Influence of agro-technical reception on agro-physical state of soil and efficiency of cultivation of sugared sorghum in conditions of light-chestnut soil of Volgograd region

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Influence of agro-technical reception on agro-physical state of soil and efficiency of cultivation of sugared sorghum in conditions of light-chestnut soil of Volgograd region

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Abstract. The key problem of modern farming is the search for an alternative to traditional arable farming, which leads to a permanent decline in soil fertility, primarily to a decrease in organic matter and significant loss of moisture. The study was aimed at studying the effect of waste and zero tillage on the agro-physical indicators of the soil, yield, sugar accumulation dynamics and the economic efficiency of cultivation of a sugar sorghum hybrid Slavic homestead. The experience was conducted in Commercial Farmers Association “Kuznetsovskaya”, Ilovlinsky District of the Volgograd Region, on zonal subtypes of light chestnut soils in the period from 2009 to 2015. Research methods were used according to generally accepted methods and recommendations. When considering the effect of treatments on soil density, there was an increase in soil compaction due to zero tillage. When determining the state of aggregation of soil by zero tillage, the number of valuable aggregates was 69.43 % versus 65.43 % for land tillage. The coefficient of structure was zero tillage. The yield of sugar sorghum amounted to 54.7 t/ha, which showed an increase of 7 % relative to dump soil treatment. The zero tillage profitability ratio was 104 %. The transition to zero processing will provide increased productivity, reduce the need for labor and technology, reduce the time for field work, make it more optimal, increase the income of agricultural enterprises, increase the wages of workers and improve their social conditions, which is an important economic and social advantage of resource-saving technology.

1. Introduction

One of the main tasks of agriculture at the present stage of development of the agro-industrial complex is the steady increase in agricultural production. This can be achieved, first of all, through the widespread use of intensive technologies, through the use of a set of measures for the cultivation of various sugar-containing crops [1].

Under the conditions of intensification of farming, among the numerous agro-technical methods, tillage is given a leading role in the formation of the crop, since it is a universal means of influencing many physical, chemical and biological properties of the soil [2].

2. Materials and methods

The relevance of the study is the study of the cultivation of a hybrid of sugar sorghum Slavic homestead on the dump and zero tillage in the conditions of the Lower Volga region.

Objective: to study the effect of waste and zero tillage on the density, aggregate composition, criterion of water strength of soil aggregates, yield and economic efficiency of the production of sugar sorghum.
Tasks:
- determine the effect of soil treatments on the agro-physical state of the soil;
- determine the yield of sugar sorghum on the dump and zero soil treatments;
- compare the direct costs in case of waste and zero tillage in the cultivation of sugar sorghum;
- calculate the profitability of the cultivation of sugar sorghum.

The object of the study is the tillage system (dump and zero) and the hybrid of sorghum Slavic Household.

The studies were conducted in Commercial Farmers Association «Kuznetsovskaya», Ilovinsky district of the Volgograd region, on zonal subtypes of light chestnut soils in the period 2009-2015. Experience one-factor was conducted four times.

Research methods are based on generally accepted methods and recommendations developed by leading research institutions. Determination of the economic efficiency of cultivation was carried out at actual cost using a routing.

The forerunner in the experiment was winter wheat. After harvesting the predecessor, the field began to be prepared immediately for the soil tillage for sugar sorghum. At the experimental plot, the PNO-3 was plowed to a depth of 0.22–0.25 m, with the emergence of weeds. In the spring, care began with early spring harrowing in two tracks with BDT - 10 harrows in an aggregate with an Agromash-90 TG tractor. Depending on the weediness of the research year, 2 cultivations were carried out with a KPS-4 cultivator to destroy weeds and mulch the upper fertile layer. The first cultivation was carried out to a depth of 0.10-0.12 m, and the second pre-sowing was carried out to a seed embedment depth of 0.06-0.08 m. Sorghum was sown with a steady warming of the soil at a depth of seeding to 12-14°C, which was the first or second decade of may. Sowing was carried out broadbly, with a row spacing of 0.70 m, with a seeder SUPN-8 to a depth of 0.07 m, with a seed rate for sugar sorghum 160 thousand viable seeds per hectare.

For destruction of weeds 4-5 days after sowing, pre-emergence harrowing of BZSS-1.0 was performed. The first inter-row treatment was started when rows of shoots were designated. The total number of treatments was determined based on weather conditions, soil conditions and the presence of weeds (3-5 cultivations during the growing season). The treatment depth was 0.08–0.10 m. The second cultivation was carried out after 3 weeks, when weeds appeared earlier. To control weeds, the crops were sprayed with a “Keritox” sprayer with the Luvaram herbicide at the rate of 1-2 l/ha in the phase of formation of 3-5 leave. In due time, the harvest was carried out by a forage harvester - KSK-600 Combine, manufacturer “Polesye” [3].

The second technology is the use of zero processing, i.e. the rejection of all types of tillage, including only the system of plant protection, especially weeds, pests and diseases. The main principles of this treatment are the preservation and accumulation of crop and root residues on the soil surface, the development and use of crop rotations, including profitable crops and cultures that improve the potential fertility of the soil, the use of high-quality seed material: varieties and hybrids adapted to zone conditions [4].

With zero treatment since autumn, when weed vegetation appeared, the treatment of stubble with a continuous action herbicide of tornado 200 at the rate of 2 l/ha was used, the working fluid consumption rate was 200 l/ha. At this autumn-winter agro-technical activities ended. In the spring, in the event of the appearance of weeds, the stubble was re-treated with a continuous-action herbicide. Sowing was carried out at the same time as for the dumping treatment of the MTZ-1221 tractor with a Gimetal direct-seeder equipped with cutting disc coulters to provide minimal mechanical impact on the soil. Weed control was carried out in the same phase and at the same dosage with dump processing. In a timely manner, the harvest was done.

3. Influence of agro-technical methods on sugar sorghum crops and the results obtained
In the experiments, the density of the soil on waste processing was lower than on zero treatment. During the years of research on the experimental plot, the density of the soil before sowing sugar sorghum in a layer of 0.0–0.1 m was 1.09 t/m³. The lower lying layer of the arable layer, despite the use of tillage,
had a greater density value – 1.20 t/m³. The soil layer of 0.2-0.3 m was more compacted, and had a density of 1.25 t/m³.

The density of the soil on zero tillage was higher than on dump soil tillage. When sowing sorghum, the seeder loosened only the top layer of the soil, to the depth of sowing of seed (0.06-0.08 m). The rest of the soil horizon was not affected, and had a denser state than by dump tillage. Before sowing sugar sorghum, the soil density for zero tillage was 1.26 t/m³ in a layer of 0.0–0.1 m, 1.34 t/m³ in a layer of 0.1–0.2, and 1.00 t/m³ in a layer of 0.2–0.3 (table 1).

Table 1. Effect of cultivation technology on soil density on sugar sorghum crops, t/m³ (average 2009-2015)

| Soil layer, m | Before sowing | Before harvest | Average | Before sowing | Before harvest | Average |
|--------------|---------------|----------------|---------|---------------|----------------|---------|
| 0.0-0.1      | 1.09          | 1.16           | 1.13    | 1.26          | 1.33           | 1.29    |
| 0.1-0.2      | 1.20          | 1.26           | 1.23    | 1.34          | 1.39           | 1.37    |
| 0.2-0.3      | 1.25          | 1.29           | 1.27    | 1.39          | 1.45           | 1.42    |
| 0.0-0.3      | 1.18          | 1.24           | 1.21    | 1.33          | 1.39           | 1.36    |

Re-determination of the density was carried out at the end of the growing season of sugar sorghum. Soil compaction in the studied soil horizon was observed for both treatments. According to the zero tillage, the density of addition was higher; in the layer of 0.0-0.1 m it was 1.33 t/m³, in the layer of 0.2-0.3 m – 1.45 t/m³, which is 0.17 and 0.16 t/m³ more than in the studied layers by dump processing soil.

For all years of research, the density of the soil for zero treatment during the entire growing season is more dense. At the same time, the greatest increase in density was observed from 2009 to 2013, because at this time there was no tillage, no destruction of the soil horizon. On the 6-7 year of research, the density in the arable horizon of 0.0-0.1 m decreased by 0.01 t/m³ as a result of the accumulation of plant residues on the field.

A comparative analysis of the two soil treatments, dump and zero, concluded that an increase in soil compaction was observed with respect to zero soil treatment. After zero tillage, a direct dynamics of soil compaction was observed in the cultivation of crops. In the study of the aggregate composition of soil and water-resistant aggregates, differences were observed in the variants of tillage (table 2).

Table 2. Influence of the cultivation technology on the aggregate composition of the soil on the crops of sugar sorghum (average 2009-2015)

| Soil treatment | Soil layer, m | More 10 mm | 10-0.25 mm | Less 0.25 mm | KS |
|---------------|---------------|------------|------------|-------------|----|
| Dump tillage  | 0.0-0.1       | 19.9       | 63.0       | 17.1        | 1.70 |
|               | 0.0-0.2       | 22.0       | 65.9       | 12.1        | 1.93 |
|               | 0.2-0.3       | 23.9       | 67.4       | 8.7         | 2.07 |
| Zero-tillage  | 0.0-0.1       | 22.2       | 67.6       | 10.3        | 2.09 |
|               | 0.1-0.2       | 23.9       | 69.7       | 6.3         | 2.31 |
|               | 0.2-0.3       | 25.2       | 71.0       | 3.8         | 2.45 |

In our studies, the evaluation of the aggregate composition of the soil in a layer of 0.0–0.3 m was characterized according to the classification by A.Okolelova, as good by both technologies. At the beginning of the laying of experience (2009), the number of valuable soil aggregates in the 0.0-0.3 m layer was in the amount of 66.5 % by mold processing, at the end of the experiment (2015) – 64.4 %. The aggregative state of soils was estimated as excellent by the value of the structural coefficient. The maximum COP value for moldboard processing was in the 0.2-0.3 m layer – 2.07, which is 0.37 more than in the 0.0-0.1 m layer. A pattern was observed: an increase in agronomically valuable aggregates
increased the coefficient of structure. In 2009, in the 0.0–0.1 m layer, the number of valuable aggregates for soil tillage amounted to 64.2 %, COP — 1.79 in layer 0.2–0.3 m, valuable aggregates — 68.5 %, COP — 2.17. In 2015 for moldboard processing, the number of units with a size of 10–0.25 mm in a layer of 0.0–0.1 m contained 61.8 %, KS — 1.62 in a layer of 0.2–0.3 m valuable aggregates — 66.4 % and KS — 1.98. Reducing the number of valuable aggregates was directly dependent on the effect of tillage, mechanical impact on the soil led to a decrease in valuable aggregates of the soil [5].

The method of tillage had a significant impact on the aggregate composition of the soil. According to the zero tillage technology at the beginning of the experiment, in the 0.0-0.1 m layer, the number of valuable aggregates was 65.4 %, KS — 1.89, in the 0.2-0.3 m layer — 69.1 %, and KS — 2.24. By the end of the experiment (2015), the number of valuable aggregates in the 0.0–0.1 m layer was 70.1 %, KS — 2.34, in the 0.2–0.3 m layer — 72.4 % and 2.62, respectively. This treatment shows a tendency to increase the number of agronomically valuable aggregates, which is reflected in the magnitude of the coefficient of structure. From this it follows that the soil treated by zero treatment has a higher potential for structuring compared to soil treated by dump processing.

The most objective indicator of the structural and aggregative state of the studied soils is the assessment of the aggregate water criterion, which takes into account the proportion of air-dry and water-resistant aggregates, and its ability to resist the eroding action of water [6] (Table 3).

**Table 3.** Influence of the cultivation technology on the criterion of water-proof aggregates on the crops of sugar sorghum (average 2009-2015)

| Soil treatment | The content of agronomically valuable aggregates of 1.25 mm, % by weight of dry soil | API criteria |
|----------------|----------------------------------------------------------------------------------|--------------|
|                | air-dry | water resistant |                |                |
| Dump tillage   | 68.6    | 46.5             | 67.7           |
| Zero-tillage   | 73.4    | 52.7             | 71.8           |

The results show that the water resistance is assessed as satisfactory for the variants of both soil treatments throughout the entire observation period, in other words, despite fluctuations in the numerical value of the API and a tendency to increase from 67.7 to 71.8 %, no qualitative changes occurred.

In the case of zero tillage, a positive trend was observed. The water resistance of the structure at the time of the first selection (2009) was 67.76 %, which is characterized, according to the criterion of the API, as satisfactory. Subsequent sampling results in an increase of this indicator above 73 % (2013, 2014, 2015), the difference with control is observed by more than 4 %, which is evidence of improved water resistance of soil segregations, according to the API criterion.

The impact of soil treatments affected not only the agro-physical state of the soil, but also affected the yield of the studied crop (Table 4). The yield of green mass of sugar sorghum on soil tillage, on average for 7 years of research, amounted to 52.4 t/ha. The mass of the panicle with the grain counted 10.7 % of the total mass, the leaves — 11.3 %, the rest of the mass was the stem. On soils treated with zero treatment, an increase was observed according to these indicators: the mass of the panicle with the grain was 6.6 t/ha, the leaves — 6.6 t/ha, the stem — 17.1 t/ha.

**Table 4.** Dependence of the yield of green mass of sugar sorghum from tillage (average 2009-2015)

| Soil treatment | Whisk with grain | Leaves | Stems | Yield of green mass, t/ha |
|----------------|------------------|--------|-------|--------------------------|
|                | t/ha              | %      | t/ha  | %                        | t/ha |
| Dump tillage   | 5.6              | 10.7   | 5.9   | 11.3                     | 40.9 | 78.1 | 52.4 |
| Zero-tillage   | 5.9              | 10.8   | 6.1   | 11.2                     | 42.7 | 78.1 | 54.7 |

Soil tillage had a significant impact on the yield of sugar sorghum over the years (Table 5).
Calculations of the economic efficiency of the production of sugar sorghum showed that for soil treatment, the cost of funds amounted to 51924.6 rubles/ha, for zero soil treatment costs were lower on average by 2400 rubles/ha, which is associated with the smallest number of operations carried out on this treatment soil, herbicide costs compensate for some mechanical operations (table 7). When calculating the coefficient of profitability of the cultivation of sugar sorghum on dump tillage, it was 87 %.

### Table 5. Effect of tillage on the yield of sugar sorghum by year, t/ha

| Soil treatment | 2009   | 2010   | 2011   | 2012   | 2013   | 2014   | 2015   |
|----------------|--------|--------|--------|--------|--------|--------|--------|
| Dump tillage   | 53.5   | 53.5   | 52.4   | 53.0   | 51.2   | 52.1   | 51.1   |
| Zero-tillage   | 49.9   | 50.6   | 51.1   | 53.2   | 57.5   | 58.9   | 61.5   |
| HCP 05(abs.)   | 2.76   | 3.09   | 3.93   | 1.89   | 0.67   | 1.73   | 3.12   |
| HCP 05(ref, %) | 5.34   | 5.93   | 7.59   | 3.50   | 1.24   | 3.11   | 5.54   |

At the beginning of the study (2009), a decrease in the yield of sugar sorghum on zero tillage by 7% relative to the dumping was observed, then in the fifth year (2013) of the study, an increase in yield by 12% occurred, which amounted to 57.5 t/ha. In 2015, the yield on zero tillage reached 61.5 t/ha. The correctness of the calculations confirmed the mathematical processing of yield data. The smallest significant difference is 2010, 2011, 2012. Was insignificant as regards 2009, 2013, 2014, 2015 the actual difference between the variants is greater than the NDS, which means that the differences between the variants are significant.

The yield regression equation is an integral expression of the interaction of plants with environmental factors. In our study, a regression equation for the yield of sugar sorghum was derived by year: $y = 0.219x^2 + 0.3119x + 49.043$; $R^2 = 0.973$. It showed a change in the yield of sugar sorghum under the influence of tillage over the years. The correlation coefficient had a positive value, therefore, the relationship between the signs is high and direct.

Next, observations were made on the dynamics of the accumulation of sugars in the stalk of sugar sorghum (table 6).

### Table 6. Effect of tillage on the dynamics of accumulation of sugars in the stalks of sugar sorghum, % (average 2009-2015)

| Soil treatment | Tillering | Ear formation | Flowering | Milky ripeness | Wax ripeness |
|----------------|-----------|---------------|-----------|----------------|--------------|
| Dump tillage   | 5.1       | 13.2          | 15.2      | 17.1           | 18.1         |
| Zero-tillage   | 5.7       | 13.8          | 15.7      | 17.5           | 18.3         |

In the study of the dynamics of accumulation of sugars, a relatively weak increase in sucrose was observed from the moment the panicle was ejected until the end of flowering, mainly due to a decrease in simple sugars, as a result of which the total amount of sugars remained almost unchanged during this period. The next stage - full bloom is characterized by an extremely sharp rise in the accumulation curve of sucrose, which from this time increased by 5.1% at the beginning of flowering to 15.2% from mold processing, from 5.7% to 15.7% from zero tillage. In the phase of waxy ripeness of grain, there was the greatest accumulation of sugars, which amounted to 18.1 and 18.3% for tail and zero tillage, respectively. The increase in total sugar occurs solely due to a very rapid increase in the amount of sucrose. Later, as the seeds ripened, a weaker increase in sucrose occurred, as well as the amount of sugars. The difference in the accumulation of sugar plants sorghum depends directly on the yield of stems.

The calculation of the economic efficiency of the cultivation of sugar sorghum was made on the basis of calculations of direct costs for process maps, norms of production and fuel consumption for all work in the field, prices for material and technical resources and sales prices of the resulting products [7].

Calculations of the economic efficiency of the production of sugar sorghum showed that for soil tillage, the cost of funds amounted to 51924.6 rubles/ha, for zero soil treatment costs were lower on average by 2400 rubles/ha, which is associated with the smallest number of operations carried out on this treatment soil, herbicide costs compensate for some mechanical operations (table 7). When calculating the coefficient of profitability of the cultivation of sugar sorghum on dump tillage, it was 87%.
Table 7. Economic efficiency of the cultivation of sugar sorghum, %

| Soil treatment | Yield of green mass, tons per 1 ha | Cost of funds, rubles/ha | The cost of 1 ton of green mass, rubles | The cost of gross output, rubles/ha | Conditional net income, rubles/ha | Profitability, % |
|----------------|----------------------------------|------------------------|--------------------------------------|----------------------------------|---------------------------------|----------------|
| Dump tillage   | 52.4                             | 51924.6                | 990.9                                | 96940.0                          | 45015.4                        | 87             |
| Zero-tillage   | 54.7                             | 49513.5                | 905.2                                | 101195.0                         | 51681.5                        | 104            |

Reducing the cost of cultivation of sugar sorghum for zero tillage has led to an increase in fair-term income and profitability, reducing the cost of green mass. According to zero tillage, the value of the coefficient of profitability was counted 104 %.

Analysis of the efficiency of cultivation of sugar sorghum on the territory of the Volgograd region showed that profitability increased in terms of zero tillage.

4. Conclusion
The influence of cultivation technology on soil density has a significant impact. In general, there was an increase in soil density before harvesting. The soil density of the arable layer before sowing sugar sorghum can be attributed according to the classification according to N.A. Kaczynski, to a satisfactory level for the arable horizon, was unsatisfactory before harvesting, but at that time the culture under study used the nutrients of the lower soil layers. The phenomenon of relatively high density is characteristic of low-humus poorly structured soils, which is the seasonal dynamics of density, which increased from the beginning to the end of the growing season and reached high values.

The structural coefficient increased as a result of an increase in agronomically valuable aggregates. By dump and zero treatments in the layer of 0.0-0.3 m, the coefficient was equal to 1.9 and 2.28, respectively. Despite the difference in the value of the coefficient of structure, the aggregate state of the soil was assessed as excellent. According to the criterion of water resistance of the aggregates, the water resistance of the soil structure in both treatments was satisfactory.

The green mass yield of sugar sorghum for zero tillage on average over the years of research was 54.7 t/ha, which is more than 4% compared to dump processing. The result of the increase in yield was noted in the fifth year of experience. Statistical processing of yield data by year shows that the difference between the options is significant.

When analyzing the dynamics of accumulation of sugars in the stem, it was noted that according to our research, the greatest accumulation of sugars occurred during the period of tillering - sweeping. The accumulation of sugars in the stem increased throughout the growing season, and reached a peak during the wax ripening phase.

The cultivation of sugar sorghum on zero tillage has led to a reduction in production costs by reducing the cost of labor, the amount of fuel, depreciation and repair equipment. At the same time, an increase in crop yield and economic efficiency of the production of sugar sorghum was observed for zero tillage.

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