

Some Techniques Used to Minimize Fuel Consumption and Wheel Slip in Crop Production Growth on Clay Loam Soil

Tayel, M. Y.¹, M. Ismaiel², S. M. Shaaban¹ and H. A. Mansour^{1*}

¹Water Relations and Field Irrigation Dept., Agricultural Division, National Research Centre (NRC), 33 Elbehouth St., El-Dokki, Giza, Cairo, Egypt.

²Soil, Water and Environment Research Institute (SWERI), Agricultural Research Center, 9 Cairo University St., Giza, Cairo, Egypt.

Abstract : Field experiment was conducted on clay loam soil at El-Dokki, Giza Governorate as a cooperative work between the National Research Centre and the Agricultural Research Center

to study the effects of soil water content at plowing θ_1 , θ_2 and θ_3 (8.1, 17.1; 26.4 % w/w),

plowing depth D1, D2 and D3 (10, 15; 20 cm) and plowing speed S1 and S2 (1.99; 10.33 km/h), respectively on minimizing both fuel consumption and tractor wheel slip. It was found

that: Increasing (D) and (θ) had positive effects on fuel consumption and tractor wheel slip,

whereas increasing (S) has positive effect on the 1st set and negative one on the 2nd. The maximum values and the minimum one of fuel consumption and tractor wheel slip were

achieved in the following interactions: (D3xS2x θ_3 , D1xS2x θ_1) and (D3xS1x θ_3 and

D1xS1x θ_2), respectively. The main effect of (D, S; θ) and their interaction have significant

effects on fuel consumption and tractor wheel slip at the 5% level.

Keywords: Soil water content, plowing depth, speed, fuel consumption and wheel slip.

Introduction:

Performance data from various tractors and implements are essential for both their manufacture and management. Proper selection of tractors and implements for a particular farm conditions is a must to minimize energy consumption used in crop production Al-Suhaibani¹. It becomes more critical as energy costs escalate

since the field tools constitute a major portion of the total cost of crop production system. Global researches indicated that the draft requirement of chisel plow was about half of that of the moldboard one equal in width and operation depth Kohnke². According to Shafei³ extensive activities for replacing moldboard plow by chisel one in dry farming have done all over the world. It is worthy to mention that both water and fossil fuel are two limited and precious natural resources in many countries including Egypt. Agriculture consumes energy in different aspects i.e., soil tillage, irrigation, fertilizer processing, crop harvesting and transportation etc. Only water pumping can use as 13 % of the energy used in agriculture (Pimental and Giampietro⁴ and Smajestria *et al.*,⁵).

The following techniques have been used to decrease fuel consumption and increase its use efficiency 1-Many researchers showed that increasing of overall energy efficiency and subsequently decreasing fuel consumption can be achieved through optimal splitting the gross tractor weight between the front and rear axles and using correct matching of tractor, the company tools and agricultural machinery (Mobarak⁶, Nasr⁷, Iowa State University⁸, Srivastava⁹). This is important to transfer as much energy power as possible to the drawbar. Too little weight or ballast results in excess drive wheel slip. Conversely, carry much ballast or weights on a tractor dramatically lowers wheel slip but results in greater rolling resistance as the tractor sinks too far into the soil, causing wheels to be constantly climbing out of a deep rut. Since only wheels on powered axles supply traction. It is also important to distribute ballast properly between front and rear axles. Optimal weight split between axles is affected by tractor style and whether the attached implements are pulled or mounted -2-Seedbed preparation should be performed at the right conditions concerning soil moisture content, plowing speed and plowing depth (Korayem and Ismail¹⁰, Tayel *et al.*,¹¹, Bayoume¹²).

Nasr *et al.*,¹³ reported that increasing plowing depth increased both cohesion and adhesion forces of soil. They added that this increased rolling resistance of tractor and decreased its tractive efficiency. Hrrigan and Roosenberg¹⁴ stated that plow draft can vary greatly in the same soil group depending on its conditions. Lee *et al.*,¹⁵ Said that the power tillers depends on the purpose of the operations, size of tractors, power tillers and field shape. Ahmed¹⁶ found that the draft force and tillage energy required using chisel plow are linear function with both plowing speed and depth. Adewoyin and Ajav¹⁷ mentioned that the increase both plowing speed and depth increased tractor fuel consumption. According to the same authors plowing depth was the most impactful factor in tractor consumption during fuel plowing process. According to Iowa State University⁸ to maximize transfer of power from drive axles to the drawbar the optimum amounts of wheel slip depends on the soil surface and should be in the following ranges: a) 6-13% on firm untilled soil, b) More slip 8-16% on a tilled surface, c) With slightly more yet on a non-cohesive sandy soil and d) 4-8% on concrete. Checking wheel slip is a must to be determined to know if tractor is optimally applying fuel and horsepower to the drawbar. Al-Ani and Al-Ani¹⁸ studied the relationship between tractor practical speed and different soil moisture content on plowing soil layer.

The present experiment was conducted to study the influence of seedbed preparation conditions concerning soil moisture content at plowing, plowing speed and plowing depth on fuel consumption and tractor wheel slip.

Materials and Methods

Field experiments were conducted at the experimental station of the Agricultural Research Center, Ministry of Agriculture and Land Reclamation, El-Dokki, Giza, during the year 2016 as a cooperative work between the National Research Centre and Soils, Water and Environment Research Institute. The objectives of the present research was to study the effect of seedbed preparation conditions i.e. soil moisture content at plowing Θ_1 , Θ_2 and Θ_3 (8.1, 17.1; 26.4 % w/w), plowing depth D1, D2 and D3 (10, 15; 20 cm) and plowing speed S1 and S2 (1.99; 10.33 km/h) on minimizing both fuel consumption and tractor wheel slip.

Fuel consumption:

Fuel tank was completely filled at the beginning of plowing each plot under the specified working conditions and refilled at its end using 500 ml measuring cylinder. tractor wheel slip % was measured after Srivastava (1990) using the following equation:

$$\text{Wheel slip \%} = [(L1-L2)/L1] \times 100$$

Where: L1 = advance distance per 10 wheel revolution with no pull (m), L2 = advance distance per 10 wheel revolution with pull (m).

The experiment layout was in random plots split twice. Three replicates were used. Data obtained were subjected to statistical analysis after Snedecor and Cochran¹⁹.

Results and Discussions:

The main effect of Θ , D and S:

Table (1) and all figures (1, 2, 3, 4, 5 and 6) indicates the main effects of plowing depth (D), soil moisture (Θ) at plowig and plowing speed (S) on fuel consumption and tractor wheel slip. The increases in fuel consumption and tractor wheel slip were: (91.72; 151.67% and (30.11; 97.22%), respectively at D2=15 cm and D3=20cm, relative to D1 =10 cm.

Table (1): Effect of soil moisture, tractor speed and plowing depth on fuel consumption and wheel slippage in clay loam soil

Soil Moisture content at plowing w/w%	Tractor speed	plowing depth	Fuel consumption	Wheel slippage
	(km/h)	(cm)	(L.fed ⁻¹)	(%)
$\Theta 1$ 8.11	speed 1	10	6.8	4.8
	1.93	15	8.06	8
		20	12.73	10.9
	speed 2	10	5.73	4.18
	10.33	15	13.66	5.36
		20	17.4	8.35
$\Theta 2$ 17.06	speed 1	10	8.6	3.6
	1.93	15	18.33	4.74
		20	19.27	11.72
	speed 2	10	7.13	6.5
	10.33	15	16.2	7.5
		20	22.53	13.3
$\Theta 3$ 26.37	speed 1	10	5.86	11.72
	1.93	15	10.47	14.52
		20	13.73	15.14
	speed 2	10	7.26	5.86
	10.33	15	12.56	7.55
		20	18.4	12.88
Mean of tillage depth (cm)		10	6.89	6.11
		15	13.21	7.95
		20	17.34	12.05
Mean of tractor speed (Km/h)		1.93	11.53	9.46
		10.33	13.42	7.94
Mean of tillage at moisture content (w/w %)		$\Theta 1=8.11$	10.73	6.93
		$\Theta 2=17.06$	15.34	7.89
		$\Theta 3=26.37$	11.38	11.28
LSD _{0.05} of means			1.12	2.01
LSD _{0.05} of interactions			0.08	0.05

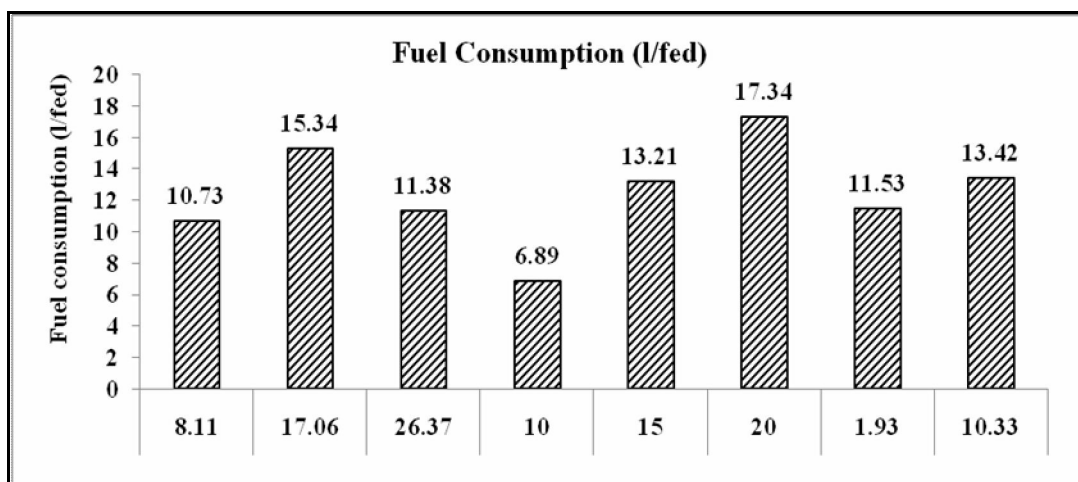


Fig. (1) Effect of soil tillage moisture, soil tillage depth, and tractor tillage speed on fuel consumption.

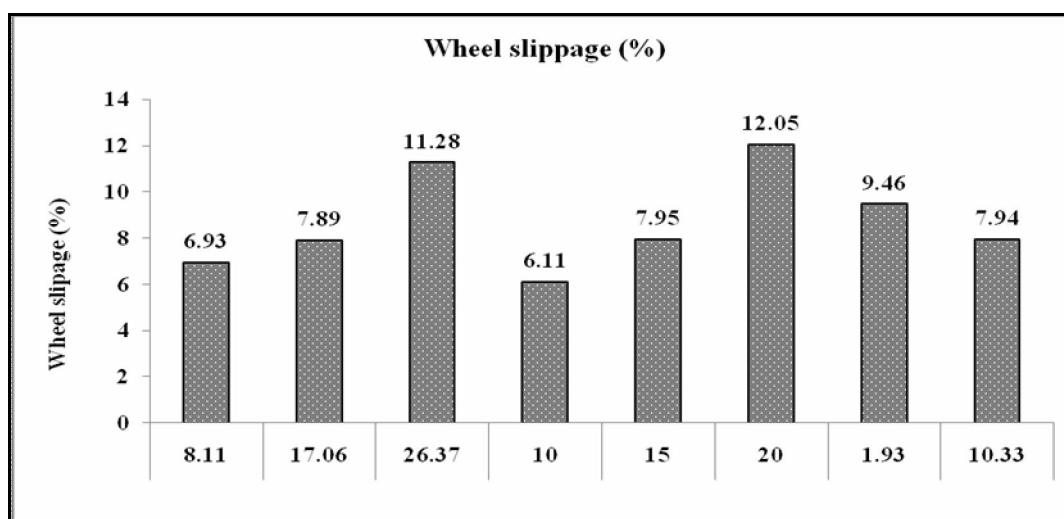


Fig. (2) Effect of soil tillage moisture, soil tillage depth, and tractor tillage speed on wheel slippage .

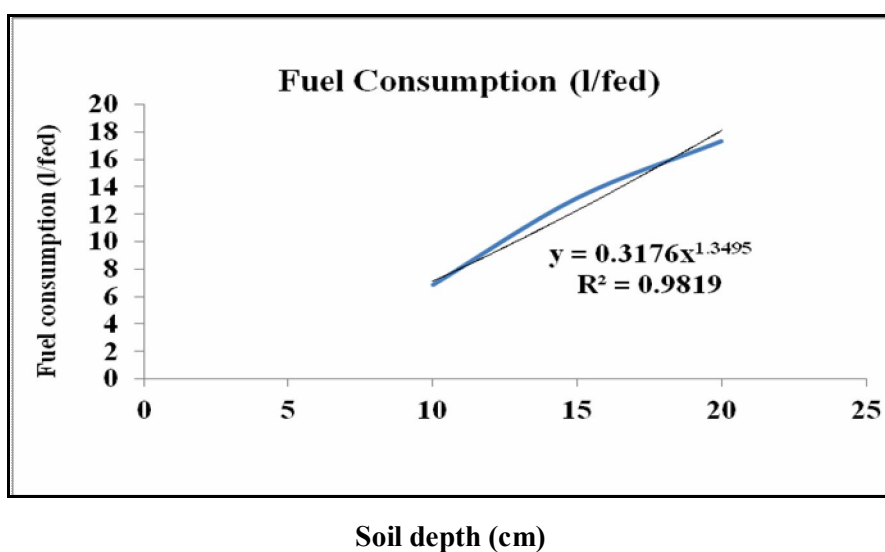


Fig. (3) Relationship between soil depth and fuel consumption

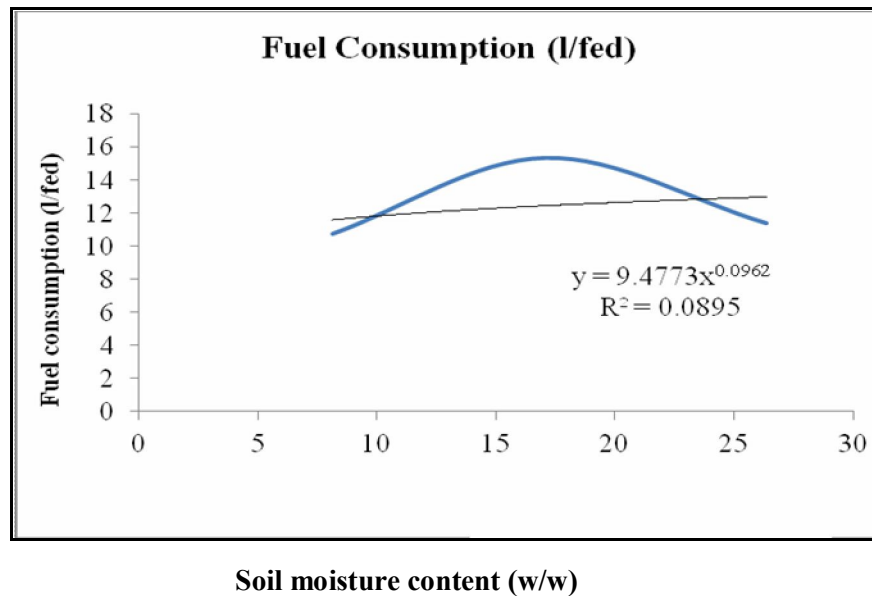


Fig. (4) Relationship between Soil moisture content and fuel consumption

1- Relationship between soil tillage characteristics and wheel slippage percent:

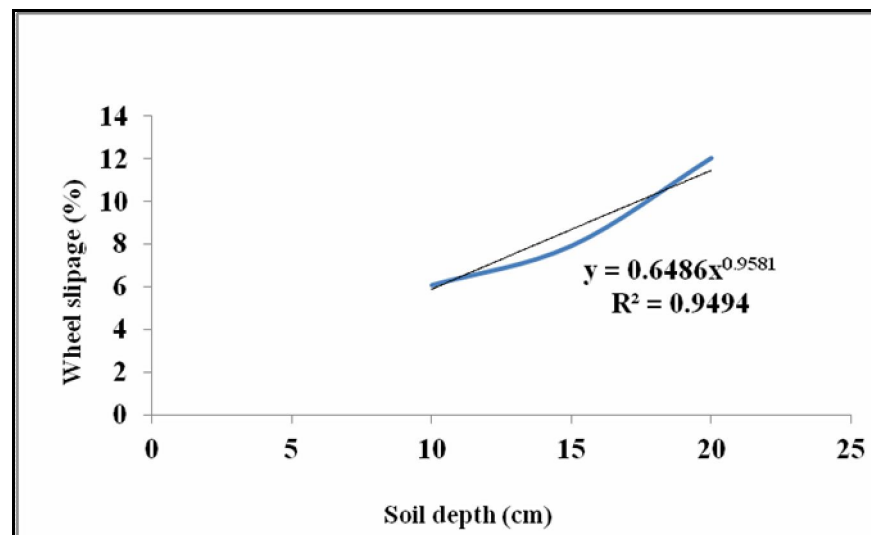


Fig. (5) Relationship between soil depth and wheel slippage percent

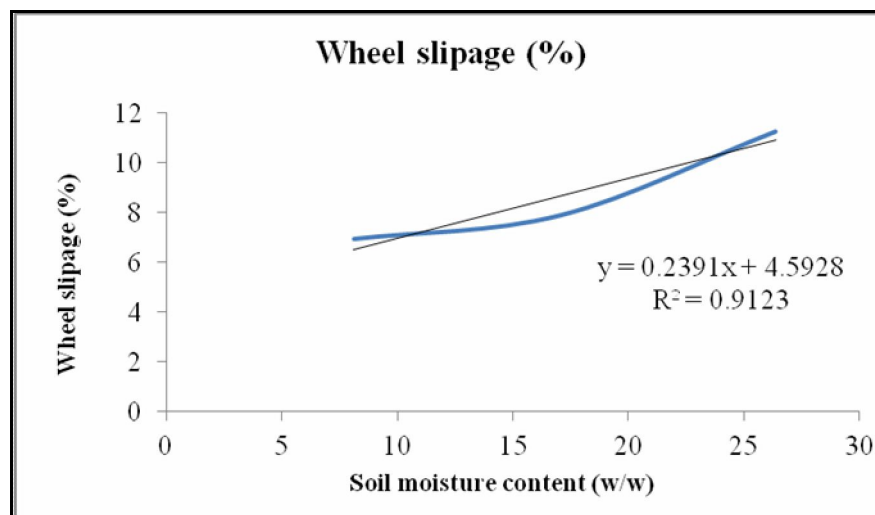


Fig. (6) Relationship between Soil moisture content and wheel slippage percent**The interaction of DxSxΘ:**

Regarding the effect of the interaction D_xS_xΘ on fuel consumption and wheel slip, the obtained data can be seen in Table (1) and Figs. (7 and 8). It is obvious that the interaction: D_xS_xΘ have pronounced effect on both fuel consumption and wheel slip. The maximum and the minimum values of fuel consumption and wheel slip were achieved in the interactions: (D3xS2xΘ2); (D1xS2xΘ1) and (D3xS1xΘ3 , D1xS1xΘ2), respectively. The main effects of D, S and Θ and their interactions on both fuel consumption and wheel slip were significant at the 5% level.

Data obtained could be due to one or more of the following reasons: 1- the weight of the above soil layers on the lower ones (overburden pressure) is vertically pressing downward on chisel increased with depth., 2- increasing plowing depth increased cohesion and adhesion forces, 3- increasing plowing depth increased soil pulverization, 4- increasing plowing speed increased soil pulverization , 5- soil organic matter that acts as a lubricant material relieving friction among soil particles decreases with depth, and 6-weight of the tools used was not properly distributed between the front and rear axles.

Conclusion:

There is an increased need to study the beneficial effects and the detrimental ones of some seedbed preparation conditions concerning soil moisture content at plowing (Θ), plowing depth (D) and plowing speed (S) on fuel consumption and tractor wheel slip. Results of the study showed that:

1. Increasing D and Θ in the ranges: 10-20 cm, 8.1-26.4 (w/w %) increased both fuel consumption and tractor wheel slip.
2. Increasing (S) from 1.39 – 10.33 km/h has positive effect on fuel consumption and negative one on tractor wheel slip.
3. The maximum fuel consumption (22.53) and the minimum one (5.73 l/fed) were achieved in the following interactions: : D3xS2x Θ2 (20 cm x 10.33 km/h x 17.1 w/w %) and : D1xS2xΘ1 (10 cm x 10.33 km/h x 8.1 w/w %, respectively.
4. The maximum tractor wheel slip (15.14%) and the minimum one (3.6 %) were found in the following interactions: D3xS1xΘ3 and D1xS1xΘ2, respectively.
5. Both the main effect of : D, S, and Θ and their interaction have significant effects on fuel consumption and tractor wheel slip at the 5% level.

References:

1. Al-Suhaibani, S.A., 1992. Use efficiency of farm machinery in Saudi Arabia. ASAE Paper No. 92-1044, ASAE, St. Joseph, Michigan, USA.
2. Kohnke, H.(1968).Soil Physics, Tata McGraw-Hill-Pub-Conf.
3. A. Shafei , 1995. Tillage Implements, (fifth ed.)University of Tehran, Tehran, Iran
4. Pimental, D. and Giampietro, M. (1994).Food.Land, Population and the U.S. Economy.Carring Capacity network.<http://www.diff.com>. page 55.htm.
5. Smajestria, A.C., Castro, B.F. and Clark, G.A. (2002).Energy requirments for drip irrigation in North Florida University, Univ. of Folrida, IFAS Extension Bul-289.
6. Mobarak, M.M. (1985): Agricultural tractors Engineering, Faculty of Agriculture, Ain Shams University(Arabic).
7. Nasr, G.M. (2008).AgriculturalMachinization, faculty of Agriculture, Cairo Univ. (Arabic).
8. Iowa State University (2010).Ballasting tractor for fuel efficiency, University Extension.
9. Srivastava, A.C.(1990). Elements of farm machinery, Oxford and IBH Publishing Co. New Delhi, pp. 89-117.

10. Korayem, A. and Ismail, N.A. (1991).Effect of moisture content on soil disturbance and draft of flat chisel. Alex. J. Agriculture Research. 19(1):1-12.
11. Tayel, M.Y.,Shaaban, S.M.,Mansour, H.A.(2015). Effect of plowing conditions on the tractor wheel slippage and fuel consumption in sandy soil. International Journal of ChemTech Research, Vol.8, No.12 pp 151-159.
12. Bayoume, D. S. I. (2016). Design of a combined machine for seedbed preparation for onion. MSc. Thesis, Agri Eng. Dept., Faculty of Agric. Cairo Univesity.
13. Nasr, G.E, Tayel, M. Y., Abdelhay, Y.B., Sabreen, Kh. P., and Dina, S. (2016).Technical evaluation of a combined machine for seedbed preparation.International Journal of ChemTech Research, Vol.9, No.5. pp 193-199.
14. Hrrigan, T. M. and Roosenberg, R. (2002).Estimating tillage draft tech. guide 209-210.Agric. Eng. Michigan State Univ., USA.
15. Lee, K.S., Pork, S.H., Pork, W.Y. and Lee, C.S.(2003). Strip tillage Characteristics of rotary tillage blades for use in dry land direct rice seeder. Soil and Tillage Research. 71(1):25-32.
16. Ahmed, Sh. A. H. (2011).Effect of tractor forward speed on field performance of tillage implements.M.Sc., University of Khartoum, Sudan.
17. Adewoyin, A. O. , and E. A. Ajav. 2013. Fuel consumption of some tractor models for ploughing operations in the sandy-loam soil of Nigeria at various speeds and ploughing depths. AgricEngInt: CIGR Journal Vol. 15(3):67-74.
18. A-Ani, A. N. and Al-Ani, F.S. (2010).The relationship between tractor practical speed and soil moisture content on plowing, soil layer. The Iraqi Journal of Agricultural Scince, 41(3):124-129 (Arabic).
19. Snedecor, G.W. and W.G. Cochran (1980).Statistical Methods I 7th Edin. Iowa State Univ. Press, Iowa, U.S.A.
