EFFECT OF DIFFERENCES IN SOIL MOISTURE ON WINTER WHEAT YIELD

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Abstract. It is important to define which of the plant growth factors determines the yield level. During recent years in Latvia, in most cases it was moisture. Grain yield level mostly depends on meteorological conditions during the tillering stage. Plants do not utilize all water from precipitation. Rain water efficacy depends on soil granulometric composition and content of humus. Humus content could be considered as regulated factor. Important is also distribution of precipitation during the vegetation period as well as run-off of rain water which depends on micro-relief, soil tillage type, and direction in accordance with the slope gradient. It is very important for cereal growing in what conditions tillering is done, because during that time productive stems as well as ear sprouts are formed. The aim of this research was to determine the effect of soil moisture on the growth and development of winter wheat *Triticum aestivum* L. Field trials were carried out during 2005-2007 in Kurpnieki field at the Research and Study farm „Vecauce" of the Latvia University of Agriculture. A total of 47 points (distributed as a grid of 50×50 m) were selected for sampling in the winter wheat field. In both experimental years, the increasing soil moisture in spring had a significant positive effect on the flag leaf area, which, in its turn, increased also the level of grain yield. Partial correlation analysis showed that exclusion of organic matter content and altitude above the sea level as factors, changes soil moisture at different layers of the soil insignificantly.
Key words: cereal development, precision field management, soil moisture content, winter wheat.

Introduction

Soil moisture is one of the most important factors contributing to the compaction of soil. When moisture in soil increases, strength of uncultivated soil rapidly deteriorates. The same load packs more wet soil than dry. Wet soil load affects deeper than dry soil. When the soil pores are filled with water (saturated soil), soil compacts only where the water is out of the pores (Scaffer et al., 2006).

The modern technique allows using the images from aero-photo for general soil observation. They can be useful to determine differences in the field and to find problems. These images inform about the soil mainly in indirect way through the symptoms of cultivated plants (Florinsky and Kuryakova, 2000).

Variability of soil fertility is explained by soil physical conditions: type, compaction, organic matter, and moisture content. On-the-go soil sensors are designed to test changes in the soil (Adamchuk and Christenson, 2005).

It is important to define which of the plant growth factors determines the yield level. During recent years in Latvia, in most cases it was moisture. Grain yield level most by depends on meteorological conditions during the tillering stage. Plants do not utilize all water from precipitation. Rain water efficacy depends on soil mechanical composition and content of humus. Important is also distribution of precipitation during the vegetation period as well as run-off of rain water which depends on micro-relief, soil tillage type, and direction in accordance with the slope gradient. Usage of soil moisture is highly dependent on the dynamics of development of crop root system. Essential is the initial development stage because very often in Latvia moisture deficit occurs in late April and early May, when there is not enough precipitation and soil surface dries quickly. Groundwaters through capillary rise up slowly and reache field surface only when it is not deeper than 0.40-0.80 m in the ground (Lapins, 1997). The aim of this research was to determine the effect of soil moisture on the growth and development of winter wheat.

Materials and Methods

Field trials were carried out during 2005-2007 in Kurpnieki field (latitude: N 56º 28´, longitude: E 22º 53´) at the Research and Study farm „Vecauce" of the Latvia University of Agriculture.

Soil characteristics: predominant soil type - sod podzolic loam soil, humus content - 14-91 g kg^{-1} (by Tyurin's method), soil reaction - pH $_{KCl}$ 6.0-7.4, phosphorus content - 102-394 mg kg^{-1}, and potassium content -102-333 mg kg^{-1} (by Egner-Riehm method). Relief - wavy terrain, area with explicit macro-relief. The field had a drainage system.

The same agrotechnology for growing of winter wheat variety 'Tarso' was used on the entire field: forecrop winter oilseed rape *Brassica napus* ssp. *Oleifera*; soil tillage before drilling soil deep loosening at the depth of 0.35-0.50 m, and following soil ploughing at the depth of 0.18 m. Drilling of winter wheat was done with combined drilling-soil tillage equipment with a vertical power harrow, using 400 germinate able seeds per m^2. Fertilizers: in autumn - $N_6P_{26}K_{30}$ at the rate of 300 kg ha^{-1}; in spring - ammonium nitrate (N_{34}) two times at the rate of

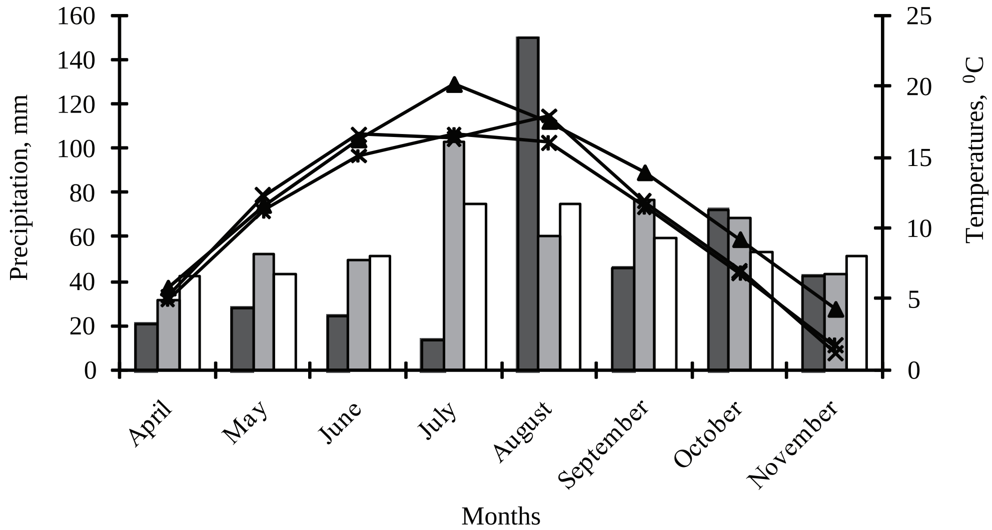

Figure 1. The average day and night air temperatures and precipitations in years 2006 and 2007, °C (according to Vecauce Metpole and long term to Dobele HMS):
2006 2007 long term 2006 2007 long term

200 kg ha^{-1}. Weed control and fungicide application was done according to the needs.

Winter wheat variety 'Tarso' was grown in 2006 and 2007. The agrotechnology used in wheat cultivation was equal in the whole field and in both trial years. A total of 47 points (distributed as a grid of 50×50 m) for sampling were selected in the winter wheat field. All points were attached to their geographic coordinates. The coordinates of observation points were defined by GPS receiver Garmin IQ 3600 using AGROCOM software AgroMAP Professional that allows to find the coordinates by accuracy of ±3 m, as well as to determine the field boundaries. Information from Garmin IQ 3600 was transferred into a computer and processed by the program AgroMAP Professional. Data characterizing growth and development of winter wheat (number of leafs, total weight of plant, mass of roots, the length of roots, coefficient of tillering, and area of flag leaf) were determined from 10 plants in each sampling point two times in autumn at winter wheat growth stage BBCH 11-12, and in spring at growth stage BBCH 25-29. Soil moisture content, %, was measured with Eijkelkamp Agrisearch Equipment instrument in 0.00-0.45 m soil layers, 3 replications in each sampling point. Flag leaf area was determined by using a specialized computer program WinFOLIA in growth stage BBCH 37-39. Samples for organic matter content were taken from the depth of 0.20 m using a probe. Sampling was done after harvesting on August 14, 2006, in 3 replicates in each sampling point. The samples were analyzed in the certified laboratory VSIA „Agroķīmisko pētījumu centrs" („Agrochemical Research Centre"), using local standard method LV ST ZM 80-97. The yield was harvested by combine CLASS LEXION 420. Mapping was created using specialized software AgroMAP. Data analysis was performed using a mathematical descriptive statistics, correlation and partial correlation analysis.

Meteorological conditions varied in the research years, and the main indices - average daily temperature and precipitation - are shown in Figure 1. The observed average air temperatures were above the long-term average in both trial years, especially in the second part of the year 2006.

The average temperature of July 2006 was by 3.5 ºC higher than the long-term observed. Alongside with insufficient amount of precipitation it caused rapid ripening and early harvesting of winter wheat compared with long-time observed harvesting time. The sum of precipitation was low in both trial years, but during the period April-August it was lower in the year 2006 if compared to 2007, despite the high amount of precipitation in August 2006 (Figure 1).

Results and Discussion

Importance of soil moisture, as one of partly regulated plant growth factors, will be described in connection with the growth and development of winter wheat for the yields in 2006 and 2007. The results showed that differences in soil moisture were significant only in the autumn of 2006 which was characterized by low amount of precipitation (Table 1). In trials in Lithuania it was found that the greatest soil moisture variation for all soil tillage systems was in the 0.00-0.05 m topsoil layer, which is more affected by the meteorological conditions.

From the beginning to end of the crop growing season, in a loam soil, in conventional tillage system, moisture content in the ploughlayer declined on average by 29.9%, in reduced tillage system - by

Table 1

Soil moisture effect on winter wheat development in the autumn of 2006 and 2007

Indices	Moisture, %, 0.00-0.05 m		Moisture, %, 0.20-0.25 m	
	r_{yx}	p-value	r_{yx}	p-value
2006				
Total weight of plant, g	-0.278	0.095	-0.233	0.164
Length of roots, cm	-0.401*	0.013	-0.409*	0.011
Number of leaves	-0.381*	0.019	-0.273	0.101
2007				
Length of roots, cm	-0.108	0.469	-0.010	0.942
Total weight of a plant, g	-0.100	0.499	-0.178	0.229

*p< 0.05.

38.8%, and in direct drilling system - by 37.4%, whereas in a sandy loam soil - by 32.4%, 29.8% and 17.2%, respectively, i. e., was nearly twice as low as in a loam soil. When direct drilling was applied, the soil absorbed moisture more slowly, and under droughty conditions the soil was able to retain moisture in the ploughlayer longer. Soil moisture depends on the chosen soil tillage system, and application of direct drilling can be one of the ways of economical use of moisture (Kadžiene, 2009).

Assessment of soil moisture in spring 2006 showed that moisture content at the 0.00-0.05 m soil layer has significant positive effect on the coefficient of tillering, area of flag leaf, and winter wheat yield ($p<0.05$), but at the 0.20-0.25 m deep soil layer on the area of flag leaf, and winter wheat yield (Table 2).

The results show that soil moisture at both tested soil layers has significant ($p<0.01$) positive effect on the area of flag leaf in both trial years. Effect on winter wheat yield was significant ($p<0.05$) for soil moisture at the depth of 0.20-0.25 m in both trial years, but significance of moisture content at the top soil layer on winter wheat yield was found only in the year 2006 (Table 2). A significant effect of soil moisture at the top soil layer on winter wheat grain yield was found also in trials with soil deep loosening (Dinaburga, 2007).

Correlation analysis in the year 2006 showed that at the yield level below 7.00 t ha^{-1}, significant positive effect on winter wheat yield soil moisture content in autumn at the depth of 0.00-0.05 m had ($p<0.05$). In places where the yield was above 7.00 t ha^{-1}, soil moisture showed significant effect in autumn at 0.20-0.25 m depth and in spring at 0.40-0.45 m depth ($p<0.05$), but significant effect with higher probability ($p<0.01$) showed soil moisture in spring at 0.00-0.05 and 0.20-0.25 m depth (Figure 2). Whereas in the year 2007, significant positive effect to winter wheat yield

Table 2

Soil moisture effect on winter wheat yield and its formation in 2006 and 2007

Indices	Moisture, %, at 0.00-0.05 m		Moisture, %, at 0.20-0.25 m	
	r_{yx}	p-value	r_{yx}	p-value
2006				
Coefficient of tillering	0.312*	0.032	0.195	0.186
Total weight of a plant	0.038	0.796	0.038	0.799
Mass of roots	-0.096	0.520	-0.140	0.346
Area of flag leaf	0.464**	0.001	0.535**	0.000
Yield	0.470**	0.004	0.370*	0.028
2007				
Coefficient of tillering	0.056	0.707	0.039	0.791
Total weight of a plant	0.161	0.278	0.179	0.227
Mass of roots	0.233	0.114	0.268	0.068
Area of flag leaf	0.418**	0.003	0.420**	0.003
Yield	0.228	0.122	0.299*	0.040

*p< 0.05; **p<0.01.

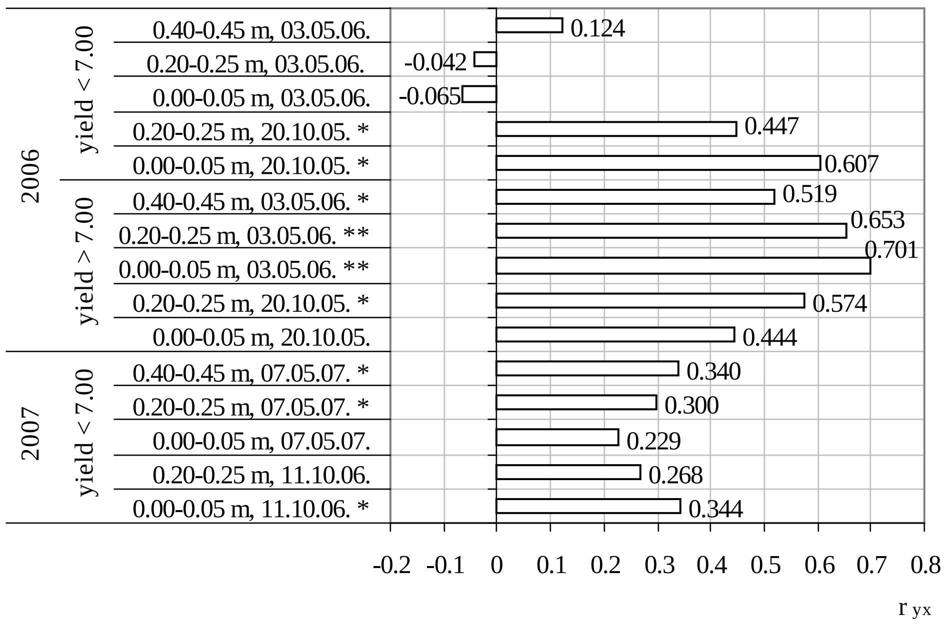

Figure 2. Correlation between soil moisture at various depths of soil and winter wheat grain yield at different levels; *p< 0.05; ** p<0.01.

showed soil moisture content in autumn at 0.00-0.05 m depth (similar with year 2006) and moisture content in spring at 0.20-0.25 and 0.40-0.45 m depth (p<0.05). The influence of soil moisture in subsoil layer (at the depth of 0.40-0.45 m) or winter wheat yield has been found also in trials with soil deep loosening, and the obtained coherence was described by equation: $y = -0.654x + 24.708$ (Dinaburga, 2007).

Correlation analysis between soil moisture and area of flag leaf shows significant effect of moisture only at subsoil layer in places with winter wheat yield level above 7.00 t ha^{-1} in the year 2006. But in the year 2007, the effect of moisture in soil was significant with high probability (p<0.01) in all tested layers of soil both in autumn and spring (Figure 3).

The area of winter wheat flag leaf had a significant positive effect on the grain yield at both considered yield levels; in 2006 the only difference was in the probability level: at the yield level below 7.00 t ha^{-1}, the probability level was higher, but correlation was insignificant in the year 2007 (Figure 4). A significant positive effect (r_{yx} = 0.532) of the area of flag leaf

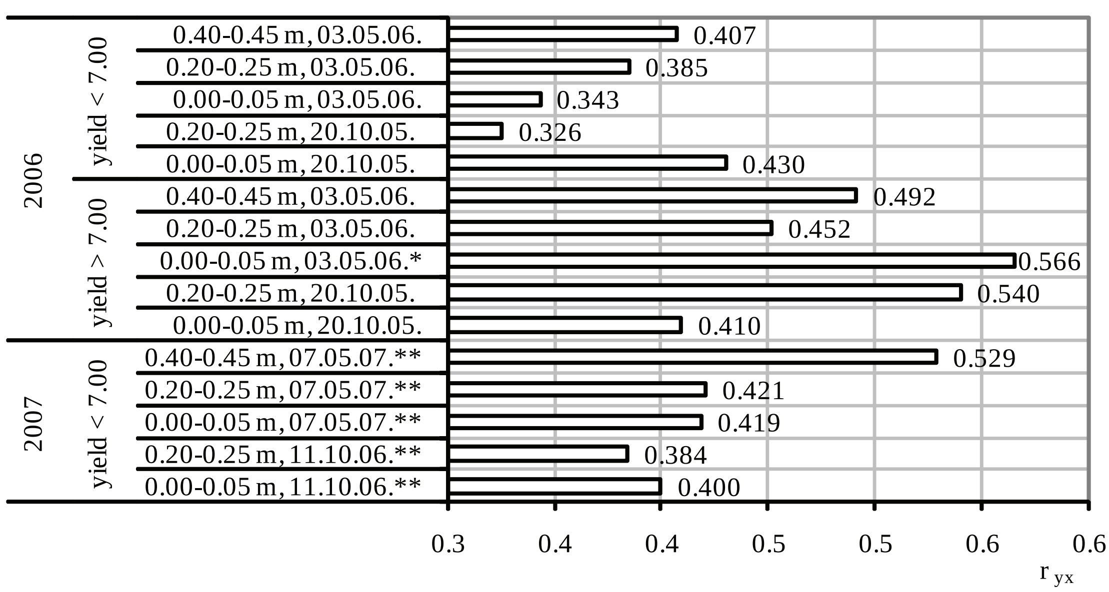

Figure 3. Correlation between soil moisture at various depths of soil and area of wheat flag leaf at different levels of winter wheat yield; *p< 0.05; ** p<0.01.

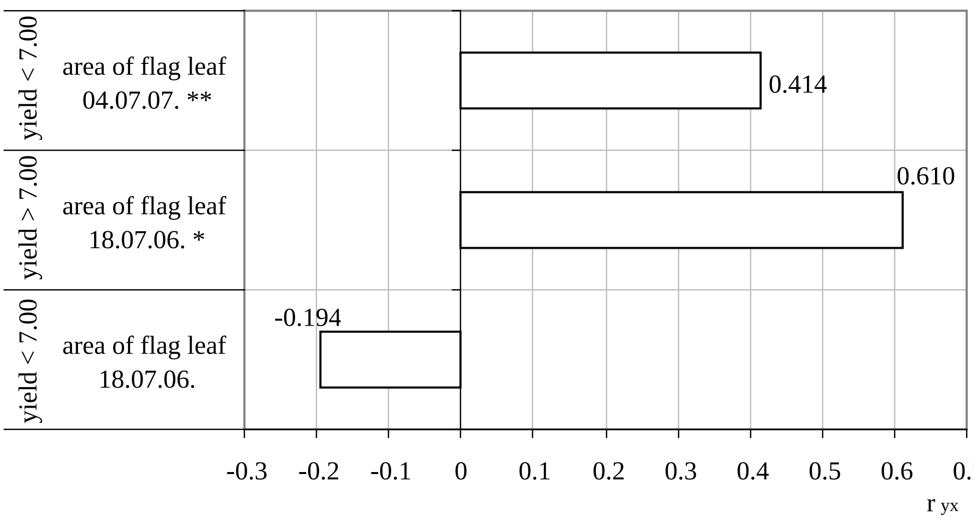

Figure 4. Correlation between the area of flag leaf and winter wheat grain yield at different yield levels; *p< 0.05; ** p<0.01.

on wheat yield has been found also in other trials (Dinaburga, 2007).

In the trials with soil deep loosening it has been found that only 18.1% of winter wheat yield changes can be explained by moisture differences at the depth of 0.20-0.25 m, and 30.0% of changes by moisture content at the depth of 0.40-0.45 m (Dinaburga, 2007).

Partial correlation analysis showed that exclusion of the effect of organic matter content and relative height above the sea level causes no significant changes in conclusions about soil moisture influence on the formation of winter wheat yield. The only important difference concerns soil moisture at the top soil in autumn - the relationship becomes significant if partial correlation analysis is used (Figure 5).

Also other researchers have found that the greatest influence on variability of the yield components is exerted by moisture and by penetration resistance of soil. Decreased soil moisture mainly brings about a reduction in the number of ears on a unit of area (Weber et al., 2004).

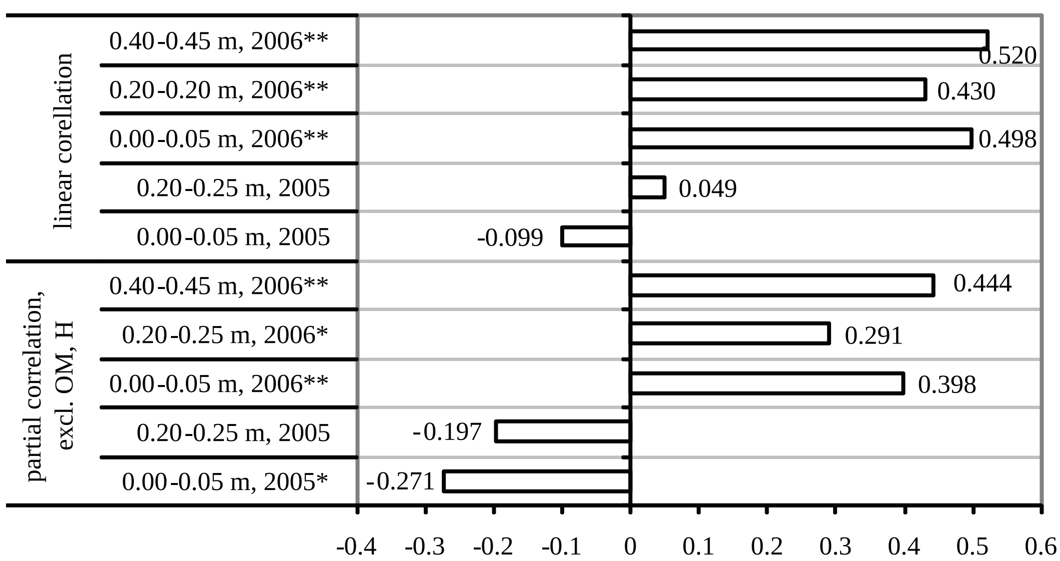

Figure 5. Coefficients of linear correlation, r_{yx} and partial correlation, between winter wheat grain yield, t ha^{-1}, (y) and soil moisture content, %, (x); *p< 0.05, ** p<0.01; OM - organic matter content (mg kg^{-1}); H - relative height above the sea level, m.

Conclusions

1. Effect of soil moisture in autumn on parameters characterizing growth and development of winter wheat was significant only in the autumn of 2006 when low amount of precipitation was observed.
2. Soil moisture in spring had significant ($p<0.01$) positive effect on the area of flag leaf at both tested soil layers 0.00-0.05 m and 0.20-0.25 m.
3. Soil moisture effect to winter wheat yield was significant ($p<0.05$) for soil moisture at the depth of 0.20-0.25 m in both trial years, but significance of moisture content at the top soil layer on winter wheat yield was found only in year 2006.
4. Analysis of correlation between soil moisture and area of flag leaf showed significant effect of moisture at subsoil layer in places with winter wheat yield level above 7.00 t ha^{-1}.
5. Partial correlation analysis showed that exclusion of the effect of organic matter content and relative height above the sea level makes no significant changes in conclusions about soil moisture influence on the formation of winter wheat yield.

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