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# Optimization of sowing time for grain sorghum and millet

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Currently, in the Lugansk region, the areas of millet and sorghum cultivation make up no more than 4.3% of the total sown area of spring grain crops. The relevance and feasibility of conducting research is dictated by noticeable changes in the climate of the territory in the direction of warming and increase its aridity. This made it necessary to study the earliest April sowing dates for the productivity of mid-early and mid-ripening hybrids of grain sorghum, which had not matured before in this territory. As a result of 5-year field experiments with grain sorghum, it was found that it is most profitable and advisable to sow crops (mid-early hybrid Dash E) not on May 15 at a generally accepted date, but earlier on April 25. This contributes to a longer vegetation period of sorghum (up to 110 days), an increase in the number of grains (by 360 pieces or 23.6%) and grain weight (by 8.8 g or 22.5%) in the panicle and some decrease in grain moisture during harvesting harvest (2.6%). At the same time, a reliable increase in yield was also obtained - on average by 0.50 t / ha (8.6%) in comparison with the sowing period generally accepted in production (May 15). Conducting 3-year (2016-2018) field investigation during the cultivation of millet showed out that this crop has a high degree of plasticity by the timing of sowing. For all 6 sowing periods (from April 15 to June 5), almost the same yield was obtained (within 2.27–2.46 t / ha). At the same time, earlier (April 15) sowing dates had some advantage. The late June sowing dates enable millet crops to efficiently use the July rainfall in the most critical phases of crop development to shape the future crop.

**Keywords: grain sorghum, millet, sowing dates, phenological observations, biological crop structure, grain yield, economic efficiency.**

## INTRODUCTION

In the condition of global climate changes on the planet towards warming, especially in the steppe arid regions, a very urgent task is the selection and expansion of cultivated areas for the most drought-tolerant heat-resistant and high-yielding crops and refinement of technologies for their cultivation (Kapustin et al., 2018, Volodin et al., 2018). For the agro-industrial complex of the steppe zone, which includes the territory of the Lugansk region, the main problem remains drought, which has now become a frequent and natural phenomenon (Baranovsky et al., 2019, Baranovsky et al., 2020). According to the conditions of moistening, the Lugansk region belongs to the arid zone. The hydrothermal coefficient (HTC) is 0.7-1.0. The probability of dry years is 10%, very arid - 25%, arid - 35%, slightly arid - 20%, wet - 5%, very wet - 5% (Losev et al., 2004).

The average annual air temperature in the region for 1838-2008. amounted to 8.1ºC, over the past 12 years it increased to 10.2ºC. The amount of precipitation for April-September on average for 1986-2005 amounted to 309 mm, and over the past 12 years - 270 mm (Sokolov et al., 2010). In recent decades, there has been a noticeable warming of the climatic conditions of the area and a significant decrease in precipitation in the warm season. On average, in 2008-2019, the average annual precipitation according to the weather station of Lugansk was 475.5 mm, and the average annual total active temperature (t ≥ 10ºC) increased to 3497ºC, with a multi-year norm, respectively, 528 mm and 3148º. This is the relevance, feasibility and prospects of revising the sown area structures in favor of more drought-resistant and heat-resistant late spring crops - millet and sorghum, the genetic potential of grain productivity of modern varieties and hybrids of which respectively reaches 5-6 and 10-12 t / ha of grain. Due to a number of adaptive properties, these crops are least affected by frequent and prolonged droughts during the growing season and long rainless periods (Elagin, 1987, Kajuna, 2001, Zotikov et al., 2010, Kapustin et al., 2019). These crops have the lowest transpiration coefficients (200-250) among field crops, very economically consume moisture to form a unit of their biomass. They are unpretentious to soils, have high plasticity to sowing dates and plant density (Chapke et al., 2018, Habiyaremye et al., 2017). The cultivation of millet and sorghum contributes to the formation of high and stable yields of food and feed grain, which will significantly increase and stabilize grain production in the steppe regions (Titkov et al., 2013, Seiter et al., 2019, Reddy et al., 2014).

Sorghum and millet are quite plastic in terms of sowing, which allows them to be sown both in the early stages (in April) and in the late (late May - first half of June). This makes them especially valuable when sowing the dead crops of winter crops and other crops.

The soil and climatic conditions of the Lugansk region are suitable for the cultivation of these crops (Baranovsky et al., 2014). With an average long-term accumulation of the sum of active temperatures during the growing season, reaching 3500°C, it is possible to grow not only ultra-ripe and early ripe varieties and hybrids of sorghum, but also mid-early, mid-ripening and even late ripening varieties, with a vegetation period exceeding 120 days.

The increase in the productivity of millet and sorghum is based on taking into account their biological characteristics and critical periods of maximum demand for moisture and nutrients. In addition to questions of process of optimizing the levels of mineral nutrition and the phytosanitary condition of crops, an important factor in increasing the productivity of cereal crops is the selection of the best timing of sowing.

The purpose of the research is to establish the optimal sowing dates for millet and sorghum due to climate changes, the duration of the interphase periods of crops grown and the vegetative period as a whole in the arid conditions of the Lugansk region.

## MATERIALS AND METHODS

The studies were carried out on the experimental field of the Lugansk National Agrarian University when studying the timing of sowing of grain sorghum during 2013-2017, millet - from 2016 to 2018 in accordance with generally accepted methods of field experience (Dospekhov, 1985).

Agrotechnics of sorghum and millet cultivation was generally accepted (Baranovsky et al., 2014) with the exception of the studied factor. The predecessor is spring barley. Sowing was carried out in 6 terms with an interval of 10 days, from April 15 to June 5. Mineral fertilizers with the norm N30P30K30 of the active substance were introduced under pre-sowing cultivation. The sowing method is wide-row with a row-spacing of 45 cm for millet and 70 cm for sorghum. The seeding rate of millet was 2.5 million / ha of germinating seeds, and grain sorghum - 250 thousand / ha. The high-yielding recommended mid-early hybrid of grain sorghum Dash E, the regionalized sort of millet - Mironovsky 51 was sown.

The soil of the experimental plot is ordinary chernozem, carbonate, and heavy loamy on loesslike loam. The arable (0-25 cm) soil layer contains: humus - 3.4%, easily hydrolyzable nitrogen - 113.2 mg / kg, mobile phosphorus - 80.1 mg / kg, exchange potassium - 156.2 mg / kg.

The area of the registration plot was 25 m2, the repetition was 3-4-fold, the location of the plots was randomized. As control, the millet sowing period adopted in production was taken on April 25 (II term), and grain sorghum - May 15 (IV term).

Weather conditions in the years of research varied significantly.

The year 2013 was very dry in the first and wet in the second half of the growing season. In April-September, 202.4 mm of precipitation fell (norm 309 mm), the average air temperature was 18.8ºC (norm 16.1ºC), days with a relative humidity of less than 30% were 68, and the hydrothermal coefficient - 0.58 (norm - 1.00).

The year 2014 turned out to be favorable due to the hydrothermal conditions of the growing season (the amount of precipitation is 309.5 mm, the average air temperature is 17.9ºC, the days with a relative humidity of 30% or less are 54, and the hydrothermal coefficient is 1.14.

2015 is set arid and hot. The amount of precipitation for April-September is 273.9 mm, the average air temperature is 19.0ºC, the hydrothermal coefficient is 0.56 (normal 1.00), the number of days of drought has reached 82.

2016 was a favorable year for hydrothermal conditions. During April-September, 335.1 mm of precipitation fell, the average air temperature was 18.6ºC, the number of drought days was 32, and the hydrothermal coefficient was 1.03.

The growing season in 2017 was arid. Precipitation was 283.0 mm, the average air temperature was 19.7ºC, the number of days of drought reached 57. The hydrothermal coefficient was 0.99.

The vegetation period in 2018 was even drier: the amount of precipitation for April-September is 234.8 mm, the average air temperature is 20.9 ºC, the number of days of drought is 71, and the hydrothermal coefficient was 0.67.

In general, the most favorable conditions for the hydrothermal regime on average over 6 years were in the third decade of April (HTC - 1.63) and the first ten days of May (HTC - 1.38), and the worst in August (HTC averaged over 6 years 0.44). Such humidification conditions are inherent in the dry steppe zone.

## RESULTS AND DISCUSSION

Based on 5-year field studies of investigating the effect of sowing dates on the productivity of grain sorghum, it was found that in years with different moisture supply and temperature conditions of the growing season, early April sowing dates are more preferable. In this case, the initial phases of plant growth and development take place in cooler conditions in May and early June. Ripening occurs mainly in August at high air temperature and low relative humidity. Plants of sorghum sown at the latest dates have a shorter growing season due to the reduction of interphase periods. Ripening of these crops occurs in colder September. At the same time, the ripened grain has a significantly higher humidity and the harvested grain mass requires immediate cleaning and drying.

On average, during the period of 2013-2017, the maximum duration of the growing season of agrophytocenosis of grain sorghum was in April sowing periods and amounted to 113-110 days, and full ripeness occurred at the end of August, the driest and warmest month during the growing season (average HTC in August is 0.61). For the period of the HTC research in August, it amounted to only 0.44 (Table 1). With the sowing date in mid-May, the sowing-seedling period was shorter (by 4 days) than with sowing on April 25th. But at the same time, the duration of the entire vegetation was shorter (by 4 days) and amounted to 106 days. In this case, ripening began already in the cool and rainy September (the long-term HTC norm is 1.16). The average grain moisture during harvesting was 14.1 and 16.7%, respectively. When sorghum was sown on June 5 in humid and rainy conditions in September 2013 and 2014, grain sorghum plants generally did not reach the full ripeness phase in their development. In this case, the vegetation period averaged 104.5 days. Due to the increased hygroscopicity of sorghum grains in comparison with other crops and a sharp decrease in the active heat input during September, late crops have a high risk of falling into ripening season under autumn thaw and even under snow, which greatly complicates harvesting and impairs grain quality.

An analysis of the main indicators of the crop structure of cereal sorghum plants also indicates a noticeable advantage of early April crops over medium or late periods. The highest values of indicators of grain productivity were noted during the sowing of sorghum on April 25 (in the II term). In comparison with the traditional sowing period IV (May 15) in this variant, on average over the years of experience, the weight of the grain from the panicle increased by 8.8 g (22.5%), and the number of grains in the panicle increased by 360 pieces (23.6%). At the same time, the density of the productive stalk per 1 m2 and the mass of 1000 grains did not change significantly. And the height of plants at the second sowing period even had an insignificant tendency to increase (3.7%).

**Table 1: Phenological observations and main indicators of the structure of the biological crop of grain sorghum plants, depending on the timing of sowing and weather conditions over the years of research**

| Sowing time | Dates of the main phases of the development of cereal sorghum plants | | | Vegetation period, days | The indicators of the structure of the biological crop of sorghum plants in the air-dry state | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | seedlings | bloom | full ripeness | | the density of productive stems, pcs / m² | panicle structure | | | weight of 1000 grains, g | plant height, cm |
| | | | | | | length, cm | grain weight, g | the number of grains | | |
| 2013 | | | | | | | | | | |
| I term (April 15) | 29.04 | 4.07 | 19.08 | 113 | 14.7 | 23.8 | 47.4 | 1874 | 25.3 | 103.2 |
| II term (April 25) | 5.05 | 7.07 | 22.08 | 110 | 15.0 | 21.2 | 49.7 | 1912 | 26.0 | 104.9 |
| III term (May 5) | 14.05 | 12.07 | 28.08 | 107 | 15.8 | 21.3 | 43.3 | 1718 | 25.2 | 106.4 |
| IV term (May 15) | 23.05 | 22.07 | 13.09 | 113 | 14.3 | 20.0 | 48.4 | 1906 | 25.4 | 102.5 |
| V term (May 25) | 2.06 | 29.07 | 25.09 | 115 | 15.7 | 19.0 | 32.6 | 1698 | 19.2 | 104.2 |
| VI term (June 5) | 12.06 | 9.08 | - | 109 | 15.0 | 18.5 | 35.3 | 1665 | 21.2 | 101.2 |
| 2014 | | | | | | | | | | |
| I term (April 15) | 3.05 | 9.07 | 29.08 | 119 | 15.7 | 25.1 | 35.9 | 1617 | 22.2 | 98.6 |
| II term (April 25) | 8.05 | 13.07 | 2.09 | 117 | 15.7 | 25.9 | 36.1 | 1598 | 22.6 | 99.1 |
| III term (May 5) | 16.05 | 20.07 | 9.09 | 115 | 14.3 | 23.3 | 37.2 | 1610 | 23.1 | 96.2 |
| IV term (May 15) | 24.05 | 28.07 | 19.09 | 118 | 14.3 | 24.8 | 29.6 | 1233 | 24.0 | 97.2 |
| V term (May 25) | 3.06 | 4.08 | 28.09 | 117 | 14.3 | 23.2 | 22.1 | 1052 | 21.0 | 90.4 |
| VI term (June 5) | 11.06 | 13.08 | - | 111 | 14.3 | 18.6 | 15.4 | 782 | 19.7 | 90.2 |
| 2015 | | | | | | | | | | |
| I term (April 15) | 6.05 | 8.07 | 26.08 | 112 | 18.8 | 25.6 | 39.0 | 1494 | 26.1 | 88.3 |
| II term (April 25) | 10.05 | 10.07 | 26.08 | 108 | 15.1 | 27.3 | 52.3 | 1959 | 26.7 | 89.9 |
| III term (May 5) | 17.05 | 15.07 | 29.08 | 104 | 14.3 | 25.9 | 49.6 | 1976 | 25.1 | 85.2 |
| IV term (May 15) | 25.05 | 22.07 | 31.08 | 98 | 15.0 | 25.1 | 43.7 | 1682 | 25.9 | 81.1 |
| V term (May 25) | 2.06 | 29.07 | 6.09 | 96 | 13.7 | 23.6 | 38.3 | 1557 | 24.6 | 83.2 |
| VI term (June 5) | 11.06 | 4.08I | 30.09 | 111 | 14.1 | 22.7 | 28.4 | 1224 | 23.2 | 80.4 |
| 2016 | | | | | | | | | | |
| I term (April 15) | 7.05 | 11.07 | 24.08 | 109 | 17.2 | 17.5 | 43.3 | 914 | 27.4 | 96.6 |
| II term (April 25) | 11.05 | 14.07 | 25.08 | 106 | 16.4 | 24.9 | 62.8 | 2211 | 28.4 | 91.6 |
| III term (May 5) | 14.05 | 16.07 | 29.08 | 107 | 17.5 | 24.7 | 45.9 | 1702 | 27.0 | 86.8 |
| IV term (May 15) | 23.05 | 19.07 | 4.09 | 104 | 16.1 | 24.4 | 39.6 | 1321 | 29.8 | 81.4 |
| V term (May 25) | 1.06 | 24.07 | 10.09 | 102 | 18.9 | 24.5 | 37.6 | 1147 | 32.8 | 86.3 |
| VI term (June 5) | 12.06 | 27.07 | 20.09 | 100 | 17.0 | 26.0 | 39.3 | 1272 | 30.9 | 88.9 |
| 2017 | | | | | | | | | | |
| I term (April 15) | 7.05 | 15.07 | 26.08 | 111 | 13.2 | 22.5 | 40.0 | 1702 | 22.5 | 92.6 |
| II term (April 25) | 10.05 | 18.07 | 27.08 | 109 | 15.3 | 21.3 | 38.6 | 1762 | 21.9 | 86.2 |
| III term (May 5) | 18.05 | 23.07 | 31.08 | 104 | 15.0 | 21.9 | 34.9 | 1594 | 21.9 | 86.1 |
| IV term (May 15) | 27.05 | 26.07 | 2.09 | 98 | 15.2 | 22.6 | 34.1 | 1496 | 22.8 | 92.4 |
| V term (May 25) | 2.06 | 28.07 | 5.09 | 95 | 14.2 | 22.6 | 30.1 | 1447 | 20.8 | 89.8 |
| VI term (June 5) | 16.06 | 9.08 | 16.09 | 92 | 15.3 | 23.4 | 28.5 | 1524 | 18.7 | 103.2 |
| Average for 2013-2017 | | | | | | | | | | |
| I term (April 15) | sowing-seedling period - 19.4 days | | | 113 | 15.9 | 22.9 | 41.1 | 1520 | 24.7 | 95.9 |
| II term (April 25) | sowing-seedling period - 13.8 days | | | 110 | 15.5 | 24.1 | 47.9 | 1888 | 25.1 | 94.3 |
| III term (May 5) | sowing-seedling period - 10.8 days | | | 107 | 15.4 | 23.4 | 42.1 | 1720 | 24.5 | 92.1 |
| IV term (May 15) | sowing-seedling period - 9.4 days | | | 106 | 15.0 | 23.4 | 39.1 | 1528 | 25.6 | 90.9 |
| V term (May 25) | sowing-seedling period - 8.0 days | | | 105 | 15.4 | 22.6 | 32.1 | 1380 | 23.7 | 90.8 |
| VI term (June 5) | sowing-seedling period - 7.4 days | | | 104 | 15.1 | 21.8 | 29.4 | 1293 | 22.7 | 92.8 |
| $r \pm S_r$ | | | | 0.67 ±0.30 | -0.92 ± 0.20 | 0.93 ±0.19 | 0.92 ±0.19 | 0.86 ±0.25 | 0.86 ±0.25 | 0.27 ±0.48 |
| $t_r$ | | | | 1.80 | -4.59 | 5.01 | 4.82 | 3.44 | 3.31 | 0.55 |

On average, between 2013 and 2017, the strongest direct significant correlation was observed between productivity and panicle length (r = 0.93), grain weight per panicle (r = 0.92), and the number of grains in a panicle (r = 0.86) and weighing 1000 grains (r = 0.86). A weak and insignificant correlation was noted between the yield of sorghum grain and plant height (r = 0.27). Depending on weather conditions during the growing season, the highest yields of grain sorghum over the years of research on average for all sowing periods were formed in 2016 - 7.31 t / ha, and the lowest - in 2014 - 4.30 t / ha and 2017 year - 4.94 t / ha. On average, over 5 years, the maximum yield of sorghum was obtained during sowing in the II term (April 25), which significantly exceeded this indicator with the traditional sowing period for sowing sorghum (May 15) by 0.50 t / ha or 8.6% (Table. 2). At the same time, the June sorghum crops provided grain harvest of only 4.35 t / ha, or 44.6% less than in the third decade of April. This was obtained in connection with significantly lower indicators of the quantity and mass of grain per panicle, as well as a significantly smaller mass of 1000 grains.

The analysis of economic efficiency indicators also indicates the advantage of the early April sowing period of this hybrid of grain sorghum. At this sowing date (April 25), in comparison with the generally recognized sowing date (May 15), an increase in the value of the grown products by 4,500 rubles / ha (8.1%), of conditionally net income by 5111 rubles / ha (15.1%) was obtained), and the level of profitability increased by 27.9%. Compared to June crops in the third decade of April provided an additional conditionally net income of 18,997 rubles / ha (or 116.9%) and an increase in profitability by 94.1%.

A study of the sowing dates of millet during 2016-2018 showed that the average vegetation period of the culture in the experiment was 76 days. When sowing in the second decade of April (control), the duration of the growing season was 84 days. With sowing dates of April 15 and May 5, the growing season was reduced by 3-4 days in comparison with the control. Sowing in the second half of May - the first decade of June reduced the vegetation of millet plants by 11-20 days relative to the control. This is due to a significant reduction in the period of sowing - seedlings. With the April sowing dates, this period lasted 22-24 days, with sowing in the I-II decade of May - 10 days and with sowing in the III decade of May - I decade of June - 8-9 days (Table 3).

Productivity of the studied culture at different sowing periods varied from 2.27 t / ha (III sowing term) to 2.46 t / ha (I sowing term). The grain productivity of millet is determined by the indicators of the crop structure - the mass of grain per panicle, the mass of 1000 grains, the number of grains in a panicle. On average, over the years of research, the weight of the grain from one panicle was 1.3 g. The weight of 1000 grains slightly varied from the sowing dates, and on average was in the range of 7.8-8.1 g. The number of grains in the panicle varied from 167.4 pcs. (III term of sowing) up to 184.4 pcs. (I term of sowing).

With early (April) and medium (I-II decades of May) sowing periods, the sowing-seedling period, as well as on sorghum crops, takes place in cooler conditions of May and the first half of June. Wax ripeness of crops occurs in the third decade of July - the first decade of August, with a high average daily temperature and low relative humidity.

At later sowing dates (III decade of May - I decade of June), grain ripens on average in the second decade of August, in the driest summer month.

An analysis of indicators such as the length of the panicle showed that it slightly varied from the timing of sowing and, on average, was 26.8 cm from experience. The average height of plants in the experiment was 84.1 cm.

On average, over 3 years of field research, the strongest direct significant correlation was observed between productivity and the number of grains in a panicle (r = 0.82), weak - between a grain mass from a panicle (r = 0.33) and plant height (r = 0.32).

With an early sowing period (April 15), the yield increased by 0.12 t / ha or 5.1% in comparison with the control. With a shift in sowing dates by the first decade of May (May 5), a decrease in productivity by 0.19 t / ha or 8.1% was noted. At the fourth sowing date (May 15), the yield did not deviate from the control - 2.34 t / ha.

With the fifth and sixth sowing dates (May 25 and June 5), the yield increased insignificantly - by 0.01-0.04 t / ha or 0.4-1.7% (Table 4).

Economic calculations have shown some advantage in the earliest sowing period. Depending on the timing of the sowing, the values of the conditional net income and the level of profitability of the cultivation of crops changed slightly.

**Table 2: Grain moisture during ripening, yield and economic efficiency of growing grain sorghum, depending on the timing of sowing and weather conditions during the growing season (average for 2013-2017)**

| Sorghum sowing dates | Grain moisture when ripening,% | The average grain yield, t / ha | The increase to control, t / ha | The cost of production, rubles / ha | Production costs, rubles / ha | Conditionally net income, rubles / ha | Profitability level,% |
|---|---|---|---|---|---|---|---|
| I term (April 15) | 13.6 | 5.95 | +0.16 | 53550 | 20338 | 33212 | 163.3 |
| II term (April 25) | 14.1 | 6.29 | +0.50 | 56610 | 21356 | 35254 | 165.1 |
| III term (May 5) | 14.5 | 6.15 | +0.36 | 55350 | 21545 | 33805 | 156.9 |
| IV term (May 15), control | 16.7 | 5.79 | - | 52110 | 21967 | 30143 | 137.2 |
| V term (May 25) | 19.9 | 5.34 | -0.45 | 48060 | 22278 | 25782 | 115.7 |
| VI term (June 5) | 26.5 | 4.35 | -1.44 | 39150 | 22893 | 16257 | 71.0 |
| $SSD_{05}$, t / ha | | 0.140.22 | | | | | |

**Table 3: Phenological observations and basic indicators of the structure of the biological crop of millet plants depending on the sowing dates and weather conditions during the years of research (average for 2016-2018)**

| Sowing dates | Dates of the main phases of millet plant development | | | Vegetation period, days | Indicators of the structure of the biological crop of millet plants in the air-dry state | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | seedlings | bloom | wax ripeness | | the density of productive stems, pcs / $m^2$ | panicle structure | | | weight of 1000 grains | plant height, cm |
| | | | | | | length, cm | grain weight, g | the number of grains | | |
| 2016 | | | | | | | | | | |
| I term (April 15) | 30.04 | 28.06 | 21.07 | 82 | 187.0 | 27.8 | 1.5 | 193.9 | 7,7 | 102,0 |
| II term (April 25) | 05.05 | 05.07 | 07.08 | 94 | 193.7 | 28.2 | 1.5 | 204.4 | 7,3 | 102,7 |
| III term (May 5) | 13.05 | 10.07 | 07.08 | 86 | 199.0 | 28.1 | 1.3 | 162.4 | 8,0 | 100,7 |
| IV term (May 15) | 26.05 | 12.07 | 08.08 | 74 | 190.3 | 27.5 | 1.7 | 213.7 | 7,8 | 97,7 |
| V term (May 25) | 02.06 | 13.07 | 18.08 | 77 | 179.0 | 26.2 | 1.5 | 188.3 | 8,0 | 94,7 |
| VI term (June 5) | 11.06 | 25.07 | 21.08 | 71 | 173.0 | 25.9 | 1.8 | 236.2 | 7,8 | 99,7 |
| 2017 | | | | | | | | | | |
| I term (April 15) | 07.05 | 01.07 | 01.08 | 86 | 202 | 20.9 | 1.2 | 219.7 | 6,9 | 59,5 |
| II term (April 25) | 07.05 | 01.07 | 01.08 | 86 | 232 | 20.5 | 1.8 | 228.8 | 7,3 | 61,6 |
| III term (May 5) | 15.05 | 03.07 | 06.08 | 83 | 203 | 24.8 | 1.4 | 247.0 | 6,9 | 70,7 |
| IV term (May 15) | 25.05 | 15.07 | 08.08 | 94 | 207 | 24.3 | 1.3 | 243.5 | 6,9 | 70,0 |
| V term (May 25) | 03.06 | 21.07 | 15.08 | 73 | 212 | 28.2 | 1.4 | 255.2 | 7,3 | 87,4 |
| VI term (June 5) | 16.06 | 25.07 | 21.08 | 66 | 179 | 20.4 | 1.2 | 198.1 | 7,4 | 55,2 |
| 2018 | | | | | | | | | | |
| I term (April 15) | 15.05 | 19.06 | 25.07 | 71 | 184 | 31.0 | 1.3 | 139.5 | 9,5 | 91,1 |
| II term (April 25) | 15.05 | 19.06 | 25.07 | 71 | 202 | 29.8 | 1.0 | 116.0 | 8,7 | 82,1 |
| III term (May 5) | 18.05 | 03.07 | 31.07 | 74 | 197 | 27.2 | 0.9 | 92.9 | 9,3 | 69,6 |
| IV term (May 15) | 25.05 | 09.07 | 30.07 | 66 | 199 | 28.9 | 0.8 | 78.7 | 9,2 | 86,0 |
| V term (May 25) | 01.06 | 15.07 | 06.08 | 66 | 205 | 32.2 | 0.7 | 92.8 | 9,0 | 87,2 |
| VI term (June 5) | 14.06 | 18.07 | 08.08 | 55 | 210 | 29.3 | 0.9 | 113.8 | 8,1 | 96,5 |
| Average for 2016-2018 | | | | | | | | | | |
| I term (April 15) | sowing-seedling period - 22 days | | | 80 | 191 | 26.6 | 1.3 | 184.4 | 8.0 | 84.2 |
| II term (April 25) | sowing-seedling period - 14 days | | | 84 | 209.2 | 26.2 | 1.4 | 183.1 | 7.8 | 82.1 |
| III term (May 5) | sowing-seedling period - 10 days | | | 81 | 199.7 | 26.7 | 1.2 | 167.4 | 8.1 | 80.3 |
| IV term (May 15) | sowing-seedling period - 10 days | | | 72 | 198.8 | 26.9 | 1.3 | 178.6 | 8.0 | 84.6 |
| V term (May 25) | sowing-seedling period - 8 days | | | 72 | 198.7 | 28.9 | 1.2 | 178.8 | 8.1 | 89.8 |
| VI term (June 5) | sowing-seedling period - 9 days | | | 64 | 187.6 | 25.2 | 1.3 | 182.7 | 7.8 | 83.8 |
| $r \pm S_r$ | | | | -0.15 ±0.49 | -0.56 ±0.41 | -0.15 ±0.49 | 0.33 ±0.47 | 0.82 ±0.29 | -0.26 ±0.48 | 0.32 ±0.47 |

**Table 4: Indicators of economic efficiency of millet cultivation at different sowing periods (average for 2016-2018)**

| Experience Options | Productivity, t / ha | The increase to the control, t / ha | The cost of production, rubles / ha | Production costs, rubles / ha | Conditional net income, rubles / ha | Profitability level, % |
|---|---|---|---|---|---|---|
| I term (April 15) | 2.46 | + 0.12 | 44280 | 18180 | 26100 | 143.6 |
| II term (April 25), control | 2.34 | - | 42120 | 18535 | 23585 | 127.2 |
| III term (May 5) | 2.27 | - 0.07 | 40860 | 18902 | 21958 | 116.2 |
| IV term (May 15) | 2.34 | 0.0 | 42120 | 18909 | 23211 | 122.8 |
| V term (May 25) | 2.35 | + 0.01 | 42300 | 19284 | 23017 | 119.4 |
| VI term (June 5) | 2.38 | + 0.04 | 42840 | 19287 | 23553 | 122.1 |
| $SSD_{05}$, t / ha | 0.12 0.30 | | | | | |

Sowing in the second decade of April (April 15) is economically more profitable, as production costs are reduced by 354.4 rubles. (1.9%) due to fewer cultivations. When sowing at a later date of sowing (May-June), production costs increase by 367.5-752.5 rubles. (2.0-4.1%) compared with the control.

With late sowing periods (from III to VI), the profitability level of millet cultivation was 116.2-122.8% or 4.4-11% lower than in the control and 20.8-27.4% lower than at the first sowing period.

Contingent net income increased by 2515 rubles compared to control in the early period of sowing (April 15). (10.7%) and slightly decreased during sowing on May 5 (by 1627 rubles or 6.9%). When sowing at a later date, the reduction in the conditional net income was 32.5-568.6 rubles. or 0.1-2.4%.

The cost of grown products depends on the crop yield. In the experiments, the cost of grain harvest varied in the range of 40860-44280 rubles. and was maximum with early sowing.

Production costs for millet cultivation increased slightly from early to late sowing and reached a maximum (19,287 rubles / ha) during the June sowing period, which was 1107 rubles / ha (6.1%) higher than the minimum cost at the earliest (15 April) sowing date.

## CONCLUSION

In the arid conditions of the Lugansk region, a certain advantage of earlier sowing dates for cereal crops - sorghum and millet - were noted. When sowing on April 25, grain sorghum provides more full-bodied (by 22.5%) and grazed (by 23.6%) panicles, higher ones yield (by 0.5 t / ha or 8.6%), conditionally net income ( by 15.1%) and the level of profitability (by 27.9%) than with the sowing date generally accepted in production - May 15.

When millet is cultivated, a shift in the sowing dates for an early period (April 15) relative to the generally accepted (April 25), leads to an increase in the productivity of crops by 0.12 t / ha of grain (5.1%), a decrease in production costs by 1.9%, an increase conditional net income by 10.7% and profitability by 16.4%.

Millet is a very plastic crop for sowing dates, has a relatively short growing season, and even June (June 5) crops ripen by the beginning of the third decade of August. The sowing dates of millet did not have a significant impact on such indicators as the mass of 1000 grains, the mass of grain from a panicle and the number of grains in a panicle.

## CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest.

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## AUTHOR CONTRIBUTIONS

AVB and ASS designed and performed the experiments. AVB and SIK wrote the manuscript. SIK and ASK performed data analysis. All authors read and approved the final version.

with these terms.

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