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STUDY ON THE MECHANIZATION OF FEED DISTRIBUTION IN AQUACULTURE

Kamal M. Abd El-Hamid[1*], M.M. Morad[2], M.M. Ali[2] and K.E. Hegazi[1]

1. Agric. Eng. Inst., Agric, Res. Cent., Dokki, Egypt

2. Agric. Eng. Dept., Fac. Agric. Zagazig Univ., Egypt

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ABSTRACT: The present research aimed to optimize some different operating parameters affecting the performance of the feed blowing machine to be used successfully for feeding fish in ponds. Two experiments were carried out for this purpose**.** The first experiment was run in the laboratory under four different blower revolving speeds (1500, 1700, 2700 and 3000 rpm) and three types of blades (backward curved blades, radial blades and forward curved blades). The second experiment was run in the field under four different tractor forward speeds (2, 3.13, 4.5 and 6 km/hr.) and the same three types of blades at constant blower revolving speed of 2700 rpm. All experiments were conducted using floating type aquatic feed pellets. Performance of the feed blowing machine was evaluated in terms of distribution width, coefficient of variation, coefficient of uniformity, pellets flow rate, machine productivity, energy requirements and operational cost. The obtained results revealed that the optimum operating parameters for the feed blowing machine were 2700 rpm blower revolving speed with the use of forward curved blades at 3.13 km/hr., tractor forward speed. Under these parameters the coefficient of uniformity value was 0.945, coefficient of variation value was 1.56% and distribution width was 8 m.

Key words: Blowing machine, revolving speed, forward speed, machine productivity.

INTRODUCTION

Aquaculture is an important sector for both food security and economic development in Egypt. Aquaculture production in Egypt is estimated as 1137.1 thousand Mg, equivalent to 1.54 % of world production (FAO, 2016). The increase of any fish production in both quantity and quality does not depend only on the improvement of water and fish conditions, but also largely on using improved methods and technology to fulfill the aquaculture processes in correct time, and keep down production cost. So, it is necessary to use a mechanical machine to distribute feed in ponds to achieve uniform distribution and reduce the time, effort and costs in large aquaculture. Feed is distributed within the rearing facilities, usually by mechanical or air-compressed spreading in order to achieve good distribution over the pond/tank/cage surface. Sometimes, these systems can be equipped with solar power units. The latest feeding systems used in Europe are highly automated and allow, through distribution network installed throughout the fish farm, the supply of food to the fish without any handling (Curt and Eric, 1998).

Guillaume *et al.* (2001) reported that manual distribution is still widely used. It has advantage of involving surveillance of the fishes' behaviour, especially if they are hot free range and can be easily observed. However, the cost of this often high in relation to margins cleared by fish farming.

Abd El-Mottaleb *et al.* (2008) aimed at raising the efficiency of the use of a scattering fertilizer machine to become valid for scattering

* **Corresponding author: Tel. :** +201226710394
E-mail address: kamal.mamdoh@yahoo.com

the artificial feed fish farm ponds within the various fish species. The machine was developed by adding the composition of external installed with nails so that qlaooz dismantled and used for original purpose to spread chemical fertilizer and installing his agent blend can be used for industrial scattering suspension of fish within the basin fish. The application rate of scattering suspension decreases with increasing forward speed of machine and increasing with every increase of the screw speed and spinner speed.

Hemeda *et al*. (2008) developed and evaluated a mounted type machine for fish feeds distribution by blowing air system. The performance of the developed machine in terms of accuracy of feed distribution (uniformity of feed distribution) was investigated. In this study, three machine parameters were studied such as, tractor forward speed, blower revolving speed, and aquatic feed rates. The optimum operating parameters for the modified feed blowing machine were 16 kg/min feeding rate, 3000 rpm for blower revolving speed (22.9 m/sec., air speed) and 4.83 km/hr., tractor traveling speed. At these values, a satisfactory coefficient of uniformity (CU) of 0.947 and permissible coefficient of variation 12.92% were obtained. Moreover, using these parameters recorded the highest distribution width of (10 m) which provide equal feeding opportunities for as many fish as possible.

Sousa *et al*. (2013) reported that automatic feeders are being used in various sector of agribusiness and recently in aquaculture. The adjustment of the frequency with which food is offered to the fish is of utmost importance for the proper utilization of food in order to achieve the best productive performance of tilapia and other cultured species. The best frequency of the feed dispersal of automatic feeder is observed during the early larval rearing of tilapia (0-14 days). The highest frequency of feed dispersal of the automatic feeder resulted to higher liveweight gain and survival rate, thus the use of automatic feeder is feasible and efficient during the initial phase of tilapia rearing.

Songphatkaew *et al.* (2014) conducted a comparative study of two different feeding methods; fixed station feeder (AF) and mobile blower feeder (BF), on growth, water quality and economical performance in Nile tilapia (*Oreochromis niloticus*). Results showed that survival, yield, body composition and feed utilization in fish fed using (AF) and (BF) were not statistically difference (P>0.05). However, growth performance was higher in fish fed using blower feeder. Therefore, the (AF) might be the considerable options of feeding machine which can improve growth performance for Nile tilapia commercial farming.

The objectives of the present study are to:

1. Utilize blowing machine to mechanize feed distribution in aquaculture.
2. Optimize some different operating parameters affecting the performance of the feed blowing machine.
3. Evaluate the performance of the feed blowing machine from the economic point of view.

MATERIALS AND METHODS

Laboratory and field experiments were carried out at Al-Kanayat, Sharkia Governorate, Egypt, to study the effect of some operating parameters on the performance of the feed blowing machine which used for feeding fish in ponds.

Materials

Tractor

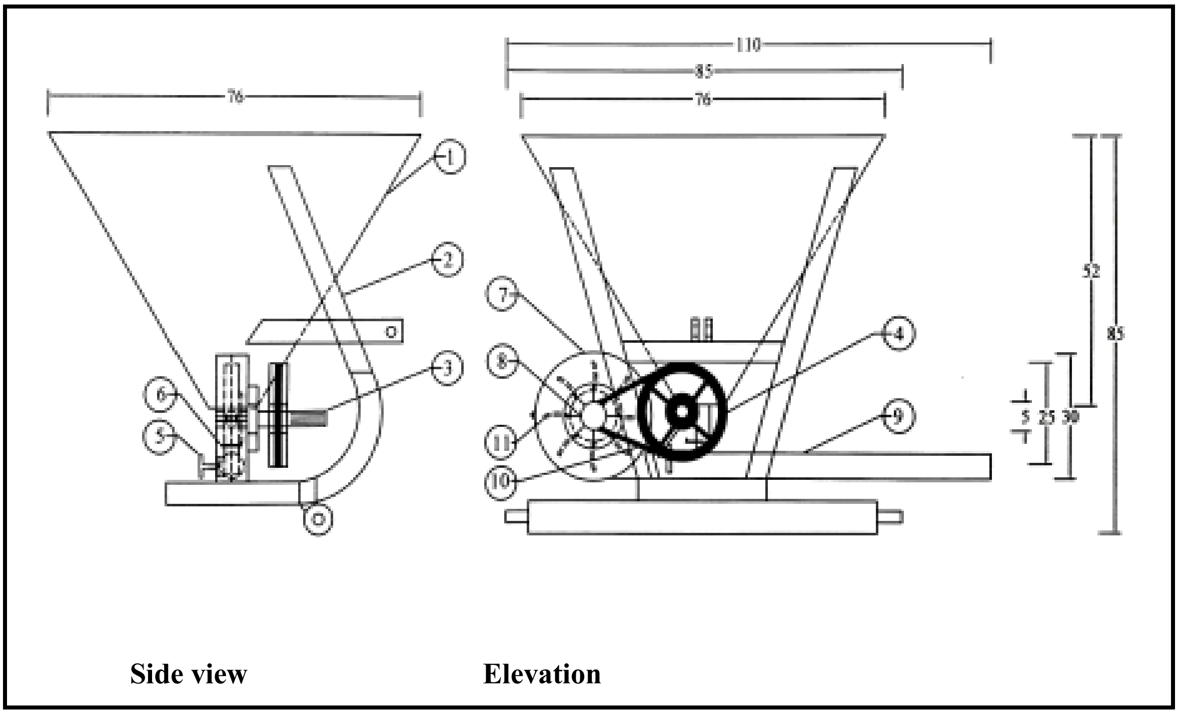
All experiments were carried out using Kubota tractor with the following specification: model Kubota V1702-Di-A, Diesel 4-cylinder, Power 34hp (25.4kW), PTO speed rpm (500-1000) and mass, 2081 kg.

The feed blowing machine

The feed blowing machine (Fig.1) consists of the following main parts:

Hopper

A hopper with a cone-shape was constructed to permit feed to fall gradually to the hopper bottom. It was made from 2 mm sheet metal with a hight of 0. 52 m, upper diameter 0.76 m, bottom diameter 0.0 5 m, perimeter 2.38 m and volume 0.08 m³.



No.	Part name	No	Part name
1	Hopper	7	Blower
2	Frame	8	Blower pulley
3	PTO	9	Feed outlet
4	Driven pulley	10	Belt
5	Sliding gate	11	blades
6	Feeding gate		

Fig. 1. The feed blowing machine

The machine blowing system

The machine blowing system consists of blower which fixed on a rotor with 3 blades. The blades rotate in a volute casing having a diameter of 30 cm, which delivers the air stream through a flexible tube to blower outlet. The blower adapted with flanges bearing on center, connects to the transmission pulley. A blower and duct for forcing air are located at one side of the hopper, to force the air from the blower with feeds to pass through a coupling of open steel cylinder with 10 cm diameter and 75 cm length which was connected with the hopper bottom. A sliding gate with lever was fixed in the blower duct to adjust the forcing air rate.

The transmission system

The transmission system consists of two pulleys and V-belt. The first pulley is connected to the tractor PTO shaft by means of a universal joint; the second pulley transmits the power to the blower. Four aluminum pulleys were used to obtain four different revolving speeds.

The used fish feeds

Experiments were carried out using a local fish feeds (floating type of aquatic feed pellets). The feeds were obtained from Aller Aqua for feed company, sixth of October.

Some physical and engineering characteristics of fish feeds (floating) were noted as shown in Tables 1 and 2.

Methods

Laboratory and field experiments were conducted to optimize some different operating parameters affecting the performance of the fish feed blowing machine.

Experimental Conditions

Laboratory experimental parameters

- Four different blower revolving speeds of 1500, 1700, 2700 and 3000 rpm.
- Three types of blades: forward curved blades (Fb), radial blades (Fs) and backward curved blades (Ff) (Fig. 2).

Field experimental parameters

- Four different tractor forward speeds of 2, 3.13, 4.5 and 6 km/hr.
- Three types of blades: forward curved blades (Fb), radial blades (Fs) and backward curved blades (Ff).

Procedures

Laboratory experiments were conducted using trays having dimensions of (30×20×10) cm which put on a linoleum having dimensions of 20 ×10 m. The tractor was standing at its place away (1m) from the first row of trays with a feeds outlet height of (1m) above the ground surface. The spreader hopper was filled with feeds, and the delivery gate was set on the position of the required application rate. The tractor was engaged to operate the blower through the P.T.O shaft. Each test was replicated three times and means values were calculated.

Measurements and Determinations

Performance of the fish feed blowing machine was calculated taking into consideration the following indicators:

Distribution width

Distribution width was obtained by measuring the distance between feed outlet and the last tray filled with feed.

Flow rate (FR)

Flow rate was calculated by the following equation:

$$FR = \frac{Ms}{t}, \text{ kg/hr. .... (1)}$$

Where:

FR: Flow rate, kg /hr,

Ms: Mass of sample, kg

t : The time consumed in the flow operation, hr.

Coefficient of variation (C.V%)

Coefficient of variation was calculated according to Coates (1992) and Srivastava *et al.* (1995):

$$\delta = \sqrt{\frac{\sum (x - \bar{x})}{n-1}}$$

Where:

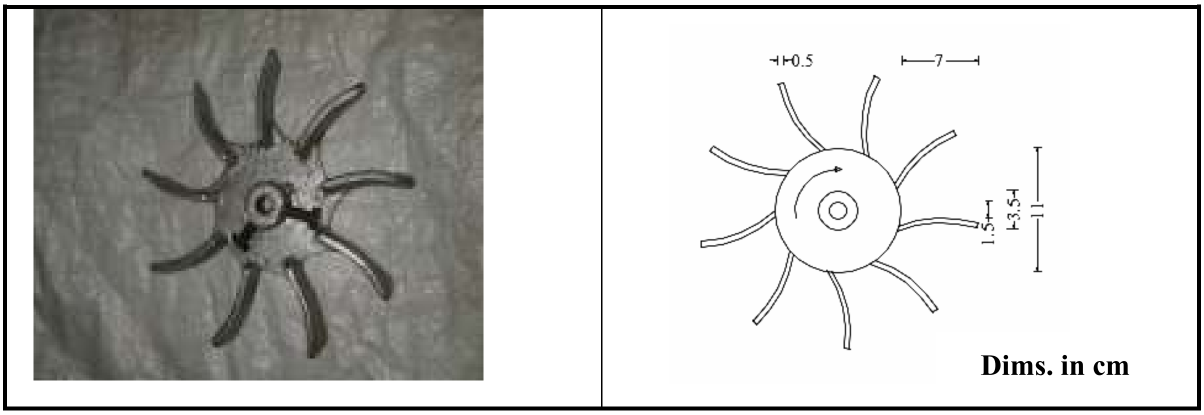
δ: Standard deviation

Table 1. Some physical characteristics of the used fish feed

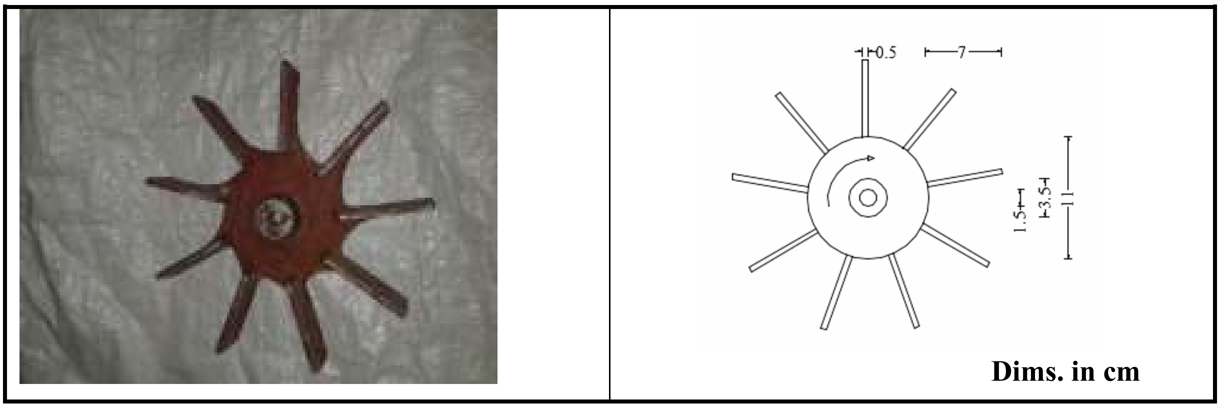
Type of aquatic feed pellets	Length, (mm)	Diameter, (mm)	Moisture content (%)	Bulk density, (g /cm³)	Hardness (N)	Floating time (hr.)
Floating feed	3	3	11.3	0.52	11	24

Table 2. Some engineering characteristics of the used fish feed

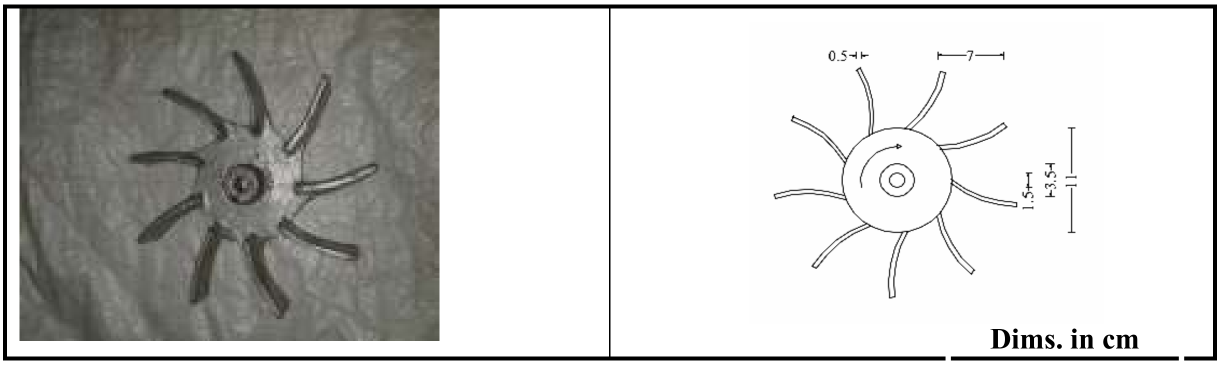
Type of aquatic feed pellets	Repose angle, deg	Friction angle, deg	Terminal velocity (m/sec.)
Floating feed	25	14	8.4



Forward curved blades



Radial blades



Backward curved blades

Fig. 2. Types of blades

X: Mass of particle in each tray (g)

$\bar{X}$: Average mass of particles in all trays (g)

n: total number of collection trays

$$C.V = \frac{\delta}{\bar{x}} \times 100 \quad ...... \ (2)$$

Where:

C.V: Coefficient of variation

Coefficient of uniformity (CU)

The coefficient of uniformity was calculated as follows:

$$C.U = 1- \left[\frac{\Sigma(x-\bar{x})^2}{n-1} / \bar{x} \right] \ ... \ (3)$$

Where:

C.U: Coefficient of uniformity

Machine productivity

Assume that the pond have dimensions of (60×70) m equivalent to faddan and actual distribution width was 6m. The operation of distribution covers one side of length and width of pond .Hence, the covered area of pond was $780m^2$.

Actual machine productivity can be calculated as follows:

$$AMP = \frac{1}{Ta}, \text{ pond/hr.} \ ...... \ (4)$$

Where:

AMP: Actual machine productivity, pond/hr.

Ta: Total actual consumed time per pond, hr.

Working efficiency can be calculated as follows:

$$\eta_w = \frac{AMP}{TMP} (\%) \ .... \ (5)$$

Where:

TMP: Theoretical machine productivity

Theoretical machine productivity is calculated by multiplying machine forward speed by working width of the machine.

Required power (p)

Required power was estimated from the fuel consumed during the feed distribution operation using the following formula (Barger *et al.*, 1963):

$$p = F_c \frac{1}{3600} \times \rho_f \times L.C.V \times 427 \times \eta_{th} \times \eta_m \times \frac{1}{75} \times \frac{1}{1.36}, kW \ .(6)$$

Where:

ρ_f: Density of fuel (kg/L), (for diesel fuel 0.85)

LCV: Calorific value of fuel, (10000 kcal/kg)

η_{th}: Thermal efficiency of the engine, (for diesel engine, 35%)

427: Thermo-mechanical equivalent, (kg.m/ kcal)

η_m: Mechanical efficiency of engine, (for diesel engine, 85%)

$P = 3.46 \ F_c$

Energy requirements

Estimation of the energy required for operating feed distribution was carried out using the following formula:

$$\text{Energy requirements} = \frac{P \ (kW)}{AMP \ (pond/hr.)}, \text{ kW. Hr./pond} \ .(7)$$

Hourly cost (HC)

Both the tractor and feed blowing machine costs were determined using conventional method of estimating both fixed and variable costs.

Operational cost

The operational cost was determined using the following formula:

$$\text{Operational cost} = \frac{HC \ (LE/hr.)}{AMP \ (pond/hr.)}, \text{ L.E/pond} ...(8)$$

RESULTS AND DISCUSSION

Discussion will cover the results obtained under the following heading:

Results of Laboratory Experiments

Effect of some operating parameters on distribution width

The effect of blower revolving speeds on distribution width is shown in Fig. 3. The obtained results show a remarkable increase in distribution width with the blower revolving speed increased.

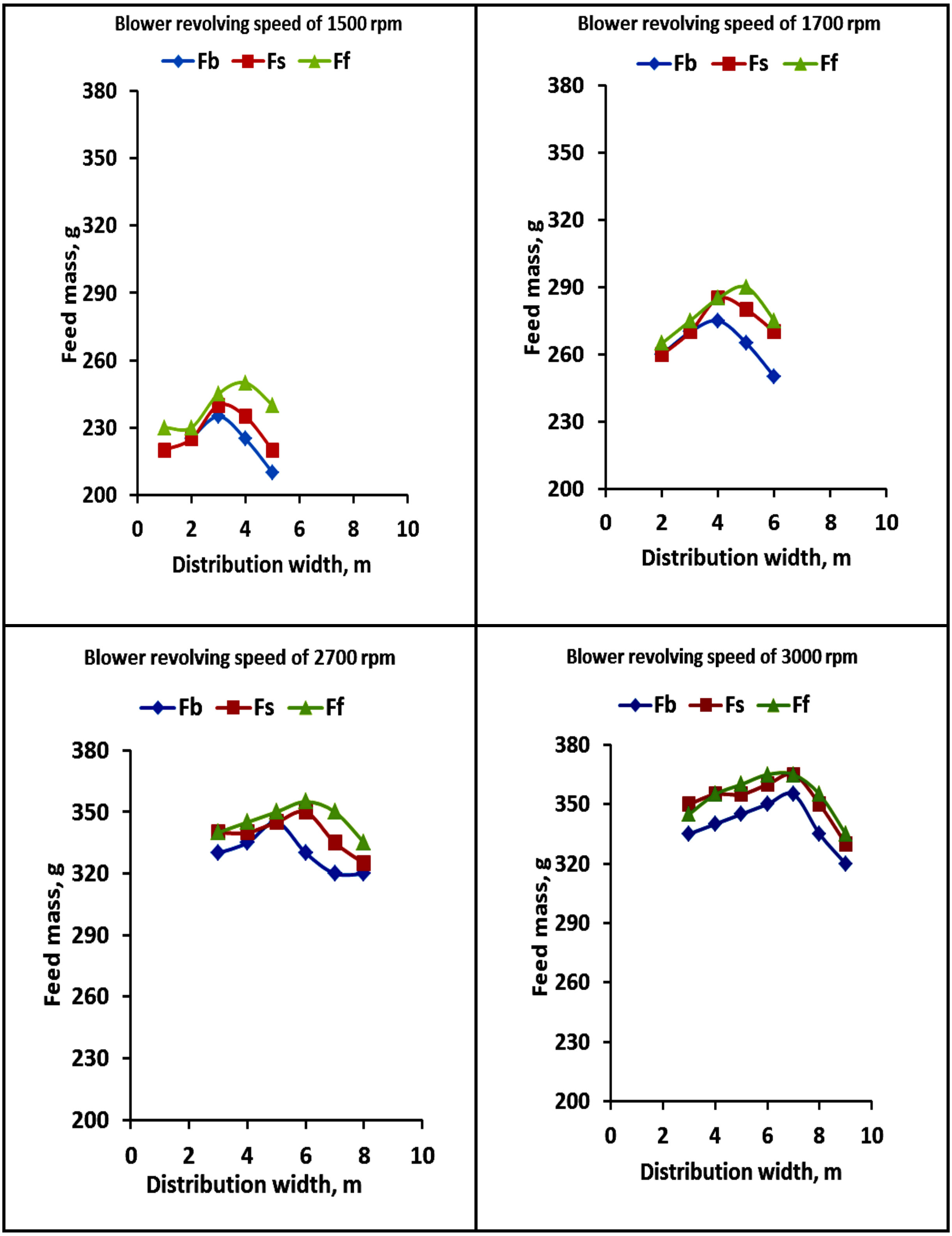


Fig. 3. Effect of some operating parameters on distribution width of the feed blowing machine

Results showed that distribution width at 1500 rpm was 5 m from feed outlet gate to tray number 5. Increasing blower revolving speed to 1700 rpm keeps distribution width of 6 m from feed outlet gate to tray number 6 but the feed was confined from tray number 2 to tray number 6. Also increasing blower revolving speed to 2700 rpm leads to increase distribution width to 8 m from feed outlet gate to tray number 8, but the feed was confined from tray number 3 to tray number 8. Also increasing blower revolving speed to 3000 rpm leads to increase distribution width to 9 m from feed outlet gate to tray number 9, but the feed was confined from tray number 3 to tray number 9. Increasing blower revolving speed to 3000 rpm leads to great friction between the machine moving parts. While decreasing it to 1500 rpm leads to the existence of losses on the sides of pond.

The major reason for the increase in distribution width by increasing blower revolving speed is due to the more produced air stream velocity.

The same results show that type of blades did not affect the distribution width. But their effect was different concerning mass of sample in trays. Forward blades gave the highest values of sample mass in trays compared to the other two types of blades.

Effect of some operating parameters on flow rate

The effect of blower revolving speed on flow rate is shown in Fig. 4. In general the results showed that increasing blower revolving speed leads to increase flow rate values. The obtained results showed that increasing blower revolving speed from 1500 to 3000 rpm leads to increase flow rate values from 0.312 to 0.510 Mg/hr., using backward curved blades, from 0.367 to 0.541 Mg/hr., using radial blades and from 0.382 to 557 Mg/hr., using forward curved blades.

The increase in flow rate by increasing blower revolving speeds may be attributed to increase the produced air stream velocity.

The effect of blades type on the flow rate is also shown in Fig.4. Data showed that the highest flow rate value of 0.557 Mg/hr., was obtained by using forward curved blades at blower speed of 3000 rpm. While the lowest flow rate value of 0.312 Mg/hr., was obtained by using backward curved blades at blower speed of 1500 rpm.

The reason that a forward curved blades deliver high fish feed rate is because this type of blades delivers the greatest air volume in relationship to blower size and speed.

Effect of some operating parameters on coefficient of uniformity and coefficient of variation

The effect of blower revolving speeds on coefficient of uniformity and coefficient of variation is shown in Fig. 5.

The obtained results showed that by using backward curved blades, increasing blower revolving speed from 1500 to 2700 rpm leads to increase CU values from 0.630 to 0.727 while, CV values were decreased from 4.07 to 2.87%. On the other hand, further increase in blower revolving speed from 2700 up to 3000 rpm leads to decrease CU value from 0.727 to 0.607 while increased CV values from 2.87 to 3.39%. In the same trend by using radial blades, increasing blower revolving speed from 1500 to 2700 rpm leads to increase CU values from 0.639 to 0.781 while CV values were decreased from 3.96 to 2.53%. Any further increase in blower revolving speed from 2700 up to 3000 rpm leads to decrease CU values from 0.781 to 0.648 while increased CV values from 2.53 to 3.16%. Also, the increase in blower revolving speed from 1500 to 2700 rpm using forward curved blades leads to increase CU values from 0.665 to 0.843 while CV values decreased from 3.74 to 2.12%. Increasing blower revolving speed more than 2700 up to 3000 rpm leads to decrease CU values from 0.843 to 0.660 and increase CV values from 2.12 to 3.09%.

The decrease in coefficient of uniformity and increase in coefficient of variation at blower revolving speed of 3000 rpm may be attributed to the occurrence of dispersion in feed pellets.

The effect of blades types on coefficient of uniformity and coefficient of variation is also shown in Fig. 5. The obtained results showed that generally, coefficient of uniformity values were higher and coefficient of variation values were lower by using forward curved blades compared with the other two blades types.

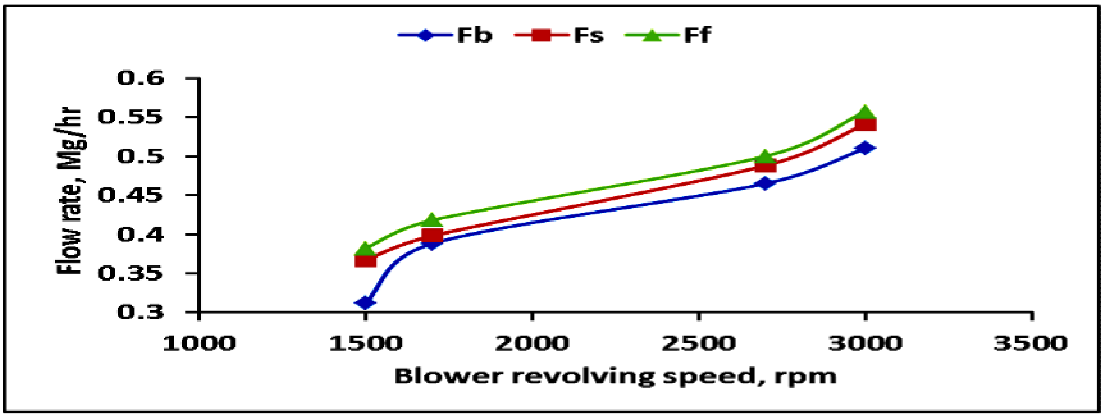


Fig. 4. Effect of blower revolving speed and blades type on flow rate

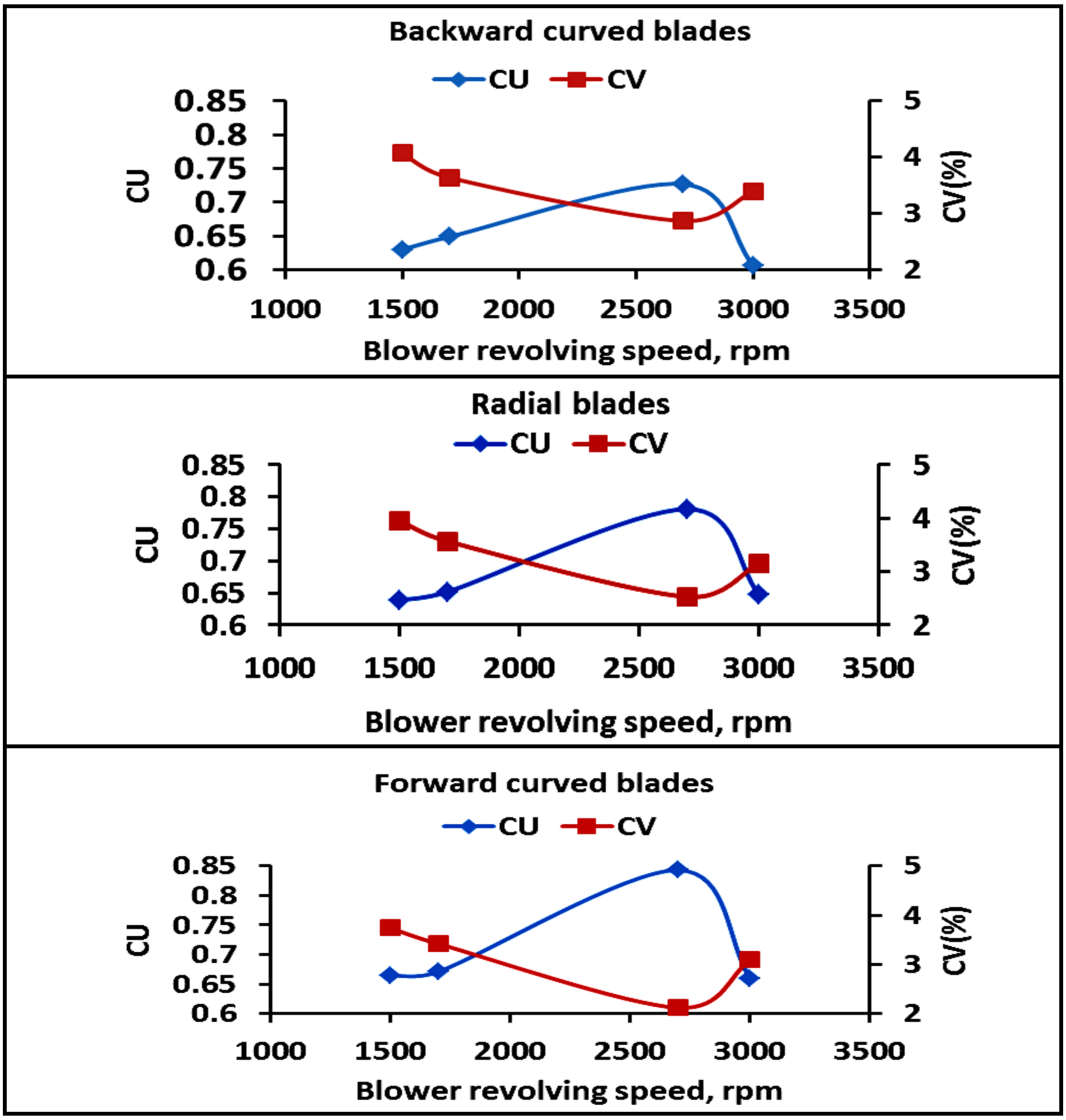


Fig. 5. Effect of blower revolving speed and types of blades on coefficient of uniformity and coefficient of variation

Results showed that the highest CU value of 0.843 and the lowest CV value of 2.12% were obtained by using forward curved blades at 2700 rpm blower revolving speed. While the lowest CU value of 0.607 and the highest CV value of 4.07% were obtained by using backward curved blades at 1500 rpm blower revolving speed.

Results of Filed Experiments

Effect of tractor forward speed on machine productivity and working efficiency

The effect of tractor forward speed on machine productivity and working efficiency shown in Fig. 6. In general increasing forward tractor speed leads to increase machine productivity while, working efficiency values were decreased. The obtained results showed that machine productivity values were 13, 19.25, 25.6 and 30.75 pond/hr., while working efficiency values were 84.7, 80, 74 and 66.6% at 2, 3.13, 4.5 and 6 km/hr., respectively. Results showed that the highest machine productivity value was 30.75 pond/hr., and lowest working efficiency value was 66.6% which were obtained at 6 km/hr., while, the lowest machine productivity value was 13 pond/hr., and the highest working efficiency value was 84.7% were obtained at 2 km/hr.

Effect of some operating parameters on coefficient of uniformity and coefficient of variation

The effect of tractor forward speed on coefficient of uniformity and coefficient of variation is shown in Fig. 7.

The obtained results showed that increasing tractor forward speed from 2 to 3.13 km/hr., leads to increase CU values from 0.839 to 0.881while, decreasing CV values from 3.97 to 2.36% by using backward curved blades, in the same trend increasing CU values from 0.853 to 0.892 while, decreasing CV values from 3.22 to 2.22% by using radial blades. Also, increasing CU values from 0.879 to 0.945 while, decreasing CV values from 2.53 to 1.56% by using forward curved blades. On other hand, increasing tractor forward speed from 4.5 to 6 km/hr., leads to decrease CU values from 0.806 to 0.728 and increasing CV value from 4.53 to 5.11% by using backward curved blades. Also, decreasing CU values from 0.818 to 0.733 and increasing CV values from 4.23 to 4.97% by using radial blades. Similarly, decreasing CU values from 0.841 to 0.797 and increasing CV values from 3.05 to 4.28% by using forward curved blades.

The effect of types of curved blades on coefficient of uniformity and coefficient of variation is also shown in Fig. 7.

Results showed that the highest CU value of 0.945 and the lowest CV value of 1.56% were obtained by using forward curved blades under tractor forward speed of 3.13 km/hr. While the lowest CU value of 0.797 and the highest CV value of 4.28% were obtained by using backward curved blades under tractor forward speed of 6 km/hr.

The decrease in coefficient of uniformity values and increase coefficient of variation values at forward speed of 2 km/hr., may be due to increase overlap between the feed samples. While decrease in coefficient of uniformity values and increase CV value at 4.5 and 6 km/hr., may be attributed to increase the vibration effect of the tractor by increasing tractor forward speed.

Effect of Tractor Forward Speed and Types of Curved Blades on Required Power and Energy Requirement

Required power

The required power is highly affected by tractor forward speed. Fig. 8 shows a remarkable increase in required power by increasing tractor forward speeds.

Results obtained showed that required power values of 10.94, 11.41, 11.64 and 12.35kW were obtained at 2, 3.13, 4.5 and 6 km/hr., tractor forward speeds, respectively by using backward curved blades. Also by using radial blades required power values were 11.05, 11.76, 12.16 and 12.94 kW. Similarly, required power values were 11.53, 12.13, 12.7 and 13.41 kW by using forward curved blades under the same previous forward speeds. The increase in required power by increasing tractor forward speed is due to increase in fuel consumption.

Required power is also affected by blades types as shown in Fig. 8. Results showed that the highest required power value of 13.41 kW at 6 km/hr., by using forward curved blades. While the lowest required power value of 10.94 kW at 2 km/hr., by using backward curved blades.

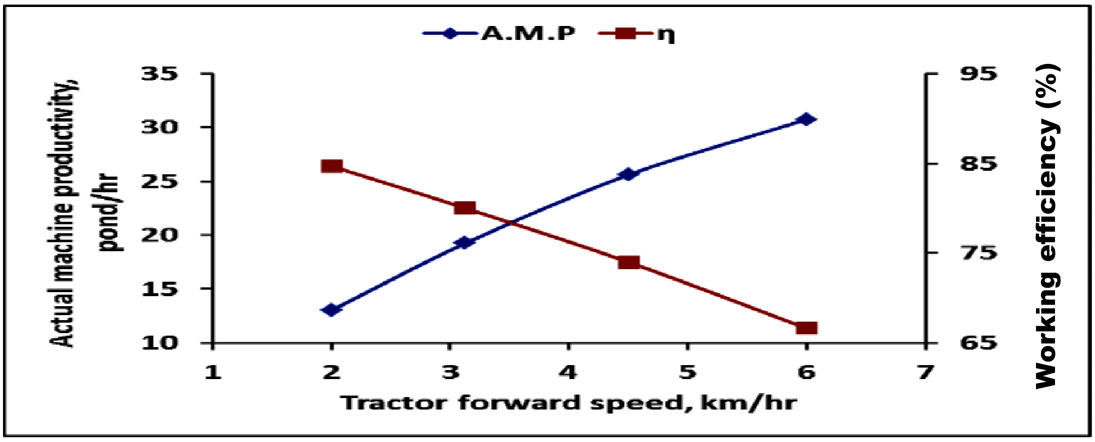


Fig. 6. Effect of forward tractor speed on machine productivity and working efficiency

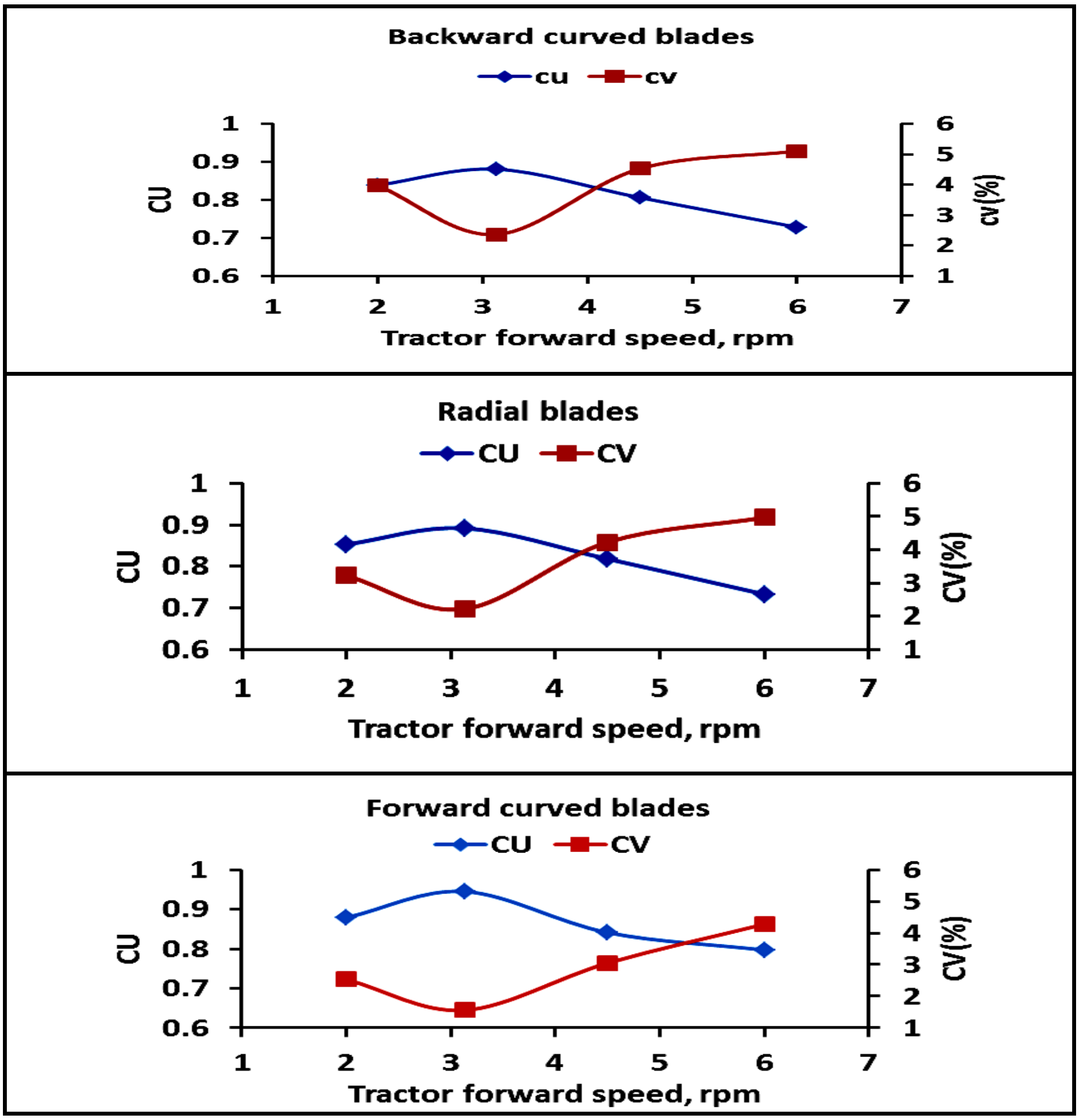


Fig. 7. Effect of tractor forward speed and types of blades on coefficient of uniformity and coefficient of variation

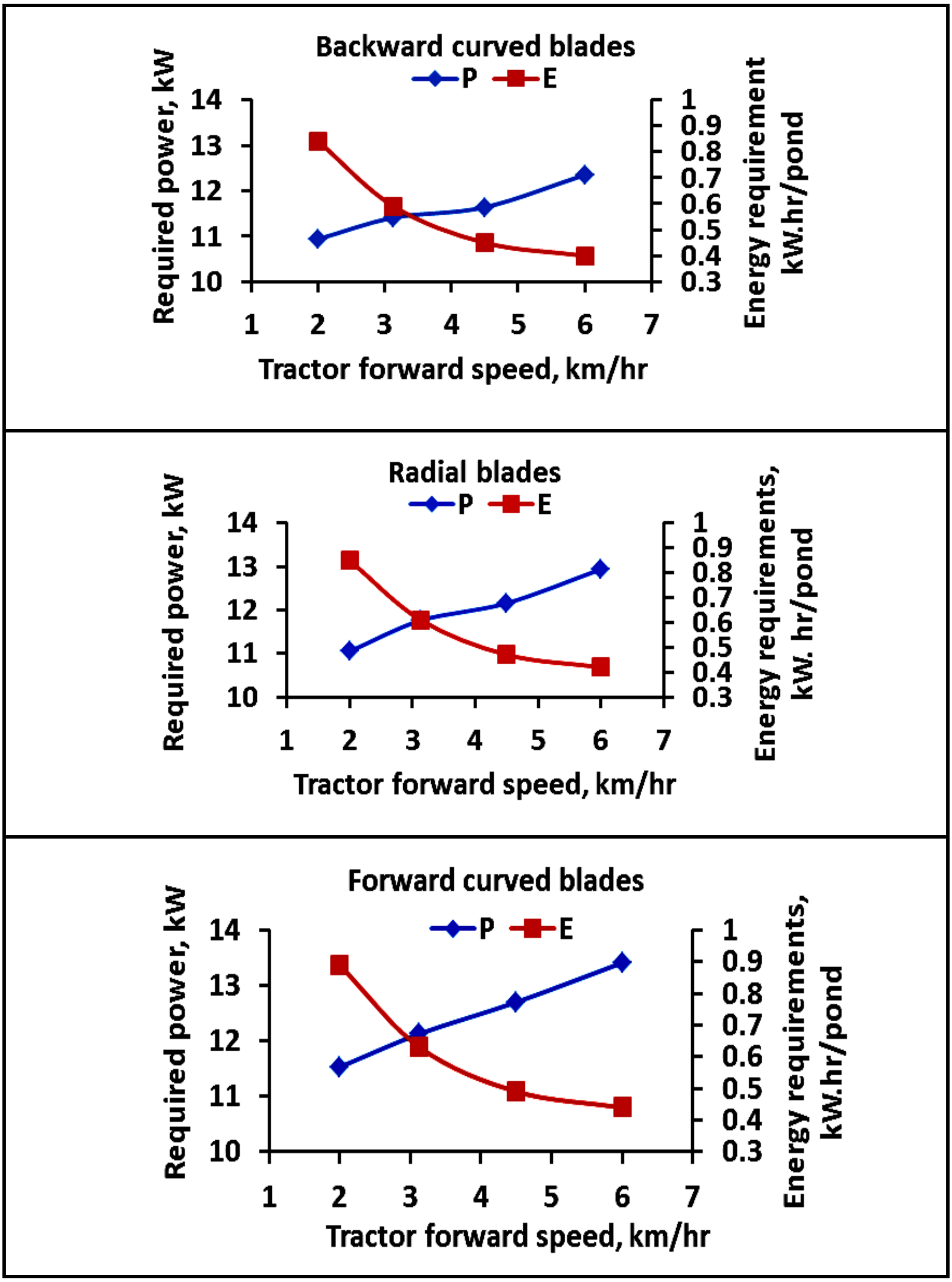


Fig. 8. Effect of tractor forward speed and types of curved blades on required power and energy requirements

Energy requirements

Energy requirement is highly affected by tractor forward speeds and types of blades. Fig. 8 showed a remarkable drop in the energy requirement as the forward speed increased with the use of backward curved blades. Results showed that increasing tractor forward speed from 2 to 6 km/hr., leads to decrease energy requirements from 0.84 to 0.4, from 0.85 to 0.42 and from 0.89 to 0.44 kW.hr./pond using Fb, Fs and Ff, respectively. The decrease in energy requirements by increasing tractor forward speeds could be due to the high increase in actual machine productivity compared with the increase in required power.

Results showed that the highest energy requirement value of 0.89 kW.hr./pond was obtained at 2 km/hr., with using forward curved blades. While the lowest energy requirement value of 0.4 kW.hr./pond was obtained at 6 km/hr., using backward curved blades.

Effect of tractor forward speed and types of blades on operational cost

The effect of forward speeds on operational cost is shown in Fig. 9. In general, operational cost decreased by increasing tractor forward speed. The obtained results showed that increasing tractor forward speed from 2 to 6 km/hr., leads to decrease operational cost values from 2.65 to 1.2, from 2.75 to 1.25 and from 2.8 to 1.4 LE/ pond by using Fb, Fs and Ff, respectively. The decrease in operational cost at high tractor forward speed is due to its high actual machine productivity.

Results showed that the highest operational cost value of 2.8 LE/pond was obtained at 2 km/hr., using forward curved blades. While the lowest operational cost value of 1.2 LE/pond was obtained at 6 km/hr., using backward curved blades.

Conclusion

The obtained results revealed that the optimum operating parameters for the feed blowing machine were 2700 rpm blower revolving speed with the use of forward curved blades at 3.13 km/hr., tractor forward speed. Under these parameters the coefficient of uniformity value was 0.945, coefficient of variation value was 1.56% and distribution width was 8 m.

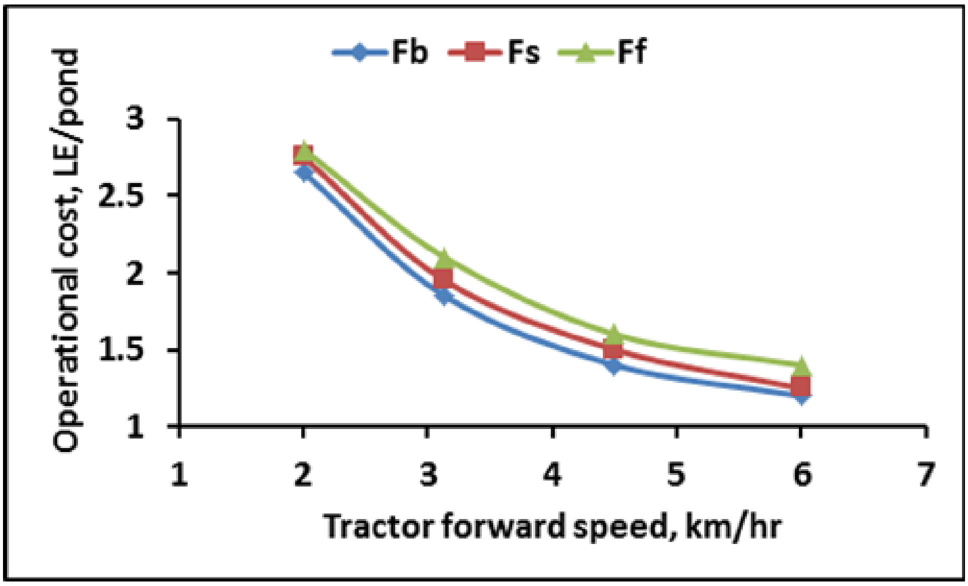


Fig. 9. Effect of tractor forward speed and types of blades on operational cost

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دراســـــــــة علـــى ميكنـــــة تـــوزيــــــع الأعـــــــلاف فـــــى المــزارع الســـمكيـــــــة

كمال ممدوح عبدالحميد[١] - محمد محمد مراد حسن[٢] - محمود مصطفى على على[٢] - كريم السيد صالح حجازى[١]

١- معهد بحوث الهندسة الزراعية - مركز البحوث الزراعية- الدقى - مصر

٢- قسم الهندسة الزراعية - كلية الزراعة - جامعة الزقازيق - مصر

نظراً للأهمية الكبيرة للمزارع السمكية فى مصر فى تغطية العجز فى إنتاج الأسماك حيث يقدر إنتاج المزارع السمكية فى مصر حوالى ١١٣٧,١ ألف طن أى ما يعادل ١,٥٤% من الإنتاج العالمى طبقا لمنظمة الفاو ٢٠١٦، التغذية هى أهم العمليات المزرعية حيث تمثل ٦٠-٧٠ % من إجمالى تكاليف الإنتاج لذلك وجود فواقد فى العلف أثناء توزيعه فى الأحواض أو زيادة كميات العلف عن المعدل المطلوب يؤدى إلى زيادة تكاليف الإنتاج ويؤثر على جودة الماء، لذلك كان من الضرورى استخدام آلة ميكانيكية تقوم بتوزيع العلف في الأحواض تحقق التوزيع المنتظم وتقلل الوقت والجهد والتكاليف خاصة فى المزارع الكبيرة، تم إجراء الدراسة بمدينة القنايات محافظة الشرقية خلال الموسم الشتوى ٢٠١٦ وذلك لدراسة تأثير بعض عوامل التشغيل على أداء وإنتظامية توزيع الأعلاف باستخدام آلة التغذية بنظام دفع الهواء حيث تم تنفيذ الدراسة على مرحلتين: المرحلة الأولى (التجارب المعملية): تم تنفيذها وذلك لإختيار الظروف المثلى لبعض عوامل التشغيل وهى أربع سرعات دورانية للمروحة ١٥٠٠، ١٧٠٠، ٢٧٠٠، ٣٠٠٠ لفة/د وثلاث زوايا إنحناء لريش المروحة وهى الريش المنحنية للخلف والريش المستقيمة والريش المنحنية للإمام، المرحلة الثانية (التجارب الحقلية): تم تنفيذها باستخدام ثلاث زوايا إنحناء لريش المروحة وهى الريش المنحنية للخلف و الريش المستقيمة و الريش المنحنية للأمام مع أربع سرعات للجرار وهى ٢، ٣,١٣، ٤,٥، ٦ كم/س تحت سرعة ثابتة لعمود المروحة ٢٧٠٠ لفة/د، وذلك لمعرفة تأثير العوامل السابقة على قياسات أداء الآلة وتشمل الآتى: عرض التوزيع - معدل التدفق - معامل الإنتظامية ومعامل الإختلاف - إنتاجية الآلة وكفاءة التشغيل- إستهلاك الوقود والقدرة والطاقة المطلوبة لعملية التوزيع – التكاليف، هذا وقد اظهرت النتائج: أن أفضل أداء لآلة التوزيع من حيث إنتظام التوزيع وتقليل كلا من الطاقة المطلوبة وتكاليف التشغيل يكون تحت ظروف التشغيل الآتية: أفضل سرعة لعمود المروحة ٢٧٠٠ لفة/د، أفضل إنحناء لريش المروحة الريش المنحنية للأمام، أفضل سرعة أمامية ٣,١٣ كم/س.

المحكمون :

١- أ.د. محب محمد أنيس الشورباصي أستاذ الهندسة الزراعية – كلية الزراعة – جامعة دمياط.

٢- أ.د. محمـــود عبدالعزيز حســــن أستاذ الهندسة الزراعية المتفرغ – كلية الزراعة – جامعة الزقازيق.