EFFECT OF DIFFERENCES IN UNREGULATED FACTORS ON YIELD OF WINTER OIL SEED RAPE AND WINTER WHEAT

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ABSTRACT. *The objective of this study: to determine the basis for the view that developing of cartograms for differentiation of growing technologies for winter oil seed rape and winter wheat needs also analyses from subsoil layer. Field characterized with wavy land form morainic hill. Growing of winter oil seed rape in season 2008/2009 followed by winter wheat in 2009/2010. 48 observation points were set to determine following parameters in both soil arable and subsoil layers: organic matter content, soil texture classes, yield of winter oil seed rape and of winter wheat. Obtained data of organic matter content and soil texture classes were used to calculate index of soil density. Crop roots mass and the length of the main root were determined in autumn after crop germination and in spring after renewal of vegetation. Found that root length and total root mass in a spring of winter oil seed rape and winter wheat is the most significant parameter what determines formation of yield. Positive effect of soil density index in both soil arable layer and in subsoil layer on winter wheat yield was explicit with a very high probability. Soil density index in subsoil layer has significant positive effect on the mass of oil seed rape roots in a spring. Significant negative effect of soil moisture in subsoil layer in hill lower slope point was established for oil seed rape and winter wheat yield.*

Keywords: *winter oilseed rape, winter wheat, precision agriculture.*

Introduction

Number of farms what implements precision farming technologies with GPS and GIS applications gradually increases in Latvia. Typically results from soil arable layer is used for differentiation of technologies and for explanation of differences in yield, as well as characteristics of photosynthetic mass is used for description of development of processes in field. Already in previous researches carried out at the Research and Study farm 'Vecauce' of Latvia University of Agriculture was determined high importance of soil agrochemical properties for differentiation of technologies (Vilde, Lapins *et al*., 2007, Dinaburga, Lapins, Kopmanis 2010). Researches on differentiation of field management technologies were carried out also in EU and USA (Moore 1997, Bourennane, Nicoullaud, *et al*., 2003). However researches with cereals and winter oil seed rape shows that crops in favourable growing conditions have very deep root system thus hypothesis can be drawn that soil subsoil layer has important role to growth and development of crops as well.

The objectives of this study: to determine the basis for the view that developing of cartograms for differentiation of growing technologies for winter wheat and winter oil seed rape needs also analyses from subsoil layer; to determine significance of root system development for precision field management technologies.

Materials and methods

Field trials were carried out at the Research and Study farm 'Vecauce' of Latvia University of Agriculture during the years 2008 to 2010 in a drained field 'Lielermani'. Field characterized with wavy mesorelief with relative height above the sea level between 88.5 and 98.6 m. Growing of winter oil seed rape cv. 'Catalina' in season 2008/2009 followed by winter wheat cv. 'Tarso' in 2009/2010. 48 observation points in a grid of 25x25 m were determined. The coordinates of observation points were defined by GPS receiver Garmin IQ 3600 using AGROCOM software AgroMAP Professional. Altitude of stationary observation points was determined by using Trimble GeoXT. On top and as well as on slopes of morainic hills in trial area eroded sod-calcareous and eroded sod-podzolic soils can be found, but sod-gley soils were found on the foot of the hills. All observation points can be divided into four groups according to their location:

- points at the toe of the slope (hereafter TS) with expressed water confluence;
- points at the slope (SL) with water runoff to the toe of the slope;
- points at the head of the hill (HH);
- points at the foot of the slope (FS) with water flow to open drainage system.

Soil analysis was done in a certified laboratory 'Valsts SIA Agroķīmisko pētījumu centrs' using nationally approved standard methods. All data are determined in two soil layers – in soil arable layer at the depth of 0−0.2m and in subsoil layer at the depth of 0.2−0.4 m. Organic matter content in trial field in soil arable layer was on average 28 g kg^{-1}, soil reaction pH$_{KCl}$ on average 6.5, available for plants content of potassium on average 418 mg kg^{-1}, available for plants content of phosphorus on average 306 mg kg^{-1}. Soil granulometric composition was determined by using field method and described as content of physical clay (Guidelines for soil ..., 2007, 2008). Obtained data of organic matter content and granulometric composition were used to calculate index of soil density. Calculations are based on coherences between soil bulk density, organic matter content and soil texture classes (Guidelines for soil ....., 2007).

Yield of winter oil seed rape was harvested with harvester Claas Lexion 420 to create yield map using AGROCOM software, but yield of winter wheat was determined by taking 3 plant samples in each observation point from 0.1 m^2 area. Determination of winter wheat yield formatting elements was done in the same time.

Crop roots mass and the length of the main root were determined in autumn after crop germination and in spring after renewal of vegetation. 3 oil seed rape plants and 10 winter wheat plants were taken in autumn at growth stage BBCH 11−13 and in spring at BBCH 21−22 for oil seed rape and at BBCH 25−29 for wheat. At the same time soil moisture was determined in three soil layers (0.00−0.05 m, 0.20−0.25 m, and 0.40−0.45 m) and soil penetrometric resistance in five soil layers (0.00−0.10 m, 0.10−0.20 m, 0.20−0.30 m, 0.30−0.40 m and 0.40−0.50 m).

Meteorological conditions in trial years were characterized with increase amount of precipitation in both summers of 2009 and 2010 but temperatures especially in July 2010 was highly above the long term observed (Table 1).

Table 1. The average day and night temperature and precipitation during growing season in 2009−2010 and in comparison with long term average

Month	Long-term average temperature	Temperature, ^{0}C		Long-term average precipitation	Precipitation, mm	
		2009	2010		2009	2010
May	11.2	11.0	11.9	43	18.0	72.6
June	15.1	13.7	14.6	51	95.0	37.8
July	16.6	17.1	20.8	75	136.0	131.8
August	16.0	15.8	18.2	75	38.8	133.4
September	11.5	12.9	10.8	59	39.8	78

Data analysis was performed using mathematical descriptive statistics and correlation analysis.

Results

Differences in relative height in wavy mesorelief conditions effected content of organic matter and thickness of humus horizon. Significantly increased content of organic matter was detected at the foot of slopes (Figure 1). Significant differences in content of organic matter between topsoil and subsoil layers were detected only at the top of the hills.

Thickness of humus horizon on the top of the hills (0.29 m) was significantly ($P < 0.05$) lower if compare with foot of the slopes (0.48 m). While head of the hill characterized with significantly increased content of physical clay. Differences in content of physical clay between topsoil layer and subsoil layer were not detected in any part of morainic hill area.

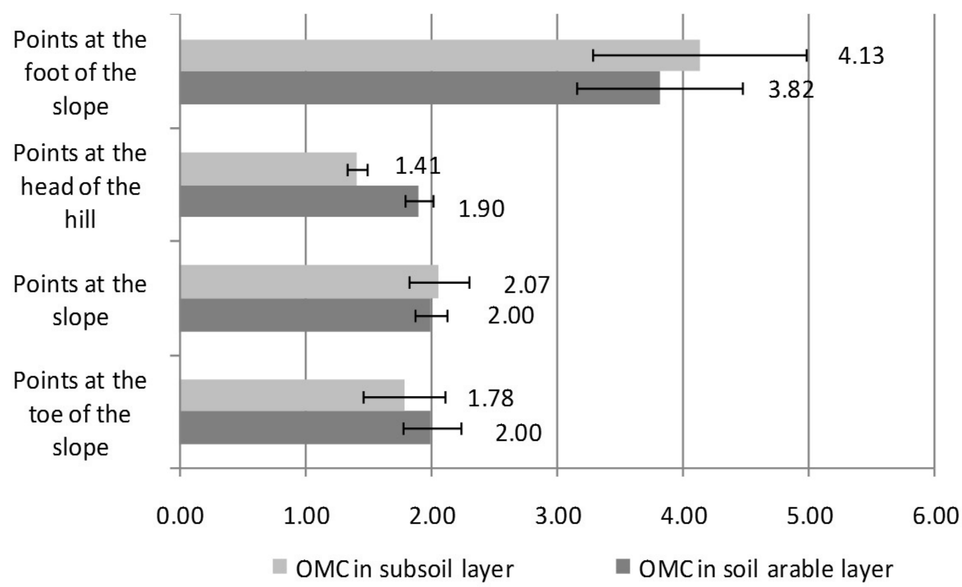

Figure 1. Organic matter content (OMC) in different groups of observations points, g kg^{-1}

Found that root mass of winter oil seed rape in spring is the most significant parameter ($r_{yx} = 0.4521, P < 0.001$) what determine formation of oil seed rape yield (Table 2). Also the length of main root and root mass in autumn showed significant positive effect to the winter oil seed rape yield. Positive effect to oil seed rape yield showed also biomass of oil seed rape plants in both autumn and spring time. Significant negative effect to winter oil seed rape yield showed increase soil moisture content in spring in subsoil layer at the depth of 0.20− 0.25 m and 0.40−0.45 m. None of such unregulated factors as content of organic matter in soil arable layer and subsoil layer, thickness of humus horizon and granulometric composition showed significant effect to winter oil seed rape yield.

Table 2. Factors effected yield of winter oil seed rape, t ha $^{-1}$

Factors, *x*	r_{yx}
Root mass in spring, 12.05.2009 ***	0.4521
Oil seed rape biomass in spring, 12.05.2009 **	0.3932
Oil seed rape biomass in autumn, 07.10.2008 **	0.3602
Root mass in autumn, 07.10.2008 *	0.3130
The length of main root in autumn, 07.10.2008 *	0.2864
Soil moisture at 0.40−0.45 m, 27.05.2009 *	−0.3138
Soil moisture at 0.20−0.25 m, 27.05.2009 *	−0.3083

Significance: * $P < 0.05$; ** $P < 0.01$; ***$P < 0.001$.

Results showed that root mass of oil seed rape plants in spring time has positive correlation with oil seed rape biomass in spring, root mass in autumn and soil penetrometric resistance in autumn at the soil layer of 0.00−0.10 m (Table 3). Positive correlation found also between index of soil density in topsoil layer and subsoil layer as well and root mass of oil seed rape in spring. That can be explained with soil ploughing what was used for before drilling. Significant negative effect to development of root system of oil seed rape plants showed increased soil moisture in spring at the depth of 0.20 to 0.45 m.

Table 3. Factors effecting root mass of winter oil seed rape in spring

Factors, *x*	r_{yx}
Oil seed rape biomass in spring, 12.05.2009 ***	0.8975
Root mass in autumn, 07.10.2008 **	0.4038
Soil pemetrometric resistance in autumn before drilling at depth 0.00−0.10 m, 10.08.2008. **	0.3560
Soil density index in subsoil layer *	0.3263
Oil seed rape biomass in autumn, 07.10.2008 *	0.3247
Soil penetrometric resistance in autumn before drilling at depth 0.30−0.40 m, 10.08.2008. *	0.2690
Soil density index in topsoil layer *	0.2669
Soil penetrometric resistance in autumn before drilling at depth 0.20−0.30 m, 10.08.2008. *	0.2611
Soil penetrometric resistance in autumn before drilling at depth 0.10−0.20 m, 10.08.2008. *	0.2604
Soil moisture in autumn before drilling at depth 0.20−0.25 m, 10.08.2008 *	−0.2655
Soil moisture in spring at depth 0.20−0.25 m, 27.05.2009 *	−0.2689
Organic matter content in subsoil layer *	−0.2946
Soil moisture in spring at depth 0.40−0.45 m, 27.05.2009 *	−0.2953
Soil moisture in autumn at depth 0.40−0.45 m, 07.10.2008 *	−0.2972

Significance: * $P < 0.05$; ** $P < 0.01$; $P < 0.001$.

Significance of growth and development effecting factors differed for winter wheat when growing it after winter oil seed rape. Factors with increased positive significance ($P < 0.001$) to winter wheat grain yield were soil density index in topsoil and subsoil layers and relative height above the sea level (Table 4). Significant positive effect on the winter wheat grain yield showed also the length of the main root in the autumn, total root mass and biomass of winter wheat in a spring. Significant negative ($P < 0.01$) relationship found between winter wheat grain yield and increased soil moisture and soil penetrometric resistance in subsoil layer.

Table 4. Factors effected yield of winter wheat grain yield, t ha $^{-1}$

Factors , *x*	r_{yx}
Soil density index in topsoil layer ***	0.7598
Soil density index in subsoil layer ***	0.7431
Relative height above the sea level ***	0.6121
Soil penetrometric resistance in spring at depth 0.00−0.10 m, 11.05.2010. ***	0.4798
Root mass in spring, 11.05.2010. **	0.3740
Biomass of one wheat plant in spring, 11.05.2010. **	0.3449
The length of main root in spring, 11.05.2010. **	0.3389
Root mass in autumn, 26.11.2009. *	0.3094
Soil penetrometric resistance in spring at depth 0.10−0.20 m, 11.05.2010. *	0.3043
Soil penetrometric resistance in autumn at depth 0.10−0.20 m, 19.08.2009 *	0.2710
Biomass of one wheat plant in autumn, 26.11.2009 *	0.2708
Soil penetrometric resistance in autumn at depth 0.00−0.10 m, 19.08.2009 *	0.2434
Soil moisture in spring at depth 0.00−0.05 m, 11.05.2010 *	−0.2579
Soil moisture in spring at depth 0.40−0.45 m, 11.05.2010 *	−0.2613
Soil penetrometric resistance in autumn at depth 0.40−0.50 m, 19.08.2009 *	−0.2890
Soil moisture in spring at depth 0.20−0.25 m, 11.05.2010 **	−0.4169
Soil penetrometric resistance in sprig at depth 0.30−0.40 m, 11.05.2010. **	−0.4833
Soi penetrometric resistance in spring at depth 0.40−0.50 m, 11.05.2010. ***	−0.6109
Organic mater content in topsoil layer ***	−0.6498
Organic matter content in subsoil layer ***	−0.6603

Significance: * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$.

High ($P < 0.001$) and significant negative linear correlation between increased content of organic matter and winter wheat grain yield can be explained by multicorrelative coherence. Increased content of organic matter was observed in lower parts of morainic hill slopes what characterized with increased soil moisture. Negative significant relationship decreases when using partial correlation analyses between organic matter content in topsoil and subsoil layers and winter wheat grain yield if adding soil moisture and soil penetrometric resistance as controlling variables (Table 5).

Positive effect to root mass of winter wheat in spring showed soil density index in both soil arable layer and in subsoil layer what shows importance of this factor to ensure development of high crop yields (Table 6).

Table 5. Analyses of coherence between winter wheat grain yield, t ha^{-1}, and organic matter content

Factor , *x*	r_{yx}, without controlling variables	r_{yx}, if using soil moisture data in spring at depth 0.20−0.25 and 0.40−0.45 m as controlling variables	r_{yx}, if adding soil penetrometric resistance data in spring at depth 0.3−0.4 and 0.4−0.5 m as controlling variables
Organic matter content in topsoil layer	−0.6498 ***	−0.6039 **	−0.5100 **
Organic matter content in subsoil layer	−0.6603 ***	−0.6078 **	−0.5459 **

Significance: ** *P < 0.01; *** P < 0.001.*

Table 6. Factors effecting root mass of winter wheat in spring

Factors, *x*	r_{yx}
Biomass of one wheat plant in spring, 11.05.2010. ***	0.8975
Soil density index in subsoil layer *	0.3263
Biomass of one wheat plant in autumn, 26.11.2009. *	0.3247
Soil density index in topsoil layer *	0.2669
Soil penetrometric resistance in spring at depth 0.2−0.3 m, 11.05.2010. *	0.2611
Organic matter content in subsoil layer *	−0.2946
Soil moisture in spring at depth 0.20−0.25 m , 11.05.2010 *	−0.2957

Significance: * *P < 0.05;* ** *P < 0.01; P < 0.001.*

Evaluating effect of wavy mesorelief on yield of winter oil seed rape and winter wheat it have to be taken into consideration that trial area has good drainage system and field is well cultivated. Crop did not suffered from accumulation of precipitation on soil surface and crop drowning in springs and autumns. In such conditions winter oil seed rape cv. ‘Catalina’ showed more stable yield level compare to winter wheat cv.’Tarso’ (Figure 2). Yield decrease of winter wheat was significant in field areas with lowest relative height above the sea level and with runoff to open drainage system.

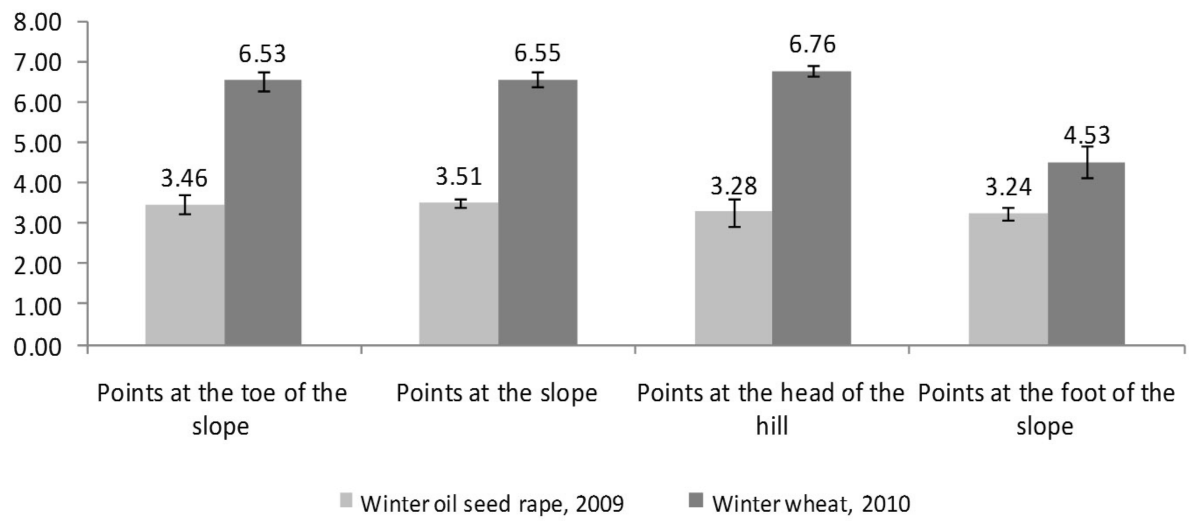

Figure 2. Effect of relief to yield of winter oil seed rape and winter wheat, t ha^{-1}

Discussion

Trial results shows that the view that agrochemical and agrophysical analyses from subsoil layer is important as well for developing of cartograms for differentiation of growing technologies for winter wheat and winter oil seed rape. It is partly proved also in authors previous researches (Vilde, Lapins *et al*., 2007, Dinaburga, Lapins, Kopmanis 2010). Researches on differentiation of field management technologies taking into account specific relief forms and characteristics of subsoil layer were carried out also in EU and USA (Moore 1997, Bourennane, Nicoullaud, *et al*., 2003; Si, Farrell 2004; Shepdt, Nikitina 2009; Kadžiene 2009; Ferrara, Trevisiol *et al*., 2009). Soil density index can be easily and successfully used for evaluation of potential possibilities for growing winter oil seed rape and winter wheat (Guidelines for soil ..., 2007, 2008). Organic matter content is determined during inspection for soil agrochemical properties, but soil texture class to determine clay content can be managed by farm’s agronomist himself. Significance of crop root system for yield formation shows further possibilities to investigate and use this factor for precision farming, although some researches has been made in this direction as well (Wallace, Mielke *et al*., 1982; Barracloung 1989; Barzegar, Mossavi *et al*., 2004). However root system is determined by genotype and it have to be specified for each individual cultivar.

Conclusions

Differences in relative height in wavy mesorelief conditions effected content of organic matter and thickness of humus horizon although differences in content of organic matter between topsoil and subsoil layers were detected only at the top of the hills.

Thickness of humus horizon on the top of the hills was significantly lower if compare with foot of the slopes while head of the hill characterized with significantly increased content of physical clay.

Root mass of winter oil seed rape in spring is the most significant parameter what determine formation of oil seed rape yield. Also the length of main root and root mass in autumn showed significant positive effect to the winter oil seed rape yield, but significant negative effect to winter oil seed rape yield showed increase soil moisture content in spring in subsoil layer at the depth of 0.20–0.25 m and 0.40–0.45 m.

Root mass of oil seed rape plants in spring time had positive correlation with oil seed rape biomass in spring, root mass in autumn and soil penetrometric resistance in autumn at the soil layer of 0.00–0.10 m.

Factors with positive significance to winter wheat grain yield were soil density index in topsoil and subsoil layers, relative height above the sea level, the length of the main root in the autumn, total root mass and biomass of winter wheat in a spring. Significant negative relationship found between winter wheat grain yield and increased soil moisture and soil penetrometric resistance in subsoil layer.

Positive effect to root mass of winter wheat in spring showed soil density index in both soil arable layer and in subsoil layer.

In wavy mesorelief area with good drainage system and in well cultivated fields winter oil seed rape cv. 'Catalina' showed more stable yield level compare to winter wheat cv.'Tarso'.

Yield decrease of winter wheat was significant in field areas with lowest relative height above the sea level and with runoff to open drainage system.

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