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Energy efficiency and soil conservation in conventional, minimum tillage and no-tillage

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Abstract

The objective of this research was to determine the capacity of a soil tillage system in soil conservation, in productivity and in energy efficiency. The minimum tillage and no-tillage systems represent good alternatives to the conventional (plough) system of soil tillage, due to their conservation effects on soil and to the good production of crops (Maize, 96%–98% of conventional tillage for minimum tillage, and 99.8% of conventional tillage for no till; Soybeans, 103%–112% of conventional tillage for minimum tillage and 117% of conventional tillage for no till; Wheat, 93%–97% of conventional tillage for minimum tillage and 117% of conventional tillage for no till. The choice of the right soil tillage system for crops in rotation help reduce energy consumption, thus for maize: 97%–98% energy consumption of conventional tillage when using minimum tillage and 91% when using no-tillage; for soybeans: 98% energy consumption of conventional tillage when using minimum tillage and 93 when using no-tillage; for wheat: 97%–98% energy consumption of conventional tillage when using minimum tillage and 92% when using no-tillage. Energy efficiency is in relation to reductions in energy use, but also might include the efficiency and impact of the tillage system on the cultivated plant. For all crops in rotation, energy efficiency (energy produced from 1 MJ consumed) was the best in no-tillage — 10.44 MJ ha^{-1} for maize, 6.49 MJ ha^{-1} for soybean, and 5.66 MJ ha^{-1} for wheat. An analysis of energy-efficiency in agricultural systems includes the energy consumed-energy produced-energy yield comparisons, but must be supplemented by soil energy efficiency, based on the conservative effect of the agricultural system. Only then will the agricultural system be sustainable, durable in agronomic, economic and ecological terms. The implementation of minimum and no-tillage soil systems has increased the organic matter content from 2% to 7.6% and water stable aggregate content from 5.6% to 9.6%, at 0–30 cm depth, as compared to the conventional system. Accumulated water supply was higher (with 12.4%–15%) for all minimum and no-tillage systems and increased bulk density values by 0.01%–0.03% (no significant difference) While the soil fertility and the wet aggregate stability have initially been low, the effect of conservation practices on the soil characteristics led to a positive impact on the water permeability in the soil. Availability of soil moisture during the crop growth period led to a better plant watering condition. Subsequent release of conserved soil water regulated the plant water condition and soil structure.

Key Words: No-tillage, Minimum tillage, Yield, Energy efficiency, Soil conservation

1 Introduction

Cultures respond to the system of soil tillage in a way that is hard to predict. The results depend on one hand on the soil characteristics and microclimate and on the association of different practices, such as: the amount of soil preparation, the sowing dates, the equipment used, the crop rotation, the species or the hybrid used, the way in which it is fertilized (the time and the way it is applied), and weed control. The relation between the production – its profit & energy efficiency and the systems of soil tillage, is mostly influenced by the previous management of the soil and by weather. Consequently, the use of new systems of soil tillage must occur with managerial input, considering the results acquired by research and the creation of new species & hybrids

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and technology.

Sustainable agricultural activity must be organized in a system, scheduled in a sequence and always analysed as part of the relationship: soil-plant-climate area-socio-economic conditions-crop-efficiency (Wang et al., 2008; Bucur et al., 2011; Afzalinia et al., 2012; Domuta et al., 2012). Recommendation of flexible and multifunctional technologies consequently aims at reducing the consumption of energy, particularly in the field of aggressive soil tillage, as well as obtaining high yields, soil conservation and environmental protection (Jitareanu et al., 2006; Li and Mu, 2006; Marin et al., 2011; Ailincai et al., 2011; Gao et al., 2012).

The essence of the living system consists in the unique capacity of plants to convert, through photosynthesis, the solar energy, carbon dioxide and water into biochemical alimentary energy. Therefore, a successful measure in agriculture is the quantity of energy gathered under the form of biomass, as a result of efficient human and fossil energy use (Jones, 1989; Glendining et al., 2009; Coman and Rusu, 2010; Jackson et al., 2011; Akdemir et al., 2012).

Soil tillage has as its main purpose a series of immediate effects (with a positive side), resulting from the objectives of the soil tillage themselves: basic tillage, germinal layer preparation, field maintenance. Still, the effects of soil tillage can often have an immediate positive or negative short or long term lasting effects, (Marin et al., 2012; Molnar et al., 2012; Moraru and Rusu, 2012; Ranta et al., 2012; Rusu and Bogdan, 2012; Stanila et al., 2012; Zhou et al., 2012).

The influence of soil tillage systems on soil properties and energy efficiency is shown by the important factors of soil fertility conservation and evaluation of the sustainability of the agricultural system (Uhlin, 1998; Rusu, 2001; Sarauskis et al., 2009; Vural and Efecan, 2012). Long-term field experiments have provided excellent opportunities to quantify the long-term effects of soil tillage systems on accumulated soil water (Rusu et al., 2006; Romaneckas et al., 2009; Ponjican et al., 2012). The hydrological function of the soil (especially the capacity to retain optimum water quantity, and then gradually make this available for plant consumption) is one of the most important functions determining soil fertility, productivity and soil evolution. Intrinsic soil properties such as organic matter and texture, along with applied tillage practices combine to modify the soil structure, porosity, permeability and water capacity. This, in turn, is a critical factor in the water cycle and affects water accumulation in the soil. The conservation of soil fertility requires a tillage system that optimizes the plant needs in accordance with the soil modifications, that ensures the improvement of soil features and the continuous producing of high crop yields. Thus, the conservation of soil fertility is tied to maintaining and improving the soil fertility indices and to the productivity of the tillage system.

The objective of this paper is to determine the capacity of the soil tillage system in soil conservation, in productivity, and in ensuring optimized energy efficiency.

2 Materials and methods

The experiments were conducted at the University of Agricultural Sciences and Veterinary Medicine in Cluj Napoca, Romania (Fig. 1; 46º 46' N, 26º 36' E), on a moderately fertile Fluvisoil (SRTS, 2003). The humus content was 3.01%, pH was 7.2, and soil texture was clay (42% clay in the arable stratum). The experimental field has an annual temperature of 8.2℃ and annual rainfall of 613 mm.

Fig. 1 Experimental field