J.Soil Sci. and Agric. Eng., Mansoura Univ., Vol. 10 (5): 291 - 297, 2019

Interaction of the Press Wheel Planter with Soil

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ABSTRACT

The good pressing of the soil around seeds at planting moment is mean that perfect of seeding depth consequently increasing seeds germination rate. So, the technology of planter press wheel helpful to keep up the requirements of pressing the soil above the seeds, covering and seeds depth. The objectives of this study is to determine the statics and dynamics forces requirements to realize a suitable compress on planted furrow for different types of seeds crops. The constructed press-wheel unit tested under different variables of two press-wheel ratio (W1=7.3 and W2=3.3), four spring index "C" (10.5, 9.3, 7.7 and 7.1) and four adding load "AL" (99, 126, 167 and 204 N for the first press wheel "W1 = 7.3" and 120, 157, 198 and 234 N for second press wheel "W2 = 3.3"). All variables were conducted for sandy soil under two soil moisture contents of 4.8 and 13.9% "wb". The response each of; applied loads, spring index, press wheel factor on proposed press wheel structure, it easy to define the reaction of applied loads as changing in displacements or differences between Kinetic and Potential Energy. The arbitration criteria for judging on the final relationship between action (as adding load) and soil reaction (as soil rut) can be summarized as change in soil deflection relative to travel system. From the results it can concluded that the highest soil rut recorded at wheel ratio of 3.3, the two soil moisture contents, press on soil and at decreasing the forward speed and spring index. The high total energy found at the highest forward speed, applied load and lowest the both of spring index and wheel ratio.

INTRODUCTION

The press wheel with regulator springs unit was adding to the planting machine for recognizing and ensuring about the best covering seeds requirements and there control depth that identifying better environment around the seeds at different growing-root stages and firm the furrow sides. Most of the error in seeding depth is due to flotation, depth of soil cover over the seed and less accurate depth control (Ismail, 2012).

In researches of Rainbow (1994), Hannah *et al.* (2010) and O'Laery (2013) on seeds floatation in a sand soil, the absence of frame flotation errors, the vertical variation in seed placement in the soil is less than 10mm and pointing out of the importance of the surface soil cover. It found that yield advantages can be significant if attention is paid to the depth of cover on all rows. Planting with excessive load could over compact the soil. While not enough load could result in a shallower seeding depth (Karayel and Sarauskis, 2011) and both situations could result in poor root development (Raper and Kirby, 2006) and uneven plant emergence (Gratton *et al*., 2003; Hannah *et al*., 2010 and Karayel and Sarauskis, 2011). The advantages of adding wheel to press or firm the furrow are: uniform and consistent seeding depth (Sharda *et al*., 2017); increase efficiency and durability of seed emergence (O'Laery, 2013); decrease soil moisture losses from convective evaporation (Rainbow, 1994); facilitate the flow of moisture through the soil to the seed (https://www.vicnotill.com.au, 2009); modify the depth and cover thickness (Murray *et al*., 2006); prevent surface light penetration and reduce the risk of premature sub surface leaf emergence (O'Laery, 2013). Also it cleared that broad-wedge type of press-wheel is makes a good depth-control in medium to light soils. It provides a good balance between seed-soil contact and moisture harvest and it is an ideal for single, narrow-row seeding. Wide flat type gives good depth control in medium to light and sandy soils. It is good for canola and other small seeds. Meanwhile, wide-wedge tire type has a good depth control in light and sandy soils and with the seeds want low-pressure. Also, narrow-wedge tire type gives high-pressure. It is good for cereals and larger seeds. It is ideal for single narrow-row seeding in heavy soils. Whoever, medium and narrow flat tires type can used efficiently in medium to light and sandy soils. It has low to medium-pressure, and good in scattering of loose soil on pressed-seed. The optimum pressure of press wheel depends on soil type, soil moisture level during planting durations and grain or seeds verities (O'Laery, 2013 and Ismail, 2014). There were recommended that the pressure may be in between 2.0 and 4.0 kg/cm2 of tire face. Sharda, *et al*. (2017) determined optimum down-force can be stimulating in terms of providing the enough load to prevent loss of soil-contact of row units at varying soil conditions and at increasing planting speeds. Correctly down-force can typically increase emergence by 10% to 25% as well as improving seedling durability.

The objective of this research is to recognize the optimum required of supply pressure from press wheel upon seeds planted in rows. So, achieving that required judging response for each of applied loads, spring index, press wheel ratio on proposed press wheel structure and identified them as the reaction of above variables on changing in differences between kinetic and potential energy.

MATERIALS AND METHODS

Developed press-wheel

The developed press-wheel unit was constructed (Fig. 1) and supported (Fig. 2) on the soil bin, which systematized by Ismail (2010) in Agricultural Engineering Department, Mansoura University. The major parts of the developed unit are; press wheel unit, trolley, soil bin, transmission system and source of power. The wheel press unit consists of five main parts namely; press wheel, spring, depth controller (to control the press-wheel initial depth), plate load (to carrying the adding load) and frame to support the press-wheel arms and up-down by the depth controller.

Soil properties

The soil bin fill with the soil texture as each experiments condition. In this research the sandy soil was used. The soil properties are shown in table (1).

Table 1. Soil properties

Soil texture	Particles size distributions, %			Bulk density, g.m-3	Moisture content, %
	Clay	Silt	Sand		
Sandy	0.10	0.15	99.75	1.15	4.8

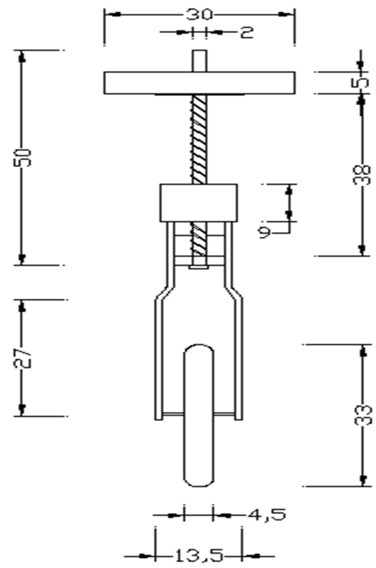


Fig. 1. Schematic of developed press-wheel unit

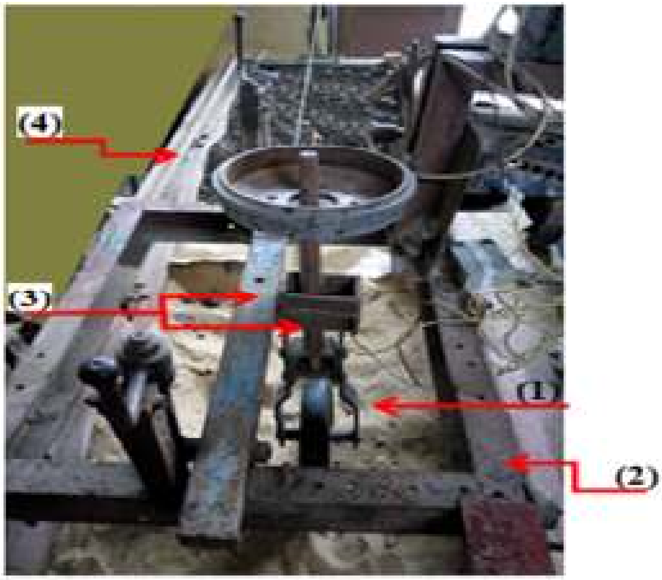


Fig. 2.The developed wheel press unit
1- Press-wheel unit, 2- Trolley, 3- Frame of unit, 4- Soil-bin

The experiments procedure includes the pre-tests to determine the studied variable levels. The studied variables include:

Two press-wheel: flat wheel "W1" of 330mm diameter, 45mm width and 3.60kg mass (with wheel ratio of "W1" = 7.3) and wide flat wheel "W2" of 245mm diameter, 75mm width and mass of 6.0kg (with wheel ratio W2 = 3.3).

Four spring index "C": the relation between the spring diameter and wire diameter name as spring index ratio. So, four of spring index were used namely 7.1; 7.7; 9.3 and 10.5.

Four applied load "AL": 99, 126, 167 and 204 N for "W1 = 7.3" and 120, 157, 198 and 234 N for "W2 = 3.3".

Two-soil moisture contents "M": 4.8 and 13.9 % wb.

The following measurements were determined to achieve the aims of research;

1- Measure compress soil surface "CSS" (soil rut "SR") by measure the longitudinal of soil profile at the center of row.

2- Calculate the press wheel kinetic and potential energy using the common equations, then calculate the total energy as the sum of kinetic and potential energies.

3- Determine the optimum operating for proposed press wheel structure by knows and compare the seed requirements, via the press-load and soil rut.

The experiments were done in split split plot design with three replicates. The main plot include adding load and the sub-plot include spring index which the sub-sub plot include the wheel-press type. The using forward speed was adjusted at about 0.22 m/s. The projected area for each wheels were measured to calculate the press on soil "kPa" by divided the applied load of unit on the projected area.

RESULTS AND DISCUSSION

To judge response each of applied loads, spring index, press wheel ratio on proposed press wheel structure, it easy to define the reaction of above variables as changing in differences between kinetic and potential energy. The arbitration criteria for judging on the final relationship between action (as applied loads– "AL") and soil reaction (as reaction acting upon the proposed press wheel structure to compress soil surface - CSS) can be summarized as change in soil deflection (soil rut, SR) relative to travel system.

A- Judging criteria of compress soil surface "CSS"

1-Influence of applied loads on soil rut "SR"

The strength of the pressure wheel on the field surface has been identified to make the wheel printing or deformation on the upper surface. This deformation can be referred as the soil rut. The relationship between soil rut (SR, cm) as affecting by different applied loads (AL, N) is illustrated in Fig. (3) under two different wheel ratios (W1= 7.3 and W2 = 3.3) and two sandy soil moisture contents (M1 = 4.8 and M2 = 13.9% wb). Using press wheel with "W" ratio of 7.3, the average soil rut (SR) was found to be increasing as the "AL" level is increased and reached its to 3.64 cm at maximum "AL" of 203.7 N for spring index of 7.7 (Fig. 3-A) and soil moisture content of M1 (4.8% wb). On the other side, for soil moisture content of M2 (13.9% wb), the maximum value of "SR" recorded 3.58cm at same of AL (203.7N) but at spring index of 7.1 (Fig. 3-B). While, the maximum values of SR recorded 3.66 cm at 7.1 spring indices and 3.76cm at 7.7 spring index for press wheel systems W2M1 and W2M2, respectively (Fig. 3 C and D).

Regarding the enlargement of the circle as shown in the Fig. (3), it easy to conform that the average of soil rut

(SR, cm) at AL 140N were ranged from 2.6 to 2.9 cm for different spring index at W1M1 (Fig. 3-A). This range become (2.6 to 2.7 cm) at W1M2 (Fig. 3-B). Also ranged from 2.7 to 2.9 cm and 2.9 to 3.3cm at W2M1 (Fig. 3-C) and W2M2 (Fig. 3-D) respectively but at "AL" of 160 N. So, for example if the farmer wanted to plant corn and the agronomy requirement recommend to cover the corn kernel with soil of 2.5 cm height, then the press wheel can adjusted at "AL" of 95 and 127N during using W1 and C of 7.7. (Fig. 3-A and 3-C).

2- Influence of spring index on soil rut

Generally as shown in Fig. (3), the inversely relationship were found as effecting spring index on soil rut. It means that increasing spring index decreasing the soil rut but the rate of decreasing varies relative to values of applied loads. During operating the proposed press wheel structure at W1M1 conditions, the rate of soil rut recorded 1.19; 0.95; 0.97 and 1.01 as decreasing spring index from 10.5 to 7.1 under different applied loads 90.0; 126.25; 167.5 and 203.7N, respectively. The same rate was found under W2M1 operating condition but the rate of increasing were found under more applied loads. For example, it 1.11 and 1.06 times at "AL" of 167.5 and 203.7N, respectively. Increasing spring diameter decreasing the spring index (C). Then, at achieving the agronomy requirement recommend to cover the corn kernel with soil of 2.5 cm height, then the press wheel can adjusted at AL of 105; 120; 127 and 130N during using W1M1 and C of 7.1; 7.7; 9.3 and 10.5 index (Fig. 3-A).

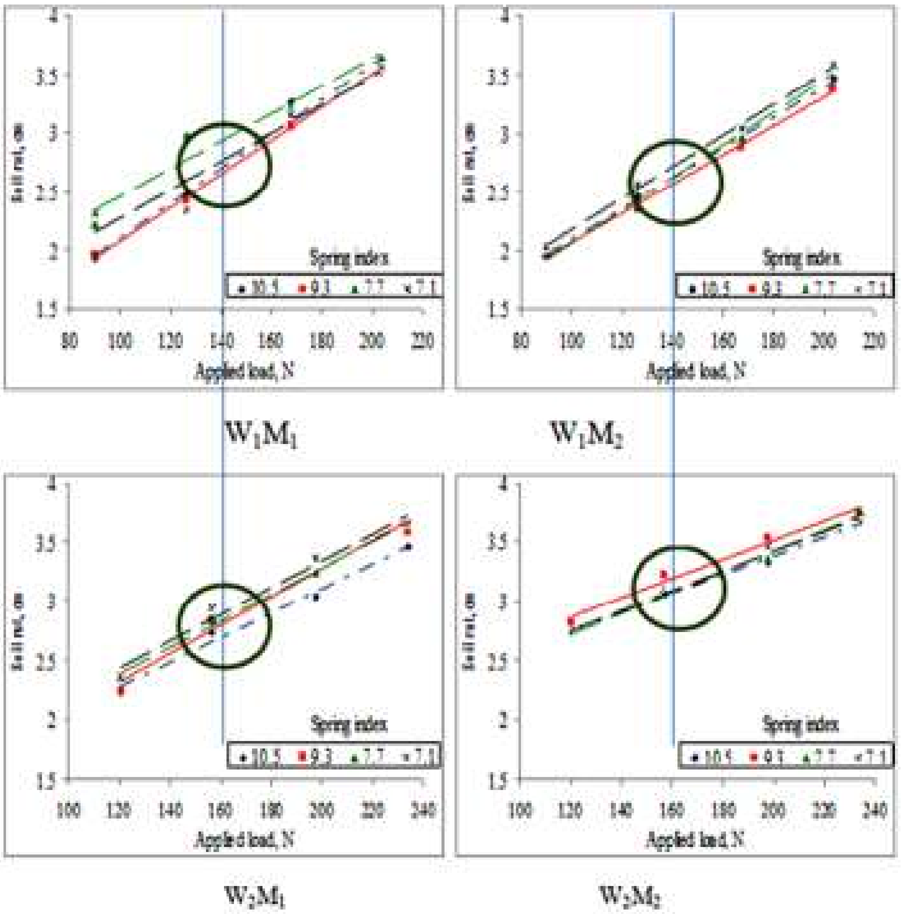


Fig. 3. Influence of applied loads on soil rut at different wheel ratio and moisture content

N.B. The applied loads included fixed load (press system total mass) adding with supply mass.

The above results indicated that at the same soil moisture content but only the variation in wheel press ratio which with the lowest wheel ratio (3.3) recorded increasing of soil rut with decreasing spring index. It may be because of the lowest wheel ratio means that wide width of wheel rim consequentially it need more applied force to achieve good required press on soil surface.

3- Influence of press wheel forward speed on soil rut

Basically, increasing the forward speed decreasing the height of soil rut and to keep the same values of soil rut it need more of applied loads (Ismail and Ismail, 2007). Fig. (4) indicated the influence of press wheel forward speed on soil rut relative to different applied loads at 7.1 spring index.

As shown in Fig. (4), the increment of "AL" the "SR" increased under all treatments at consent press wheel forward speeds. On the other hands, at constant "AL" there were differences in "SR" values and there no clear trend. For example, the values of "SR" recorded 3.54; 3.52; 4.4 and 3.56 cm at 0.13;0.16; 0.19 and 0.22m/s, respectively under W1M1 and spring index of 7.1 conditions Fig. (4-A). Also, the Fig. (4-B) indicated the same trend, which, the values of "SR" recorded 3.58; 3.54; 3.56 and 3.64 cm at 0.13; 0.16; 0.19 and 0.22 m/s respectively under conditions of W1M2 and 7.1 spring index.

B- Judging criteria of variables on press wheel kinetic and potential energy

1- Influence of press wheel forward speed

The relationship between the press wheel forward speed and the total energy (kinetic and potential energy) were constructed in Figs. (5 and 6) under different spring index. Generally, increasing the press wheel forward speeds directly increasing the total energy under different all press wheel positions and treatments. For example, increasing the forward speed from 0.0 to 1.0 m/s the total energy gradually increased with rate of 3.03 and 2.38 times as increasing land wheel forward speeds from 0.0 to 1.0 m/s and from 1.0 to 1.75 m/s respectively during "AL" of 204 N; "WR1" of 7.3 and spring index (C) of 10.5 as shown in Fig. (5).

Regarding to Fig. (6), the same trend was found as influence above parameters but with low rate. For example, increasing the forward speed from 0.0 to 1.0 m/s the total energy gradually increased with rate of 2.53 and 2.25 times as increasing land wheel forward speeds from 0.0 to 1.0 m/s and from 1.0 to 1.75 m/s, respectively during "AL" of 198 N; "W2" of 3.3 and spring index (C) of 10.5.

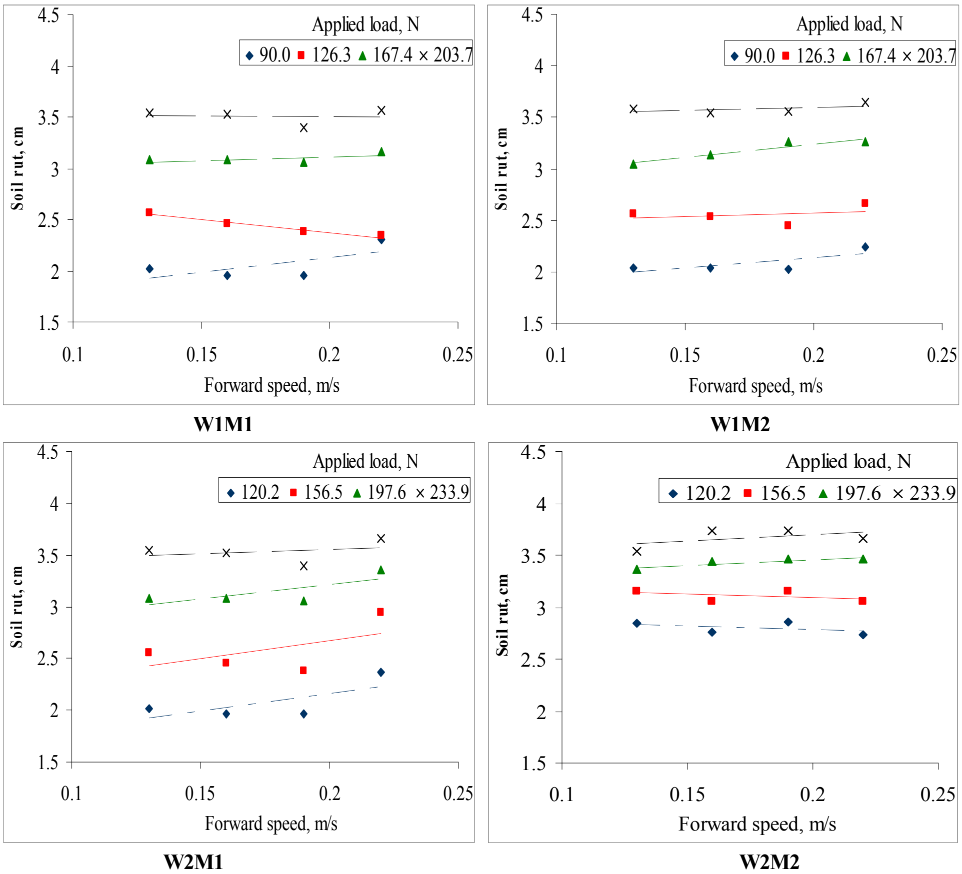


Fig. 4. Influence of press wheel forward speed on soil rut "SR"

2- Influence of applied load on total energy

Generally, increasing the applied load directly increasing the total energy under different all press wheel positions and treatments. For example, increasing the "AL" from 90 to 204 N the total energy gradually increased with rate of 1.38; 1.41; 1.458 and 1.46 times as decreasing spring index from 10.5; 9.3; 7.7 and 7.1, respectively during press wheel speed of 1.0 m/s and "W1" of 7.3 as shown in Fig. (5).

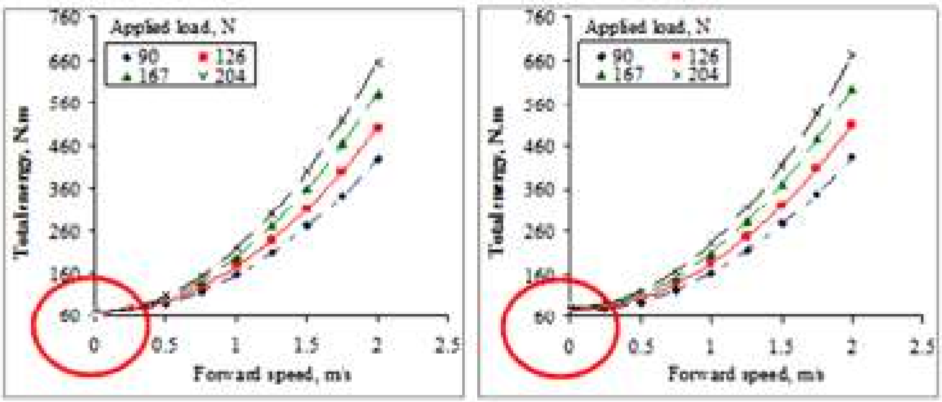
Referring to the zooming of the segment on the curve that referred under the circle was identified in Fig. (5), it easy to indicate that the amount average of potential energy recorded 70.36; 81.05; 101.31 and 103.96 N at 10.5; 9.3; 7.7 and 7.1 spring index respectively

Regarding to Fig. (6), the same trend was found as influence above parameters but with low rate. For example, increasing the "AL" from 120 to 234N, the total energy slowly increased with rate of 1.45; 1.48; 1.53 and 1.53 times as decreasing spring index from 10.5; 9.3; 7.7 and 7.1 respectively during press wheel speed of 1.0 m/s; and "WR" of 3.3.

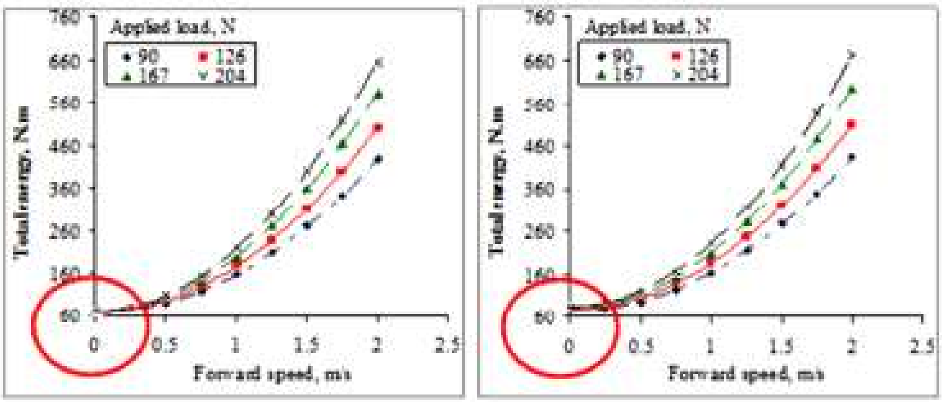
Referring to the zooming of the segment on the curve that referred under the circle in Fig. (6), it easy to indicate that the amount average of potential energy recorded 69.68; 80.36; 100.62 and 103.27 N at 10.5; 9.3; 7.7 and 7.1 spring index respectively.

3- Identification the optimum operating for proposed press wheel structure

Generally as shown in Fig. (7), there were a directly relationships at effecting press load and forward speeds on soil rut. It means that increasing press load increase the soil rut but the rate of increasing varies relative to values of press loads. During operating the proposed press wheel structure at W1M1 and W1M2 conditions, the soil rut (SR,cm) increased from 2.04 to 3.51 and from 2.09 to 3.58 cm throughout increasing the press load from 12.5 to 69.8 kPa respectively at forward speed of 0.22 m/s. While the corresponding valued at W2M1 and W2M2 were 2.29 to 3.58 and 2.80 to 3.67 cm by increasing the press load from 14.7 to 82.5 kPa respectively at forward speed of 0.22 m/s.

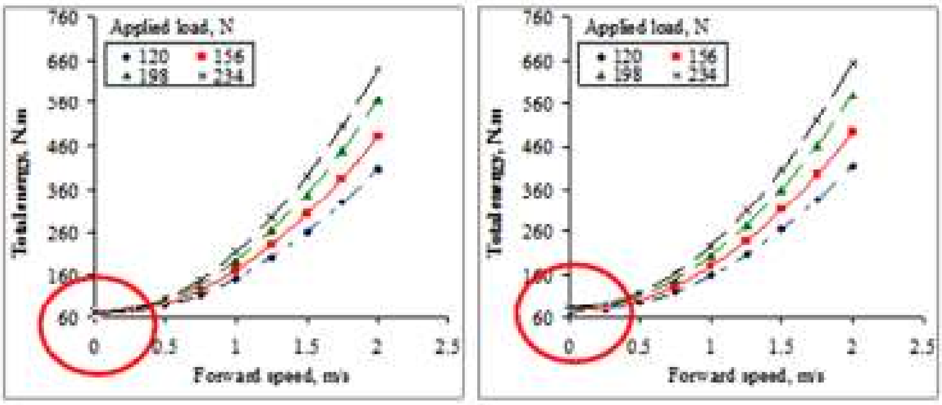


Spring index 10.5 Spring index 9.3

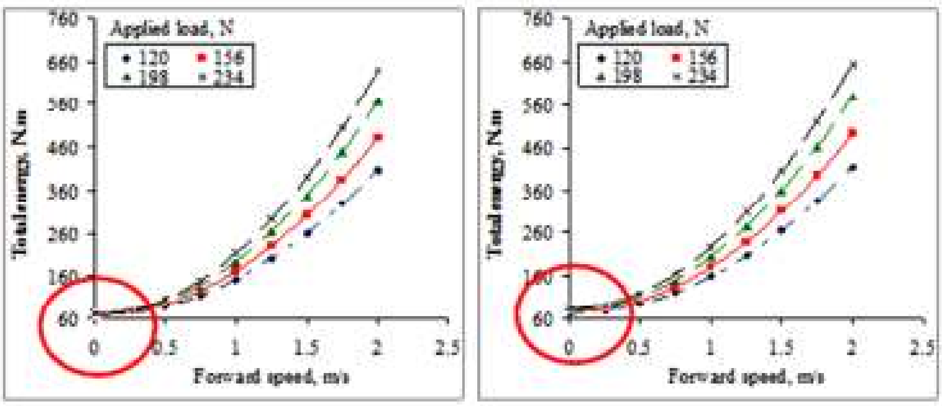


Spring index 7.7 Spring index 7.1

Fig. 5. Influence of press wheel (W1) forward speed on total energy (Nm) under different applied loads



Spring index 10.5 Spring index 9.3



Spring index 7.7 Spring index 7.1

Fig.6. Influence of press wheel (W2) forward speed on total energy (Nm) under different applied loads

On the another side, the rate of soil rut increasing by increasing the forward speeds at various wheel types and soil moisture contents. The recorded data clear that increasing rate of soil rut by increasing the forward speeds from 0.13 to 0.22 m/s were 1.104, 0.914, 1.026 and 0.1.006 respectively at press load 12.5, 44.6, 62.1 and 69.8 kPa for W1M1, then for W1M2 the soil rut recorded 0.91, 0.96, 0.93 and 0.98 respectively under the above variables. Hence, the increasing rate of soil rut recorded 1.001, 1.065, 1.063 and 1.058 cm and 0.965, 0.968, 1.030 and 1.034 cm respectively at press load 12.5, 44.6, 62.1 and 69.8 kPa at use W2M1 and W2M2.

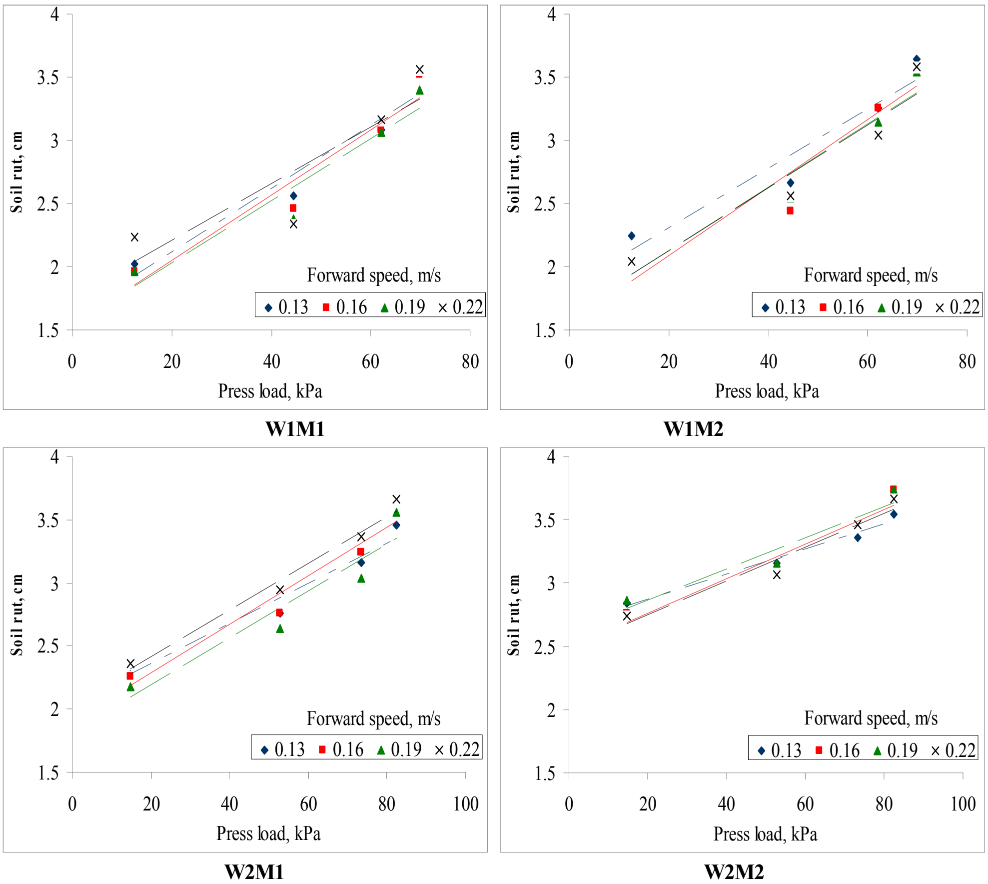


Fig. 7. Influence of press load on soil rut at different wheel ratio and moisture content

CONCLUSION

From the obtained results it can be concluded that, the press-wheel unit system can adjustment as the concluded for planting seed type. For example, if the required pressure above the seeds during planting is about 61 kPa to conform good germination with lowest energy, this condition can identify by select the type of press-wheel as wide flat then measure the soil moisture contents of 13.9%. Then, the press-wheel unit can adjust to conform 3.2 cm of soil rut that realize at forward speed of 0.16 m/s, spring index of 7.1 and applied load of about 184N the total energy is about 147.25 N.m.

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إرتباط عجلة الضاغط لآلة الزراعة مع التربة

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الضغط الجيد على التربة فى منطقة البذور يعني عمق البذر الصحيح والتغطية المناسبة للبذور. ولهذا فإن التطور المستمر فى تقنية العجلات الضاغطة لآلات الزراعة بما يناسب البذور المختلفة يكون هدف دائم للحصول على أفضل إنتظامية إنبات للبذور. وعلى هذا فإن الهدف من هذه الدراسة هو تحديد القوى الإستاتيكية والديناميكية المطلوبة للحصول على أفضل ضغط لسطح خط الزراعة بما يتوافق مع نوع البذور المنزرعة. ولتحقيق هدف الدراسة تم تركيب وحدة لعجلة ضغط تعمل بنظام الياى الضاغط وتركيبها فى إطار يتحرك داخل حوض للتربة وقد روعى أن تكون الوحدة حرة الحركة رأسياً. وتم إختبار الوحدة تحت متغيرات دراسية: عجلتى ضغط بنسة قطر على العرض "W" 7,3، 3,3، أربعة دليل ياى "C" : 10,5 ، 9,3 ، 7,7 و 7,1، أربعة أوزان على التربة "AL": 99، 126، 167 و 204 نيوتن للعجلة 7.3 = W1، 120، 157، 198 و 234 نيوتن للعجلة 3.3 = W2، محتوى رطوبة التربة 4.8 و 13.9 ٪. ولتحديد معايير الحكم على الضغط لسطح التربة تم تقدير؛ مقدار الإنخفاض الناتج عن ضغط سطح التربة "CSS"، طاقى الحركة والوضع وكذلك الطاقة الكلية لعجلة الضغط والضغط الأمثل لتشغيل العجلة الضاغطة المقترحة. من النتائج يمكن أن نستنتج أن أكبر إنخفاض فى سطح التربة سجل عند العجلة 3,3، محتويان رطوبة للتربة، وزيادة الأوزان الواقعة على التربة وإنخفاض كلٍ من سرعة التقدم ودليل الياى. كما نتج أن أعلى طاقة كلية سجلت عند أعلى سرعة تقدم، أعلى وزن واقع على التربة، وأقل دليل للياى ونسبة قطر على عرض للعجل 3,3.