Effects of tillage and oilseed rape cultivar (*Brassica napus* L.) on soil physical properties and yield

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Abstract
Winter oilseed rape (*Brassica napus* L.) became one of the most important crops grown in north-eastern Romania. The objectives of this research study refer to creating technological options adapted to local conditions for farmers in the area and assessing tillage effect on soil physical properties and rapeseed yield in three different locations. Soil bulk density (BD), penetration resistance (PR) and hydric stability of aggregates (HS) were determined at different rapeseed fenological stages in moldboard (MT), chisel (CT) and disk-harrow (DT) tillage treatments. No significant differences existed among tillage treatments concerning BD and HS. PR determined at plant full growth was significantly higher in DT in two out of three locations. Yield varied with tillage, with no significant differences between MT and CT, but was lower in DT (p=0.05).

Keywords: bulk density, penetration resistance, aggregate stability, cropping system

Introduction
Soil degradation, decrease in soil's actual and potential productivity owing to land misuse, is a major threat to agricultural sustainability and environmental quality (Lal, 1993). Intensive tillage has worldwide resulted in soil degradation, causing a long term threat to future yields (D'Haene et al., 2008). It is generally accepted that practices such as minimum tillage reduces the environmental impact of cultivation. Many research studies have shown that conversion to such practices preserves and improves soil physical properties with little or no impact on yield.
Soil bulk density is probably the most frequently measured soil quality parameter in tillage experiments (Ozpinar and Cay, 2006) and a useful parameter in studies of soil and crop responses to machinery traffic in agriculture (Diaz-Zorita, 2000; Yavuzcan, 2000). Penetration resistance can also be used to highlight differences between tillage systems; when accurately determined, it is a more sensitive measurement of soil compaction than bulk density. Soil structure is a key factor in the functioning of soil, its ability to support plant and animal life, and moderate environmental quality (Bronick and Lal, 2005). Water stability of aggregates is often the most used parameter to characterize soil structure (Young and Young, 2001; Six et al., 2000) and it is sensitive to soil management practices. Conventional tillage disrupts soil aggregates and compacts soil (Plante et al., 2002) while applying reduced and no-till management systems resulted in more stable aggregates (Filho et al., 2002).
In north-eastern Romania winter oilseed rape crop (*Brassica napus* L.) is of great importance for farmers because it requires relatively low technological costs and guarantees profit even at medium yield levels. Determining various agronomical properties including soil physical parameters for enhanced oilseed rape (*Brassica napus* L.) yield with low technological impact on the environment can be of both economic and ecological great importance.

Materials and methods

Experimental design and procedure

The research started in august 2010, when field trials have been setup in three locations from Central-Northern Area of Moldavian Plateau (north-eastern Romania): Agricultural Research and Development Station (ARDS) Suceava, ARDS Secuieni – Neamț county and ARDS Podu-Iloaiei – Iaşi county. In the first location (Suceava) the soil is a cambic phaeozem (Romanian Soil Taxonomy System - 2003) with 31.6% clay in 0-20 cm soil layer, 5.6-5.8 pH units and 3% humus content. The soil from Secuieni is a loamy cambic chernozem, 2.4% humus content and 6.2 pH units. The cambic chernozem from Podu-Iloaiei has 423 g clay, 315 g loam and 262 g sand/1000 g of soil, and around 3% humus (table 1).

Table 1. Soil and climate conditions

Location	Soil	Multi-annual mean temperature	Multi-annual mean rainfall
Suceava	cambic phaeozem (loamy, moderate acid, medium humus content)	7.8°C	586.8 mm
Secuieni	cambic chernozem (loamy, slight acid, medium humus content)	8.6°C	576.9 mm
Podu-Iloaiei	cambic chernozem (clay-loamy, slight acid to neutral, medium humus content)	9.6°C	542.0 mm

The trials were arranged as split-plot on the basis of completely randomized block design. The main plots were tillage systems: conventional tillage using moldboard plow (MT) and minimum tillage using chisel (CT) and disc-harrow (DT); 50 winter oilseed rape (*Brassica napus* L.) cultivars in three replications were assigned to the subplots. The cultivars were selected from the comercial offer of companies such as Pioneer Hi-Bred, Monsanto, Dieckmann, Euralis, Biocrop etc.

Each subplot included eight 8 m rows with 25 cm inter row spacing and 1 m inter plot spacing. Each main plot had 150 sublopts (50 cultivars x 3 replications/cultivar) covering a cultivated area of 4800 m^2/location. Tillage was made in early august 2010, and in early september, the rapeseed cultivars were sown using a plot seeder – Plotseed XL (Wintersteiger), after complete P and K fertilizer application with seedbed preparation. Weeds were controlled using pre- and post-emergent herbicides. The entire dose of N fertilizer was applied in early spring 2011, when rapeseed resumed growth, and pests were chemically controlled during the growing season.

Soil and yield measurements

Soil physical properties were determined as follows: bulk density (BD) was determined using undisturbed soil samples collected from nontrafficked areas with steel rings (100 cm^3) from different depths – 0-10 cm, 10-20 cm, 20-30 cm, and 30-40 cm – right after sowing, before wintering and right after crop harvesting, from every main plot (tillage system) in at least 3 replications. The samples were oven-dried at 105°C to constant weight and BD was calculated by dividing the weight of the dried soil to the volume of the steel ring. Penetration resistance (PR) of soil, also known as „cone index", was measured at the beginning of plant flowering (early mai 2011) using a digital penetrologger (Eijkelkamp Equipment, 2006). Measurements were made a few days after significant rainfall, when soil moisture was close to field capacity. At least ten penetration resistances were taken from each tillage treatment, up to 50 cm depth, measurements being made every centimeter. The penetrologger had a 30° cone and a base area of 1 cm^2, and the penetration speed was 2 cm/s. Hydric stability (HS) of aggregates resulted according to Kemper and Rosenau (1986), a standard method (Nimmo and Perkins, 2002). Disturbed soil samples were taken from different depths (0-10 cm, 10-20 cm, 20-30 cm) right after crop sowing, before wintering and right after harvesting, from every main plot (tillage system) in at least 3 replications. The samples were air-dried for several days, then sieved with AS-300 dry-sieving machine (Retsch) to extract the aggregates with 1-2 mm in diameter; 4 g from the resulted samples were processed with Wet-Sieving Apparatus (Eijkelkamp Agrisearch Equipment) for 3 mins. in distilled water to eliminate the soil without water stability (diameter < 0.25 mm). The soil with stability was then separated from the sand particles and plant debris by sieving the same sample in aqueous solution of NaOH 2‰ for 5-8 mins. Hydric stability was determined according to relation:

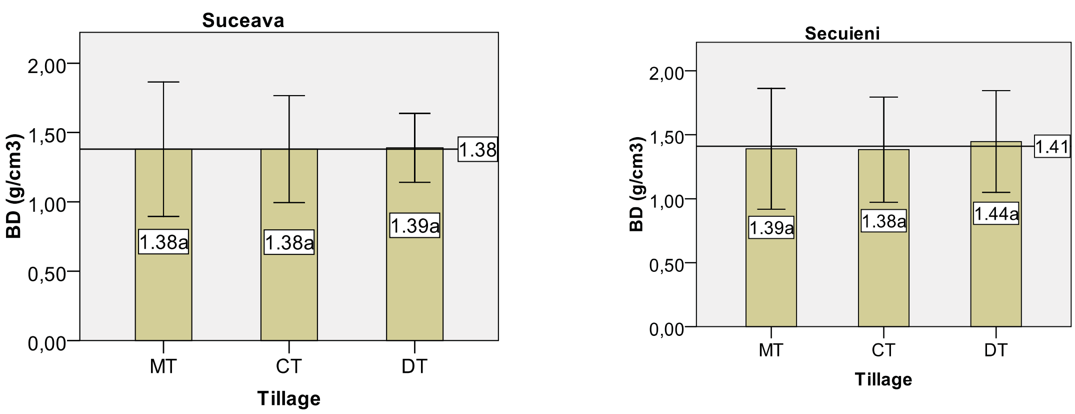
$$HS\ (\%) = B \times 100 / (A + B) \quad (1)$$

where A is the soil without stability from the sample (g), and B the soil with stability from the sample (g).
Seeds from every sub-plot were harvested using a plot combine – Classic (Wintersteiger) and weighed with Grain Gage (Juniper Systems), a weighing system mounted on the combine.
Statistical analysis of results was performed using the ANOVA procedure and multiple comparisons method (Duncan test) for α=0.05 in SPSS (v. 17.0, IBM SPSS Statistics).

Results

Effect of tillage on soil physical properties

In 2010/2011, averaged over the entire growing season, lowest values of BD in 0-40 cm soil horizon were in MT (1.38 g/cm^3, 1.39 g/cm^3, and 1.32 g/cm^3) and highest in DT (1.39 g/cm^3, 1.44 g/cm^3, and 1.39 g/cm^3) in all three locations, with insignificant differences (p=0.05) between tillage treatments as shown in Figure 1, probably due to soil recompaction tendency after tillage operations (Lampurlanes and Cantero-Martinez, 2003) and under the effect of rainfall.



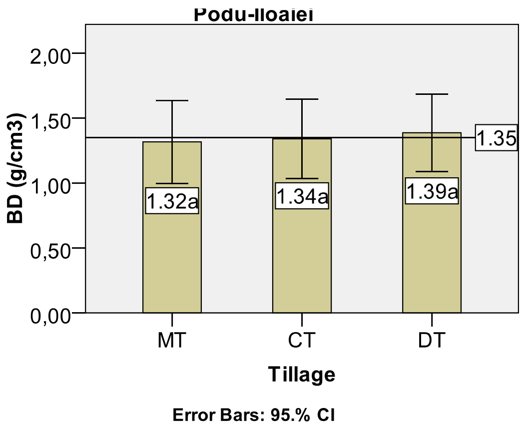


Figure 1. Effect of different tillage systems on soil bulk density

Meanwhile, PR determined at maximum plant growth (early mai 2011), showed more significant differences ($p=0.05$), as it is a more sensitive indicator of soil compaction in different tillage systems than BD (Canarache, 1990). PR was significantly higher in DT in two out of three locations: 1.27 MPa at Suceava and 1.52 MPa at Podu-Iloaiei, while at Secuieni, the highest value was in MT (1.48 MPa), probably because of the plow pan formed at 20-30 cm (Figure 2). PR varied also with depth, with the highest values in the subarable horizon: 20-30 (35) cm in MT, 15-30 (35) cm in CT, and (5) 10-35 cm in DT in all locations, influencing root penetration capacity under the arable horizon.

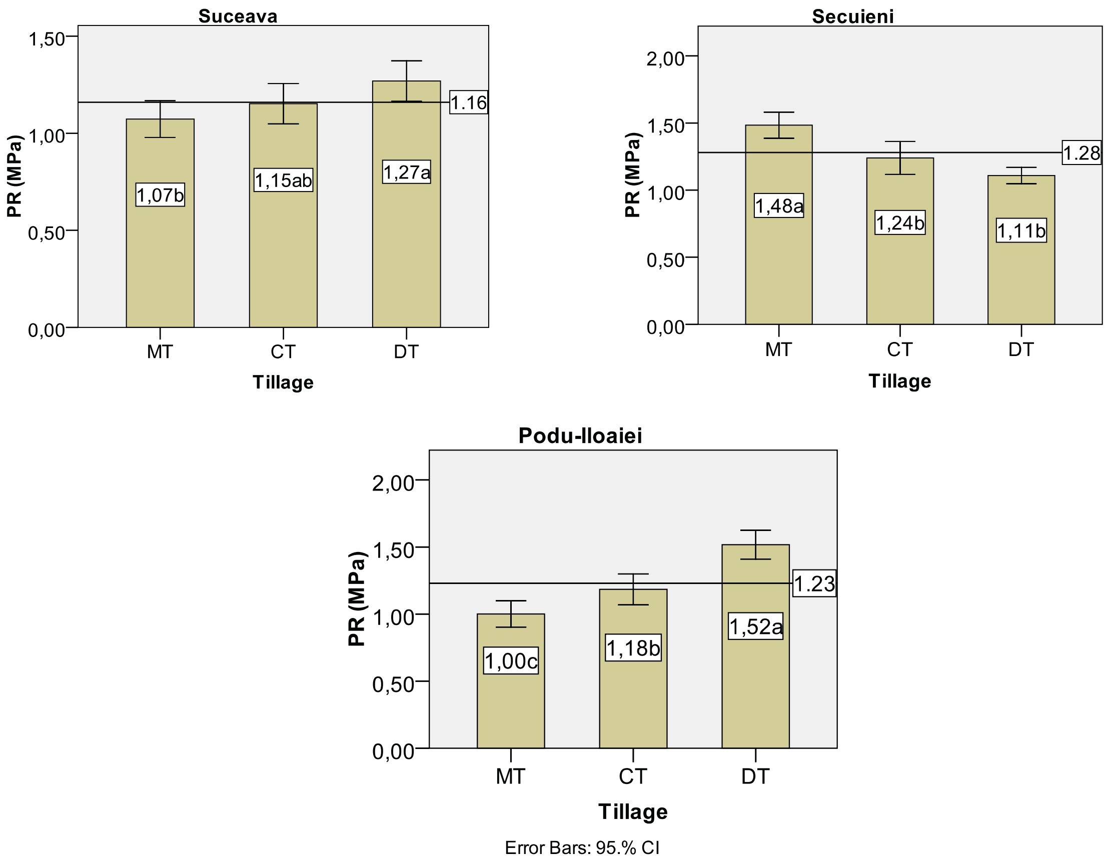


Figure 2. Effect of different tillage systems on soil penetration resistance

In 2010/2011, the 0-30 cm soil layer of CT had the highest proportion of water stable aggregates (Figure 3): 66.8% - Suceava, 68.8 % - Secuieni, and 70.1% - Podu-Iloaiei, proving that this tillage treatment had the least impact on soil structure, although differences from other systems were insignificant (4.2%-9.8% for p=0.05).

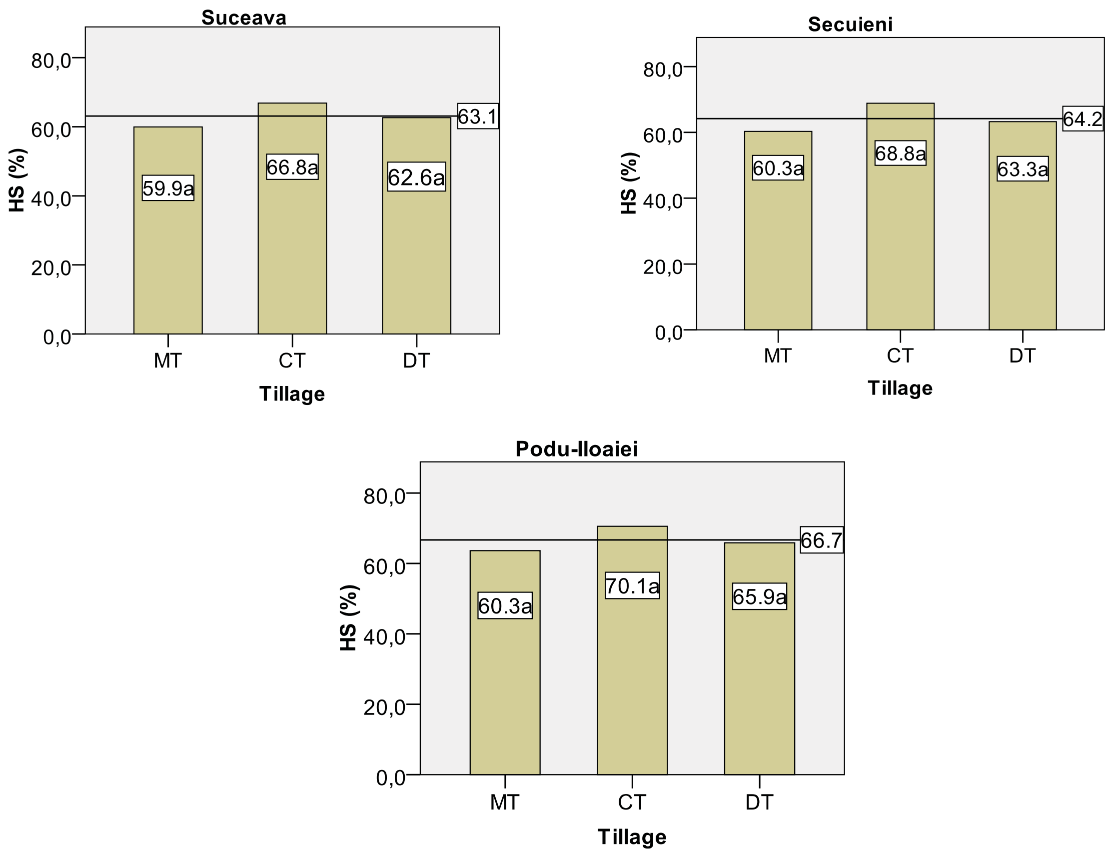
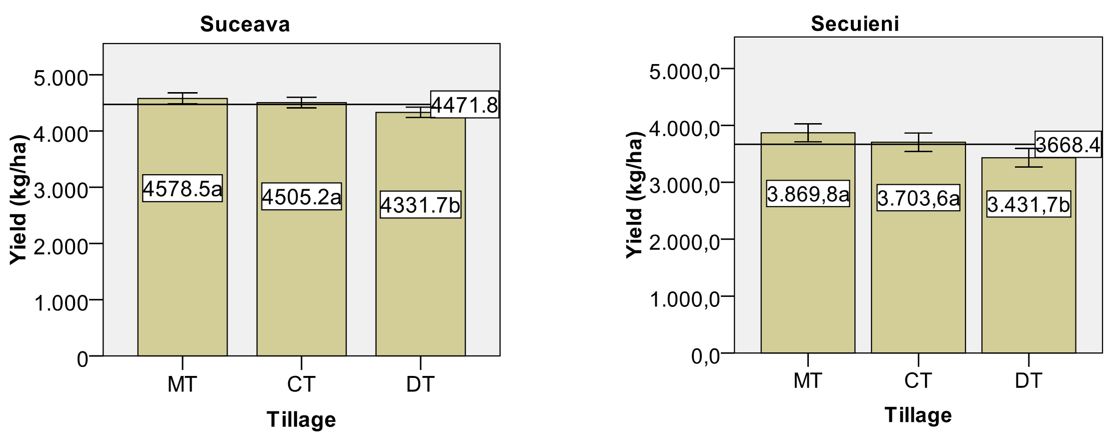


Figure 3. Effect of different tillage systems on aggregates hydric stability

<u>Effect of tillage on yield</u>

The mean winter oilseed rape yield, resulted from 150 individual values (50 cultivars x 3 repetitions/cultivar), varied with tillage, as shown in figure 4.



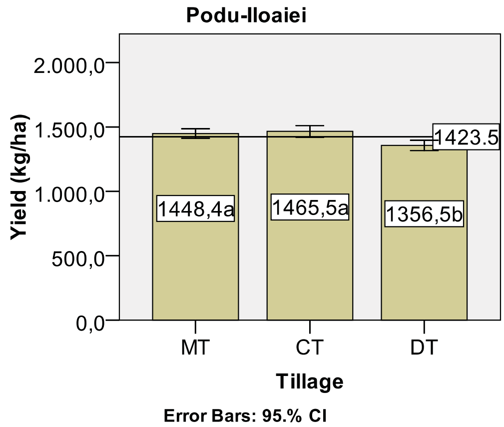


Figure 4. Effect of different tillage systems on winter oilseed rape yield

The highest yield was obtained in MT in two out of three locations (Suceava and Secuieni) and in CT at Podu-Iloaiei, although the differences between the two treatments were insignificant (p=0.05). DT gave significantly (p=0.05) lower yields in all locations (4331.7 kg/ha, 3.431,7 kg/ha, and 1356 kg/ha) compared to MT and CT, probably because of the poor crop establishment. The low yields (1423.5 kg/ha on average for the entire field) from Podu-Iloaiei showed once again the vulnerability of this crop to different climatic accidents – hail in this case – that occur from siliquae formation to crop harvest.

Conclusions

MT gave higher rapeseed yields in two out of three locations although not significantly different from CT, and had a more pronounced impact on soil physical state, while CT affected less soil compaction and structure indices. From all experimented tillage treatments, DT produced the most unfavorable conditions for crop establishment and growth, due to insufficient depth and to the aggressiveness of disks, which reflected in significantly reduced yields. Further research needs to be done to clearly establish the effect of experimented tillage systems on soil physical properties and rapeseed yield in north-eastern Romania.

Acknowledgements

This study was made possible by financial support from the research project „MOLECULAR GENETICS STUDIES ON WINTER OILSEED RAPE (*BRASSICA NAPUS* L.) ADAPTATION TO BIOTIC AND ABIOTIC STRESS CONDITIONS, AND OPTIMISING THE CROP TECHNOLOGY FOR EXTENDING THE CULTIVATION AREA" co-funded by the European Regional Development Fund (ERDF), project ID no. 714, 12687 SMIS-CSNR code. The project beneficiary is University of Agricultural Sciences and Veterinary Medicine „Ion Ionescu de la Brad" from Iasi.

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