Effect of the Main Soil Tillage Types on the Agronomic Response of Wheat in the Region of South Dobrudza

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Summary

Wheat yield (Triticum aestivum L. – cv. Enola) obtained under different main soil tillage systems in 4-field crop rotation (common bean-wheat-sunflower-grain maize), is strongly influenced by the regional soil (Haplic Chernozems) and the climatic conditions. This study was carried out at the trial field of Dobrudzha Agricultural Institute-General Toshevo from 2014 to 2016. The influence of seven main soil tillage systems (MSTS) on the yield and the physical properties of wheat grain was investigated. Four of these MSTS were applied independently and annually in crop rotation: 1. CP - conventional plowing (24-26 cm); 2. D – disking (10-12 cm) 3. C – cutting; 4. NT - nil tillage (direct sowing). The other three MSTS systems included: 5. Plowing (for spring crops) – Direct sowing (of wheat); 6. Cutting (for spring crops) - Disking (for wheat) and 7. Plowing (for spring crops) - Disking (for wheat). The mineral fertilization in the crop rotation was as follows: Common bean – N 60P60K60; Wheat – N120P120K60; Sunflower - N60P120K120 and Maize – N120P60K60. The objectives were: (i) to investigate the seasonal variability in wheat yield as influenced by the tillage systems; (ii) to investigate the variability in the physical properties of wheat grain and (iii) to evaluate the correlations between the grain yield and the physical properties of wheat grain.

A significant differentiation in the productivity of wheat was found depending on the tested MSTS systems. Lowest mean yields were obtained at the annual use of systems 3 and 4 - 4541 kg ha⁻¹. Among the annually applied systems, constant disking was the most favorable for expression of the crop’s production potential. The mean addition to yield according to constant plowing in the crop rotation was 4541 kg ha⁻¹. The systems involving annual alternation of tillage types with and without turning of the plow layer exceeded with 232.0 kg ha⁻¹ (4.77%) the same systems, which were applied independently. The alternation of plowing for root crops with direct sowing of wheat was most efficient from an agronomic point of view. In comparison to annual plowing, the increase of productivity was with 280.5 kg ha⁻¹ (5.62%). The values of the physical properties of grain were also highly differentiated according to MSTS. The constant application of disking in the crop rotation contributed to the production of grain with the best physical indices – absolute weight 43.15 g and test weight 76.86 kg. The use of the systems Cutting – Cutting and Direct sowing – Direct sowing had negative effect on both the yield and the physical properties of gain. Averaged for the period, the correlation between the grain yield and the physical indices of grain was high and positive. The mean value of the correlation coefficient between the yield and the test weight (0.930”) was higher than the correlation coefficient of the yield with 1000 kernel weight (0.780”). The correlation between the absolute and the test weight of grain was very high in all three years of the investigation.

Key words

main tillage of soil, wheat, yield, physical properties of grain

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Introduction

An agricultural production, where “yields are increased without adverse environmental impact and without the cultivation of more land”, is defined as “Sustainable intensification” SI (The Royal Society London, 2009). This form of production combines energy flows, nutrient cycling, population-regulating mechanisms, and system resilience to intensify existing arable land without harm to the environment or other economic or social factors (Pretty, 2008). Soil tillage is a fundamental factor influencing soil quality, crop performance and the sustainability of cropping systems because tillage can alter soil physical properties, the depth of soil profile, and the management of crop residues applied to the soil (Munkholm et al., 2012). As a crop production factor, tillage contributes up to 20% and affects the sustainable use of soil resources through its influence on soil properties (Khurshid et al., 2006; Lal and Stewart, 2013).

Conventional tillage (CT) practices are one of the many emerging environmental agronomic-economic issues that are addressed in contemporary cropping systems (Jug et al., 2011). In nowadays European Community’s Agricultural Policy has strongly encouraged soil conserving tillage practices (and in some instance the conversion of cropland into set-aside land) in order to decrease soil loss, although new demands of bio-fuel production will decrease set-aside land (European Union, 2000).

At the beginning of the 90th of the XX century Kladivko et al. (1986) concluded that NT systems have a greater positive effect on crop growth and yield when used on soil characterised by low organic matter levels and poor structure, rather than on well-structured soils high in organic matter. Whether conservation tillage practice performs better than the long practiced traditional tillage practices in terms of improvement of edaphic and yield influencing characters of the specific and unearthy soil-water-plant ecosystem of the region is still unknown (Alam et al., 2014).

Interactions between natural factors (e.g., soil type, climate and weather) and crop selection determine the intensity, depth, frequency, and timing of tillage (Strudley et al., 2008). There is a need for understanding the tillage effects on soil properties, tractor performance and crop yield (Servadio and Bergonzoli, 2012). Tillage systems are location specific, so the degree of their success depends on soil, climate, and management practices (Hajabbasi and Hemmat, 2000; Servadio et al., 2014).

In recent years the weather conditions in Bulgaria have been unstable. In the summer months (July and August) the soil is usually very dry. In the last years the sum of autumn-and-winter rainfalls is more than 300 mm and early in the spring the soil is wet. This sometimes impedes the timely performance of a number of agronomy practices involved in the rotation of the field crops. Furthermore, according to Russeva (2006), about 84% of the lands in Bulgaria have 3° inclination, which is a prerequisite for the occurrence of water erosion processes. The long-term testing of different tillage systems of Vertisol and Chromic Luvisol in Bulgaria show that best productive results are obtained after applying rational cultivation systems which include different kinds of tillage at various depths. The application of tillage systems to the investigated soils demands a flexible approach because the established coefficients of the yield stability are low and the performing of envisaged cultivations have to be done after determining the main physical soil characteristics (Dimitrov and Borisova, 2004). The elaborated criteria generalize scientific examination of many years’ duration. Having in mind the reliability of the results, we consider that they can serve as an appliance of the agricultural producers in the choice of the main tillage with concrete agroecological conditions. On the basis of these criteria and the agrotechnical valuation of the cultivated surface the agrotechnical measures can be made with minimum risk of negative influence over the soil fertility (Dimitrov, 2014).

Therefore, the objectives of this study were to assess which tillage techniques and main soil tillage systems could be considered as adaptation to climate change scenarios. The objectives were: (i) to investigate the seasonal variability in wheat yield as influenced by the tillage systems; (ii) to investigate the variability in the physical properties of wheat grain and (iii) to evaluate the correlations between the grain yield and the physical properties of wheat grain.

Material and methods

This study was carried out at the trial field of Dobrudzha Agricultural Institute-General Toshevo from 2014 to 2016. The influence of seven main soil tillage systems (MSTS) on the yield and the physical properties of wheat grain were investigated. Four of these MSTS were applied independently and annually in crop rotation: 1. CP - conventional plowing (24-26 cm); 2. D – disking (10-12 cm) 3. C – cutting (24-26 cm); 4. NT- nil tillage (direct sowing). The other three MSTS systems included: 5. Plowing (for spring crops) – Direct sowing (of wheat); 6. Cutting (for spring crops) - Disking (for wheat) and 7. Plowing (for spring crops) - Disking (for wheat). The mineral fertilization (kg/ha) in the crop rotation was as follows: Common bean – N60P60K60, Wheat – N120P120K60, Sunflower - N60P120K120 and Maize – N120P60K60. Mineral fertilization was done with common ammonium nitrate NH₄NO₃ (34% N), triple superphosphate (46% P₂O₅) and potassium chloride (60 % K₂O). Wheat cultivar Enola was sown at density 550 germinating seeds/m².

Weed control was uniformly carried out on the whole experimental surface after harvest of each crop in the rotation, by treatment with 10 liters/ha herbicide (glifosat 360 g/l). At the beginning of permanent spring vegetation, the crop was treated with 33 g/ha Derbi-Super (150.2 g/kg florasulam+300.5 g/kg aminopiralid K). For all main soil tillage systems, harvesting was performed with the harvester specific for experimental fields.

The resulted data were statistically processed using variance analysis, F test and LSD (Least Significant Difference) test, which are commonly utilized in the multi-criterial statistical analysis. We used the SPSS version 16.0 statistical package. Significance of the treatments’ effect was considered at 0.05 probability level. After performing the analysis of variance, we compared the means for each treatments using the Waller-Duncan’s Multiple Range Test. Finally, Pearson correlation coefficients (“R coefficients”) were computed and tested for significance.

Results and discussions

The variances of the productivity, averaged for the investigated period, revealed high statistical significance of the independent and combined interaction of the factors Year and Main soil tillage systems (MSTS) (Table 1). The independent action of MSTS influenced significantly the wheat productivity in 2014 and 2016, while the effect of the different soil tillage systems in 2015 was not statistically significant.
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The obtained results clearly show that the meteorological conditions were the main factor determining yield. The strength of its effect in this experiment during the period of investigation was calculated to 98.92%. Machado et al. (2008) reported, that tillage and year significantly influenced wheat grain yield but there were no significant tillage and year interactions. In our case two factors and their interaction had a significant effect on grain yield during the investigated period. Year x MSTS interaction was significant (P<0.01) for grain yield per hectare. This interaction can be explained mainly by the important differences among the conditions of years of experimentation. Except 2015 MSTS have a significant effect on wheat productivity.

The three years significantly differed by the monthly dynamics of the main meteorological factors (Figure 1). The sum rainfalls were the abundant rainfalls during planting (156.3 mm – October of 2013) and during heading and harvesting – 78.2 mm and 192.5 mm, respectively. This year can be defined as humid, exceeding the long-term norm 1.54 times. Harvest years 2015 and 2016 were also characterized with higher precipitation sum during the wheat growth season. The exceeding of the long-term precipitation norm (1953–2013) was with 38.2 mm and 71.9 mm, respectively. The distribution of rainfalls was extremely uneven during the period April – June. In 2015 their sum was lowest – only 90.5 mm.

With regard to temperature, the years were characterized with warmer conditions for the development of the crop during the entire vegetative growth – a mean of 10.3°C exceeding the mean long-term temperature norm with 1.3°C. Besides the warmer conditions for autumn-and-winter vegetative growth, the period from April till the end of the vegetation exceeded the mean values during the investigated period with 1.2°C (2014), 0.7°C (2015) and 1.9°C (2016), respectively.

This brief characterization of the dynamics of the main meteorological elements is a prerequisite for the serious effect of this factor on the productivity of wheat determined over years of investigation (Figure 2).

Although year 2014 was with the highest sum of rainfalls during the vegetative growth of wheat, their extremely uneven distribution, and especially the abundant rainfalls in June (192.5 mm) combined with lower temperatures, caused development of diseases and lodging of crops. All this complex of unfavorable circumstances during grain filling resulted in very low yields. The low productivity of wheat in that year was accompanied with statistically well-founded

<table>
<thead>
<tr>
<th>Source</th>
<th>Dependent Variable</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Years (1)</td>
<td>Yields 2014–2016</td>
<td>2</td>
<td>6205329.519</td>
<td>4207.654</td>
<td>.000</td>
</tr>
<tr>
<td>MSTS (2)</td>
<td>Yields 2014–2016</td>
<td>6</td>
<td>12655.023</td>
<td>8.581</td>
<td>.000</td>
</tr>
<tr>
<td>1 x 2</td>
<td>Yields 2014–2016</td>
<td>12</td>
<td>4914.583</td>
<td>3.332</td>
<td>.001</td>
</tr>
<tr>
<td>By years</td>
<td>Yield – 2014</td>
<td>6</td>
<td>5512.225</td>
<td>6.658</td>
<td>.000</td>
</tr>
<tr>
<td></td>
<td>Yield – 2015</td>
<td>6</td>
<td>2471.118</td>
<td>.910</td>
<td>.507NS</td>
</tr>
<tr>
<td></td>
<td>Yield – 2016</td>
<td>6</td>
<td>14500.808</td>
<td>16.021</td>
<td>.000</td>
</tr>
</tbody>
</table>

Table 1. Analysis of the variances of productivity during 2014-2016
The highest yield was obtained under the system with differentiation of productivity between the separate MSTS was clearly than the climatic norm. These amounts, plus the April rainfalls, did not allow the short drought in May to influence negatively the conditions of this year was the effect of direct sowing and cutting constantly used in the crop rotation.

Table 2. Effect of the soil tillage system on the productivity of wheat over years, kg ha⁻¹

<table>
<thead>
<tr>
<th>No</th>
<th>Soil tillage system</th>
<th>2014</th>
<th>2015</th>
<th>2016</th>
<th>Sig</th>
<th>Sig</th>
<th>Sig</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Plowing – Plowing</td>
<td>1540.6</td>
<td>9878.7</td>
<td>3542.6</td>
<td>cd</td>
<td>0.000</td>
<td>cd</td>
</tr>
<tr>
<td>2</td>
<td>Disking – Disking</td>
<td>1884.2</td>
<td>10491.9</td>
<td>3750.0</td>
<td>d</td>
<td>0.000</td>
<td>cd</td>
</tr>
<tr>
<td>3</td>
<td>Cutting – Cutting</td>
<td>1124.9</td>
<td>9975.8</td>
<td>2521.8</td>
<td>a</td>
<td>0.000</td>
<td>cd</td>
</tr>
<tr>
<td>4</td>
<td>Direct sowing – Direct sowing</td>
<td>749.3</td>
<td>10427.9</td>
<td>2446.7</td>
<td>a</td>
<td>0.000</td>
<td>cd</td>
</tr>
<tr>
<td>5</td>
<td>Plowing – Direct sowing</td>
<td>1350.5</td>
<td>10406.3</td>
<td>4047.6</td>
<td>d</td>
<td>0.000</td>
<td>cd</td>
</tr>
<tr>
<td>6</td>
<td>Cutting – Disking</td>
<td>1510.7</td>
<td>10465.2</td>
<td>3249.2</td>
<td>b</td>
<td>0.000</td>
<td>cd</td>
</tr>
<tr>
<td>7</td>
<td>Plowing – Disking</td>
<td>1077.5</td>
<td>10291.2</td>
<td>3441.9</td>
<td>bc</td>
<td>0.000</td>
<td>cd</td>
</tr>
</tbody>
</table>

The mean productivity in the experiment was 10277 kg ha⁻¹. The mean yield of the trial in 2016 was 3286 kg ha⁻¹ and the difference in the value of the obtained results in comparison to annual independently applied constant disking and after the alternation of plowing prior to root crops and direct sowing of wheat. In comparison to annual plowing, the increase of productivity was with 2805 kg ha⁻¹ (5.62%).

Contrary to our results Akgun et al. (2014) established that the most favorable treatment for winter wheat in Middle Anatolian Region was direct sowing application. The recorded mean grain yield in this system was 24% and 22% higher than those registered in conventional tillage and reduced tillage, respectively.

The analysis on the variances of the grain's physical properties (1000 kernel weight and test weight) demonstrated the high effect of the tested factors on their values, averaged for the investigated period (Table 3). Maximum level of significance of the MSTS on the values of these indices was found over years, as well.

During the investigated period, the factor year had greater strength of effect on the values of the obtained results in comparison to MSTS and their interaction (Figure 4). The effect of the meteorological factor was much stronger on the values of test weight than on the values of 1000 kernel weight.

The largest and plumpest grain was produced in 2015 - 44.86 g (Figure 5). The mean values of 1000 kernel weight in 2014 and 2016 were low and approximately the same, and therefore the Waller-Duncan test put them in the group of lowest rank. Averaged for the investigated period, the independent long-term types of soil tillage contributed to the formation of grain with a mean value of the absolute weight of 40.80 g. Their alternation in the crop rotation, however, had a positive effect on the value of the index, increasing it to 41.42 g.
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Test weight, a parameter which gives an idea about the weight of the grain, was with the highest mean values again in 2015 - 81.31 kg. The values of this index were very well differentiated by years in comparison to the index 1000 kernel weight. They once again confirmed the fact that year 2014 was the least favorable for formation of the grain's physical properties according to a complex of meteorological conditions.

Regardless of the considerable dynamics in the values of the grain’s physical properties over years of investigation, within each year the values of the two indices varied significantly according to MSTS (Table 4). The variation of the absolute grain weight by year was as follows: 2014 - from 37.20 g (Direct sowing – Direct sowing) to 42.00 g (Plowing-Plowing); 2015 - from 43.00 g (Direct sowing – Direct sowing) to 45.25 g (Plowing - Plowing and Plowing – Disking); 2016 - from 35.63 g (Direct sowing–Direct sowing) to 42.66 g (Disking-Disking). Thus, averaged for the investigation period, a tendency was outlined toward a high positive effect of the systems Disking–Disking (43.15 g) and Plowing-Plowing (42.05 g) on the weight of the grain (Figure 6).

Over the years, the variation in the values of test weight was also marked by a considerable dynamics depending on MSTS. Averaged for the period, it was from 74.36 kg (Plowing-Disking) to 76.86 kg (Disking-Disking). The tendency towards a better expressed positive effect of the systems Disking–Disking and Plowing–Plowing on the test weight in comparison to the other soil tillage systems was again confirmed.

Averaged for the period of investigation, high values of the correlations between yield and the physical properties of grain were found. The correlation between grain yield and test weight was highest - 0.930**. The correlation between the two physical indices of grain was also at a high level of statistical significance - 0.745**.

During the individual years of the investigation, the correlation coefficient values, modulated on the basis of the tested soil tillage systems, varied significantly (Table 5). In 2015, the correlation of yield with 1000 kernel weight, and with test weight, respectively, was not significant. Under its much more favorable conditions for development and formation of productivity, the correlation between the two physical indices of grain was clearly expressed. The
extremely unfavorable conditions during the vegetative growth of wheat in 2014 were reflected in high statistically significant values of the investigated correlations.

Conclusions

A significant differentiation was determined in the productivity of wheat depending on the tested systems for main soil tillage. The lowest mean yields were obtained after long-term annual use of cutting and direct sowing - 4541 kg ha-1. Among the annual independently applied systems, constant disking was most suitable for expression of the production potential of the crop. The mean addition to yield according to the constant plowing in the crop rotation was 3881 kg/ha. The systems involving annual alternation of tilths with and without turning of the plow layer exceeded the independently applied ones with 2320 kg ha-1 (4.77%). From an agronomic point of view, most efficient were the alternation of cutting and direct sowing - 4541 kg ha-1. Among the annual independently applied systems, constant disking was most suitable for expression of the production potential of the crop.

Averaged for the investigated period, the correlation between grain yield and the physical indices of grain was high and positive. The value of the correlation coefficient between yield and test weight (0.930**) was higher in comparison to the correlation of yield and 1000 kernel weight (0.780**). The correlation between 1000 kernel weight and test weight over years (Pearson Correlation) was very well expressed in all three years of the investigation.

References

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