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Effect of different types of main soil tillage on the vertical distribution of maize seeds in the soil layer and on the development of the plants

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Abstract. The investigation was carried out during 2008–2010 in the trial field of Dobrudzha Agricultural Institute on slightly leached chernozem. To determine the effect of different types of soil tillage on the vertical distribution of the maize seeds in the soil layer and the subsequent development of plants, the following variants of a stationary field experiment were analyzed: plowing at 24–26 cm, disking in autumn and double cultivation in spring (check variant); cutting at 24–26 cm, pre-sowing treatment with total herbicide (adapted direct sowing); double disking at 10–12 cm accompanied by autumn disking and double spring cultivation. Hybrid Anast was sown at plant density 55 000 plants/ha. The most even vertical distribution of the maize seeds in the soil layer was ensured at adapted direct sowing performed with high quality. Under constant cutting and annual disking, the percent of maize seeds below and above the optimal depth increased in comparison to adapted direct sowing. The variation in the depth of planted seeds was the highest when sowing the seeds in the plowed soil. At planting under conditions of lower temperatures, cutting, adapted direct sowing and disking retarded the rates of germination in comparison to plowing and elongated the developmental stage of maize with 3–5 days. The number of germinating plants under these main types of soil tillage decreased by 6 to 15 %.

Under favorable thermal regime after planting, the rate of germination of maize seeds in the variants with reduction and exclusion of the main soil tillage was 2.2 °C higher than normal (Figure 1). The mean diurnal air temperature in April of 2006, maize needs well cultivated soil which allows quality active vegetative growth of maize occurs were warmer than the precipitation norm. The analysis of the air temperature showed that April, at the end of which emergence of the maize plants occur, was in 2009 cooler than normal (Figure 1). The mean diurnal air temperature in April of 2008 was 2.2 °C higher than normal. The rest of the months when active vegetative growth of maize occurs were warmer than the norm.

The aim of this investigation was to follow the effect of different ways of soil tillage on the vertical distribution of maize seeds in the soil layer and on the development of plants.

Keywords: maize, main tillage of soil, distribution of seeds down the depth profile, plant development

Introduction

The mass introduction of chemicals in contemporary agriculture when growing maize decreased the role of soil tillage in the production technology of this crop. The wide usage of mineral fertilization also imposed the necessity to reconsider the significance of deep plowing as a major means of increasing soil fertility. The function of traditional plowing with turning of the soil layer for weed control was also considerably limited with a view of the currently available rich variety of system contact herbicides used in the growing of maize. According to Klochkov (1986), on the basis of these prerequisites technologies should be developed for growing maize under minimal and nil tillage and soil tillage without turning the soil layer, which would ensure equal or higher yields while significantly reducing labor, fuel and equipment expenses.

According to the data provided by Ilyn (1984) and Shpaar (2006), maize needs well cultivated soil which allows quality distribution of the seeds at planting and their uniform emergence which ensures the unobstructed development of roots in the plow layer and the underlying horizons. Additionally, a number of researchers (Barev, 1975; Holmov, 1990; Milashtenko, 1977) have concluded that a strictly differential approach is necessary with regard to main tillage of soil for maize in accordance with the specific soil conditions and the local micro relief of the land. The officially adopted technology for production of cereals by Klochkov et al. (1988) recommends the optimal planting depth for maize to be 6–8 cm.

The aim of this investigation was to follow the effect of different ways of soil tillage on the vertical distribution of maize seeds in the soil layer and on the development of plants.

Material and methods

The investigation was carried out during 2008–2010 in the trial field of Dobrudzha Agricultural Institute – General Toshevo. The effect of different ways of soil tillage on the productivity of agricultural plants and some physical and chemical characteristics of the slightly leached chernozem soils ([1] FAO, 2002) have been investigated in a stationary field trial initiated in 1987. Crops typical for the region (wheat, grain maize, bean and sunflower) were included in a 6-field crop rotation. According to Yolevsky et al. (1959) the physical properties of the slightly leached chernozem soils determine favorable hydro and air regime.

The sum of vegetation rainfalls (April-August) in 2008 was close to the precipitation norm (Figure 2). In 2009 the sum of vegetation rainfalls was lower. In 2010 the amount of rainfalls was higher than the precipitation norm.

For the purposes of this study the following variants of main soil tillage of maize were chosen:

- Plowing at 24–26 cm, disking in autumn and double cultivation in spring (check);
- Cutting at 24–26 cm, disking in autumn and double cultivation in spring;
- Cutting at 24–26 cm, pre-sowing treatment with total herbicide (adapted direct sowing);

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according to developmental stages on 50 plants in 4 replications. The statistical processing of data was done with the help of SPSS 16.0 and Microsoft Excel 2007.

Results and discussion

Distribution of the seeds in the soil layer

The distribution of the seeds in the soil layer is determined by the quality of the soil tillage with respect to the size of soil units and the uniformity of the depth of its performance, as well as by the presence of plant residues. The data characterizing the vertical distribution of the seeds in soil subjected to various ways of tillage for main and pre-sowing preparation for maize showed that within the optimal depth (6–8 cm), the greatest amount of seeds were planted after adapted direct sowing, and the lowest – after main tillage of soil performed as disking (Figure 3). At depth lower than the favorable, double disking at depth 10–12 cm accompanied by autumn the highest number of seeds were registered after disking: a total of disking and double spring cultivation.

Sowing was done with pneumatic seeder for root crops. Hybrid Anasta was sown at density 55000 plants/ha. The depth of seed planting was determined after the end of germination by measuring the etiolated part of the stems of the uprooted plants at grouping interval of 1 mm. Since the emergence of the first plants, the dynamics of germination was registered daily. It was expressed as percent from planted seeds. The growth of maize was evaluated according to developmental stages on 50 plants in 4 replications.

The analysis of variances showed that the effect of the main types of soil tillage for maize on the vertical distribution of seeds at

![Figure 1](image1.png)

**Figure 1.** Air temperatures from April to September during 2008–2010

![Figure 2](image2.png)

**Figure 2.** Precipitation sum during the vegetation period (April–August)

- Double disking at depth 10–12 cm accompanied by autumn disking and double spring cultivation.

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**Results and discussion**

*Distribution of the seeds in the soil layer*

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The analysis of variances showed that the effect of the main types of soil tillage for maize on the vertical distribution of seeds at

![Figure 3](image3.png)

**Figure 3.** Distribution of maize seeds along depths according to the type of soil tillage (%)
the respective depths was statistically significant (Table 1). The effect of the investigated factor on the studied character was significant for the 5–6 cm layer at $P = 0.01$, and for all other depths at $P = 0.001$. Duncan’s test allowed following the effect of the respective levels of the tested factor on the investigated agronomy parameter (Table 2). The widest range of vertical scattering of seeds and their subsequent occurrence in a greater number of different groups was observed after disking and plowing. Within a narrower range were distributed the seeds after adapted direct sowing and cutting. The test divided these types of soil tillage into two groups (a and b) according to the different investigated depths. The greater lack of planting depth uniformity after disking due to the shallower distribution of seeds was probably due to the greater compactness of the zone immediately below the cultivated horizon caused by the working parts of the soil tillage tools. The reason for the high percent of seeds planted at depth greater than the optimal after plowing is the insufficient texture stability of the plow layer and its loose structure at the moment of sowing. The applied cutting and the adapted variant of direct sowing eliminated the surface unevenness and contributed to higher soil compaction thus ensuring more uniform depth of seed planting.

### Table 1. Variance analysis of the investigated index (Values of parameter p)

<table>
<thead>
<tr>
<th>Depth, cm</th>
<th>3–4 cm</th>
<th>4–5 cm</th>
<th>5–6 cm</th>
<th>6–7 cm</th>
<th>7–8 cm</th>
<th>8–9 cm</th>
<th>9–10 cm</th>
<th>over 10 cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Significant</td>
<td>.000</td>
<td>.000</td>
<td>.003</td>
<td>.000</td>
<td>.000</td>
<td>.001</td>
<td>.000</td>
<td>.001</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Index</th>
<th>Plow at 24–26 cm</th>
<th>Cutting at 24–26 cm</th>
<th>Adapted no-till</th>
<th>Disking at 10–12 cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groups (Values)</td>
<td>a (0.0)</td>
<td>b (5.7)</td>
<td>a (19.3)</td>
<td>a (22.5)</td>
</tr>
<tr>
<td></td>
<td>b (4.9)</td>
<td>a (14.8)</td>
<td>b (25.2)</td>
<td>a, b (26.4)</td>
</tr>
<tr>
<td></td>
<td>(27.5)</td>
<td>a, b (28.0)</td>
<td>a, b (26.7)</td>
<td>a, b (23.2)</td>
</tr>
<tr>
<td></td>
<td>b (13.2)</td>
<td>a, b (26.7)</td>
<td>b (12.9)</td>
<td>a (7.2)</td>
</tr>
<tr>
<td></td>
<td>c (8.5)</td>
<td>b (12.3)</td>
<td>b (4.7)</td>
<td>a (1.8)</td>
</tr>
<tr>
<td></td>
<td>c (5.9)</td>
<td>b (4.5)</td>
<td>a (0.0)</td>
<td>a (0.0)</td>
</tr>
</tbody>
</table>

The dynamics of germination after the respective types of soil tillage was followed under various mean diurnal temperatures during the period between sowing and germination (Figure 4). Under mean diurnal temperature of 9.3°C the germination after cutting and adapted direct sowing began later and occurred at lower rate. Under this temperature, 17 days after sowing, the emerging plants were 68% after plowing, 51% after cutting, 42% after adapted direct sowing and 28% after constant disking. The lower percent of emerging plants in the observed variants of main soil tillage as compared to plowing under these mean diurnal temperatures was probably due to the lower viability of seeds as a result of the less favorable thermal and aeration soil conditions caused by the above types of tillage.

*Germination and growth of plants*

<table>
<thead>
<tr>
<th>Days after sowing</th>
<th>0</th>
<th>5</th>
<th>7</th>
<th>11</th>
<th>13</th>
</tr>
</thead>
<tbody>
<tr>
<td>% of emerged plants</td>
<td>0</td>
<td>15</td>
<td>30</td>
<td>45</td>
<td>60</td>
</tr>
<tr>
<td>% of emerged plants</td>
<td>15</td>
<td>30</td>
<td>45</td>
<td>60</td>
<td>75</td>
</tr>
</tbody>
</table>

*Figure 4. Dynamics of maize emergence after different soil tillage (%)*
The variation in the depth of seed planting was the highest after sowing and annual disking. Seven days after sowing the emerging plants were 50% after plowing, 55% after cutting, 60% after adapted direct sowing and 62% after disking. On day 11, the rate of germination became even and the stage was concluded simultaneously, at comparatively equal percent of emerging plants after all main soil tillage types. The more intensive emergence after the reduced number of tilths and nil tillage under favorable temperature regime after sowing can be explained by the more compact bed and the better contact of seeds with the soil, and by the available soil moisture. The comparison of the data on germination under the two thermal regimes showed that under insufficient temperature the percent of emerging plants after all types of main soil tillage was lower. After plowing and cutting, under unfavorable thermal regime, the emerging plants were by 9% and 13% less than the percent of emerging plants under conditions of sufficient warmth during the period between sowing and germination. After adapted direct sowing and annual disking, these differences were higher reaching 17% and 24%, respectively.

The growth parameters (Table 3) showed variations in plant height depending on the types of soil tillage during the earlier developmental stages. At stage 5–7 leaf of maize, plants were the highest after main soil tillage performed as disking and the shortest—after adapted direct sowing. After plowing and cutting plant height was comparatively uniform. At stage 10–11 leaf plants were the shortest after disking and the highest after plowing. The variations were significant at P = 0.001. At this stage of the vegetative development of maize, this index was with comparatively equal values for cutting and adapted direct sowing. At silking stage the plants were the shortest after annual disking—statistically significant at P = 0.01. After adapted direct sowing the highest plant height of maize was measured. Plowing and cutting ranked second according to this index. The more depressed plant height after main soil tillage performed as disking was accompanied by smaller stem diameter measured at 10–11 leaf and silking stages. Stems had the highest diameter after adapted direct sowing followed by cutting and plowing. The variations, however, were not statistically significant.

### Table 3. Effect of soil tillage on stem height and diameter at different stages of maize plant development

<table>
<thead>
<tr>
<th>Soil tillage</th>
<th>Plant height, cm</th>
<th>Stem diameter, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5–7 leaf stage</td>
<td>10–11 leaf stage</td>
</tr>
<tr>
<td>Plowing at 24–26 cm</td>
<td>18.7</td>
<td>60.3</td>
</tr>
<tr>
<td>Cutting at 24–26 cm</td>
<td>18.4</td>
<td>56.5</td>
</tr>
<tr>
<td>Adapted no–till</td>
<td>18.0</td>
<td>57.6</td>
</tr>
<tr>
<td>Disking at 10–12 cm</td>
<td>20.5</td>
<td>47.7</td>
</tr>
<tr>
<td>Gd</td>
<td>2.54</td>
<td>4.91</td>
</tr>
<tr>
<td></td>
<td>3.85</td>
<td>7.43</td>
</tr>
<tr>
<td></td>
<td>6.18</td>
<td>11.95</td>
</tr>
</tbody>
</table>

a, b, c – Statistical significance of F for rates 5, 1 and 0.1 %, respectively

The most even vertical distribution of the maize seeds in the soil layer was ensured by adapted direct sowing done with high quality. In comparison, after constant cutting and annual disking, the percent of maize seeds planted above and below the optimal depth increased. The variation in the depth of seed planting was the highest after sowing of maize in plowed soil.

After sowing under lower temperatures, cutting, adapted direct sowing and disking lead to retarded rate of emergence in comparison to plowing and elongated the developmental stage of maize with 3–5 days. The number of emerging plants after these types of main soil tillage decreased by 6% to 16%. Under favorable thermal regime after sowing, the rate of germinating of the maize seeds in the variants with reduced main soil tillage was more intensive only at the beginning. The duration of the emergence stage and the percent of emerging plants were equal at all types of tillage.

At the early stages of maize development, the rate of plant growth in height was the most intensive after shallow main tillage performed as disking. With the advance of the vegetative development of the crop, after adapted direct sowing, plowing and cutting, the stems of the plants were with greater height and diameter in comparison to annual disking.

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