The influence of the tillage method on watermelon yield under wind erosion

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Abstract. The article presents the results of comparison of the methods of spring tillage for melons in the steppe ilmeni on the Baer hillocks. Agrophysical soil properties, wind resistance, weediness and yield were determined. During the growing of watermelon sprouts, the microaggregate soil structure was wind–unstable. In crops of watermelon cultivated after plowing and deep flat–cutting cultivation, a 2.6–2.8–fold decrease in the number of weeds was observed. The highest yield of Astrakhan was obtained as a result of spring tillage – 42.1 t/ha and deep plane–cutting – 41.3 t/ha. Flat–cutting treatment and the use of the fallow preserved the stubble and contributed to a 5–11–fold reduction in sand transfer under the influence of wind.

1. Introduction
The Russian Southern Federal District, including Astrakhan oblast, plays a leading role in the production of watermelon. Agricultural plants with such universal application as melons are rarely found in nature; they are used for pickling and other types of canning. Fruits of melons have a high nutritional value and excellent taste [3, 5, 7].

In 2015–2017, in Russia, the average annual per capita consumption of vegetables and melons increased by 28.7 % (from 87 to 112 kg), in Astrakhan region, it increased by 24.4 % (from 135 to 168 kg at the recommended rate of 140 kg) [9]. Watermelon is the main melon crop [2].

One of the main technological operations aimed to ensure the stable crop yield is soil cultivation. It is being improved to increase soil fertility, destroy weeds and improve phytosanitary conditions [1, 8, 11]. In the arid regions of southern Russia, the main task of the soil tillage system is accumulation and preservation of moisture to create optimal conditions for the growth and development of cultivated crops [6, 12, 13].

The purpose of the research is to study the influence of various methods of the main spring tillage of watermelon under conditions of western steppe ilmeni on physical soil characteristics of the soil, taking into account the wind erosion, the species composition of weed flora, and the yield.

2. Methods and materials
In 2015–2017, we studied the effect of various methods of primary cultivation on physical soil parameters, weediness, plant growth, yield of Astrakhan watermelon (VNIIOOB selection). The following treatment methods were studied: I and II – spring plowing to a depth of 0.25–0.28 m with a PLN–4–35 plow; III – spring flat cutting to a depth of 0.25–0.28 m by the KPG–250 cultivator–plane cutter–deep–ripper; IV – spring flat cutting to a depth of 0.08–0.12 m; V – "zero" treatment. In option
I (control), weed control, jumper crafts were carried out manually; in options II–V, the KNB–5.4 cultivator was used. The watermelon sowing scheme was 1.8 x 1.05 m. There were no differences in plant density (5.2 thousand plants/ha) in the experimental options. In the steppe ilmeni on the Baer hillocks, the main tillage is carried out in spring before sowing. This is due to the fact that in the autumn–winter period, sandy soils are subject to wind erosion – blowing and transfer of soil particles of less than 1.0 mm. It is known that in the presence of such particles in the soil, the soils lose their wind resistance. Wind erosion is very dangerous, where there is no stubble and plant debris. Soil erosion during the emergence of watermelon seedlings is especially dangerous [11]. The total area of the plot is 6000 m², the accounting area is 113.4 m². Repeatability is three times. The soil density (t/m³) was determined by the cutting ring method. A micro–aggregate analysis was carried out by the sieve swing method according to N.M. Bishkeev. Plant density, the number of weeds and the yield were recorded. Mathematical processing of experimental data was performed by the analysis of variance [4].

3. Results
The study of the soil showed that in the microaggregate structure of the surface soil layer (0.00–0.05 m) during the watermelon sprouting period, in all options, the dominant fraction was particles smaller than 1.0 mm in size. Their share was 73–81 %. Moreover, the fraction of particles of less than 0.25 mm was 62–66 %; in case of the deep plow cutting, it was 51 %; in case of shallow flat cutting, it was 39 %. In the fallows, the share of such particles was 32 %. There were 6–18 % of large particles (more than 3.0 mm) depending on the option (Table 1).

Table 1. Structural composition of soil depending on the method of basic soil treatment and the phase of plant development (2015–2017).

| Option | The content of fractions, % and particle size, mm |
|--------|-----------------------------------------------|
|        | up to 0.25 mm  | 0.25–1 mm  | 1–2 mm  | 2–3 mm  | 3–5 mm  | 5–7 mm  | 7–10 mm |
| Watermelon seedlings | | | | |
| I (c.) | 66 | 9 | 4 | 5 | 4 | 3 | 9 |
| II | 62 | 11 | 4 | 5 | 3 | 4 | 11 |
| III | 51 | 30 | 6 | 6 | 3 | 2 | 2 |
| IV | 39 | 42 | 7 | 2 | 2 | 4 | 4 |
| V | 66 | 9 | 4 | 5 | 4 | 3 | 9 |
| Flowering | | | | | | | |
| I (c.) | 44 | 10 | 11 | 11 | 9 | 7 | 8 |
| II | 45 | 10 | 11 | 10 | 9 | 8 | 7 |
| III | 29 | 18 | 19 | 9 | 8 | 7 |
| IV | 20 | 18 | 19 | 20 | 9 | 7 | 7 |
| V | 13 | 21 | 16 | 23 | 10 | 9 | 8 |
| Harvesting | | | | | | | |
| I (c.) | 36 | 20 | 17 | 15 | 7 | 3 | 2 |
| II | 31 | 11 | 22 | 17 | 6 | 5 | 8 |
| III | 22 | 11 | 18 | 22 | 12 | 7 | 8 |
| IV | 20 | 17 | 22 | 19 | 12 | 6 | 4 |
| V | 11 | 21 | 22 | 29 | 10 | 5 | 2 |

Thus, during the emergence of watermelon sprouts on the soils of the western steppe ilmeni (Baer hillocks), the probability of wind erosion is very high, especially when plowing and deep treating with a plane cutter.

An analysis of the soil structure carried out in the flowering phase revealed changes in the distribution of fractions by the particle size. In all options, the content of particles of less than 1.0 mm and especially less than 0.25 mm sharply decreased. In case of plowing, this decrease was 18–21 %; in case of flat–cutting treatment, it was 42–43 %. Despite a slight decrease in the number of particles of less than 1.0 mm, their share was 54–55 %, which was a high level and dangerous for the occurrence
of wind erosion. In case of flat–cutting treatment, the share of particles of less than 1.0 mm was
34–39 %, which can cause the soil erosion.

By density of the solid phase in the layers of 0.0–0.2 m and 0.2–0.4 m, differences were observed in
the experimental options depending on the type of treatment. The lowest density values were observed
after plowing and deep treatment with a plane cutter – 1.26–1.32 t/m$^3$ in the layer of 0.0–0.2 m and
1.44–1.50 t/m$^3$ in the layer of 0.2–0.4 m. The soil was much denser in the options with shallow flat–
cutting (1.51 and 1.73 t/m$^3$) and fallows (1.64 and 1.75 t/m$^3$). Spring plowing and flat–cutting to a depth
of 0.25–0.28 m reduced the density 1.14–1.19 times in a layer of 0.0–0.2 m and 1.15–1.20 times in a
layer of 0.2–0.4 m, compared with shallow treatment with a plane cutter; 1.24–1.30 times in a layer of
0.0–0.2 m and 1.16–1.20 times in a layer of 0.2–0.4 m.

During the harvesting period, differences in density between the options were insignificant. The
density of the solid phase was close to the initial value in the fallows.

When cultivating watermelon, the best conditions for its growth are light, well–loosened soils with
a lower density of the solid phase [10]. Therefore, the appropriate tillage methods are plowing and
deep treatment with a plane cutter.

The study of wind erosion by the trap method showed that there was a significant difference in the
wind resistance of the field surface depending on the method of primary tillage. In 2015, deep
treatment by a plane cutter reduced sand transport 8 times compared with plowing; small–plane
treatment reduced it 19 times; the untreated fallow reduced it 28 times. In 2016–2017, in the options
involving plane–cutting treatment and fallows, the wind transfer of particles was 3–4 times weaker
than in options involving plowing. It was due to the preserved stubble.

The main weeds were *Amaranthus retroflexus* L., *Chenopodium album* L., *Poa annua* L., *Avena
fatua* L., *Elytrigia repens* L. The most effective weed reduction was observed in options involving
spring plowing and deep treatment with a plane cutter (Table 2).

| Option | 2015 | 2016 | 2017 | Average | % of the control |
|--------|------|------|------|---------|-----------------|
| I (control) | 12 | 17 | 51 | 26.7 | 100.0 |
| II | 16 | 13 | 42 | 23.7 | 88.8 |
| III | 11 | 21 | 45 | 25.6 | 95.9 |
| IV | 32 | 34 | 67 | 44.3 | 165.9 |
| V | 74 | 57 | 71 | 67.3 | 252.0 |
| HCP _0.05_ | – | – | – | 17.8 | – |

Compared to the fallow, during the period of watermelon sprouting, the amount of weed vegetation
decreased 2.6–2.8 times, and shallow treatment reduced the weediness 1.5 times.

According to the yield of standard watermelon fruits, agrotechnical methods showed the following
results. The mechanized treatment with a plow cutter, the highest yield was 41.3–42.1 t/ha against
37.3 t/ha in the control option. An increase in the yield was due to the quantity and the size of
watermelon fruits (Table 3).

| Option | 2015 | 2016 | 2017 | Average | % of the control | Average mass of one fruit, kg |
|--------|------|------|------|---------|-----------------|-----------------------------|
| I (control) | 29.8 | 47.5 | 34.6 | 37.3 | 100.0 | 5.1 |
| II | 34.9 | 51.8 | 39.7 | 42.1 | 112.9 | 6.2 |
| III | 37.6 | 36.0 | 50.2 | 41.3 | 110.7 | 6.7 |
| IV | 34.6 | 31.3 | 49.5 | 38.5 | 103.2 | 5.8 |
| V | 29.9 | 35.8 | 46.8 | 37.5 | 100.5 | 5.3 |
| HCP _0.05_ | – | – | – | 2.6 | – | – |
4. Conclusion
During the emergence of watermelon sprouts, the microaggregate soil structure, regardless of the type of pre-sowing treatment, was wind-resistant. The share of particles with a size of 1.0 mm and less was 73–81 %, which caused the risk of wind erosion and required the implementation of anti-erosion measures. Spring plowing and flat-cutting tillage to a depth of 0.25–0.28 m reduced density of the solid phase 1.14–1.19 times in a layer of 0.0–0.2 m and 1.15–1.20 times in a layer of 0.2–0.4 m, compared to shallow treatment with a plane cutter; 1.24–1.30 times in a layer 0.0–0.2 m and 1.16–1.20 times in a layer 0.2–0.4 m – compared with the fallow. When plowing and deep plane-cutting, the number of weeds decreased 2.6–2.8 times, which created the best conditions for the growth and development of watermelon plants throughout the growing season. Plowing and treatment with a plane cutter to a depth of 0.25–0.28 m with further mechanized anti-erosion measures contributed to the highest yield of watermelon fruits, exceeding the control one by 11–13 %. The flat-cutting and the fallow kept the stubble and reduced sand transfer 5–11 times compared with the plowing.

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