Journal of Soil Sciences and Agricultural Engineering

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

Productivity Modeling of Collect-Packing Machine for Garden-Residues

Ismail, Z. E.[1*]; N. K. Ismail[2] and Zeinab S. Hamza[1]

[1] Agric. Eng. Dept., Fac. of Agric., Mansoura Univ.
[2] Bio-system Eng. Dept., Agric. Eng. Res. Inst. (AEnRI), ARC

Cross Mark

ABSTRACT

The collecting of garden-residues (leaves, seeds, flowers, ... etc.) using a modest machines is not done as a completely mechanization operations. For these reasons, the aim of this work was identified to constructive, confirm and investigate a machine to collect and packing the garden residues, which included two main units, the collecting and delivery units. The variable parameters comprise revolutions of blower "RB" (1000; 1700; 2400 and 3100rpm) and delivery tube diameter "DTD" (10; 15 and 20cm) under two residues moisture contents "RMC" of 14% (free dropped) and 64% (forced dropped). The performance of collect-packing machine "CPM" were done by identifying residues bulk density "BD" at go out moment and rate of residues volume reduction "RV", machine productivity "RP" and specific energy consumed "SEC". Then the regression modeling was identified as combine relationship among studied variables. The results concluded that the "CPM" is suitable for collecting free and forced dropped garden residues. The best level of the "RB" and "DTD" are 3100 rpm and 15 cm under 14% "RMC" and 3100 rpm and 20 cm for 64% "RMC" respectively. At "RMC" of 14%, the highest "BD", "RV", and "RP" are 45.3kg m^{-3}, 29.22% and 257.26 kg h^{-1} respectively at lowest "SEC" of 0.196 kW h Mg^{-1}. The corresponding values at "RMC" of 64% were 32.32 kg m^{-3}, 88.01%, and 294.79 kg h^{-1} at "SEC" of 0.251 kW h Mg^{-1} respectively. The regression modeling has a strong relation to describe the effect of studied variables under different machine performance.

Keywords: Blower, Bulk density, Collecting residues, Delivery, Packing, Volume reduction.

INTRODUCTION

Plant residues falling from trees and other plantings in orchards and public gardens, is one of the elements distorting the aesthetic appearance of the surrounding environment? Generally, the organic residues are includes of agricultural, food from household, etc…. They are benefits as, an animal fodder, but it incinerated to dispose. These residues are rich materials in many nutrients that could be used (Abdel-Shafy, 2018). It is can use as substrates or raw materials such as, organic fertilizer or as sustenance for poultry and animals. Hence, it is importance for developing an easy method to collect and transport these residues.

Many studies during previous time periods have indicated different methods for collecting these residues, whether by manual rakes for raking grass then leaves from lawns and flower beds then accumulating into piles. After that removing the amassed material and transferring to a box, wheel barrow, or another receptacle in which it may be used, (Morris and Conn, 1953 and Palazzolo, 2007). Furthermore, yard residues are may place in loose piles at the curb and picked up with a pincer bucket or mechanical claw attached to a small front-end loader. This method is convenient and fast. But the disadvantage of this method is that the capture rate of the material is only about 90 percent, (Evanylo *et al.*, 2009). The design of leaves collector aimed at increasing the speed of the process. Many designs were made to achieve this aim as a claw is loading pincer that attached to the front-end lift assembly of a tractor. It uses to hoist the materials into a transport vehicle–commonly a rear packer or dump truck, (O'Brien 2015). The vacuum trucks are used to collect leaves that are set-out loose on the street. That work is done by sucking leaves into a shredder, then blowing them into a transport vehicle in many cases the leaves can be compact.

Portable leaves sweeper is used by high-velocity air (Sanders *et al.*, 2004). Also, the hand-held blowers can use which is made from plastic fan, and source of small gasoline-powered engine. It pulls the outside air when operating with the residues and forces, it moves through a small-diameter tube (Reeves, 2008). Azadbakht *et al.* (2014) designed a leaves collector machine with suction-blower. The machine had a tank to store the collecting leaves. The revolution of suction fan, were considered to be 3200 rpm with total power consumption to be around 14.634 kW and the operation was conformed with tractor of 18.6425 kW (25 hp). However, the all of the above collectors systems did not gain popularity because they are lost the ease of product packing and handling, still under study and testing, as well as because of the high purchase price and difficulty of maintenance if we import.

For these reasons, the major work was done to constructive, confirm and investigate a machine to collect and packing the garden residues. The minor research aimed to evaluate the collect-packing machine parameters such as revolutions of blower "RB", delivery tube diameter "DTD" and residues moisture contents "RMC".

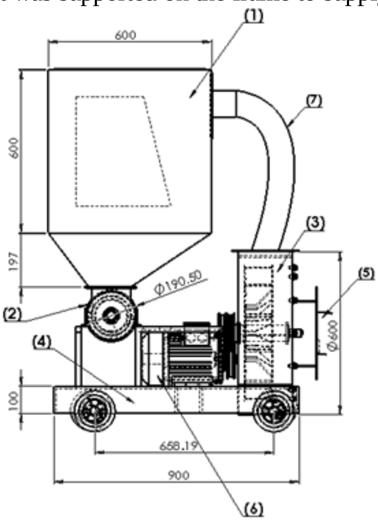
MATERIALS AND METHODS

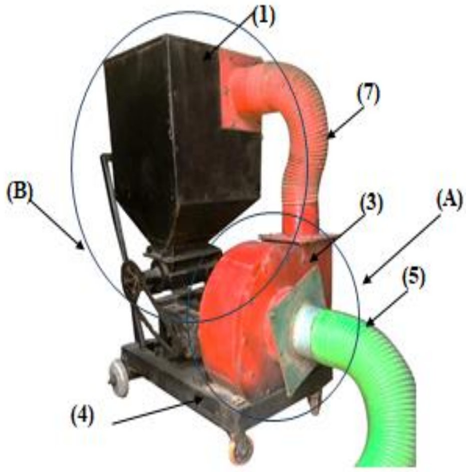
The experiments were done in Agric. Eng. Dept., Fac. of Agric., Mansoura Univ., at 2019 to 2021 to evaluate the collect-packing machine "CPM" (Figs. 1 and 2). It was constructed, fabricated and confirmed in a special workshop at Dakahlia Governorate in 2019. It is involves two main units; collecting unit "CU" and delivery-packing unit "DPU". The assistance shares of "CPM" are a source of power, transmission system and frame. But, the essentially parties included suction tube, blower and collecting chamber. The three coordinate dimensions of the

* **Corresponding author.**
E-mail address: ebrahimzi@yahoo.com
DOI: 10.21608/jssae.2021.160422

investigated machine "CPM" are 900 mm; 700 mm and 1350 mm for length, width and height respectively.

Firstly, the collecting unit was constructed from two parts namely; inlet tube with 15 cm diameter and suction blower with outer diameter of 600 mm. Secondly, the delivery unit was contain delivery tube, collecting chamber and horizontal auger for packing residues. The power source is three phases electrical motor with 4.0 hp (2.98 kW) at max 1450 rpm. It was supported on the frame to supply power to all "CPM" units using pulley and V-belt drives (Fig. 3). The inverter "model: IG5A" was added to control blower speeds. The worm gear was located packing auger to reduce the revolution numbers to about tenth. The frame constructed to support the "CPM" units beside motor and worm gear. On the base of frame a four carrier wheels were connected to keep "CPM" machine easy to move while guidance it by hand, while the two front wheels supplied with simple brakes to fix the machine during collecting residues.



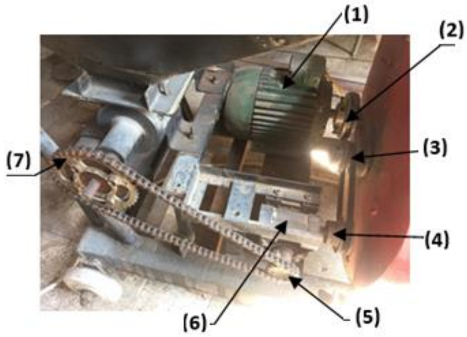


A- Collecting unit B- Delivery-packing unit

1- Tank 2- Packing auger 3- Blower 4- Frame 5- Suction tube 6- Motor 7- Delivery tube

Fig. 1. Sketch view of the collecting-packing machine

Fig. 2. The collecting-packing machine



1- Motor 2- Motor shaft pulley 3- Impeller shaft pulley
4- Gearbox shaft pulley 5- Gear (15 teeth) 6- Gearbox
7- Gear (24 teeth)

Fig. 3. The transmission system

The garden residues include fresh (forced dropped) and dry (free dropped) materials produced from shed the tree -leaves. Some properties of these garden-residues tabulated in Table (1).

Table 1. The properties of the green and dry from shed of tree.

Residues state	Moisture content, %	Bulk density, kgm^{-3}	Terminal velocity, $m\ sec^{-1}$	Shear stress, N
Forced dropped	64±2.07	214.48±0.72	1.35±0.05	2.3±0.16
Free dropped	14±1.04	35.15±0.64	0.42±0.02	4.1±0.14

In the tests, the trees residues fallen were collected from gardens of Mansoura University. The test procedure began with a mass of 1.0 kg from samples that were collected and spread on the ground in an area of 1.0 m^2 to easy calculate the inlet flow rate. To keep synchronize of the operating machine parts, the studied variables include:

1- Residues moisture contents of 14% (that samples were free dropped and collected after three weeks) and residues of 64 % (that samples were forced fell and collected in green condition).
2- Four levels of blower revolution "RB" of 1000, 1700, 2400 and 3100 rpm (controlled by electrical inverter device).
3- Three different of delivery tube diameters "DTD" of 10, 15 and 20 cm.

At evaluation the machine performance, three samples for each test were taken to measure, determine and calculate the each of:

- The moisture content was determined using the oven-drying method. It was calculated on a wet basis as follows:

$$\mathbf{MC} = \frac{(\mathbf{WW} - \mathbf{DW})}{\mathbf{WW}} \times \mathbf{100}\ , \quad \%$$

Where: MC = the moisture content (%)
WW = the wet mass of the sample and dish (g)
DW = the dry mass of the sample and dish (g)

- Bulk density and rate of residues volume reduction after and before tests were determined as:

$$\mathbf{Bulk\ density} = \frac{\mathbf{Wet\ mass}}{\mathbf{Volume}}\ , \quad \mathbf{kg\ m^{-3}}$$

$$\mathbf{Rate\ in\ volume\ reduction} = \frac{\mathbf{Volume\ before\ collecting} - \mathbf{Volume\ after\ packing}}{\mathbf{Volume\ before\ collecting}} \times \mathbf{100}, \ \%$$

- Productivity of collecting-packing machine "CPP" is estimated using the following formula**:**

$$\mathbf{Productivity\ of\ "CPP"} = \frac{\mathbf{Mass\ of\ the\ outlet\ sample\ (kg)} \times \mathbf{3600}}{\mathbf{Operating\ time\ (sec)}}\ , \mathbf{kg.h^{-1}}$$

- The Specific energy consumed "SEC" in (kW h ton^{-1}) was calculated from following equation:

$$\mathbf{Energy\ consumed} = \frac{\mathbf{kW}}{\mathbf{W}}\ x\ C\ , \quad \mathbf{kW\ h\ Mg^{-1}}$$

Where: kW = The consumed power, kW
W = Productivity of collecting-packing machine, Mg h^{-1}.
C = component constant

The consumed power (kW) was calculated from the knowledge line current strength (I) and potential difference values (V) using the following formula:

$$Total\ \ consumed\ \ power = \frac{\sqrt{3}\ \mathrm{I\ V\ cos}\theta\ \eta}{1000}$$

$$No\ load\ \ power = \frac{\sqrt{3}\ \mathrm{I\ V\ cos}\theta\ \eta}{1000}$$

$$Useful\ \mathrm{power} = \mathrm{Load - No\ load}$$

Where: Cos Ɵ = Power factor (being equal to 0.84).
$\sqrt{3}$ = Coefficient current three-phase (being equal 1.73).
η = Mechanical efficiency assumed (90 %).

The instruments used to determine the time is stopwatch, to determine mass of material is electrical balance with accuracy of ±0.01 g, to determine shaft rotational speed is digital photo/contact tachometer ranged from 0.5 to 19999 rpm with an accuracy of ± 0.05% and super clamp meter is used to determine amber and volt.

The statistical design is factorial design in complete block design with three replicates. The regression and statistical analysis is done using the Excel program 2017.

RESULTS AND DISCUSSION

Residues bulk density “BD”

The “CPM” action is effect on residues bulk density “BD” at go out moment as shown in Fig. (4), the figure cleared that the “BD” had an inversely relationship by increasing the delivery tube diameter “DTD” and directly relationship by increasing residues moisture content “RMC”. However, the increase in revolution of blower “RB” from 1000 to 3100 rpm the “BD” increased from 34 to 45 and from 210 to 320 kg.m^{-3} for 14% and 64% “RMC” respectively. These results may due to increases impact force between blower impeller by increasing blower speed that make to bowdlerize the residues especially for leaves with high moisture content.

On the other hand, at increase “DTD” from 10 to 15 to 20cm the residues of “BD” were 387, 39.2 and 39.3 kg.m^{-3} respectively, at “RMC” of 14%. While under “RMC” of 64% the “BDs” were 265, 244 and 254 kg.m^{-3} at DTD of 10, 15 and 20 cm respectively. These results logical, that is shows, the slightly effect of the delivery tube diameter “DTD” on the bulk density “BD” of residues.

The regression analysis confirms the above results. The highly significant of “F” test was found at multiple statistical regressions then, the probability “P” values were high effect on residues “BD” occur at moisture content “RMC” followed by "RB" then DTD with the coefficient of determination “R^2” of 0.9966.

BD= 3.435 Mc - 0.1662 DTD - 0.0228 BR + (0.000002 MC^0.5 * BR^2) (R^2 = 0.9966) ---------(1)

By substitution the values in Eq. (1) under different operating of “CPM”, results indicated that the closing value with real results:

BD= (3.43425*14)-(0.1662*10)-(0.0228*1000)+((0.000002* (14^0.5)* (1000^2))) = 31.10 kgm^{-3}

BD= (3.43425*64)-(0.1662*10)-(0.0228*1000)+((0.000002* (64^0.5)* (1000^2)))= 211.33 kgm^{-3}

Rate of residues volume reduction “RV, %”

The same conduction of the above parameters was conducted to indicate its effect on residues volume reduction “RV” as shown on Fig. (5). When the revolutions of blower are increases “1000, 1700, 2400 and 3100 rpm”, the reduction in residues volume “RV” increases by about 0.7806, 3.4008, 16.17 and 29.06 %. The corresponding percentage for collecting tree leaves of 64 % moisture content were 27.56, 41.22, 56.99 and 82.69% at “RB” of 1000, 1700, 2400 and 3100 rpm respectively.

On the other sided, the effect of “DTD” deviation on “RV” had a slightly effect which were 12.44, 12.31 and 12.31% under “DTD” of 10, 15, 20 cm respectively for residues moisture content “RMC” of 14%. Whereas, at “RMC” of 64% the differences of DTD of 10, 15, 20 cm were effects on reduction in residues volume “RV” by about 61.94, 44.16 and 50.22 % respectively.

RV = 0.5168 Mc - 1.8954 DTD + 0. 0105 RB + 0.0001 (MC^0.5) *DTD *RB (R^2 = 0.962 1) ---------(2)

By substitution the values in Eq. (2) under different operating of “CPM”, results indicated that the closing value with real results:

RV=(0.5168*14)-(1.8954*15)+(0.0105*3100)+(0.000105* (14^0.5)* 15*3100) = 29.6228 %

RV=(0.5168*64)-(1.8954*20)+(0.0105*3100)+(0.000105*(64^0.5)* 20*3100) = 79.7972%

Regarding to regression analysis the highly significant "F" was found at multiple statistical regressions, then the p-values were show the high effect on reduction of residues volume “RV” occurred under “RMC” followed by RB then "DTD" with the coefficient of determination of 0.9621.

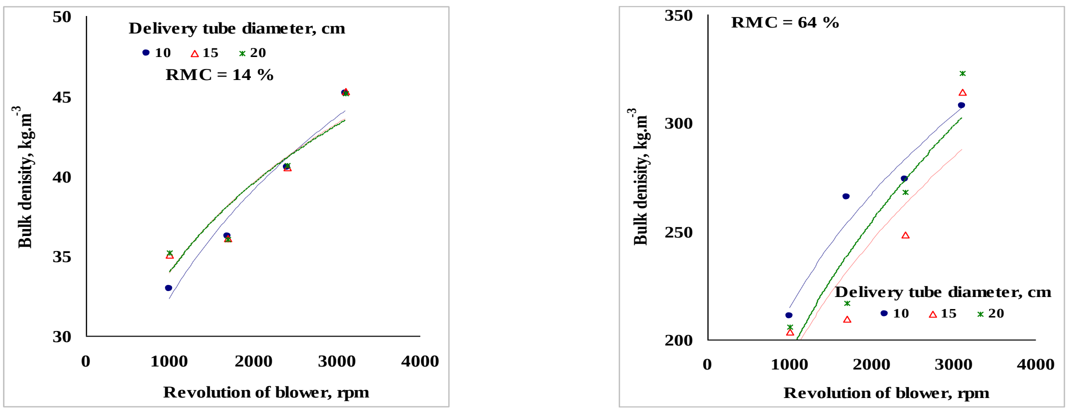


Fig. 4. Blower revolution “RB” via residues bulk density “BD”

Collecting-packing machine productivity “CPP, kg h^{-1}”

As shown in Fig (6) the productivity of “CPP” increased by increasing both of “RB, rpm” and “DTD, cm”. At collecting the residues with "RMC" of 14%, the increasing of blower revolution of 1000, 1700, 2400 and 3100 rpm increase the “CPP” of 122.41, 164.42, 186.91 and 221.22 kg.h^{-1} respectively under take the average values of “DTD” i.e. statically it means neglected the “DTD” effect (Ismail, 2012). However, the same trend was found at increasing “DTD” of 10, 15 and 20cm the “CPP” recorded 161.75, 174.90 and 184.57 kg.h^{-1} respectively at neglected the effect of “RB”.

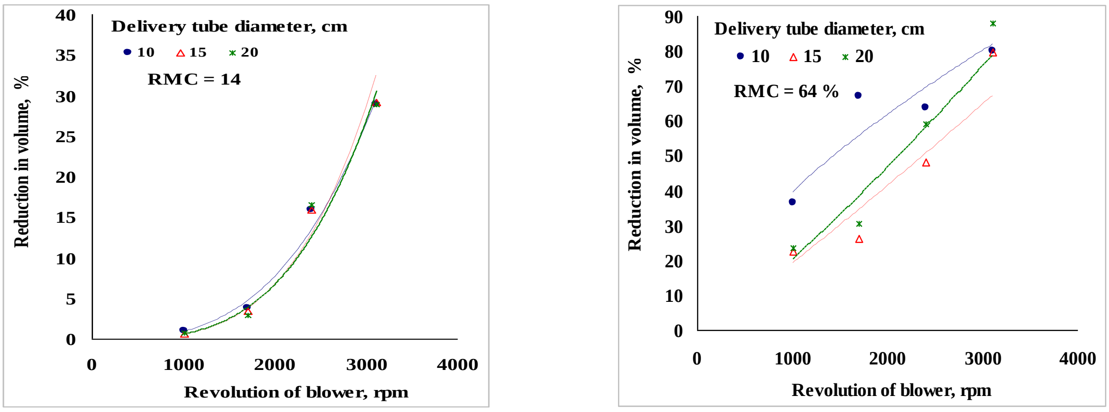


Fig. 5. Revolution of blower "RB" via residues volume reduction "RV"

The above figure conducted also that, at collecting the residues with RMC of 64%, the increases of "RB" from 1000, 1700, 2400 to 3100 rpm increased the "CPP" from 122.06; 157.28; 175.15 to 268.47 kg.h^{-1} respectively under neglected the "DTD" effect. Nevertheless, the similar tendency was established at confirmation the effect of increasing "DTD" from 10, 15 to 20 cm on the "CPP" that recorded 137.93; 188.24 and 208.54 kg.h^{-1} respectively under neglected the effect of "RB". The figure illustrated that the slightly effect were found at decrease the RMC from 14 to 64 % and by increasing "RMC" from 14 to 64% the "CPM" increased as an average from 173.74 to 178.24 kg.h^{-1}.

The regression analysis of "CPP" regarding the variables of "RMC", "DTD" and "RB" were identified. The finite model of "CPP" at different studied variables shows in following equation:

$$CPP = -0.2399\ MC + 3.5775\ DTD + 0.0566\ BR + 0.00004\ MC*DTD^{\wedge}2*BR^{\wedge}0.5 \quad (R^2 = 0.9863) \quad ---------(3)$$

By substitution the values in Eq. (3) under different operating of "CPM", results indicated that the closing value with real results:

$$CPP = -(0.2399 * 14) + (3.5775 * 15) + (0.0566 * 1700) + (0.00004 * 14*(15^{\wedge}2)*(1700^{\wedge}0.5)) = 151.719\ kgh^{-1}$$

$$CPP = -(0.2399 * 64) + (3.5775 * 15) + (0.0566 * 1700) + (0.00004 * 64*(15^{\wedge}2)*(1700^{\wedge}0.5)) = 158.278\ kgh^{-1}$$

The equation clears the directly relation of RMC, DTD and RB. The correlation of determination was 0.9863. The regression analysis also defined that a significant P-values. From p-value it can explain that the high factors effect of suction unit productivity is "RB" followed by "DTD" then "RMC".

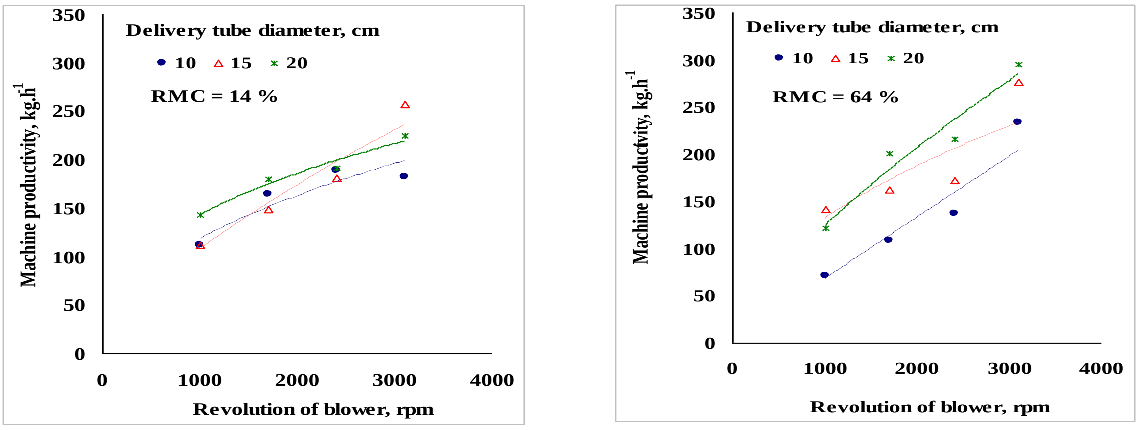


Fig. 6. Revolution of blower "RB" via machine productivity

Specific energy consumed "SEC"

The effect of revolution of blower on the specific energy consumed can be show in Fig. (7), it conducted that the specific energy had a proportion relationship with both of "RB" and "DTD". Moreover, at residues moisture content of 14 %, the decrement percentage of energy consumed regarding to the increase in revolution of blower from 1000 to 3100 rpm was establish about 55.90 %. These results due to increases of blower speeds increase the machine capacity which cause the decreases in energy consumed. At the anti-wise, the increases in "DTD" from 10 to 20 cm cause the decrement in percentage of energy consumed was about 85.91%.

The results revealed that the increase in "DTD" allow the all residues easy to transport to the tank without crowded. Likewise at residues with moisture content of 64% it found the reduced percentage of energy consumed concerning to the increase in revolution of blower from 1000 to 3100 was about 59.84 %. However, the increase in "DTD" from 10 to 20 cm foundation the decrease in energy consumed was about 75.05%.

The figure also shows that the increase of "RMC" from 14 to 64 % translate to decrease percentage of consumed energy of about 80.77, 74.85, 72.21 and 75.46 % respectively at RB of 1000, 1700, 2400 and 3100 rpm. On the other side, the increase of "RMC" from 14 to 64 % decreased the percentage of consumed energy of about 66.69, 89.40 and 76.33 % respectively at DTD of 10, 15 and 20 cm. That is may be due to the increase of "RB" increase the suction of blower that ease to collect the light mass of dry resides than the heavy mass from fresh residues.

The multiple regression analysis authorizes the above results, by the occurred highly significant "F". Also, the P-values were show the high effect on specific energy consumed found at moisture content followed by "RB" put "DTD" with nun-significant. The coefficient of determination was 0.9745.

SEC = 0.0020MC - 0.0073 DTD - 0.0004 BR + 0.0268 BR^0.5 (R^2 = 0.9745) ---------(4)

By substitution the values in Eq. (4) under different operating of "CPM", results indicated that the closing value with real results:

SEC = (0.002 * 14) - (0.0073 * 15) - (0.0004 * 3100) + (0.0268 * (3100^0.5)) = 0.2003 kWhMg^{-1}

SEC = (0.002 * 64) - (0.0073 * 20) - (0.0004 * 3100) + (0.0268 * (3100^0.5)) = 0.2588 kWhMg^{-1}

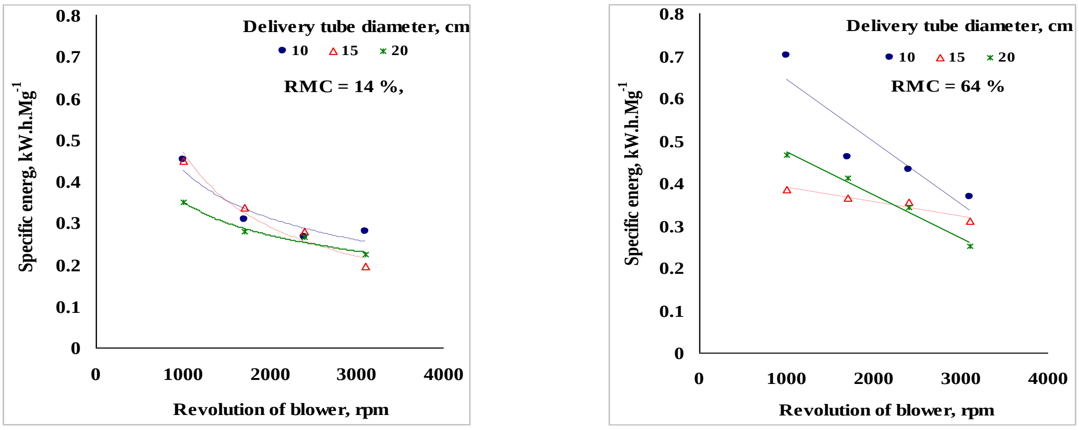


Fig. 7. Effect of revolution of blower on specific energy

CONCLUSION

From the results it can concluded that the collect-packing machine suitable for collecting the dry (14% RMC) and fresh garden residues (64% RMC). The best level of revaluation of blower "RB" and delivery tube diameters "DTD" are 3100 rpm and 15 cm for 14% "RMC" and 3100 rpm and 20 cm for 64% "RMC". At these levels for "RMC" of 14% the highest of BD "kgm^{-3}", RV "%" and CPP "kgh^{-1}" but lowest of SEC "kW.h.ton^{-1}" were 45.3 kg m^{-3}, 29.22%, 257.26 kg h^{-1} and 0.1961 kW h Mg^{-1} respectively. The corresponding values at RMC of 64% were 32.32 kg m^{-3}, 188.01%, 294.79 kg h^{-1} and 0.2511 kW h Mg^{-1} respectively. The regression modeling has a strong relation to describe the effect of studied variables and different machine performance. From the above results the collect-packing machine can recommended to use in the garden areas.

REFERENCES

Abdel-Shafy, H.I. and M.S.M. Mansour (2018). Solid waste issue: Sources, composition, disposal, recycling, and valorization. Egyptian Journal of Petroleum 27 (4): 1275–1290.

Azadbakht, M.; A. kiapey and A. Jafari (2014). Design and fabrication of a tractor powered leaves collector machine equipped with suction-blower system. Agric. Eng. Int: CIGR Journal Open access at http://www. cigrjournal. org Vol. 16, No.3: 77-86.

Evanylo, G.K.; C.A. Sherony; J. May; T.W. Simpson and A.H. Christian (2009). The virginia yard waste management manual. Produced by Communications and Marketing, College of Agriculture and Life Sciences, Virginia Polytechnic Institute and State University. 2nd Ed., www.ext.vt.edu.

Ismail, Z.E. (2012). Basics of power and farm machinery in agricultural engineering. Part one, Specifications and operation, Electronic Book, Mansoura University.

Morris, C.L. and G. Conn (1953) Rake. United state patent office. 2,652,279.

O'Brien, K. (2015). Practices for Commercial Scale Composting Operations. Michigan Compost Operator Training, Guidebook.

Palazzolo, G.S. (2007). Leaf collection device. Background of the disclosure. United state patent office 7,257,858 B2.

Reeves, R.J. (2008). Leaf removal system. Field of the invention, Patent application publication, United state patent office 0022481 A1

Sanders, D. L., T. A. Pribanic, T. D. Jewell, S. J. Verges, and D. M. Woods, (2004). Variable speed leaf blower. Technical field of the invention, United state patent office 6,834,413 B2.

نمذجة الإنتاجية لآلة تجميع وتغليف مخلفات الحدائق

زكريا إبراهيم إسماعيل[1]*، ناهد خيرى إسماعيل[2] و زينب صبرى حمزة[1]

[1] قسم الهندسة الزراعية – كلية الزراعة - جامعة المنصورة

[2] قسم هندسة النظم الحيوية – معهد بحوث الهندسة الزراعية – مركز البحوث الزراعية

العمل رفع ونقل مخلفات الحدائق المتساقطة من الأشجار "تتمثل الأوراق والبذور والأزهار وغيرها" والتي لا يتم بصورة ممكنة كاملة. لهذا السبب، تم تحديد الهدف الرئيسي من هذا العمل لبناء معده وتقييم أدائها في جمع بقايا الحدائق وتعبئتها في حين تضمن الهدف الخاص تقييم أداء آلة مطورة ودراسة خواص المنتج. تتكون الآلة المطورة من وحدتين أساسيتين، وحدة التجميع وهى عبارة عن أنبوب يوجه إلى المخلفات لشفطها بواسطة مروحة شفط تنقل المخلفات إلى وحدة النقل والتي تتكون من أنبوب ناقل لأعلى خزان تنتهى فتحته على بريمة ناقلة للتعبئة. وتتضمن المتغيرات الدراسية سرعة المروحة (1000، 1700، 2400، 3100 لفة.دقيقة-1)، قطر الأنبوب الناقل (10، 15، 20 سم)، نسبة رطوبة المخلفات (14، 64 %). ولتقييم أداء آلة التجميع والتعبئة المطورة تم تقدير الكثافة الظاهرية للمخلفات، نسبة الانخفاض في حجم المخلفات عند التعبئة، الطاقة النوعية المستهلكة، وإنتاجية الآلة. ثم تم استنتاج نموذج الانحدار لتأثير المتغيرات الدراسية على الكثافة الظاهرية ونسبة الانخفاض في الحجم وإنتاجية الآلة والطاقة المستهلكة. وقد أوصت النتائج بإمكانية استخدام الآلة المطورة لتجميع كلٍ من مخلفات الحدائق الجافة عند سرعة شفط 3100 لفة دقيقة-1، قطر الأنبوب الناقل 15 سم، وللمخلفات الرطبة عند سرعة شفط 3100 لفة دقيقة-1، قطر الأنبوب الناقل 20 سم. عند مستويات المتغيرات الدراسية السابقة أمكن الحصول على أعلى إنتاجية257.26، 294.79 كجم.ساعة-1 وأعلى كثافة ظاهرية 0.0453، 0.3232 جم.سم-3، وأعلى نسبة انخفاض في حجم المخلفات 2922، 88.01% وأقل طاقة مستهلكة 196.17، 251.05 كيلو وات ساعة كجم-1 لكلٍ من نسب الرطوبة 14، 64 % على التوالي. كما ظهر قوة نموذج الانحدار في وصف تأثير المتغيرات الدراسية عناصر تقييم الآلة