EFFECT OF TILLAGE AND CULTIVAR ON OILSEED RAPE (*BRASSICA NAPUS* L.) YIELD IN THE NORTHERN AREA OF MOLDAVIAN PLATEAU

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Abstract

A 2-year study was carried out on a cambic phaeozem (RSTS-2003) at ARDS Suceava to asses the effect of 3 tillage treatments (moldboard plough – MT, chisel – CT, disc-harrow – DT) and 50 rapeseed cultivars (41 hybrids and 9 open-pollinated varieties from 10 seed companies) on yield for highlighting the most effective tillage treatments, and for selecting the most adapted and high yielding cultivars in the area. The effect of tillage was significant and the ranking of the treatments was MT>CT>DT in both years and in terms of the annual mean yield. The differences between treatments were significant ($p \leq 0.05$) in 11 out of 12 pairwise comparisons (Duncan test). The yield was almost 35% higher in the first year and the effect of cultivar within the same seed company varied on a yearly basis. In 2010/2011, there were more than one homogeneous yield subset ($p \leq 0.05$) in 8 out of 10 companies, showing a higher variability of data than in 2011/2012, when the variability of the data was diminished, and significant differences among cultivars existed only within 1 out of 10 companies. Further research is needed to estimate the combined effect of tillage and cultivar and its impact on yield and costs.

Keywords: tillage, cultivar, yield

The current world population exceeds 7,06 billion and is projected to reach 8 billion by 2025, and the major challenge became achieving food security worldwide by enhancing food and fodder crop production. On the other hand, oil reserves will end in little more than 42 years if consumed at current rates (http://www.worldometers.info/) so it is necessary to use alternative energy sources, including biofuels, especially biodiesel made from vegetable oil. Rapeseed crop is the third most important source of vegetable oil (Beckman, 2005) used both in human nutrition and animal feeding, and for biofuel production. EU enacted the Directive on the promotion of the use of energy from renewable sources (RES-D), that specifies a 50% reduction target of GHG emissions from biofuels of in comparison to fossil fuels for the transport sector by 2017 (Majer, 2011). Increased market demands for plant oils will result in the further rise of yield levels and a yet intensification of oilseed rape production (Tiedemann, 2011).

On the other hand, the human induced degradation of natural resources, including soils represents a major concern for sustainability (Horn, 2009) and is imposing the adoption of conservation cropping systems (i.e. minimum, conservative or no-tillage) to mitigate its effects.

Current expansion of oilseed rape production in Central and Eastern Europe with low rainfall and high seasonal temperature variation face up farmers with the emerging problem of selecting productive and resistant cultivars for adaptation to such climatic conditions, and the proper cropping system in terms of sustainability and productivity.

MATERIAL AND METHODS

The present experiment takes part from a research study that aims at optimising rapeseed cropping system for adaptation to biotic and abiotic stresses in 3 Agricultural Research and Development Stations from the central-northern area of Moldavian Plateau: Suceava, Secuieni and Podu-Iloaiei.

It was carried out between 2010-2012 at Agricultural Research and Development Station Suceava, in the northern part of Moldavian Plateau (47^o61.59’ N, 26^o24.47’ E), on a cambic phaeozem (RSTS-2003) with 31.6% clay (0-20 cm soil layer), 5.6-5.8 pH units and 3% humus content. Annual mean temperature in the area is 7.8 ^oC, and rainfall 586.8 mm (Saicu, 2010).

The trial was designed using a randomized complete block arrangement with three replications. Two experimental factors were considered: i) primary tillage with different

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implements as treatments (moldboard plough, chisel and disc-harrow), and ii) rapeseed cultivar – 41 hybrids and 9 open-pollinated varieties from the commercial offer of several seed companies.
Besides tillage and cultivar choice, the cropping system was the same for all plots (tab. 1). Sowing was performed using Plotseed XL (Wintersteiger) in 8 rows of 8 m in length and 25 cm inter-row spacing. In mid july all 450 plots were harvested using a small combine (Wintersteiger Classic) and yield per plot was assesed using an automated weighing sensor system (GrainGage HM800, Junyper Systems) mounted on the combine.

Table 1

Cropping system in the field trial

Link	**Materials**	**Timing**
Fertilising scheme	$N_{16}P_{36}S_{54}Ca_{44}Mg_{4}B_{0.3}Zn_{0.2}$	Seedbed preparation
	$N_{60}S_{30}Ca_{14}Mg_{6}$	Early spring
Sowing	60 seeds m^{-2} for hybrids	August 30th
	70 seeds m^{-2} for open-pollinated varieties	
Herbicide spraying	Metazaclor 0.8 l ha^{-1} for dicotyledonous weeds control	After sowing but before seedling emergence
	Fenoxaprop-p-etil 75 g ha^{-1} for monocotyledonous	2-6 leaves of the weeds
Insect control	Tiacloprid 48 g ha^{-1} for flea beetles (*Phyllotreta spp*.), cabbage stem flea beetle (*Psylliodes chrysocephala),* sawfly *(Athalia rosae)* larvae, red turnip beetle (*Entomoscelis adonidis),* cabbage stem weevil (*Ceutorhynchus napi*);	Over economic treshold
	Deltametrin 7,5 g ha^{-1}, cipermetrin 50 g l^{-1} + 500 g l^{-1} or clorpirifos(0,75 l ha^{-1}) for pollen beetle (*Meligethes aeneus*)	In early flowering (B4-B6 CETIOM, 59-61 BBCH)
Disease control	Tebuconazole 175 g ha^{-1} for Phoma	In autumn, 4-6 leaves of rapeseed plants (F1 CETIOM, 14-16 BBCH)
	Azoxistrobin 150 g ha^{-1}+ ciproconazole 60 g ha^{-1} for foliar disease complex	Full flowering (F CETIOM, 65 BBCH)
Harvesting	Small combine for plots	8-15% seed moisture and no green siliquae

Statistical analysis was performed using IBM SPSS Statistics v.17.0. One-way ANOVA procedure was applied to test the effect of tillage and cultivar on yield for every year and for the entire period, and post-hoc multiple comparisons between treatments were made using Duncan test ($p \leq 0.05$).

RESULTS AND DISCUSSION

Effect of tillage on rapeseed yield

In rapeseed, as in all crops, the productivity of the same cultivar depends, among other factors, on region, year conditions and cropping system. Accordingly, yield can be improved by cultivar selection for specific growing conditions and by adjusting management practices such as tillage.

Tillage affect the mechanical characteristics of the seedbed and thus crop emergence (Ozpinar and Cay, 2006) and its main objective is to produce an optimal soil state that should persist throughout crop vegetation with positive effect on yield.

All tillage systems can be used in rapeseed crop (Axinte, 2006) with satisfactory output. Minimum tillage may result in crop yields which are equal or exceed those obtained after ploughing and small reductions may be tolerated if production costs are lower than with ploughing (Soane et al., 2012).

In the last century, disadvantages of soil inversion have become more evident (Gruber et al., 2011) but, with few exceptions, less is known about the extent to which minimum and conservation tillage offers advantages and disadvantages under temperate climate from Central and Eastern Europe.

As Rusu (2006) previously reported, rapeseed yield can be influenced by tillage. In the present study, yield was affected by primary tillage in both years (tab. 2). As expected, a positive yield response was observed in the conventional cropping system where moldboard

Table 2

Effect of tillage on rapeseed yield (kg ha^{-1})* at ARDS Suceava

Tillage treatment	2010/2011**	2011/2012		Mean/treatment
Moldboard plough	4577.0^{a}	3390.6^{a}		3983.8^{a}
Chisel	4505.2^{a}	2919.7^{b}		3712.5^{b}
Disc harrow	4330.7^{b}	2432.4^{c}		3381.6^{c}
Mean/year	4470.9^{a}	2914.2^{b}		3692.6

* averaged over 50 cultivars, values followed by the same letter are not significantly different ($p \leq 0.05$); **different subsets per year, mean/treatment and mean/year analyzed separately

plough (MT) was used for primary tillage. Chisel tillage (CT) followed (mean annual difference 6.8%) and disc-harrow (DT) use gave the lowest yield values, 15.1% lower than moldboard plough.

In the first year of research, no significant difference ($p \leq 0.05$) was observed between MT and CT (71.8 kg ha^{-1}) but the differences between MT and DT (246.3 kg ha^{-1}), and CT and DT (174.5 kg ha^{-1}) were significant.

In 2011/2012, the effect of tillage treatment was more pronounced. Yield values belonged to different homogeneous subsets for $p \leq 0.05$. MT was 13.9% higher in comparison to CT and 28.3% in comparison to DT. CT was 16.7% higher than DT, all significant differences for $p \leq 0.05$.

Mean yield per treatment (2010-2012) decreased from almost 4 t ha^{-1} in MT to 3,7 t ha^{-1} in CT and to only 3.4 t ha^{-1} in DT. The effect of the year, considered random, was also obvious, with a difference of 1556.7 kg ha^{-1} between 2010/2011 and 2011/2012.

Effect of cultivar on rapeseed yield

One of the most important options to obtain as much yield potential as possible (Farooq et al., 2011) in different climatic conditions and cropping systems is the selection of productive cultivars resistant to biotic and abiotic stresses.

The plant breeders are investing more and more in hybrid rapeseed that is usually higher in grain and oil yield than open-pollinated varieties (Kraling et al., 2011) and have good vigour, but sometimes traditional open-pollinated varieties are better adapted to local conditions.

Analysis of variance and post-hoc multiple comparisons performed on yield data showed that the effect of cultivar (tab. 3) was strongly infuenced by year, varietal differences within the same company being significant in most cases only in the first year. Higher yields (by 1556.7 kg ha^{-1} in average for all cultivars) and a higher data variability (range higher by 2194.1 kg ha^{-1}) were observed in 2010/2011. For marketing reasons, only cultivars within the same seed company were compared. German DSV hybrids gave similar yields, within the same homogeneous subset ($p \leq 0.05$), with a mean per company of 4437.6 kg ha^{-1}. Two homogeneous subsets for the same p value were found for the second seed company: a superior one comprising two hybrids (Tripti CS - 4651.2 kg ha^{-1} and Scelni CS - 4554.9 kg ha^{-1}), and a significantly inferior one with Nodari CS (4206.2 kg ha^{-1}) and Intense CS (4044.9 kg ha^{-1}) as representatives. Among cultivars produced by Dieckmann, Hycolor and Judie (OP) were the most performant in 2010/2011. The ranking of open-pollinated varieties produced by the romanian breeder ITC was Diana>Perla>Doina, Diana being significantly more productive (3901.8 kg ha^{-1} vs. 3562.3 kg ha^{-1} - Perla and 3556.0 kg ha^{-1} - Doina). No significant difference (6.3 kg ha^{-1}) was found between Perla and Doina.

Among the five KWS hybrids, Brutus, Turan and Traviata gave more than 4.6 t ha^{-1}, while Tassilo and Triangle were significantly inferior, yielding less than 4.4 t ha^{-1}. Monsanto participated in this study only with 3 hybrids of wich Extend was significantly better (4930.2 kg ha^{-1}) than the others (Exagone and DK Example). The seven hybrids, most of them semidwarf, that Pioneer provided, showed a greater yield variability proven through five homogeneous subsets ($p \leq 0.05$), from „a" to „e" in the following decreasing order: a – PR46W30 (5004.8 kg ha^{-1}), PR44W29 (4930.7 kg ha^{-1}); ab – PR45D05 (4846.4 kg ha^{-1}), bc – PR46W21 (4718.9 kg ha^{-1}); c – PR45D03 (4633.7 kg ha^{-1}), d – PR46W14 (4333.5 kg ha^{-1}), and e – PR44D06 (4151.3 kg ha^{-1}). Saaten Union has made available 7 hybrids and 3 good yielding open-pollinated varieties for the trial: Orkan, Noblesse and Bellevue. The best cultivar was Rohan (4584.3 kg ha^{-1}), whose yield was significantly higher than that of Visby (4384.7 kg ha^{-1}), Astrada (4271.7 kg ha^{-1}), Bellevue (4199.4 kg ha^{-1}) or Hercules (4120.8 kg ha^{-1}). The Rustica hybrids (ES Hydromel, Olano, ES Betty and ES Alias) marketed by Sumiagro Romania proved homogeneity doubled by relatively high yielding capacity (around 4.5 t ha^{-1} mean yield per 4 hybrids).

In the second year, most of the cultivars showed no significant variability within the same company; the annual mean yield level was significantly lower by almost 35% (tab. 2), probably due to low rainfall in autumn when rapeseed plants were in the first growth stages, and to temperatures lower than -20 ^{o}C during the winter. As a response, cultivars behaved differently, another ranking being observed for the rapeseed cultivars of each company. For instance, the 10 cultivars of Saaten Union were divided in two homogeneous subsets instead of four: Vectra (3117.3 kg ha^{-1}) and Astrada (2961.7 kg ha^{-1}) being in the first subset, and the open-pollinated variety Orkan (2330.9 kg ha^{-1}) in the second, while the other 7 cultivars fell in both subsets.

No significant differences ($p \leq 0.05$) were highlighted in terms of mean yield per cultivar, proving that the effect of cultivar was not consistant for the entire trial period.

Table 3

Effect of cultivar on rapeseed yield (kg/ha^{-1})* at ARDS Suceava

Company**	Cultivar	2010/2011	Cultivar	2011/2012	Cultivar	Mean
Biocrop	Compass	4528.5	Primus	3100.0	Primus	3757.3
(DSV)	WRH 352	4459.6	Hammer	2843.2	Compass	3653.8
	Dynastie	4417.7	Compass	2779.0	Hammer	3605.5
	Primus	4414.5	Dynastie	2655.6	Dynastie	3536.6
	Hammer	4367.8	WRH 352	2558.0	WRH 352	3508.8
Caussade	Tripti CS	4651.2[a]	Intense CS	2777.8	Tripti CS	3622.5
Semences	Scelni CS	4554.9[a]	Scelni CS	2672.8	Scelni CS	3613.9
Romania	Nodari CS	4206.2[b]	Nodari CS	2633.3	Nodari CS	3419.8
	Intense CS	4044.9[b]	Tripti CS	2593.8	Intense CS	3411.3
SD – Seeds	Judie(OP)	4947.6[a]	Hycolor	3144.4	Judie(OP)	4020.1
(Dieckmann)	Hycolor	4819.0[a]	Goldie(OP)	3143.2	Hycolor	3981.7
	Goldie(OP)	4313.7[ab]	Recordie	3112.3	Recordie	3793.0
	Recordie	4473.6[b]	Judie(OP)	3092.6	Goldie(OP)	3728.5
	Ecarlate(OP)	4134.9[c]	Ecarlate(OP)	3056.8	Ecarlate(OP)	3595.8
Euralis	ES Danube	4807.7[a]	ES Centurio	3237.0	ES Danube	3956.3
Semences	ES Neptune	4793.0[a]	ES Danube	3104.9	ES Neptune	3845.3
	ES Mercure	4541.8[ab]	ES Mercure	2961.7	ES Centurio	3797.0
	ES Centurio	4357.0[b]	ES Neptune	2897.5	ES Mercure	3751.8
ITC	Diana(OP)	3901.8[a]	Perla (OP)	2619.8	Diana(OP)	3214.5
	Perla (OP)	3562.3[b]	Diana(OP)	2527.2	Perla (OP)	3091.0
	Doina(OP)	3556.0[b]	Doina(OP)	2459.3	Doina(OP)	3007.6
KWS	Turan	4796.3[a]	Turan	3080.2	Turan	3938.3
Seminte	Traviata	4729.9[a]	Brutus	3076.5	Brutus	3843.9
	Brutus	4611.2[a]	Tassilo	3030.9	Traviata	3802.6
	Triangle	4347.4[b]	Traviata	2875.3	Triangle	3517.5
	Tassilo	4278.3[b]	Triangle	2687.7	Tassilo	3654.6
Monsanto	Extend	4930.2[a]	Exagone	2982.7	Extend	3937.3
Romania	DK Example	4602.7[b]	Extend	2944.4	Exagone	3738.0
	Exagone	4493.4[b]	DK Example	2737.0	DK Example	3669.8
Pioneer	PR46W30	5004.8[a]	PR44D06	3572.8	PR46W30	4178.9
Hi-Bred	PR44W29	4930.7[a]	PR46W30	3353.1	PR44W29	4102.4
Romania	PR45D05	4846.4[ab]	PR45D05	3300.0	PR45D05	4073.2
	PR46W21	4718.9[bc]	PR44W29	3274.1	PR46W21	3978.0
	PR45D03	4633.7[c]	PR45D03	3255.6	PR45D03	3944.6
	PR46W14	4333.5[d]	PR46W21	3237.0	PR44D06	3862.1
	PR44D06	4151.3[e]	PR46W14	2904.9	PR46W14	3619.2
Saaten	Rohan	4584.3[a]	Vectra	3117.3[a]	Vectra	3824.8
Union	Finesse	4551.9[ab]	Astrada	2961.7[a]	Rohan	3692.2
Romania	Orkan (OP)	4536.1[ab]	Finesse	2823.5[ab]	Finesse	3687.7
	Vectra	4532.4[ab]	Visby	2823.5[ab]	Merano	3660.7
	Merano	4515.3[ab]	Bellevue (OP)	2813.6[ab]	Astrada	3616.7
	Noblesse (OP)	4492.1[ab]	Merano	2806.2[ab]	Visby	3604.1
	Visby	4384.7[bc]	Rohan	2800.0[ab]	Noblesse (OP)	3561.5
	Astrada	4271.7[cd]	Hercules	2777.8[ab]	Bellevue (OP)	3506.5
	Bellevue (OP)	4199.4[d]	Noblesse (OP)	2630.9[ab]	Hercules	3449.3
	Hercules	4120.8[d]	Orkan (OP)	2330.9[b]	Orkan (OP)	3433.5
Sumiagro	ES Hydromel	4666.5	ES Betty	3135.8	ES Betty	3788.6
Romania	Olano	4568.2	Olano	2943.2	Olano	3755.7
(Rustica)	ES Betty	4441.4	ES Alias	2742.0	ES Hydromel	3695.0
	ES Alias	4420.1	ES Hydromel	2723.5	ES Alias	3581.1

*averaged over 3 tillage treatments, values followed by the same letter are not significantly different ($p \le 0.05$);
**different subsets per company and year, mean analyzed separately; OP = open-pollinated variety

CONCLUSIONS

The effect of tillage on rapeseed yield was significant in both years, and the best treatment in terms of productivity was MT. The differences ($p \leq 0.05$) between MT and CT were significant in 1 of 2 years and for the entire period. MT and CT were significantly superior to DT in both years.

The effect of cultivar on rapeseed yield was significant only in the first year of research, when the differences within the same company were statistically ensured ($p \leq 0.05$) in 8 out of 10 cases. In the second year, from the multiple comparisons test, different subsets resulted only in 1 of 10 cases. No different subsets were found for the entire research period.

Further study is necessary to estimate the cost efficiency of every tillage treatment and rapeseed cultivar option and the combined effect of these two factors (tillage *x* cultivar) on yield and costs.

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