Soil density, soil moisture content and maize yield using No-till technology of cultivation

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Abstract. The research was carried out at the experimental field of the North Caucasus Federal Research Center. In the field, years of experience, founded in 2012, in crop rotation of soybean-winter wheat-sunflower-corn all crops cultivated on the recommended scientific institutions technology soil treatment, and these same crops in the same crop turnover has grown by No-till technology. The recommended technology of maize cultivation consisted of soil double tillage by the heavy disk tools to the depth of 0.120-0.140 m immediately after harvesting the previous sunflower, winter plowing at 0.200-0.220 m, early spring harrowing, pre-sowing cultivation and sowing with an Optima seeder. In the No-till technology, the soil was not treated and ten days before corn sowing, the plots were sprayed with a continuous herbicide Rap 600 at a dose of 2 l/ha. The research showed that better accumulation and conservation of moisture can be provided during the flowering of maize with the content in the soil layer of 1.5 m at the depth of 34 mm, or 18.1% more moisture than usage of the technology with tillage which is recommended by scientific institutions. It contributes to a significant increase of 0.42 t/ha, or 12.0% in crop yield by using this technology.

1. Introduction
Maize is one of the most important agricultural crops as it has high yield potential and wide versatility of use. Therefore, maize is widely used in world agriculture and in our country, the sown area is 1.5-1.8 million hectares. In the Stavropol Territory it annually occupies 150-180 thousand hectares [1, 2, 3].

Maize is cultivated according to the technologies which are recommended by scientific institutions with the use of primary, secondary and pre-sowing tillage. During the growing period, inter tillage is also carried out [4, 5]. Their purpose is to create optimal water and physical soil features which provide favorable conditions for plant growth and obtaining high crop yield [6, 7, 8].

However, nowadays No-till farming [9], when the soil is not cultivated [10, 11], is becoming more and more widespread. That is why there is a great scientific and practical interest to create water and physical soil features that are optimal for the growth and development of maize plants. In this regard, the purpose of our research is to determine the effect of No-till technology on soil density, accumulation and conservation of precipitation moisture in it and maize yield in the unstable moisture zone in the Stavropol Territory [12].

2. Materials and methods
The research was carried out on the experimental field of the North Caucasus Federal Agrarian Research Centre in the unstable moisture zone in the Stavropol Territory. The sum of effective tempera-
tures here is 3306 °C and annual rainfall is 558 mm. The soil of the experimental area is ordinary, medium deep, slightly humosed, hard loamy chestnut soil formed on loess, calciferous loam.

In the field long-term experiment which was started in 2012, in the crop rotation of soybean – winter wheat – sunflower – maize, all the crops were cultivated according to the technology of soil treatment which was recommended by scientific institutions. The same crops were grown in the same crop rotation using the No-till technology, in which the soil was not cultivated.

The recommended technology for maize cultivation included double tillage with heavy disc tools to the depth of 12-14 cm immediately after harvesting of previous sunflower, fall tillage to 20-22 cm, early-spring harrowing, pre-seeding cultivation and seeding by the seeder Optima. In the No-till technology, the soil was not cultivated and the working plots were sprayed with non-selective herbicide Rap 600 at the dose of 2 l/ha, ten days before maize was sown. The seeding operations were performed by the Gimetal seeder equipped with corrugated disks (coulter, turbo disc) that cut a narrow gap in the soil, where seeds and fertilizers are embedded to the desired depth with two-disc coulters.

In both technologies, Mashuk-250 hybrid was sown. The seeding rate was 75 thousand viable seeds per 1 ha, the row width was 70 cm, the seed depth was 6-7 cm. Along with seeding, NPK-compound was applied at the dose of N32P12K32 (ANP fertilizer, 200 kg/ha). In the 4-5 leaf stage of maize crops were sprayed with herbicide Maister Power at the dose of 1.25 l/ha. Crop accounting, observations, and mathematical processing of the obtained data were performed by using standard experimental methods.

During the research years, the weather conditions had their own characteristics and differed from year to year. In terms of precipitation, 2016 and 2017 were more humid when 639 and 641 mm fell with the average annual precipitation of 558 mm. In 2018 multi-year amount (544 mm) fell, 2019 year was dry – 380 mm and 2020 was acutely dry, when only 307 mm of precipitation fell during the year.

3. Results and discussion

In the No-till technology, soil density is very important since the growth and development of cultivated plants, especially the root system as well as the accumulation and conservation of moisture in the soil, largely depend on it. For the years of our experiments, during the seeding of maize, average density of the soil layer of 0-10 cm was 0.99, the soil layer of 10-20 cm was 1.08 g/cm³. In No-till technology, the soil was slightly denser 1.13 and 1.19 g/cm³, respectively. Nevertheless, it was within the optimal range for emerging crops and initial growth of maize plants.

By the maize flowering stage, the soil density of both technologies and all the studied layers increased but it was at optimal range (Table 1).

| Technology | Soil layer, cm | 2016 | 2017 | 2018 | 2019 | 2020 | Average |
|------------|---------------|------|------|------|------|------|---------|
| Recommended | 0-10          | 1.16 | 1.15 | 1.01 | 1.24 | 1.29 | 1.17    |
|            | 10-20         | 1.23 | 1.19 | 1.17 | 1.45 | 1.42 | 1.29    |
|            | 20-30         | 1.29 | 1.20 | 1.30 | 1.46 | 1.45 | 1.34    |
| No-till    | 0-10          | 1.20 | 1.29 | 1.08 | 1.29 | 1.28 | 1.23    |
|            | 10-20         | 1.32 | 1.32 | 1.20 | 1.47 | 1.36 | 1.33    |
|            | 20-30         | 1.33 | 1.35 | 1.28 | 1.48 | 1.38 | 1.36    |
| LSD0.05    | 0.06          | 0.07 | 0.06 | 0.08 | 0.07 | 0.06 |         |

However, there was a compaction effect of soil layers of 10-20 and 20-30 cm in the dry years of 2019 and 2020, using both technologies. We associate it with droughts in these years during the growing season of plants. This is evidenced by the decrease in soil density by the time of firm ripe stage with precipitation in 2016 and 2018, and in 2017, 2019 and 2020 there was no precipitation and the
soil density did not decrease – it was higher than optimal rate.

In the arid Stavropol Territory, the first soil sample has the amount of moisture which largely determines the yield of cultivated crops. During the years of our experiments by the time of maize seeding, the 1.5 m soil layer, according to the recommended technology, contained on average 188 mm of productive moisture, while according to the No-till technology it was 222 mm, which was 34 mm, or 18.1% more.

By the maize flowering stage, the differences increased even more in favor of the No-till technology and amounted to 40.0%, especially in dry 2019 and acutely dry 2020 (Figure 1).

![Figure 1](mm)

**Figure 1.** The content of productive moisture in the 1.5 m soil layer during maize flowering.

Large content of productive moisture in the soil during maize flowering occurs for two reasons. The first one is the presence on the soil surface of previous crop residues, which let the moisture of atmospheric precipitation pass through easily but prevent its evaporation from the soil surface.

The second reason is also plant residues which cover the soil surface and have a light color. They reflect and do not transmit the rays of sun, thereby lowering the soil temperature by 3-5 °C. Therefore, according to the No-till technology, maize seedlings appear 2-3 days later and they grow and increase the green weight of top much slower than according to the traditional technology. Due to the slower growth rates, they consume significantly less water from the soil than well-developed and leafy maize plants growing according to the recommended technology.

For this reason, according to the recommended technology, by the time of flowering maize plants experience the lack of water, which is evident in leaf roll disease, icterus of lower leaves and occurring of soil cracks. Maize plants using direct seeding technology, which in the first half of the growing season had significantly lower green matter, on the contrary, by the time of flowering had good turgor, dark green color, and the soil covered with plant residues did not have cracks. All this had a significant impact on the yield formation.

In all the years of research, the yield of maize using the No-till technology was significantly higher than using the traditional technology and on average over the years of research it amounted to 0.42 t/ha, or 12.0% (Table 2).

The very low maize yield in 2020 was due to the fact that after a dry 2019 year, only 90 mm of precipitation fell from November of this year to March, 2020, which was 128 mm, or 58.7% less than the average long-term amount.

The precipitation that fell from the late May to July, the amount of which was considered as climate normal, did not have a significant positive effect on the growth and plant development according to traditional technology since in July and August atmospheric and soil droughts occurred again when there was no precipitation and the air temperature was 2.3-4.5 °C higher than usual. In such acutely
dry conditions, the yield of maize using the No-till technology, due to the sufficient amount of water for plants, was significantly higher but considerably lower in comparison to other years of research.

Table 2. Influence of cultivation technologies on maize yield, t/ha.

| Technology       | 2016 | 2017 | 2018 | 2019 | 2020 | Average | Increment t/ha | %  |
|------------------|------|------|------|------|------|---------|----------------|----|
| Recommended      | 5.69 | 4.04 | 2.45 | 4.07 | 1.31 | 3.51    | -              | -  |
| No-till          | 5.71 | 4.24 | 3.10 | 4.46 | 2.11 | 3.92    | 0.42           | 12.0|
| LSD05            | 0.16 | 0.21 | 0.09 | 0.13 | 0.07 | 0.21    | -              | -  |

4. Conclusions

Cultivation of maize using the No-till technology does not lead to over compaction of ordinary chestnut soil and better accumulation and conservation of moisture in the soil provides significantly higher crop yield than using traditional technology.

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