

P47 - Preliminary Study for the Development of Variable-Tillage Implements for Precision Farming

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Introduction

Energy demand of soil tillage implements has been reported based on different operating conditions and the chemical and physical soil properties [1,2]. However, tillage operations cannot only be evaluated according to their energy consumption; the soil structure improvement and the consequent agronomic benefits must also be considered [3]. Power harrows can adjust soil clod size by varying the velocity ratio (λ) of the machinery which is calculated from the ratio of the peripheral speed of the tine rotors and the vehicle's advancing speed [4]. This peculiarity makes it possible the development of new variable-rate tillage implements, a topic of high interest in recent years [5]. Moreover, according to Berntsen and Berre [6], a good seedbed to achieve a rapid and uniform emergence for cereals should contain roughly 50% of the weight of aggregates in the 0.5-6.0 mm range.

Objectives

This paper aims to gain deeper insight into controlling the soil structure and find correlations with the power harrow's energy requirement in different setups maintaining λ constant. Moreover, a possible correlation was sought between crop emergence and the granulometry of the tilled soil.

Materials and methods

Field tests were conducted on a 5 m working width (b) power harrow coupled with a 230 kW CVT tractor with a working depth (δ) of 15 cm. Tests were performed at constant λ , in particular four different configurations (named C λ 1-4) were performed varying the tractor speed (V_t) and the tines rotational speed (n_{ph}). Through the tractor Controlled Area Network (CAN) SAE J1939 diagnostic port and a datalogger, its speed, engine power, engine speed, fuel rate consumption (\dot{f}) and PTO speed were recorded during the tests. In addition, load pins and a torque meter were used to measure the draught force and PTO torque that the power harrow absorbed. Therefore, the power absorbed by the power harrow (P_{ph}), the fuel consumption per hectare (f_{ha}) and the energy required to process 1 m³ of tilled soil (E) were calculated using the following equations:

$$P_{ph} = P_D + P_{PTO} \quad (1)$$

$$f_{ha} = \frac{\dot{f}}{F_c} \quad (2)$$

$$E = \frac{P_{ph}}{V_t b \delta} \quad (3)$$

where P_D and P_{PTO} are the power used to tow the implement and the power used to run the power harrow rotors through the PTO, respectively. Moreover, F_c is the field capacity of the agricultural operation, obtained by multiplying the working width by the tractor speed.

Following harrowing, soil samples were sieved, and then the granulometric parameter MWD was calculated [7]. Thereafter, the field was sown with maize maintaining constant planter set up all over the field. Then, the crop emergence and phenological stage were manually monitored in the field after a few days by counting the number of plants and the number of unfolded leaves respectively. The infield measurements were repeated three times in each parcel. Then, data from tractor-power harrow system, soil granulometry and crop emergence were correlated to find any possible relationship. Each configuration was randomly replicated three times. The Pearson coefficient was evaluated to correlate MWD and crop emergence (number of emerged plants) data.

Results

The results showed that the λ parameter was between 2.6 and 2.8 during the field tests (Table 1). The energy required by the tractor-power harrow system per m³ of tilled soil was affected by the tractor speed and varied from 195.9 kJ m⁻³ at 3 km h⁻¹ to 158.4 kJ m⁻³ at 5.1 km h⁻¹. The linear

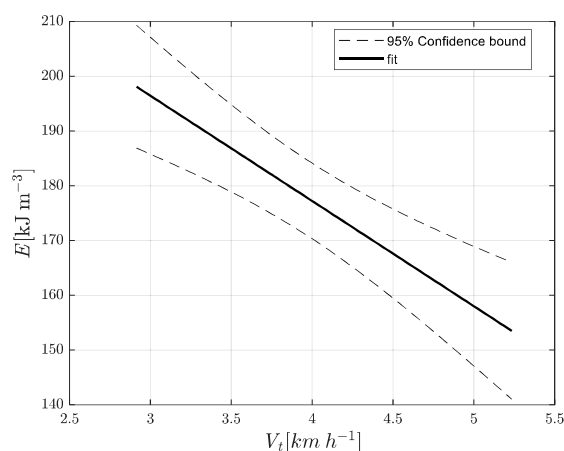
regression of the energy required to process 1 m³ of tilled soil as a function of the tractor speed is reported in Figure 1 with a coefficient of determination (R²) equal to 0.73.

The obtained Pearson coefficient, used to correlate the MWD data with the number of emerged plants, resulted to be -0.56.

Table 1. Average of the monitored and calculated data for different configurations. The standard deviation is in brackets.

Test	\bar{V}_t [km h ⁻¹]	\bar{n}_{ph} [rpm]	$\bar{\lambda}$	\bar{P}_{ph} [kW]	\bar{f}_{ha} [L ha ⁻¹]	\bar{E} [kJ m ⁻³]	\overline{MWD} [mm]
Cλ1	3.0 (1.1 E ⁻¹)	205 (2.1)	2.55 (7.1 E ⁻²)	120.1 (8.3)	25.6 (1.3)	195.9 (11)	13.6 (2.6)
Cλ2	3.4 (4.1 E ⁻²)	246 (28)	2.78 (2.9 E ⁻¹)	136.5 (3.1)	24.8 (7.9 E ⁻¹)	189.9 (2.4)	10.6 (2.0)
Cλ3	4.4 (1.7 E ⁻¹)	324 (12)	2.76 (2.1 E ⁻¹)	153 (11)	23.2 (2.1)	166.3 (18)	9.6 (2.9)
Cλ4	5.1 (1.7 E ⁻¹)	357 (3.6)	2.66 (7.1 E ⁻²)	166.8 (7.8)	20.9 (1.0)	158.4 (13)	8.6 (2.0)

Figure 1. Linear regression of the energy required to process 1 m³ of tilled soil as a function of the tractor speed.



Discussion and conclusions

The energy values per unit of volume of tilled soil decrease when the tractor speed increases, this is in line with previous results obtained by the Authors[1]. Moreover, \overline{MWD} decrease with the increase of the impact speed of the tines with the soil, as already observed by Varani et al.[4].

The Pearson coefficient shows a reverse strong correlation between MWD data with the number of emerged plants. Therefore, the higher the tractor speed and the tines rotational speed, the higher the crop emergence and the lower energy consumption are respectively.

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