EFFECT OF DIFFERENCES IN REGULATED AND UNREGULATED FACTORS IN SOIL ARABLE AND SUBSOIL LAYERS ON YIELD OF WINTER WHEAT AND WINTER OIL SEED RAPE

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Abstract. The objective of the study is to improve the basis for differentiation cartograms of growing technologies for winter wheat and winter oil seed rape. Growing of winter oil seed rape in season 2008/2009 followed by winter wheat in 2009/2010 in 48 observation points in soil arable layer and in subsoil layer were determined: organic matter content, soil texture class, content of phosphorus and potassium, soil reaction. The crop roots mass and the length of the main root were determined in autumn after crop germination and in spring after renewal of vegetation. It was found that the root mass of winter oil seed rape and winter wheat in spring is the most significant parameter what determines formation of the oil seed rape yield. The mass of oil seed rape and winter wheat roots in spring had a significant positive effect on the soil density index in the subsoil layer. A significant positive effect on the winter wheat grain yield was shown also by the length of the main root in the autumn and the total root mass in spring. Increased content of potassium in both soil arable layers and in the subsoil layer has a significant positive effect on the winter wheat grain yield.

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

Introduction

The number of farms that implement precision farming technologies with GPS and GIS applications gradually increases in Latvia. Typically results from the soil arable layer are used for differentiation of technologies and for explanation of differences in yield, as well as characteristics of photosynthetic mass are used for description of the development of processes in the field. Already in the previous research carried out on the Research and training farm “Vecauce” of the Latvia University of Agriculture high importance of soil agrochemical properties for differentiation of technologies was determined [1; 2; 3]. Researches on differentiation of field management technologies were carried out also in the EU and the USA [4; 5]. However, researches with cereals and winter oil seed rape show that crops in favourable growing conditions have a very deep root system thus a hypothesis can be drawn that the soil subsoil layer has an 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 need also analyses from the subsoil layer; to determine the significance of root system development for precision field management technologies.

Materials and methods

Field trials were carried out on the Research and training farm “Vecauce” of the Latvia University of Agriculture during the years 2008 to 2010. 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 the observation points were defined by GPS receiver Garmin IQ 3600 using AGROCOM software AgroMAP Professional. The altitude of the stationary observation points was determined by using Trimble GeoXT. The field characterized by wavy mesorelief and relatively height above the sea level was between 88.5 and 98.6 m. On the top and as well on the slopes of the moraine hills in the 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. In all observation points the following data were determined: organic matter content, soil texture class, content of phosphorus and potassium, soil reaction pH_{KCl}. All data are determined in two soil layers – in the soil arable layer at the depth of 0-0.2m and in the subsoil layer at the depth of 0.2-0.4 m. The soil analysis was done in the certified laboratory “Valsts SIA Agroķīmisko pētījumu centrs” using nationally approved standard methods. The organic matter content in the trial field in the soil arable layer was between 15 and 87 g kg^{-1} but in the subsoil layer 11 to 98 $g \cdot kg^{-1}$, soil reaction pH_{KCl} in the soil arable layer from 5.1 to 7.6 but in the subsoil layer 5.2 to 7.4, available for plants the content of potassium in the soil arable layer

73 to 344 $mg \cdot kg^{-1}$ but in the subsoil layer 85 to 228 $mg \cdot kg^{-1}$, available for plants the content of phosphorus in the soil arable layer 76 to 282 $mg \cdot kg^{-1}$ but in the subsoil layer 99 to 310 $mg \cdot kg^{-1}$. The soil texture class was determined by using the field method and described as the content of physical clay [6; 7]. The obtained data of the organic matter content and granulometric composition were used to calculate the index of soil density. The calculations are based on coherences between the soil bulk density, organic matter content and soil texture classes [6].

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

The crop root 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.

Table 1

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, ºC		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	78.0

The meteorological conditions in the trial years were characterized by the increased amount of precipitation in both summers of 2009 and 2010 but the temperatures, especially in July 2010, were highly above the long term observed (Table 1).

The data analysis was performed using mathematical descriptive statistics and correlation analysis.

Results and discussion

Analysis of factors affecting the yield of winter oil seed rape

It was found that the root mass of winter oil seed rape in spring is the most significant parameter ($r_{yx} = 0.4521$, $p < 0.001$) that determines formation of the oil seed rape yield. Also the length of the main root and root mass in autumn showed a significant positive effect ($r_{yx} = 0.2863$ and $r_{yx} = 0.3130$ respectively, $p < 0.05$) correlated with the winter oil seed rape yield. In its turn, the mass of the oil seed rape roots in spring had a significant positive ($r_{yx} = 0.3263$, $p < 0.05$) effect on the soil density index in the subsoil layer at the depth of 0.2-0.4 m. The biomass of oil seed rape plants, which had high positive and significant ($p < 0.001$) correlation with the yield, showed also positive correlation with the soil density index in the subsoil layer ($r_{yx} = 0.2837$, $p < 0.05$) as well as in the soil arable layer ($r_{yx} = 0.2248$, $p < 0.05$).

It was found that increased content of K_2O in the arable as well as in the subsoil layer has a positive, but insignificant ($p > 0.05$) effect to the winter oil seed rape yield, but soil reaction pH_{KCl} showed a significant ($p < 0.01$) negative effect (Table 2). This can be explained by the significant potassium content and soil pH_{KCl} antagonism in both soil layers.

The winter oil seed rape yield was significantly ($p < 0.05$) lower if compared with the average values when the soil density index in both soil and subsoil layers was below 1.3. Significantly ($p < 0.05$) higher oil seed rape yields (3.68 - 3.95 $t \cdot ha^{-1}$) were harvested in the field areas, where the soil density index in both the arable and subsoil layer was between 1.3 and 1.49. Results allow concluding that soil density index can be used as a parameter for differentiation of field management systems.

Table 2

Yield of winter oil seed rape, t·ha $^{-1}$, in dependence on soil pH_{KCl} and content of K_2O, mg·kg^{-1}, in soil arable and subsoil layers

Soil layers	Soil reaction pH_{KCl}	Content of K_2O, mg·kg^{-1}	Oil seed rape yield, t·ha^{-1}	Sx
Arable layer	from 5.1 to 6.4	from 73 to 156	3.75	0.11
		from 157 to 344	3.58	0.11
	from 6.6 to 7.6.	from 73 to 156	2.99	0.20
		from 157 to 344	3.38	0.20
Subsoil layer	from 5.2 to 6.5	from 85 to 165	3.69	0.11
		from 166 to 228	3.66	0.12
	from 6.6 to 7.4	from 85 to 165	3.04	0.22
		from 166 to 228	3.15	0.21

The winter oil seed rape yield was significantly ($p < 0.05$) lower if compared with the average values when the soil density index in both soil and subsoil layers was below 1.3. Significantly ($p < 0.05$) higher oil seed rape yields (3.68 - 3.95 t·ha^{-1}) were harvested in the field areas, where the soil density index in both the arable and subsoil layer was between 1.3 and 1.49. The results allow concluding that the soil density index can be used as a parameter for differentiation of field management systems.

Table 3

Effect of soil density index in soil arable and subsoil layers to winter wheat yield, t·ha^{-1}

Soil density index in arable layer	Soil density index in subsoil layer	Yield, t·ha^{-1}		
		On average in group	On average in all area + S x	On average in all area – S x
< 1.3	< 1.3	4.11	6.27	5.90
from 1.31 to 1.49	< 1.3	6.35	6.27	5.90
	from 1.31 to 1.49	5.81	6.27	5.90
	> 1.50	6.64	6.27	5.90
> 1.50	from 1.31 to 1.49	7.53	6.27	5.90
	> 1.50	6.66	6.27	5.90

Analysis of factors effecting yield of winter wheat

The data analysis showed significant ($p < 0.001$) positive correlation between the winter wheat grain yield and thousand grain mass, and as well the number of productive stems. A significant ($p < 0.05$) positive effect on the winter wheat grain yield was shown also by the length of the main root in the autumn and the total root mass in spring. A positive effect of the soil density index in both the soil arable layer and in the subsoil layer on the winter wheat yield was explicit with a very high probability ($p < 0.001$). The soil density indexes showed that this parameter can be successfully used for soil tillage differentiation (Table 3).

Table 4

Effect of potassium content to winter wheat grain yield, t·ha^{-1}

Content of potassium, mg·kg^{-1}		Yield	
in arable layer	in subsoil layer	t·ha^{-1}	S x
from 73 to 156	from 85 to 165	5.40	0.34
	from 166 to 228	6.60	0.30
from 157 to 344	from 85 to 165	5.86	0.35
	from 166 to 228	6.58	0.27

Increased content of potassium in both the soil arable and subsoil layer has a significant ($p<0.05$) positive effect to the winter wheat grain yield. Increased content of potassium only in the soil arable layer will not ensure yield increase (Table 4).

Conclusions

Analysing the factors affecting the yield of winter oil seed rape it was found:

1. The root mass of winter oil seed rape in spring is the most significant parameter ($p < 0.001$) that determines formation of the oil seed rape yield. Also the length of the main root and root mass in the autumn showed a significant positive effect ($p < 0.05$) correlated with the winter oil seed rape yield. The mass of the oil seed rape roots is affected by the soil density index, especially in the subsoil layer at the depth of 0.2-0.4 m. The soil density index showed significant impact to formation of the biomass of the oil seed rape plants;
2. Increased content of K_2O in the arable as well as in the subsoil layer has a positive but insignificant effect ($p < 0.05$), but the soil reaction pH_{KCl} a significant negative effect to the winter oil seed rape yield. This can be explained by significant potassium content and soil pH_{KCl} antagonism in both soil layers.

Analysing the factors affecting the yield of winter wheat it was found:

3. A significant ($p < 0.05$) positive effect on the winter wheat grain yield was shown by the length of the main root in the autumn and total root mass in spring. A positive effect of the soil density index in both the soil arable layer and in the subsoil layer on the winter wheat yield was explicit with a very high probability ($p < 0.001$);
4. Increased content of potassium in both the soil arable layer and in the subsoil layer has a significant positive effect to the winter wheat grain yield. Increased amount of potassium only in the soil arable layer will not ensure yield increase.

The trial results show that in fields with wavy mesorelief the soil agrochemical properties in the subsoil layer have considerable impact to successful growing of winter wheat and winter oil seed rape.

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