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STUDY ON THE EFFECT OF TRACTOR POWER AND SPEED ON SOME FIELD PERFORMANCE PARAMETERS WORKING ON A CLAY LOAM SOIL

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ABSTRACT

The objective of this study was to investigate the effect of tractor power and forward speed on the drawbar pull, wheel slippage and fuel consumption when a 2WD tractor was linked with a mounted disc plow and working on a clay loam soil. Two levels of tractor drawbar power and three levels of forward speed were evaluated. Results showed that the increase in tractor power and speed and their interaction had a highly significant effect on these three field performance parameters. It was found that as the tractor power increased from 53.2 kW to 68.4 kW, the average pull increased by 55%, while the increase in tractor speed from 5 km/hr to 9 km/hr increased the pull by 39% and 36% for the medium and large tractors, respectively. When the power of the tractor was greater, the average wheel slippage was reduced up to 55%, but when the higher speed was used the average slippage was increased by 31% and 12% for the two tractors, respectively. The average fuel consumption rate was observed to be increased with the increase in tractor power and speed giving an average increase of 60% with the bigger tractor. However, using the higher speed gave an average increase in fuel consumption of 72% and 60% for the two tractors, respectively. The multiple correlation analysis indicated that power and speed accounted jointly for 98.1%, 97.7% and 92.6% of drawbar pull, slippage and fuel consumption rate variability, respectively. The big tractor (68.4kW) working at medium speed 7km/hr showed a tendency to give optimum values of the three field parameters operating on this type of soil.

INTRODUCTION

It is important to match a given tractor with the appropriate implements with respect to soil type, soil conditions, tractor power, weight and speed to attain optimum performance in the field. The optimum combination between these factors aid the tires to transmit the tractor torque to the ground in a form of useful power which enable a tractor to pull, efficiently, an implement in addition to moving its self. Many studies have been conducted to measure draught and power requirements of tillage implements under various soil conditions. Grisso *et al.* (1994) Reviewed work reported by different researchers in measuring draught and power requirements of the most common tillage implements. The ASAE standards provide mathematical expressions for pull and power requirements for tillage implements in several soil types as a part of ASAE D497 (ASAE, 1994).

The draught needed to pull a tillage implement is basically a function of implement width, operating depth and the speed at which it is pulled. Draught also depends on soil conditions. (Upadhyaya *et al.* 1984). It has been widely reported that the draught forces on tillage implements increase significantly with speed and varies from linear to quadratic equation (Grisso *et al.* 1994). According to Barger *et al.* (1967), travel reduction is the slippage of the traction device when a wheel or track propels a tractor with or without a load over a surface. A number of factors affect wheel slippage including forward speed, drawbar pull, load, soil type and conditions (Ismail *et al.,* 1981; Bukhari *et al.,* 1988; Baloch *et al.,* 1991). Saleque and Jangiev (1990) concluded that energy waste in a tractor is reduced when wheel slippage is adjusted between 15% and 18%.

The tractor power and speed are of great important in their field performance. As tractor power and speed increase, its travel reduction decreases while the drawbar pull increases (Shebi *et al.* 1988; Bukhari *et al.* 1988). Al-Suhaibani and Al-Janobi (1997) examined the effect of speed and depth on the draught of a chisel plow, an offset disk harrow, a moldboard plow and a disc plow on a sandy loam soil. They observed that a significant increase in draught for all the tested implement with the increase in speed.

Kepner *et al.* (1978) stated that the amount of fuel consumption, draught requirement and drawbar power are mathematically interrelated. They reported that forward speed is an effective factor in machine performance. The increase in forward speed increases draught in most tillage implements. Belel and Dahab (1997) stated that when the speed was increased from 4.8 km/h to 9.6 km/h, the draught increased by 40% in clay soil and by 90% in sandy soil. They found also that as an implement draught was increased, the drawbar power, fuel consumption and wheel slippage increased while the forward speed decreased. Fuel consumption and effective field capacity were also found to increase with increase in tractor speed (Aljasim 1993). Tillage systems and speed of work in the field are among factors that determine fuel consumption rate. Dawelbeit (1998) compared the fuel consumed by four tillage implements and found that disc plough consumed the largest amount of fuel.(15.7 l/ha) followed by disc harrow (14.1 l/ha). The ridger and chisel were the least and consumed only 10.8 l/ha.

Although there are many factors which affect tractor performance with implements in the field, there has been little attempt to match a given tractor with the appropriate implements particularly in the developing countries. These countries such as Sudan and Saudi Arabia, the place of interest, have introduced tractor power for many years replacing the traditional source of power. Farmers and other advisory workers in these areas are still in need to match the power unit to the type of implement taking the account of the operating parameters (ie. speed and soil type) to achieve an optimum field performance. The objective of the present study were:

i. to investigate the effect of tractor power and speed on implement drawbar pull, travel reduction and fuel consumption when the tractor was linked to a disc plow operating on a clay loam soil.
ii. to find a correlation between the tractor power, speed and the three mentioned field performance parameters.

MATERIALS AND METHODS

An experiment was carried out on a clay loam soil in area of 1.76 ha(4.19 fe.) The soil physical properties were analyzed using the method described by Rowell (1994) as presented in Table 1. Two tractors of the same trade-mark (Italian-Sami) but of different drawbar power (i.e. 53.2 kW) and 68.4 kW, were used in the experiment. At one time, the first tractor was used as a tested tractor and the second as an auxiliary source of power for pulling. Next time, they were changed (i.e. the second tractor became the tested one and the first was used for pulling).

A three bottom fully mounted disc plow, each 60cm in diameter and 1.65, m in width, was used as a primary tillage implement. Other tools used in the study included hydraulic dynamometer, steel chain, a plastic meter type (30m), ranging poles, stop watch. 0.5 liter graduated cylinder with a minimum reading of 0.002 liter, fuel gercan and pieces of chalk.

The variables considered in this studies were two levels of tractor drawbar power (P_1 =53.2kW; P_2 =68.4kW), and three levels of tractor forward speeds (S_1= 5km/h; S_2=7km/h; S_3= 9km/h). A split plot design was used to accommodate six treatments, each replicated three times to give a total of eighteen treatments. The experimental treatments were:

1. Large tractor (P_2) with low speed (S_1),
2. Large tractor with medium speed (S_2),
3. Large tractor with high speed (S_3),
4. Medium tractor (P_1) with low speed,
5. Medium tractor with medium speed,
6. Medium tractor with high speed.

Table 1. The soil physical properties of the experimental site

Soil depth (cm)	Clay (%)	Silt (%)	Sand (%)	Texture	Bulk density (gm/cm^3)	Moisture content (%)	pH	Organic mater (%)
0-30	39.0	26.0	35.0	Clay-loam	1.17	3.7	7.69	1.4
30-60	46.6	22.9	30.5	Clay	1.83	5.2	8.00	0.8

Drawbar pull measurement :

Measurement of tractor drawbar pull was done following the method described by Narayanarao and Verma (1982). A distance of 35m was marked, then the tested tractor (68.4kW) was pulled by the second one (53.2kW), through the hydraulic dynamometer using the steel chain. Drawbar pull of the large tractor at the first speed (S_1) with the implement plowing at an average depth of 20 cm was measured. The drawbar pull was calculated as follows:

Drawbar pull = Pull with implement plowing - Pull with implement mounted

The same steps were repeated at the other two speeds (S_2 , S_3) and then with tractors changing their places and functions (i.e. the tested tractor becomes the auxiliary and vise versa).

Travel reduction measurement :

Rear wheel travel reduction (slippage) was measured by marking the wheel of the tractor at a portion tangent to the ground surface. The distance covered by five revolutions of the rear wheel at the first speed with the tractor unloaded and loaded with implement were measured. The same steps were carried out at the other two speeds for the same tractor. All these steps were also repeated for the second tractor and the travel reduction was computed according to (Turner, 1993):

Slippage (%) = (1 - (Distance with load /Distance without load))

Fuel consumption measurement :

The selected tractor started plowing the plot at the specified speed with its full fuel tank. After finishing of the plot, the fuel tank was refilled with the graduated cylinder and the amount used for refilling was recorded. The same procedure was carried out at the other two speeds and for the second tractor. The fuel consumption rate in L/hr was calculated as follows:

Fuel consumption rate = Reading of cylinder (L)/time recorded for plowing the plot (hr)

RESULTS AND DISCUSSION

Analysis of variance was, employed to evaluate the effect of tractor drawbar power and speed on drawbar pull, travel reduction and fuel consumption as represented in Table 2. The data in Table 3 show that, the tractor power and speed, and their interaction had a significant effect on drawbar pull. Increasing the tractor power and speed increased the drawbar pull. The average pull increased by 55% as the tractor power increased from 53.2 kW to 68.4 kW, while the increase in tractor speed from 5 km/hr to 9 km/hr increased the pull by 1.9kN (39%) and 3.7kN (36%) for the medium and large tractors, respectively.

Table 2. Analysis of variance of the experimental parameters

		F calculated	
Source of variance	Drawbar pull	Slippage	Fuel consumption
Main block (P)	1168.4*	2682.1**	2899.5**
Sub-block (S)	418.7**	190.2**	700.8**
Interaction (P×S)	56*	101.5**	156.2**

P = Tractor power; S = Forward speed
*** = Significant at 5% level; ** = Significant at 1% level**

Table 3. Effect of tractor power and speed on drawbar pull (kN)

Treatment	**Forward speed (km/hr)**			**Mean ± SD**
Tractor power	**5**	**7**	**9**	
53.2 kW	3.00 a	4.10 b	4.90 c	4.00 A ± 0.95
68.4 kW	6.63 d	9.60 e	10.33 f	8.85 B ± 1.96
Mean ± SD	4.8 A ± 2.60	6.85 B ± 3.90	7.60 C ± 3.84	

Means not sharing a similar letter are significantly different at P = 0.01according to Duncan's multiple range test.

Using the large tractor with high speed resulted in 71% increase in the tractor drawbar pull compared with the medium tractor at low speed. This is in line with the finding of Stafford (1979) and Shebi *et al*. (1988).

The effect of tractor power and speed was also found to have highly significant effect on wheel slippage (Table 1). Table 4 and Fig.1 illustrate that as the power of the tractor was greater, the wheel slippage was less while the pull was higher. The large tractor normally resulted in higher static and dynamic weights which improve traction, increase pull and reduce wheel slippage up to 55%. This observation is similar to that of Barger *et al.* (1967) and Qaisrani *et al.* (1992). When the speed of the medium and large tractors was increased from 5 km/hr to 9 km/hr, the slippage was increased by 31% and 12% for the two tractors, respectively. The difference between the treatments was highly significant (Table 4). This increase in slippage with speed may be due to an increase in pull (Fig. 2). It can be seen also, that the increase in slippage with speed is less when using the large tractor because it has higher static and dynamic loads on the driving wheels which increase the tractive effort obtained from tractor. Similar results were obtained by Ismail *et al.* (1981), Bukhari *et al*. (1992), Abuzeid (1999) and Widaa (1999).

Table 4. Effect of tractor power and speed on wheel slippage (%)

Treatment	**Forward speed (km/hr)**			**Mean ± SD**
Tractor power	**5**	**7**	**9**	
53.2 kW	10.60 a	13.43 b	15.3 c	13.11 A ± 2.30
68.4 kW	5.47 d	5.90 e	6.20 f	5.86 B ± 0.37
Mean ± SD	8.04 A ± 3.60	9.60 B ± 5.31	10.75 C ± 6.41	

Means not sharing a similar letter are significantly different at P = 0.01 according to Duncan's multiple range test.

Table 5 Shows the effect of tractor power and speed on fuel consumption. In general, the fuel consumption rate increased with increase in tractor power and speed (Fig. 3). As tractor power increased from 53.2 kW to 68.4 kW, the average fuel consumption rate was increased by 7.9 l/hr (60%). Increasing tractor speed from 5 km/hr to 9 km/hr, increased the fuel consumption rate by 5.5 l/hr (66%) and 15.3 l/hr (72%) for the medium and large tractors, respectively. The differences between the treatments were highly significant at 1% level. This increase in fuel consumption with speed may be attributed to the increase in drawbar pull which resulted in an increase in slip leading to more energy required in terms of fuel consumption. These findings are in agreement with those of Aljasim (1993) and Sirelkatem *et al.* (2001).

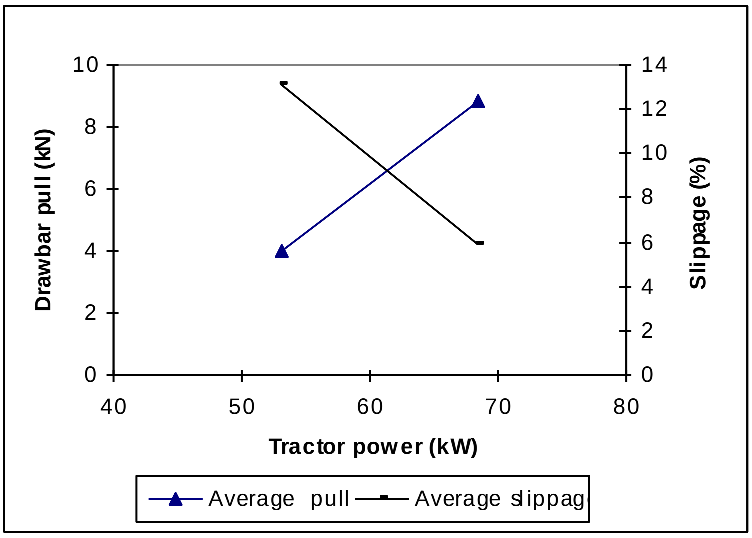

Fig.1 Relation between tractor power and drawbar pull and slippage

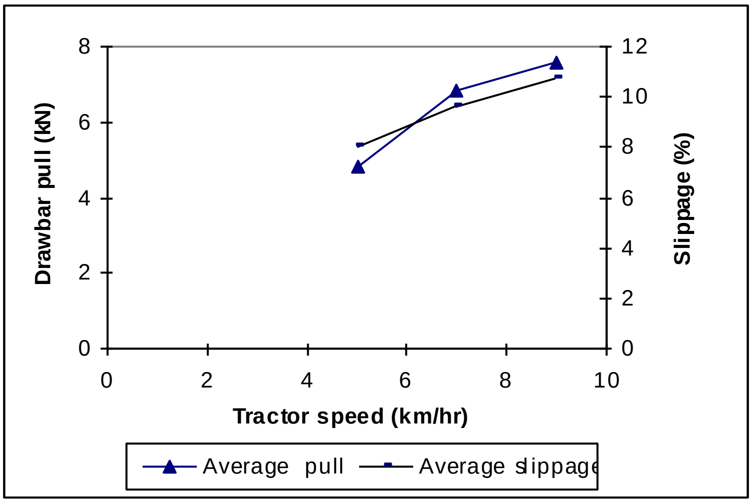

Fig. 2 Effect of tractor speed on drawbar pull and slippage

Table 5. Effect of tractor power and speed on fuel consumption rate (l/hr)

Treatment	Forward speed (km/hr)			
Tractor power	**5**	**7**	**9**	**Mean ± SD**
53.2 kW	2.78 a	4.54 b	8.26 c	5.19 A ± 2.79
68.4 kW	6.05 d	11.56 e	21.43 f	13.10 B ± 7.79
Mean ± SD	4.42 A ± 2.31	8.05 B ± 4.96	14.85 C ± 9.31	

Means not sharing a similar letter are significantly different at P = 0.01 according to Duncan's multiple range test.

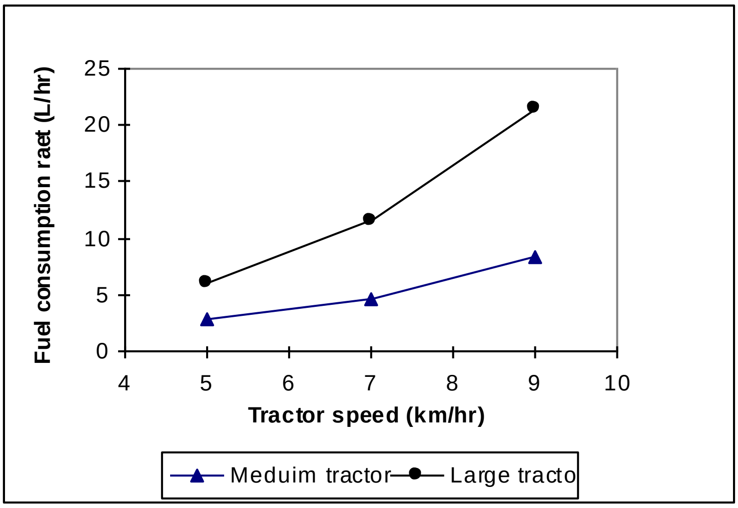

Fig. 3 Effect of tractor speed on fuel consumption rate

Simple and multiple correlation analysis of either power or speed effect on drawbar pull, slippage and fuel consumption were carried out as shown in Table 6. The simple correlation analysis showed that power accounted 88.8%, 93.4% and 63.3% of the variability in drawbar pull, slippage and fuel consumption rate, respectively. Where as speed accounted 41.8%, 28.6% and 68.9% of the variability in the above mentioned parameters, respectively. The multiple correlation analysis indicated that power and speed accounted jointly for 98.1%, 97.7% and 92.6% of drawbar pull, slippage and fuel consumption rate variability, respectively.

Table 6. Analysis of simple and multiple correlation between power, speed and the three field performance parameters

Relation	Simple r	Multiple R^2	Multiple R
Power × pull	0.888		
Speed × pull	0.418		
Power and speed × pull		0.962	0.981
Power × slippage	0.934		
Speed × slippage	0.286		
Power and speed × slippage		0.955	0.977
Power × fuel consumption	0.633		
Speed × fuel consumption	0.689		
Power and speed × fuel consumption		0.857	0.926

CONCLUSION

Working on this type of soil, the following conclusions can be listed:

1. A significant increase in the drawbar pull and fuel consumption was observed with an increase in tractor power and forward speed.
2. The wheel slippage reduced significantly with tractor power but increased with forward speed.
3. The multiple correlation analysis showed high correlation between the tractor power and speed and the field performance parameters under study.
4. The big tractor (68.4kW) working at medium speed (7km/hr) showed a tendency to give the optimum values of the three field parameters operating on this type of soil.

REFERENCES

A.S.A.E. (1994). "Standard D497". ASAE standard, Agricultural machinery management data. ASAE: St. Joseph, Michigan, USA.

Abuzeid, K.A. (1999). Soil Tillage Management for Fodder Sorghum Production. M.Sc. Thesis. Faculty of Agriculture, University of Khartoum, Sudan.

Aljasim, A.S.A. (1993). The technical and economical indicators for soil harrowing by disc harrow. The Iraqi Journal of Agricultural Science, 24(2): 260-264.

Al-Suhaibani, S.A. and A. Al-Janobi (1997). Draught requirements of tillage implements operating on sandy loam soil. Journal of Agric. Engng. Res., 66: 177-182.

Baloch, M.J.; N.M. Ali; and S. Bukari (1991). Prediction of field performance of wheel tractor. Journal of Agricultural Mechanization of Asia, Africa and Latin America, 22(4): 21-22.

Barger, E.L.; J.B. Liljedahl; W.M. Garleton and E.C.Mickibbenn (1967). Tractors and Their Power Units. John Wile y and Sons Inc. New York.

Belel, M.M. and M.H. Dahab (1997). Effect of soil condition on a two-wheel drive tractor performance using three type of tillage implements. University of Khartoum Journal of Agricultural Science, 5(2): 1-22.

Bukhari, S.; M.A. Bhutto; J.M Baloch; A.B Bhutto and A.N. Mirani (1988). Performance of selected tillage implements. Journal of Agricultural Mechanization of Asia, Africa and Latin America, 19(4): 9-14.

Bukhari, S.; J.M. Baloch; and A.N. Mirani (1992). Comparative performance of disc harrow and Sat Haree. Journal of Agricultural Mechanization of Asia, Africa and Latin America, 23(3): 9-14.

Dawelbeit, M.I. (1998). On farm Adaptive Research in Field and Horticultural Crops. White Nile Agricultural Service Project. (WNASP) and ARC. Annual Report, Wad Medani, Sudan.

Grisso, R.D.; M. Yasin and M.F. Kocher (1994). Tillage implement forces operating in silty clay loam. ASAE Paper No. 94-1532, ASAE, St. Joseph, Michigan, USA, pp.17.

Ismail, M.S. ; G. Singh and D. Clough (1981). A preliminary investigation of combined slip and draught control for tractor. Journal of Agric. Engng. Res., 26(4): 293-306.

Kepner, R. A. ; R. Bainer and E.L. Barge (1978). Principles of farm machinery, AVI Publishing Company, INC. West port.

Narayanarao, V.P. and R.S. Verma (1982). Performance of tractor mounted oscillating soil working tool. Journal of Agricultural Mechanization of Asia, Africa and Latin America, 12(2): 11-12.

Qaisrani, A.R.; Chen Bingcong and M.A. Farooq. (1992). Tractor ballasting and its effects on wheel slip and fuel consumption. Pro. of Inter. Conf. on Agr. Eng. (92-ICAE) Beijing 12-14 Oct.

Rowell, D.L. (1994). Soil Science Methods of Applications. Longman Scientific and Technology, Essex, England.

Saleque, M.V. and A.A. Jangiev (1990). Optimization of the operational parameters of wheeld tractors for tillage operation. Transactions of the ASAE, 33(4): 1027-1030.

Shebi, J. B.; K.C. Oni. and F.G. Braide (1988). Comparative tractive performance of three tractors. Journal of Agricultural Mechanization of Asia, Africa and Latin America, 19(2): 25-29.7

Sirelkatem, K.A. ; H. A. Al-Hashem and O.S. Mohamed (2001). The effect of some operating parameters on field performance of a 2WD tractor. Scientific Journal of King Faisal University, (Basic and Applied Sciences), 2(1): 153-166.

Stafford, J. V. (1979). The performance of a rigid tine in relation to soil properties and speed. Journal of Agricultural Engineering Research, 24: 41-56.

Turner, R.J. (1993). “Slip measurement using dual radar guns” . ASAE Paper No. 93-1031. ASAE, St. Joseph, Michigan, USA.

Upadhyaya, S.K.; T.H. Williams; L.J. Kemble and N.E. Collins (1984). Energy requirement for chiseling in coastal plain soils. Transactions of the ASAE, 27(6): 1643-1649.

Widaa, AM. (1999). Effect of Different Soils and Gears Type on Tillage Implement. M.Sc. Thesis. Faculty of Agriculture, University of Khartoum, Sudan.

دراسة تأثير قدرة وسرعة الجرار الزراعي على بعض عوامل الأداء الحقلي عند العمل على أرض طينية طميية

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تم إجراء هذه التجارب الحقلية على ارض طينية طميية بهدف دراسة تأثير كل من قدرة وسرعة الجرار الزراعي ثنائي عجلات الدفع أثناء تشغيله مع المحراث القرصي المعلق على كل من قدرة الجرار عند قضيب الشد، نسبة انزلاق العجلات الخلفية للجرار وكذلك معدل استهلاك الوقود. في هذه الدراسة تم استخدام جرارين مختلفين في القدرة وثلاث مستويات من سرعة الجرار لتقيم هذا التأثير. أوضحت النتائج أنه عند استخدام الجرار ذي القدرة العالية أو السرعة العالية وكذلك الجمع بينهما كان هناك تأثير معنوي كبير (عند مستوى اختبار ١%) على كل من عوامل الأداء الحقلي الثلاثة المذكورة. فقد وجد أن زيادة قدرة الجرار من ٥٣,٢ إلى ٦٨.٤ ك.وات أدى إلى زيادة متوسط قوة الشد إلى ٥٥% كما أن زيادة السرعة من ٥ إلى ٩ كم/ساعة أدى إلى زيادة قوة الشد إلى ٣٩% و ٣٦% مع الجرار متوسط القدرة والجرار عالي القدرة على التوالي. كذلك بينت النتائج انخفاض في متوسط نسبة الانزلاق للعجلات الخلفية عند استخدام الجرار ذي القدرة العالية نحو ٥٥% مقارنة مع الجرار الآخر، وأن استخدام السرعة العالية أدت إلى زيادة نسبة الانزلاق إلى ٣١% و١٢% مع الجرارين المذكورين آنفاً على التوالي. أما بالنسبة إلى معدل استهلاك الوقود فقد لوحظ أنه يزداد بزيادة كل من قدرة الجرار والسرعة حيث اتضح أن متوسط معدل استهلاك الوقود قد زاد ٦٠% مع الجرار عالي القدرة وأن استخدام السرعة العالية أعطت زيادة في نسبة الأنزلاق قدره ٦٦% و٧٢% للجرارين المذكورين على الترتيب. كما بينت النتائج أن معامل الارتباط المتعدد عند الجمع بين تأثير القدرة والسرعة على قدرة الجرار عند قضيب الشد، نسبة انزلاق العجلات الخلفية ومعدل استهلاك الوقود كان ٩٨,١% و ٩٧,٧% و ٩٢,٦% على التوالي. يبدو من النتائج أن استخدام الجرار ذي القدرة العالية ٦٨,٤ ك.وات مع سرعة متوسطة قدرها ٧كم/ساعة قد أعطى قيم مثلى متناسبة للعوامل الثلاثة السابق ذكرها وذلك عند العمل على هذا النوع من الأراضي.