Effect of forward speed and flail speed on topping efficiency at topping percentage height of 3 and 5cm (Fig.7).

They indicate that the forward speed increase from 1.8 to 5.0 km/h tends to decreased topping efficiency from 95.0 to 92.0, 94.0 to 91.0 and 93.0 to 90.0% for flail speed of 8.5,12.0 and 15.50 m/s at topping height of 3cm, respectively for season 2004. Also, increase over topping percentage from 95.5 to 92.5, 94.5 to 91.5 and 93.5 to 90.5 % at topping height of 3cm for season 2005, respectively. In the same manner, when the forward speed increased from 1.8 to 5.0 km/h leads to decrease the topping efficiency from 96.0 to 93.0, 95.0 to 92.0 and 94.0 to 91.0% at the same above mentioned flail speed at topping height of 5cm, respectively for season 2004. Also, 96.5 to 93.5, 95.5 to 92.5 and 94.5 to 91.5 % at topping height of 5cm for season 2005, respectively. In the same manner, the same increment of the flail speeds from 8.51, 12.00 and 15.50 m/s tends to decrease topping efficiency from 95.0 to 93.0, 94.5 to 92.8, 93.0 to 91.6 and 92.0 to 90.0% at the forward speeds of 1.8, 2.9, 3.6 and 5.0 km/h at topping height of 3 cm, respectively.

f) Effective field capacity, unit energy requirement and topping cost:

The results indicated that the forward speed increase from 1.8, 2.9, 3.6 and 5.0 km/h tends to increase the effective field capacity from 2.4, 2.9, 3.5 and 3.8 fed/h, respectively.

Fig.8. illustrates the effect of forward speed and flail speed on power requirements. It is conceivable that the forward speed increase from 1.8 to 5.0 km/h increase the power requirements from 13.4 to 16.1, 14.5 to 18.0 and 15.5 to 18.7 kw at flail speed of 8.51, 12.00and 15.50 m/s, respectively.

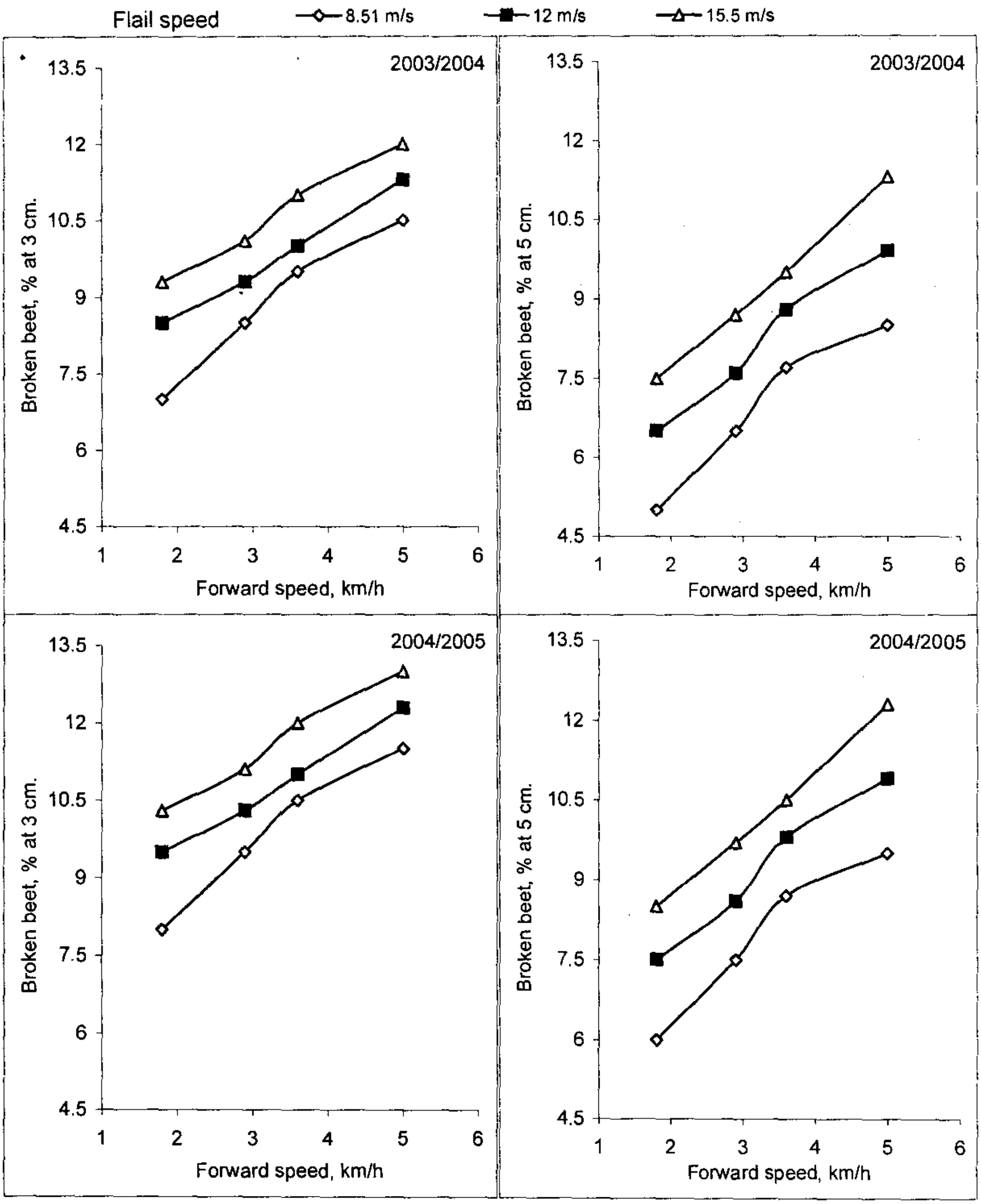


Fig. 6: Effect of forward speed and flail speed on broken beet at topping height 3 and 5 cm for two seasons.

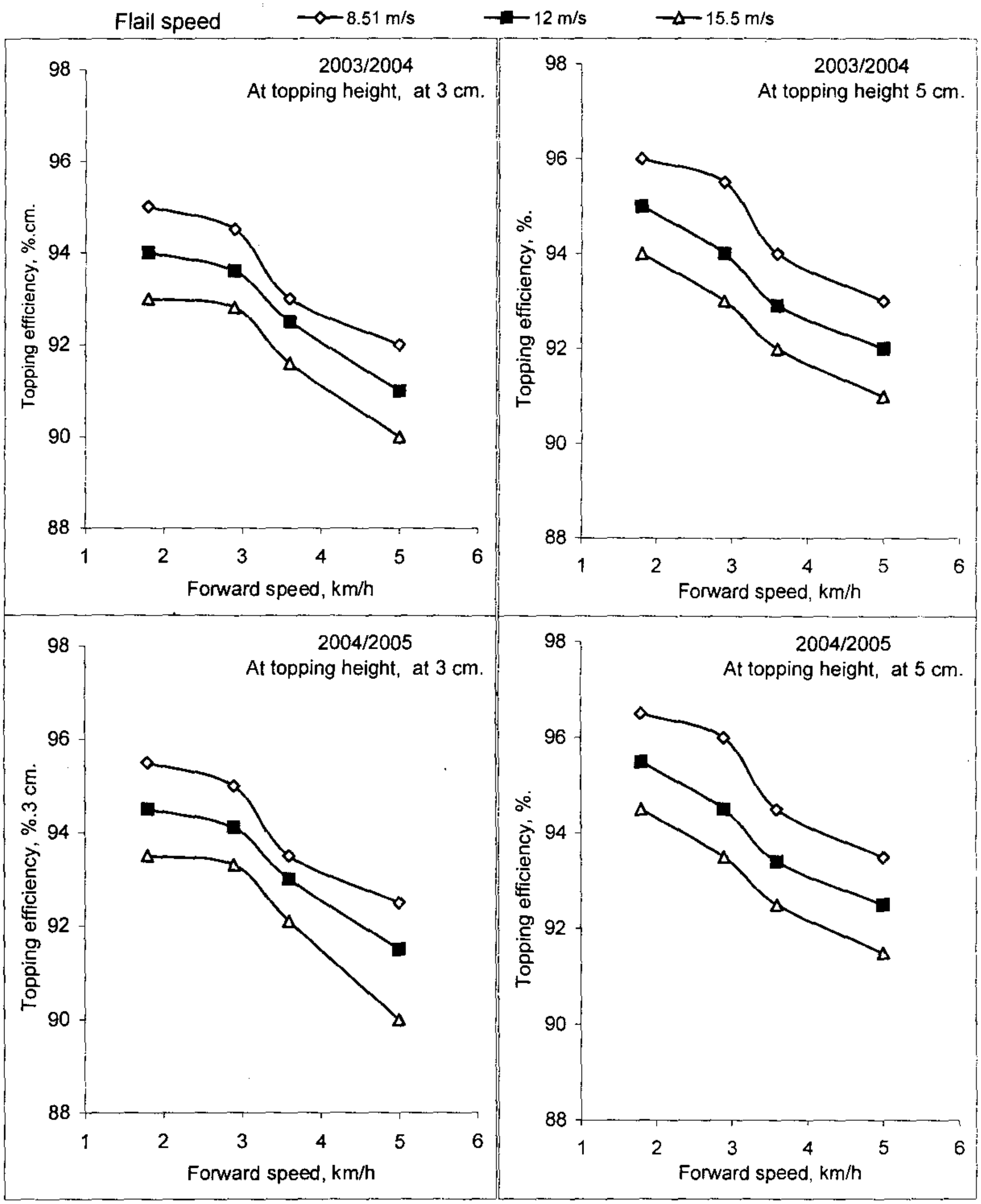


Fig. 7: Effect of forward speed and flail speed on topping efficiency at topping height 3 and 5 cm for two seasons.

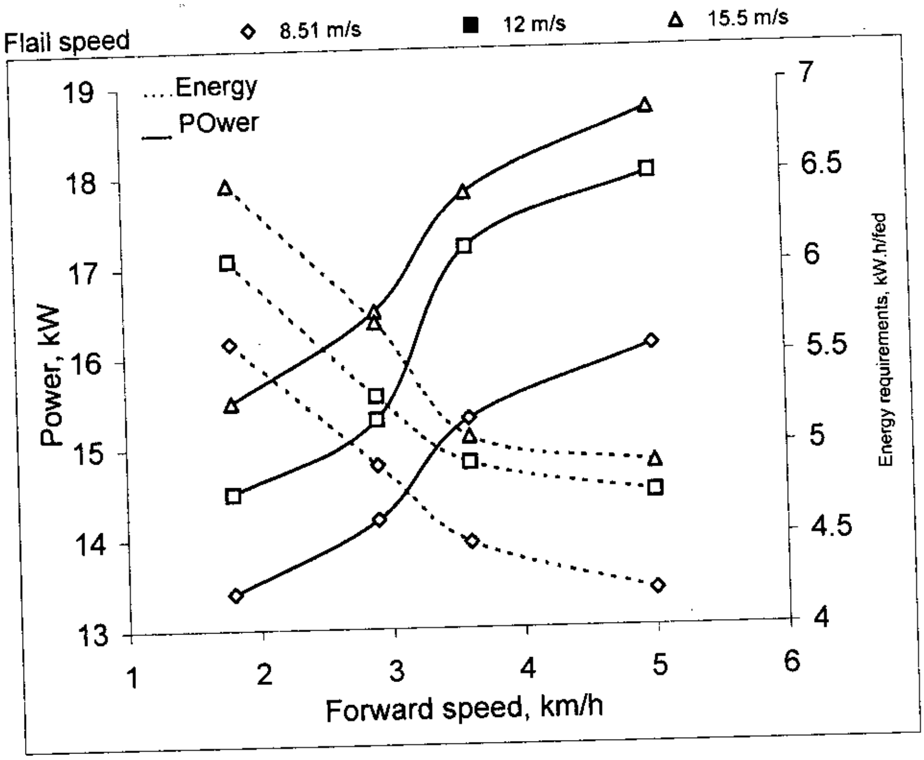


Fig. 8: The relation ship of forward speed and flail speed on power and energy requirements

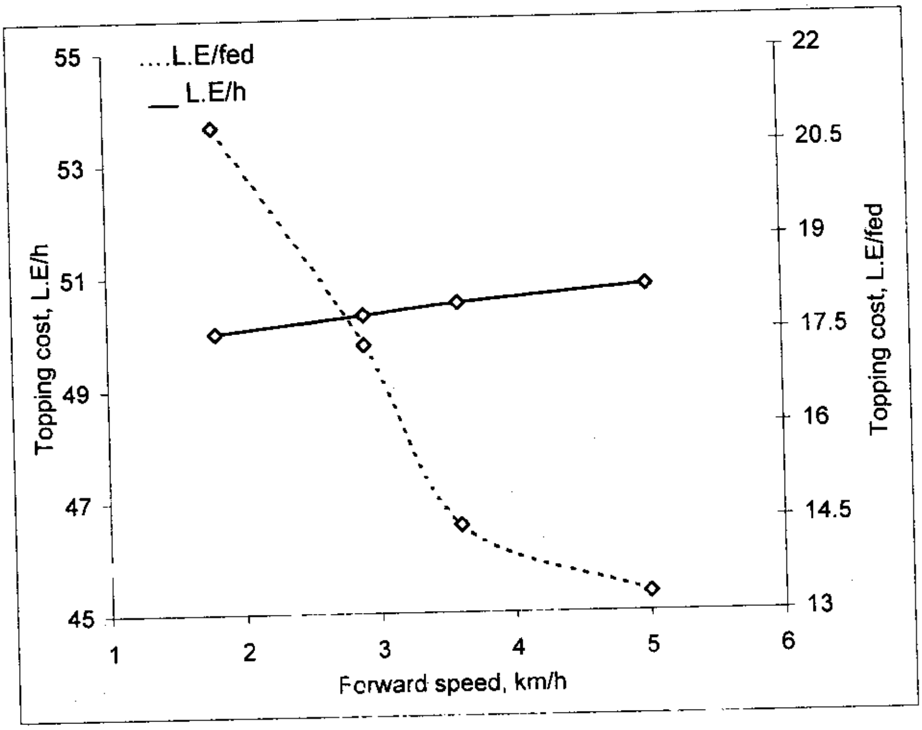


Fig. 9: Effect of forward speed by using topper machine on to, ping cost

Fig.8. indicated the effect of forward speed and flail speed on energy requirements.When the forward speed increased from 1.8 to 5.0 km/h tends to decrease the energy requirements from 5.58 to 4.20, 6.04 to 4.74 and 6.46 to 4.90 kW.h/fed at flail speed of 8.51, 12.00 and 15.50 m/s.respectively.

Fig.9. demonstrates the effect of implement forward speed on topping cost by using the topper machine. It is noticed that the obtained values of total costs were found to be 50.0, 50.3, 50.5 and 50.8 L.E/h at forward speeds of about 1.8, 2.9, 3.6 and 5.0 km/h, respectively. It is also found that the following forward speeds, 1.8, 2.9, 3.6 and 5.0 km/h gave the values of the total costs per unit area of 20.8, 17.3 14.4 and 13.3 LE/fed, respectively. Also, the manual topping cost is about 142.86 L.E/fed.

CONCLUSION

From the above results the following conclusion are derived:

1- The increment in forward speed and flail speed increases both overtopping, undertopping and broken beet percentage the minimum value of overtopping, undertopping and broken beet were 2.30, 1.70 and 5.0%, respectively at forward speed 1.8 km/h, flail speed 8.51 m/s and topping height 5cm.

2- The maximum value of untopped beet was 4.6 % at forward speed 5.0 km/h, flail speed of 8.51m/s and topping height of 3cm.

3- The increasing in forward speed and flail speed decreases topping efficiency percentage. The maximum value of topping efficiency was 96.0% at forward speed 1.8 km/h, flail speed 8.51 m/s and topping height of 5cm. Whilst, the minimum value of topping efficiency was 90.0% at forward speed of 5.0 km/h, flail speed 15.50 m/s and topping height of3cm.

4- The unit cost was reached 20.8, 17.3, 14.4 and 13.3 L.E/fed when the forward speed increased from 1.8, 2.9, 3.6 and 5.0 km/h. .Also, the manual topping cost reached about 142.86 L.E/fed

5- Increasing the forward speed from 1.8 to 5.0 km/h tends to decrease the energy requirements from 5.58 to 4.20, 6.04 to 4.74 and 6.46 to 4.90 kW.h/fed at flail speed of 8.51, 12.00 and 15.50 m/s.

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الأداء الميكانيكي لتطو يش القمم الخضراء لبنجر السكر

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٢. معهد بحوث المحاصيل السكرية – جيزة – مصر

تهدف هذه الدراسة إلى تقييم أداء آلة تطويش لمعرفة مدى ملاءمتها لتطويش القمم الخضراء لبنجر السكر حيث أجريت التجارب عامين متتاليين (موسم حصاد ٢٠٠٤ و ٢٠٠٥) فى محطة البحوث الزراعية / سخا بمحافظة كفر الشيخ.

ولقد اشتملت الدراسة على المتغيرات التالية:-

أ- السرعة الأمامية للآلة (١,٨- ٢,٩- ٣,٦- ٥ كم/ ساعة).

ب- سرعة سكاكين التقطيع (٨,٥١- ١٢- ١٥,٥ م/ثانية).

ج- ارتفاعات سكاكين التقطيع عن سطح التربة (٣-٥ سم).

ويمكن تلخيص النتائج كما يلى :-

١-أقل قيمة للتطويش الجائر والتطويش السطحى وأقل نسبة كسر فى الجذور كانت ٢,٣%، ١,٧%، ٥% على التوالى عند السرعة الأمامية ١,٨ كم/ ساعة وسرعة خطية٨,٥١ م/ث وارتفاع التطويش ٥سم.

٢-أكبر قيمة للجذور المتروكة بدون تطويش ٤,٦% عند سرعة أمامية ٥كم/ساعة وسرعة خطية ٨,٥١ م/ث وارتفاع التطويش ٣سم.

٣-أظهرت النتائج أن أعلى قيمة لكفاءة التطويش كانت ٩٦% عند السرعة الأمامية ١,٨كم/ساعة وسرعة خطية ٨,٥١ م/ث وارتفاع التطويش ٥سم. بينما أقل قيمة لكفاءة التطويش كانت ٩٠% عند سرعة أمامية ٥كم/ساعة وسرعة خطية ١٥,٥ م/ث وارتفاع التطويش ٣سم.

٤-بلغت التكاليف الكلية لتشغيل لآلة التطويش ٢٠,٨ -١٧,٣- ١٤,٤- ١٣,٣جنيه/فدان مع السرعات الأمامية للآلة وهى ١,٨- ٢,٩- ٣,٦- ٥كم/ساعة. بينما بلغت تكاليف التطويش يدويا حوالى ١٤٢,٨٦ جنيه/ فدان.

٥-أظهرت النتائج أن الطاقة المستهلكة نقصت من (٥,٥٨ إلى ٤,٢٠)، (٦,٠٤ إلى ٤,٧٤)، (٦,٤٦ إلى ٤,٩٠ كيلو وات ساعة / فدان) عند زيادة السرعة الأمامية لآلة التطويش من (١,٨- ٢,٩- ٣,٦- ٥ كم/ساعة).وسرعة خطية (٨,٥١- ١٢- ١٥,٥- م/ث) على الترتيب.