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Species composition and density of weeds in a wheat crop depending on the soil tillage system in crop rotation

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Abstract. The investigation was carried out in the trial field of Dobrudzha Agricultural Institute, General Toshevo on slightly leached chernozem soil type. For the purposes of this investigation, variants from a stationary field experiment initiated in 1987 and based on various soil tillage tools and operations were analyzed. The species composition and density of weeds were followed in a wheat crop grown after grain maize using the following soil tillage systems: plowing at 24 – 26 cm (for maize) – disking at 10 – 12 cm (for wheat); cutting at 24 – 26 cm (for maize) – cutting at 8 – 10 cm (for wheat); disking at 10 – 12 cm (for maize) – disking at 10 – 12 cm (for wheat); no-tillage (for maize) – no-tillage (for wheat). Weed infestation was read at the fourth rotation since the initiation of the trial. The observations were made in spring before treatment of the crop with herbicides. The soil tillage system had a significant effect on the species composition and density of weeds in the field with wheat grown after previous crop maize. The long-term alternation of plowing with disking in parallel with the usage of chemicals for weed control lead to lower weed infestation of the weed crop. The lower weed density after this soil tillage system was not related to changes in the species composition and the relative percent of the individual species in the total weed infestation. The long-term application in crop rotation of systems without turning of the soil layer and of minimal and no-tillage increased the amount of weeds. The reason is the greater variability of weed species which typically occur after shallow soil tillage.

Keywords: species composition, density of weeds, wheat, soil tillage systems

Introduction

Soil tillage is one of the first agricultural activities of man after his transition to a settled lifestyle. It was aimed both at loosening the surface soil layer to create favorable conditions for planting of seeds and at destroying the undesirable vegetation in the cultivated crop. The negative effect of the weed plants is expressed in direct competition for moisture and nutrients with the crops cultivated by man (Stoynev and Georgiev, 1984) this, on its part, decreases yield and deteriorates the quality of agricultural production (Glazunova, 2009). Shrestha et al. (2002) have pointed out that the developing of strategies for integrated weed control in modern agriculture requires knowledge on the mechanisms which influence the composition of the weed flora. In this relation the used types of soil tillage in crop rotation are one of the practices which affect the species in the weed associations and their density. The yield reduction by weeds in wheat may be up to 80% depending upon weed type, density, timing of emergence, wheat density, wheat cultivar and soil and environmental factors (Afentoulis and Efletherhorinious, 1996; Chhokar and Malik, 2002; Khera et al., 1995; Malik and Singh, 1995).

Studying the effect of soil tillage on the infestation of wheat with drooping brome (Bromus tectorum L.), Kettler et al. (2000) have found out that its populations decreased on plowed areas in comparison to areas with direct sowing, with 97 % and 41 % respectively, during the first and third crop rotations. Klochkov (1983) pointed out that under the contemporary level of chemical control of weeds, the infestation of the autumn crops as a function of the soil tillage is not significant.

The crop rotations, which involve numerous and variable plant species, also contribute to the suppression of weed vegetation by competing for environmental resources and by occupying all available niches in the agro systems (Anderson, 2005; Liebman and Davis, 2000). According to Rasmussen (1999) crop rotation is more important on agricultural areas where minimal soil tillage is applied than on intensively cultivated lands because it reduces to a minimum the problems related to fungal diseases and weed infestation of the grown plants.

The aim of this investigation was to study the species composition and weed density in a wheat crop depending on the applied soil tillage system in the crop rotation.

Material and methods

The investigation was carried out in the trial field of Dobrudzha Agricultural Institute, General Toshevo on slightly leached chernozem soil type [1]. The mechanical composition of these soils conditions favorable moisture and air regime (Yolevsky et al., 1959). The thickness of the humus horizon is about 70 cm. The total nitrogen content characterizes these soils as having moderate reserves. The reserves of P2O5 are low to moderate and the K2O reserves – from moderate to good. Soil reaction is neutral.

In a stationary trial initiated in 1987, 24 soil tillage systems are being tested based on various soil tillage tools and operations. The design of the variants was according to the non-standard method in two parallel crop rotations. The size of the trial plots was 25 m2. Field crops typical for the region of Dobrudzha – wheat, sunflower, grain maize and bean were involved in a six crop rotation.

In this investigation variants with wheat grown after previous crop grain maize during the fourth rotation since the initiation of the trial were analyzed. To characterize the period "beginning of
rotation” data from the first three years (2005–2007) were analyzed, and the period “end of rotation” – the results from the last three years (2008–2010) of the respective rotation. The species composition and the density of weeds were followed in the systems for soil tillage given below:

- plowing at 24 – 26 cm (for maize) – disking at 10 – 12 cm (for wheat);
- plowing at 24 – 26 cm (for maize) – cutting at 8 – 10 cm (for wheat);
- disking at 10 – 12 cm (for maize) – disking at 10 – 12 cm (for wheat);
- no-tillage (for maize) – no-tillage (for wheat).

All tilths on maize (with the exception of no-tillage – no-tillage) included additional single disking in autumn and pre-sowing harrowing in spring. To destroy the emerging weeds in the variant with direct sowing, a total herbicide was used. During the initial years, depending on the type and rate of weed infestation of maize, vegetation spraying with herbicides against broadleaf and/or grass weeds were applied besides the post-sowing treatment. Mechanical soil tillage after planting was not done.

Planting of wheat was done with Bettinson 3D seeder for direct sowing. Cultivar Enola was sown at norm 550 germinating seeds/m². Weed control was carried out according to the traditional technology for growing of this crop by treatment with herbicides at the beginning of spring. Weeds were determined as total number by species taking samples from eight replications along the diagonals of the trial plots. Reading was done in the variants sown with wheat in spring prior to treatment with herbicides.

The analysis over years according to the indices air temperatures and precipitation sum for the entire period from October to September showed that the investigation started with higher amount of rainfalls and temperatures slightly higher (2005) or close to (2006) the norm (Figure 1). A drastic drought followed in 2007 with precipitation sum 56.5% from the climatic norm and increase of temperatures. The next 2008 year was again humid and warm. It was followed by slight drought and temperatures higher than the norm in 2009. The last year of the investigation (2010) was warm and very humid, with amount of rainfalls with 49.7% higher than the norm. This demonstrated that the investigation was carried out in years of variable climatic conditions.

The data were processed with the help of the statistical software's Microsoft Excel 2007 and SPSS 16.0.

Results and discussion

At the beginning of the fourth rotation, highest was the number of the weeds in the plowing-disking system: 31.4 plants/m² (Table 1). Weed infestation was lowest at alternation of deep with shallow cutting – 20.9 plants/m². At constant direct sowing and annual disking the total number of weeds reached 25.4 and 26.2 plants/m², respectively. With regard to the weed composition, at the systems plowing – disking and disking – disking, the species black bindweed and charlock were predominant. When alternating cutting without turning of the soil layer with constant direct sowing, the major weeds were ivy-leaved speedwell and corn chamomile. At the end of the rotation the density of weeds was highest in the system disking-disking – 31.8 plants/m². It was followed according to rate of weed infestation by cutting without turning of the soil layer and constant direct sowing, with 24.2 and 27.2 plants/m², respectively. The total number of weeds was lowest at alternation of plowing with disking – 17.9 plants/m². In the last year of the rotation, at the system plowing-disking, the predominant weed species were black bindweed and charlock. At annual disking, besides black bindweed, major weeds were also corn chamomile, field poppy, green foxtail, creeping thistle, and shepherd’s purse. The corn chamomile was predominant in the system cutting-cutting, while thymeleaf sandwort, black bindweed and shepherd’s purse were also in high numbers. At constant no-tillage the main weed species were cleavers, sterile brome, shepherd’s purse, thymeleaf sandwort, corn chamomile and green foxtail.

At the end of the rotation, in comparison to the first year from its beginning, the total number of weeds decreased twice in the system plowing-disking – statistically significant at P = 0.01. According to Holm (1972) the good aeration of soil stimulates the germination of the weed seeds and most of the emerging plants are subsequently destroyed by the accompanying tilths applied to maintain plowing. The amount of black bindweed and charlock was strongly reduced, but the density of shepherd’s purse and corn chamomile increased. Meanwhile spices such as cleavers, field bindweed and field poppy occurred. The systems with minimal and no-tillage and tillage without turning of the soil layer, higher total number of weeds was observed at the end of the rotation – statistically significant at P = 0.05. According to Ball (1992) the higher weed infestation in the tilths without turning of the soil layer is due to the greater number of seeds of the predominant weed species closer to the soil surface. The
Table 1. Species composition and density of weeds in a wheat crop grown after maize, using different systems of soil tillage in crop rotation

<table>
<thead>
<tr>
<th>Weed species and number, m&lt;sup&gt;2&lt;/sup&gt;</th>
<th>Soil tillage system</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Beginning of rotation</td>
</tr>
<tr>
<td>Black bindweed/ Polygonum convolutorius</td>
<td>16.0</td>
</tr>
<tr>
<td>knotgrass/ Anthriscus sylvestris</td>
<td>0.9</td>
</tr>
<tr>
<td>charlock/ Cirsium arvense</td>
<td>0.0</td>
</tr>
<tr>
<td>Thymeleaf sandwort/ Arenaria serpyllifolia</td>
<td>1.3</td>
</tr>
<tr>
<td>Field poppy/ Papaver rhoeas</td>
<td>0.9</td>
</tr>
<tr>
<td>No-tillage</td>
<td>7.11</td>
</tr>
<tr>
<td>Cutting at 4-6 cm</td>
<td>3.7</td>
</tr>
<tr>
<td>Cutting at 8-10 cm</td>
<td>6.3</td>
</tr>
<tr>
<td>Disking at 10-12 cm</td>
<td>9.6</td>
</tr>
<tr>
<td>No-tillage</td>
<td>6.2</td>
</tr>
<tr>
<td>No-tillage</td>
<td>2.8</td>
</tr>
</tbody>
</table>

Gd – Statistical significance of P for rates 5, 1 and 0.1 %, respectively

Weed density increased most at annual diskings and least – at constant direct sowing. The higher weed infestation under these soil tillage systems, regardless of the lower number of black bindweed and charlock and the total disappearance of some ephemerals such as ivy-leaved speedwell, was a result from the increase of species typical for these types of tillage. Similar tendency has been found out by other authors as well (Chhokar et al., 2007; Murphy et al., 2006; Sans et al., 2011). Under annual disking the density of green foxtail, corn chamomile, creeping thistle, shepherd’s purse, cleavers, field poppy, knotgrass, etc. increased. The use of annual direct sowing caused at the end of the rotation increase of the amount of the species sterile brome, green foxtail, shepherd’s purse, field bindweed, cleavers, thymeleaf sandwort and creeping thistle. At alternation of deep with shallow cutting, the number of thymeleaf sandwort, shepherd’s purse, knotgrass, green foxtail, etc., significantly increased at the end of the rotation. In this relation regular replacement of the tillage without turning of the soil layer, and minimal and no-tillage with deep plowing is recommended when growing wheat as a part of the soil tillage systems in crop rotation. The variations in the density and species composition of the weeds under the different soil tillage systems which occurred at the end of the rotation were a result from the application of chemicals for control of weed infestation and the changes of the soil properties caused by not using or combining various soil tillage tools and operations. The long-term usage of the same herbicides probably homogenized the weed associations; simultaneously significant changes occurred in the ratio and quantitative characteristics of certain weeds, some of which remained dominant while others decreased in density.
The results from the dispersion analysis showed that the influence of the independent and combined investigated factors – species composition of weeds, soil tillage systems and year conditions affected the rate of weed infestation of the soil (Table 2). Their effect on the investigated trait was significant at $P = 0.001$, with the exception of the factor year conditions, which effect was significant at $P = 0.05$. Among the investigated factors, the species composition of weeds had highest influence on the density of weeds (41.15%). The percent of the soil tillage systems was 2.68%. The double interaction of the investigated indices was relatively highest by combination species composition of weeds, soil tillage systems (33.32 %), followed by interaction of the species composition of weeds x year conditions (12.14%). The percent of the triple interaction of the investigated factors reached 8.80%.

### Table 2. Significance of independent and combined effects of the investigated factors

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor A. Species composition of weeds</td>
<td>13</td>
<td>163.679</td>
<td>511.449</td>
<td>.000</td>
</tr>
<tr>
<td>Factor B. Soil tillage systems</td>
<td>3</td>
<td>9.596</td>
<td>29.985</td>
<td>.000</td>
</tr>
<tr>
<td>Factor C. Year conditions</td>
<td>5</td>
<td>.871</td>
<td>2.721</td>
<td>.019</td>
</tr>
<tr>
<td>A x B</td>
<td>39</td>
<td>44.187</td>
<td>138.070</td>
<td>.000</td>
</tr>
<tr>
<td>A x C</td>
<td>65</td>
<td>9.662</td>
<td>30.191</td>
<td>.000</td>
</tr>
<tr>
<td>B x C</td>
<td>15</td>
<td>5.145</td>
<td>16.076</td>
<td>.000</td>
</tr>
<tr>
<td>A x B x C</td>
<td>195</td>
<td>2.334</td>
<td>7.292</td>
<td>.000</td>
</tr>
</tbody>
</table>

### Conclusion

The soil tillage system had a significant effect on the species composition and density of weeds in the wheat crop grown after predecessor grain maize. The long-term alternation of plowing with disking together with the application of chemicals for weed control reduced the weed infestation in the wheat crop. The lower weed density under this soil tillage system was not related to variations in composition and relative percent of the individual species in the total weed infestation. The long-term application of systems involving tillage without turning of the soil layer, minimal and no-tillage in crop rotation lead to higher amount of weeds despite the use of chemicals. The reason for this is the greater variability of weed species typical for shallow tillage.

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