Hourly Fuel Consumption at Normal Tillage

Bogdan-Vlad AVARVAREI

***Abstract* -** The aim of the current paper is to study the influence of working velocity, soil type and plough type on hourly fuel consumption (C_h) when normal tillage is performed. For achieving the purposed goal were utilised two types of mouldboard ploughs, one of them is a conventional plough with three furrows (PP-3-30) and the second one is a reversible plough with three furrows on each side (PRP-3). Both ploughs worked in aggregate with Romanian tractor U-650 M which has 65 HP. The research was carried out on three different types of soil (a light soil - typical chernozem with a loamy sand texture; a medium soil - cambic mezocalcaric chernozem with a clay loamy texture and a heavy soil - luvosol with a clay texture), were utilised four different working velocities (4.48 km/h, 4.61 km/h, 4.85 km/h and 4.98 km/h) and working depth was 25 cm. Hourly fuel consumption presented a decreasing tendency once the working velocity increased. As the soil resistance to tillage increases so do the values of hourly fuel consumption. If tillage is carried out with reversible plough PRP-3 the hourly fuel consumption decreased if contrasted to the conventional plough PP-3-30, regardless of soil type and working velocity.

***Keywords* -** conventional plough, hourly fuel consumption, normal tillage, reversible plough.

I. Introduction

IN according with [1], "Depending on the type of fuel and the amount of time a tractor or machine is used, fuel and lubricant costs will usually represent at least 16 percent to over 45 percent of the total machine costs". Thus, fuel consumption plays a significant role in the selection and management of tractors and equipment [2]. Fuel consumption is measured by the quantity of fuel utilised during a certain and specific period of time. Farmers may consider numerous ways to estimate and reduce fuel consumption. The first step is to determine how much fuel is being used for a particular field operation and compare it to average usage [2]. So, each element which can provide even a small improvement of tillage quality, an increase of labour productivity, a decrease in the direct expenditures per hectare or in fuel consumption, have an important role upon the increase of economic efficiency [3].

II. Material and methods

To measure the hourly fuel consumption was utilised a device based on volumetric method (Fig. 1). Even if volumetric method is less precise than gravimetric method, we choose it due to the difficulties which can appear at using gravimetric method on a tractor in field working conditions [3], [4]. The device for hourly fuel consumption has four vertical cylindrical metallic tubes (3) placed on a circular circumference.

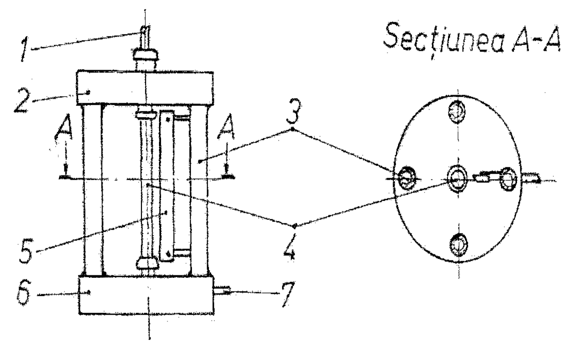

Fig. 1 Scheme of device for measuring the fuel consumption
1 – breather pipe; 2 – upper reservoir; 3 – metallic pipe for connection; 4 – central glass tube; 5 – gradated line; 6 – lower reservoir; 7 – linkage.

Through these tubes is realised not only the connection between the two reservoirs (2 and 6) of the device, but also the fuel circulation. In the central part the connection is realised through a glass tube (4), which allows viewing the fuel level in the device. Close to this central glass tube it is mounted a gradated line (5), which allows the effective reading of the volume of consummated fuel. The constant of device is 0.92 cm^3/mm height. This construction of the fuel consumption device permits to eliminate the reading errors also in the case of tractors' movement on slope fields, because the decrease of fuel level in the upper tubes is accompanied by a correspondent increase of the level in the lower tubes.

The device is placed into the fuel alimentation system, according with the scheme from Fig. 2 [3], [4].

In the construction of device were used two electro-valves (E_1 and E_2). Electro-valve E_1 has the role to permit fuelling of tractors' engine either directly from fuel tank (R), or through the device for fuel consumption determination (AC). At alimentation of the electro-valve with electric power, the engine will be supply with fuel from fuel consumption determination device. After each determination, the device is filled again so the next reading to start from zero. The extra quantity of diesel from the injection pump and injectors is bring in the admission of alimentation pump (PA), through the tank (RI), which allows to avoid the apparition of air goals at the entrance pipe in alimentation pump.

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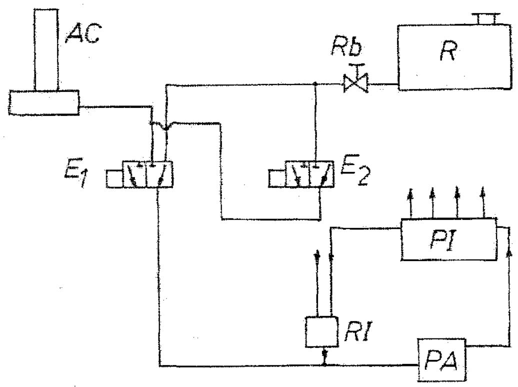

Fig. 2 Connection scheme in the injection system of the device for fuel consumption measuring
R – fuel tank; AC - device for fuel consumption determination; Rb - tap; E_1, E_2 – electro-valves; PI – injection pump; RI – intermediary tank; PA – alimentation pump.

For time measuring was utilised an electronic chronometer with four digits (Fig. 3) [4]. Countdown begins at the same time with starting of hydraulic device for fuel consumption measuring.

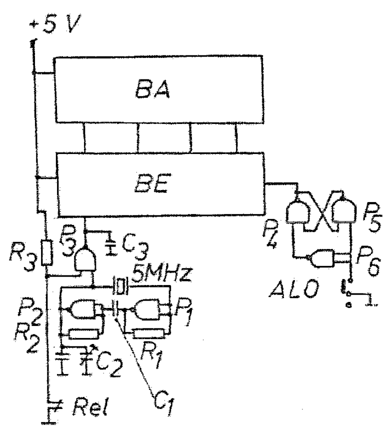

Fig. 3 Electronic scheme of chronometer
BA – display; BE – electronic block; $P_1 \ldots P_6$ – logical gates; $R_1 \ldots R_3$ – resistances; $C_1 \ldots C_3$ - condensers; ALO - button for return to zero value; Rel – normal closed contacts

The trials were carried out on the experimental plots of Agricultural Research-Development Station (S.C.D.A.) Podu-Iloaie, Iasi County, Romania (Fig. 4). S.C.D.A. Podu-Iloaie is situated in the Southern part of Moldova Plain, which is characterized by a lowland relief with an erosive origin, constituted by a series of hills and valleys oriented to Bahlui and Bahluiet rivers. Geographical position has the following coordinates: $47^{\circ}10'$ Northern latitude and $27^{\circ}20'$ Eastern longitude, and the altitude are 28 m.

Experiments were realized on three different soil types (a light soil - typical chernozem with a loamy sand texture – variant A; a medium soil - cambic mezocalcaric chernozem with a clay loamy texture – variant B and a heavy soil - luvosol with a clay texture – variant C) on a wheat stubble-field with density of 450plants/m^2 and a height of 15 cm.

Fig. 4 Iasi County, Romania

The working depth was 25 cm for all three soil types, varying working velocities. Those ones belonged to II H gear and had the following values: 4.48 km/h; 4.61 km/h; 4.85 km/h and 4.98 km/h.

We tested two tillage units: the first one was composed by a U-650 M tractor and a PP-3-30 conventional plough and the second one was composed by a U-650 M tractor and a PRP-3 reversible plough. U-650 M is a Romanian tractor and has 65 HP. Both tested ploughs are also made in Romania.

The proposed research imposed determination of some soil features such as: moisture content, specific resistance at tillage, bulk density and resistance to penetration.

Soil moisture content was gathered on three different depth of arable horizon (0-10 cm, 10-20 cm, 20-30 cm), in five repetitions. Soil samples were gathered using a Kacinski gauge and water content was determined using the drying stove method at 105^0C.

Specific resistance at tillage (k_0) for all the three studied soils is as follows: for light soil (variant A) k_0 is lower than 0.35 daN/cm^2; for medium soil (variant B) k_0 is between 0.35 and 0.55 daN/cm^2; for heavy soil (variant C) k_0 is between 0.56 and 0.75 daN/cm^2 [5], [6].

Bulk density and resistance to penetration offers a very good characterization of soil under the aspect of compaction, having changes of values function of the depth of arable horizon. This fact determined us to establish the value of bulk density (BD) and resistance to penetration (R_p), on depth of 0-10 cm, 10-20 cm and 20-30 cm and to estimate their variation.

Bulk density and resistance to penetration were studied in correlation with axis loading and the passing numbers and the conclusion is that 48% from bulk density and 43% from resistance to penetration are due to the first pass [7]. Modification of bulk density is also in connection with the depth, obtaining the greatest variation in the 0-10 cm soil layer. Resistance to penetration and bulk density increases at the same time with axis loading and tyre pressure [7]. Agro-technical demands establish many classes for soil resistance to penetration: very small=under 11 daN/cm^2, low=11...25 daN/cm^2, medium=26...50 daN/cm^2 etc. [8].

III. Results and Discussions

From the data presented in Table I resulted that on winter wheat stubble-field for all three types of soil, average values of moisture content recorded increases with the depth of arable horizon.

TABLE I
SOIL MOISTURE CONTENT OF THE STUDIED SOILS

Depth (cm)	Repetition	Moisture content (%)		
		Variant A	*Variant B*	*Variant C*
0-10	1	13,0	19,5	9,0
	2	12,5	19,0	10,5
	3	13,5	16,1	9,5
	4	13,0	18,1	10,4
	5	12,0	17,3	9,6
	Mean	**12,8**	**18,0**	**10,0**
10-20	1	16,5	18,1	14,0
	2	16,0	19,1	14,5
	3	16,5	19,3	15,0
	4	17,0	18,1	15,5
	5	15,5	18,0	13,0
	Mean	**16,3**	**18,52**	**14,5**
20-30	1	17,2	19,3	16,0
	2	17,3	20,1	16,5
	3	18,0	19,4	17,0
	4	18,2	20,0	17,5
	5	18,8	19,2	15,5
	Mean	**17,9**	**19,6**	**16,5**

The highest moisture content was obtained at variant B, on a medium soil (cambic mezocalcaric chernozem). The values of moisture content increased from 18.0% at 0-10 cm depth to 19.36 in the layers from 20-30 cm depth. Luvosol (variant C) presented the lowest moisture content regardless the deep from which soil samples were gathered.

Bulk density (BD), in average, on 0-30 cm depth, was of 1.19 g/cm^3 at variant A (typical chernozem); 1.27 g/cm^3 at variant B (cambic mezocalcaric chernozem) and 1.48 g/cm^3 at variant C (luvosol with moderate compaction). Average bulk density of repetitions increases with the deep of arable horizon (Table II).

Resistance to penetration (R_p), in average values, for the same experimental conditions was of 14.0 daN/cm^3 for variant A (typical chernozem); 18.88 daN/cm^3 at variant B (cambic mezocalcaric chernozem) and 60.00 daN/cm^3 at variant C (luvosol with moderate compaction).

The data presented in Table III also illustrates the evolution of resistance to penetration, function of depth and soil type.

Obviously stands out the higher values of resistance to penetration characteristically to heavy and compacted soils (variant C).

We present the hourly fuel consumption in conditions of performing tillage on those three soil types, with the two studied ploughing units (U-650 M+PP-3-30 and U-650 M+PRP-3) for all four working velocities.

TABLE II
VARIATION OF SOIL BULK DENSITY FUNCTION OF DEPTH

Variant	Depth (cm)	BD (g/cm^3)			
		Repetition			Mean
		I	II	III	
A	0-10	1.16	1.18	1.17	1.18
	10-20	1.19	1.18	1.18	1.19
	20-30	1.20	1.21	1.21	1.20
	Mean	**1.18**	**1.19**	**1.19**	**1.19**
B	0-10	1.23	1.24	1.22	1.23
	10-20	1.29	1.28	1.27	1.28
	20-30	1.30	1.31	1.30	1.30
	Mean	**1.27**	**1.27**	**1.26**	**1.27**
C	0-10	1.45	1.46	1.47	1.46
	10-20	1.48	1.47	1.48	1.48
	20-30	1.49	1.50	1.49	1.49
	Mean	**1.47**	**1.48**	**1.48**	**1.48**

TABLE III
VARIATION OF SOIL PENETRATION RESISTANCE FUNCTION OF DEPTH

Variant	Depth (cm)	R_p (daN/cm^2)			
		Repetition			Mean
		I	II	III	
A	0-10	12.0	13.0	14.0	13.0
	10-20	13.0	14.0	15.0	14.0
	20-30	14.0	15.0	16.0	15.0
	Mean	**13.0**	**14.0**	**15.0**	**14.0**
2	0-10	16.0	14.0	15.0	15.00
	10-20	19.0	20.0	20.0	19.66
	20-30	21.0	23.0	22.0	22.00
	Mean	**18.66**	**19.0**	**19.0**	**18.88**
3	0-10	55.0	62.0	57.0	58.0
	10-20	57.0	63.0	60.0	60.0
	20-30	58.0	66.0	62.0	62.0
	Mean	**56.66**	**63.66**	**59.66**	**60.0**

In Fig. 5 are presented the values recorded for hourly fuel consumption, when working velocity is v_1=4.48 km/h, and could be noticed that those values increased function of soil type for both tillage units.

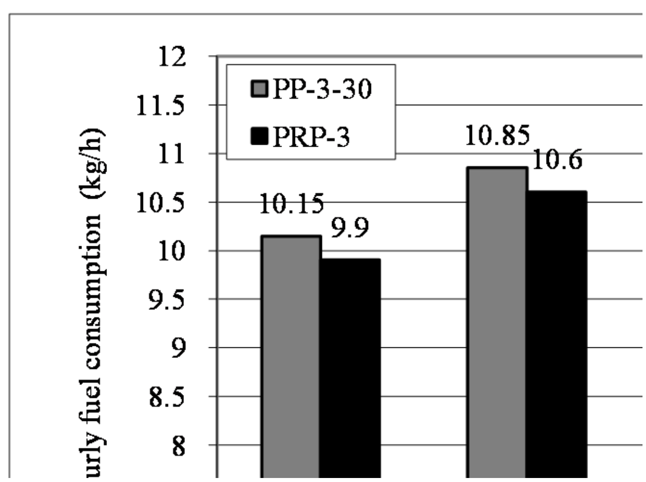

Fig. 5 Variation of hourly fuel consumption function of soil type (v_1 = 4.48 km/h)

The lowest values of hourly fuel consumption were recorded on light soil having the minimums of 10.15 kg/h (U-650 M+PP-3-30), respectively 9.90 kg/h (U-650 M+PRP-3), and the maximal values were recorded at tillage on a heavy soil (11.55 kg/h for U-650 M+PP-3-30 respectively 11.30 kg/h for U-650 M+PRP-3).

It could also be remarked that tillage unit formed by tractor U-650 M and reversible plough PRP-3 had a hourly fuel consumption lower with 0.25 kg/h for light soil, with 0.25 kg/h on medium soil and with 0.25 kg/h for heavy soil than the tillage unit formed by tractor U-650M and conventional plough PP-3-30, on all three soil types on which experiments were carried out.

This thing is also due to the fact that turns over at the end of plots were reduced for reversible plough PRP-3 because this one is provided with a shifting mechanism.

Studying the hourly fuel consumption for v_2=4.61 km/h working velocity (Fig. 6), could be remarked the increased values for hourly fuel consumption function of soil type, for both tillage units.

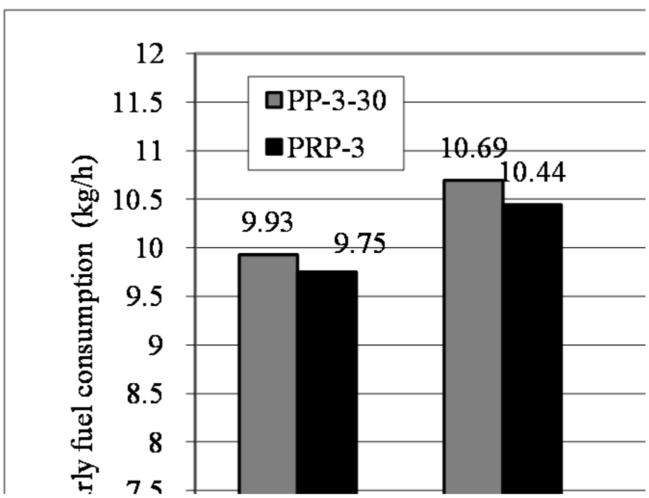

Fig. 6 Variation of hourly fuel consumption function of soil type (v_2 = 4.61 km/h)

So the lowest values of hourly fuel consumption were recorded on light soil having minimums of 9.93 kg/h (U-650 M+PP-3-30) respectively 9.75 kg/h (U-650 M+PRP-3), and the maximal values were recorded when tillage was performed on a heavy soil (11.32 kg/h for U-650 M+PP-3-30, respectively 11.19 kg/h for U-650 M+PRP-3).

For all three soil variants A, B and C tillage unit formed by tractor U-650 M and reversible plough PRP-3 had a lower hourly fuel consumption with 0.18 kg/h on light soil; with 0.25 kg/h on medium soil and with 0.13 kg/h on heavy soil, in comparison with the tillage unit formed by tractor U-650 M and conventional plough PP-3-30, on all three soil types on which trials were performed.

This thing is due to the fact that no matter which the working velocity is the turns over at the plots ends were reduced for PRP-3 plough due to the presence of shifting mechanism.

Evolution of hourly fuel consumption recorded, for working velocity v_3=4.85 km/h, increased values function of soil type, for both tillage units (Fig. 7).

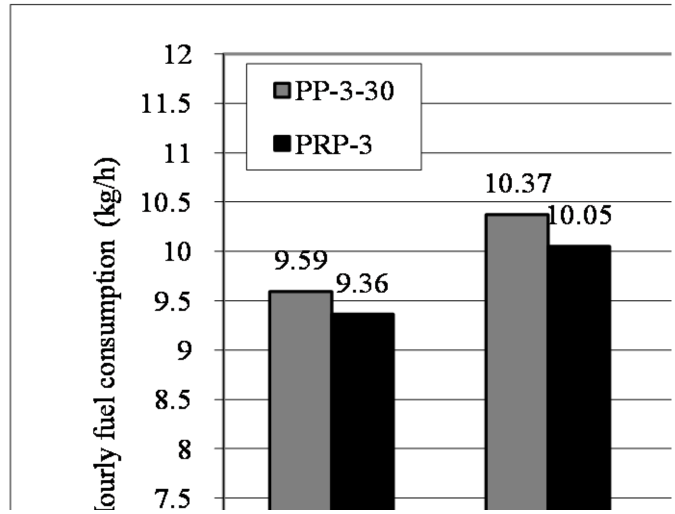

Fig. 7 Variation of hourly fuel consumption function of soil type (v_3 = 4.85 km/h)

The lowest values of hourly fuel consumption were recorded on light soil having the minimums of 9.59 kg/h (U-650 M+PP-3-30) respectively 9.36 kg/h (U-650 M+PRP-3) and the maximal values being recorded at tillage on a heavy soil (11.08 kg/h for U-650 M+PP-3-30 respectively 10.89 kg/h for U-650 M+PRP-3).

Regarding the tillage unit formed by tractor U-650 M and reversible plough PRP-3 could be remarked a lower hourly fuel consumption with 0.23 kg/h on light soil, with 0.32 kg/h on medium soil and with 0.19 kg/h on heavy soil face to tillage unit formed by tractor U-650 M and conventional plough PP-3-30, on all three experimental variants.

For both tillage units hourly fuel consumption, at v_4=4.98 km/h working velocity, recorded increased values function of soil type.

The lowest values of hourly fuel consumption (Fig. 8) were recorded also on light soil having minimums of 9.19 kg/h (U-650 M+PP-3-30) respectively 8.91 kg/h (U-650 M+PRP-3) and maximal values were recorded at tillage on a heavy soil (10.83 kg/h for U-650 M+PP-3-30 respectively 10.64 kg/h for U-650 M+PRP-3).

Also like in the case of v_1, v_2 and v_3 tillage unit formed by tractor U-650 M and reversible plough PRP-3 had the lowest hourly fuel consumption; with 0.28 kg/h on light soil, with 0.27 kg/h on medium soil and with 0.19 kg/h on heavy soil face to tillage unit formed by tractor U-650 M and conventional plough PP-3-30, on all three soil types on which trials were performed. The fact that PRP-3 plough has the advantage of shifting mechanism made that the turn over at plot ends to be reduced.

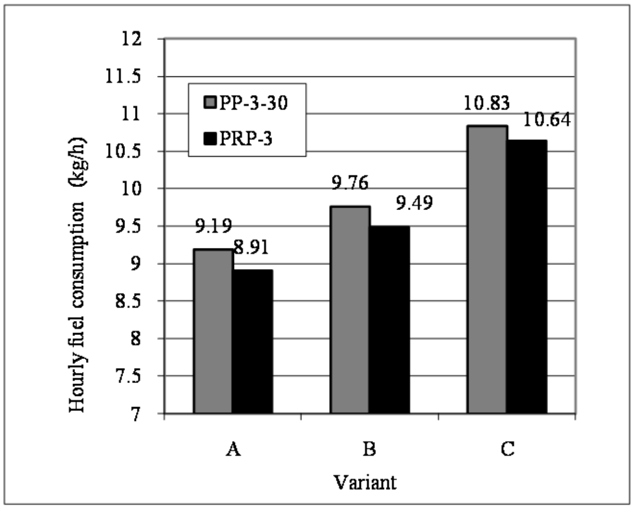

Fig. 8 Variation of hourly fuel consumption function of soil type (v_4 = 4.98 km/h)

IV. Conclusions

A first conclusion regarding the influence of soil type and working velocity on hourly fuel consumption is that this one increase functions of soil type. So, at the same time with the increasing of specific resistance to tillage also increase the hourly fuel consumption. The lowest values are recorded at tillage on light soils and the highest values being obtained at performing tillage on heavy soils.

Another conclusion drawn at the end of experimental trials was that together with increasing of working velocity hourly fuel consumption decrease, so the lowest values were recorded at superior working velocities and the maximal values were obtained when tillage was performed with lower working velocities.

If the tillage work is carried out with PRP-3 reversible plough the hourly fuel consumption decreases if contrasted to PP-3-30 conventional plough, regardless of soil type and working velocity. This situation can be explained through the fact that the turns over of tillage unit formed by tractor U-650 M and PRP-3 reversible plough are reduced in comparison with the turns over of tillage unit U-650 M and conventional plough PP-3-30, due to the existence of shifting mechanism at PRP-3 reversible plough.

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