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Full Length Research Paper

Fuel consumption distribution for machine and tractor activities in some PTO driven machine operations

S. K. Sümer[1*], H. Kocabıyık[1], S. M. Say[2] and G. Çiçek[1]

[1]Agricultural Machinery Department, Çanakkale Onsekiz Mart Univ., 17020 Çanakkale, Turkey.
[2]Agricultural Machinery Department, University of Çukurova, 01330 Adana, Turkey.

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In this study, fuel consumption values needed for the machine to operate (machine activity) and for the tractor to be able to move (tractor mobility) in field conditions in agricultural activities were determined for some PTO driven agricultural machine operations (turbo atomizer and disc fertilizer spreader). Besides, the effects of 540 and 540E PTO options on fuel consumption distribution were evaluated. Three different tractors (John Deere 5625, Massey Ferguson 3085 and New Holland TD85) were used for this purpose. In field experiments, tractor fuel consumption, PTO torque and power parameters were measured. These measurements were repeated under static conditions in the laboratory without changing the functions of the machines. In these experiments, the torque and power requirements were found to be higher for the turbo atomizer for both of the PTO operations (540 and 540E). Data analysis showed that fuel consumptions performed in the laboratory condition with the 540 PTO in turbo atomizer and disc fertilizer spreader operations for all tractors were 77.08 and 74.29%, respectively in average of overall average fuel consumption values performed in field conditions. Fuel consumptions for 540E PTO operation were determined to be 65.97 and 64.74% in average, respectively. According to the variance analysis, for all test tractors, PTO options and experiment conditions were statistically significant (P<0.01) on fuel consumption for each PTO driven machines.

Key words: Tractor, PTO driven machine, fuel consumption, PTO options.

INTRODUCTİON

The tractor is a principle power unit used with most equipment and machines. Therefore, the farm manager is dependent upon the tractor to perform most farm operations. On the other hand, the goal of farm machinery management is to increase farm profits through the optimum selection and management of tractors and equipment. Unless the engine power of a tractor is converted to traction power efficiently, either more energy is required to complete the operation or the work cannot be accomplished (Sabancı, 1997). The farm tractor power take-off (PTO) mechanism, which is a major source of power production on farms, is an important research subject from the standpoints of both scientific interest and for selection and operation of the related machinery.

Agricultural mechanization constitutes approximately 40 to 50% of total agricultural production inputs for the period from soil preparation to product harvesting (Işık, 1988; Ruiyin et al., 1999). Thus, the selection of efficient agricultural mechanization instruments and machinery is a necessity for a profitable production. The farm tractor power take-off (PTO) mechanism, which is a major source of power production on farms, is an important research subject from the standpoints of both scientific interest and for selection and operation of the related machinery.

Standard tractor PTO speeds are a function of tractor engine speeds and vary according to brand, model, and power rate of the tractor. Although PTO-driven agricultural machines are designed to operate at a standard PTO speed, they need different levels of torque and power to be run effectively. Engine and PTO mechanism in a tractor are designed together to match the power requirements of PTO-driven machines (Goering, 1986). Some agricultural machines, which require very low power at standard speed, waste energy and fuel at high engine speeds. In other words: it is an uneconomical application. To address

*Corresponding author. E-mail: sarpksumer@comu.edu.tr. Tel: +90 286 218 00 18. Fax: +90 286 218 05 45.

Abbreviation: PTO, Power take-off.

this, tractor producers have developed transmissions that deliver a standard 540 rpm PTO speed at lower speeds of the engine flywheel. The PTO units have two transmission rates, referred to as 540 and 540E. The “540E” is also called “economical PTO” (Sümer et al., 2004). Sümer et al. (2009) performed workshop and field tests and compared tractor operations at 540 and 540E PTO speeds. For this purpose, they loaded three tractors (JD 5625, NH TD85, MF 3085) with similar technical specifications, by means of a PTO dynamometer (Eddy-current) under laboratory conditions. Measurements were done on tractor PTO torque, engine fuel consumption, specific fuel consumption, and engine exhaust gas and cooling water temperatures on the basis of load steps applied at a constant PTO revolution of 540 rpm. In the field experiments, disc fertilizer spreader, turbo atomizer and rotovator were used with the three tractors, and, engine fuel consumption, tractor PTO torque and power, area rates of work parameters were determined. Laboratory Data analysis showed an average fuel saving was performed with the economical PTO of 27.18, 18.62 and 15.88% respectively for JD 5625, MF 3085, and NH TD85 tractors,. They reported that the fuel savings decreased with the increase in PTO load. An international literature search encountered no studies considering distributions of fuel consumption values needed for PTO function and tractor mobility under laboratory and field conditions. The objective of this study was to separately determine the fuel consumption values needed for the machine to operate (machine activity) and for the tractor to be able to move (tractor mobility) in the field conditions and to evaluate the effects of PTO options (540, 540E) on fuel consumption distribution.

MATERIALS AND METHOD

The tests were carried out in the workshop and fields of the Department of Agricultural Machinery at Çanakkale Onsekiz Mart University. The tractors used in the tests were John Deere 5625, Massey Ferguson 3085, and New Holland TD85. All were 2007 production year models. Each had a 62.5 kW power rating. The test tractors (JD 5625, MF 3085, NH TD85) provided 540 and 540E applications at engine speeds of 2400 -1700 rpm, 1979 -1421 rpm and 2200 -1715 rpm, respectively. Use of the tractors was donated by John Deere Company (Turkey Branch of Deere and Company), New Holland Trakmak Co., and Uzel Makine Sanayi Co., which are the companies, that supported this study. The PTO driven machines used were turbo atomizer and disc fertilizer spreader.The cone index values measured by using a penetrologger, complying with the requirements of ASAE standards, were obtained simultaneously while taking soil samples along the profile depth in experiment field (ASAE, 1987; ASAE, 2000). The cone index values measured between 0 - 80 cm depths were between 0.77 and 2.06 MPa. The slip was measured by using a magnetic sensor perceiving 8 signals in 1 revolution of the rear tire. Field and laboratory experiments were performed with each tractor and agricultural machine at the same conditions. In these experiments the machines were operated at standard PTO speed (540) and at economical PTO (540E) speed at which the same speed can be obtained with lower engine speeds. Measurements made were tractor fuel consumption, PTO torque and power values at field experiments and under static conditions in the laboratory without changing the functions of the machines. The fuel consumption values were found by using a flow-meter (Macnaught M05, Macnaught Pty. Ltd., Australia) measuring the amount of fuel passing from the fuel supply line between the fuel tank and the injection pump and a flow-meter measuring the amount of fuel returning to the tank from the injection pump and the injectors. The difference between the two measurements represents net fuel consumption. These flow-meters (oval gear type) are quite sensitive, measuring in increments of 0.644 cc at a flow rate of 0.5 L/h. The PTO torque and power values were measured by using a torque meter (Datum 420) mounted between PTO and machine shaft. In the experiments, ambient air temperature and relative humidity were measured. In the experiments, ground speed, fuel consumption, slip, PTO torque and power were measured and recorded using a microcomputer-based data acquisition system. Variance analysis was carried out according to factorial experimental designs with 3 replications by using Minitab statistical software. PTO operations (540, 540E) and tractor working conditions (dynamic, static) were the independent variables (treatments). The effects of the two factors individually and the interactions of them on fuel consumption of the tractors were examined.

RESULTS

In the experiments, ambient air temperature and relative humidity measured were found to vary among 15 - 21°C and 45 - 60%. These levels are considered to be unlikely to affect other measurements. The slip values varied between 1.95 and 3.90% for all the experiments. The fact that tractors operate with small loads can be shown to be an important factor for the small slip values. The slip values were determined to be close to each other in all operations since all the experiments were carried out on the same field surface. According to the results of the analyses made on the soil samples, the soil texture is sandy-loam (10% clay, 14% silt, and 70% sand). The surface of the field is not cultivated and is covered by grass. In the field and laboratory experiments carried out with turbo atomizer at 540 rpm PTO speed, the PTO torque and power values were determined to be on average 105.53 Nm and 5.97 kW, respectively (Table 1). These values were 106.52 Nm, 6.02 kW for 540E rpm operation. On the other hand, PTO torque and power values were determined to be on average 41.00 Nm and 2.32 kW respectively in the field and laboratory experiments carried out with disc fertilizer spreader at 540 rpm (Table 2). These values were 41.13 Nm and 2.33 kW for 540E rpm operation. As can be seen in both of the PTO operations (540, 540E) the torque and power requirements were found to be higher for the turbo atomizer. In this study, the tractor fuel consumption values under stable conditions were considered to be the consumption required to operate the machine while the difference between the higher consumption values under field conditions and the consumption values under stable conditions was considered to be the consumption made to supply energy for the tractor’s movement. As seen from the results, the fuel consumption values measured for three tractors in field experiments with PTO operations were higher than the fuel consumption values under stable

Table 1. PTO Torque values needed for the machines.

Tractor	PTO Torque, Nm							
	540				540E			
	Disc fertilizer spreader		Turbo Atomizer		Disc fertilizer spreader		Turbo Atomizer	
JD-5625	41.00	±2.53	105.67	±3.59	41.33	±2.44	106.00	±3.41
MF-3085	41.00	±2.00	106.00	±4.62	41.33	±2.61	106.00	±4.75
NH-TD85	41.33	±2.48	105.00	±3.62	41.00	±1.66	107.67	±4.32

Table 2. PTO power values needed for the machines.

Tractor	PTO Power, kW							
	540				540E			
	Disc fertilizer spreader		Turbo atomizer		Disc fertilizer spreader		Turbo atomizer	
JD-5625	2.32	± 0.14	5.97	± 0.20	2.34	± 0.14	5.99	± 0.19
MF-3085	2.32	± 0.11	5.99	± 0.26	2.34	± 0.15	5.99	± 0.27
NH-TD85	2.34	± 0.14	5.94	± 0.21	2.32	± 0.09	6.09	± 0.24

Table 3. Fuel consumption values for tractor mobility and machine activity.

Machine	Tractor	540E			
		Fuel Consumption Lh^{-1}		Fuel consumption Lh^{-1}	
		Tractor mobility	Machine activity	Tractor mobility	Machine activity
	JD-5625	8.79 ± 0.10	6.71 ± 0.08	6.29 ± 0.05	4.16 ± 0.05
Turbo Atomizer	MF-3085	6.30 ± 0.09	4.92 ± 0.12	5.36 ± 0.08	3.47 ± 0.08
	NH-TD85	6.74 ± 0.06	5.18 ± 0.11	5.75 ± 0.07	3.85 ± 0.11
	JD-5625	7.65 ± 0.14	5.72 ± 0.13	5.01 ± 0.12	3.30 ± 0.10
Disc fertilizer spreader	MF-3085	5.47 ± 0.12	4.04 ± 0.11	4.08 ± 0.11	2.61 ± 0.12
	NH-TD85	5.86 ± 0.10	4.35 ± 0.09	4.55 ± 0.10	2.94 ± 0.05

Table 4. The values of fuel consumption distribution for tractor mobility and machine activity.

Machine	Tractor	Fuel consumption distribution, %			
		540		540E	
		Tractor mobility	Machine activity	Tractor mobility	Machine activity
	JD-5625	23.63	76.37	33.86	66.14
Turbo atomizer	MF-3085	21.94	78.06	35.18	64.82
	NH-TD85	23.18	76.82	33.06	66.94
	JD-5625	25.21	74.79	34.27	65.73
Disc fertilizer spreader	MF-3085	26.25	73.75	36.20	63.80
	NH-TD85	25.68	74.32	35.32	64.68

conditions (Table 3). The fuel consumption distribution values (%) for two machines are given in (Table 4). The fuel consumption distribution required for the PTO operation and movement of the two be on average 75.68

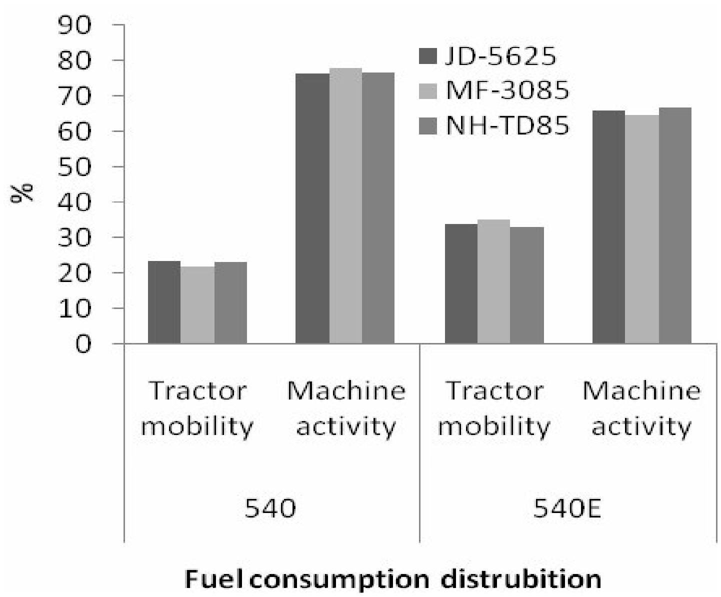

Figure 1. Fuel consumption distribution for turbo atomizer operation.

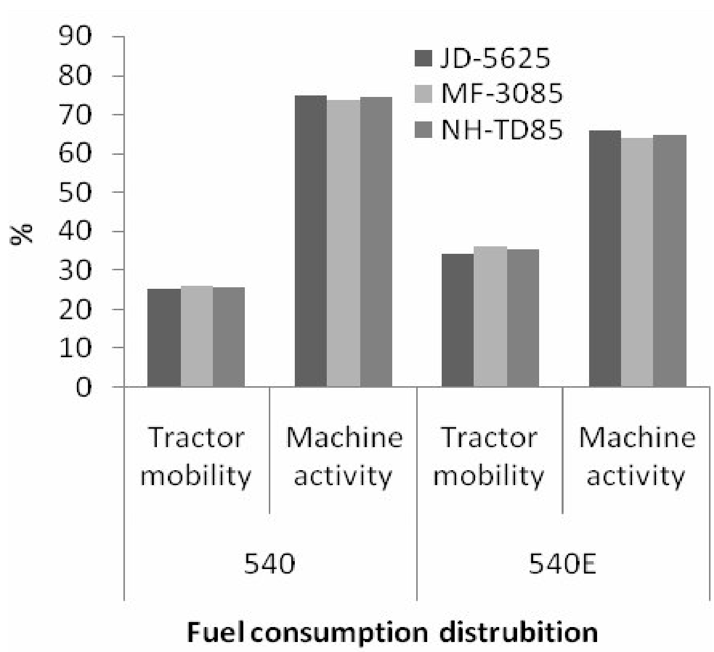

Figure 2. Fuel consumption distribution disc fertilizer spreader.

and 24.32%, respectively. These ratios have been calculated for the 540E rpm operation as machines at 540 rpm operation have been calculated to 65.35 and 34.65%, respectively. It is clear that the two PTO operations were effective on the fuel consumption distributions (Figures 1 and 2). When a general evaluation was made according to the variance analysis table given in Table 5, it was determined that the effects of 540/540E operations, and dynamic-static conditions, chosen as independent variables in the tests, were statistically significant (P<0.01) on fuel consumption considering the both individual factors.

DISCUSSION

Since the PTO speed was the same for both of the PTO operations (540 rpm), the torque and power values did not

Table 5. Summary of variance analysis table for all dependent variables.

Tractors	Machines	F values for sources of variation		
		PTO operations (540-540E)	Working conditions (dynamic-static)	Interaction
JD-5625	Turbo atomizer	1099.34**	765.63**	0.13^ns
	Disc fertilizer spreader	1398.33**	727.96**	0.16^ns
MF-3085	Turbo atomizer	630.21**	1175.86**	27.74**
	Disc fertilizer spreader	2086.17**	2230.07**	0.46^ns
NH-TD85	Turbo atomizer	29.61**	66.04**	0.63^ns
	Disc fertilizer spreader	1466.12**	1904.42**	1.99^ns

** significant at P<0.01 , ns: not significant.

show significant changes with respect to the PTO operations for the two agricultural machines (Tables 1 and 2). In the experiments carried out by using both of the machines, the fuel consumption value was slightly higher for the JD5625 tractor compared with the other tractors at the 540 rpm operation (Table 3). The fact that JD5625 tractor supplies the 540 operation at a higher motor speed (2400 rpm) compared with the other two tractors (MF3085-1979 rpm, NHTD85-2200 rpm) so this may be accepted to be the cause of this result. Since the motor speeds of the three tractors at the 540E operation were similar, it was determined that the fuel consumption values were more similar to each other (Table 3). When the fuel consumption values for the tractors used were analyzed (Table 3), it was determined that the fuel consumption values for the fertilizer spreader were higher than the fuel consumption values for the turbo atomizer for all the three tractors. The higher torque and power requirement of the turbo atomizer is the natural cause of this situation. The total fuel consumption requirement share needed for the machine to operate in the economical PTO operation (65.35%) was slightly lower than that in the other PTO operation (75.68%). The main reason of this result is the decrease in the fuel consumption for PTO movement in the economical PTO operation. The decrease in the fuel consumption needed for PTO operation has caused the share of the fuel consumption needed to move the tractor to increase.

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REFERENCES

ASAE (1987). Standard S296.3: Uniform Terminology for Traction of Agricultural Tractors, Self Propelled Implements and Other Tractions and Transport Devices, Standarts. 34th Ed. American Society of Agricultural Engineer. St. Joseph, MI-49085-9659

ASAE (2000). S313.2. Soil cone penetrometer standarts. Joseph, Mitch.

Goering CE (1986). Engine and Tractor Power. Breton Publishers, Boston.

Işık A (1988). Sulu Tarımda Kullanılan Mekanizasyon Araçlarının Optimum Makine ve Güç Seçimine Yönelik İşletme değerlerinin Belirlenmesi ve Uygun Seçim Modellerinin Oluşturulması Üzerinde Bir Araştırma. (in Turkish), MSc Thesis, University of Çukurova, Adana, Turkey.

Ruiyin H, Wenqing Y, Yadong Z, Van Sonsbeek G (1999). Improving Management System of Agricultural Machinery in Jiangsu. Proceedings of 99 International Conference on Agricultural Engineering, Beijing, China pp. I-42/45.

Sabancı A (1997). Tarım Traktörleri [Agricultural Tractors]. Ç.Ü. Ziraat Fakültesi Ders Kitapları Genel Yayın No: 46, Adana, Turkey s: 113-167.

Sumer SK, Say SM, Has M, Sabancı A (2004). Economical Tractor Park and Its Developing in Turkey. J. Faculty Agric. University of Cukurova 19(1): 17-26 Adana, Turkey.

Sumer SK, Kocabiyik H, Say SM, Çiçek G (2009). Traktörlerin Ekonomik Kuyruk Mili (540E) Çalışma Karakteristiklerinin Teknik ve Ekonomik Analizi. Tarımsal Mekanizasyon 25. Ulusal Kongresi. Bildiri Kitabı, s: 11-12 Isparta.

Sumer SK, Kocabiyik H, Say SM, Çiçek G (2009). Determination of Fuel Consumption Values For Field and Laboratory Conditions of Tractors in Some Machine Operations with 540 and 540E PTO. XXXIII CIOSTA CIGR V Conference 17-19 June, Technology and management to ensure sustainable agriculture, agro-systems, forestry and safety, Mediterranea University, Reggio Calabria, Italy.