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Economic Efficiency of Mineral Fertilizers Applied for Sorghum Growing in the Forest-Steppe Zones of the Southern Urals

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Abstract: During the period 2016-2018, field experiments were conducted in the Scientific Training center of Bashkir State Agrarian university. The aim of the experiments was to study the effect of introducing calculated doses of mineral fertilizers on the expected sugar sorghum fresh-yield in the southern forest-steppe zone of the Republic of Bashkortostan. The purpose of the research work is to determine the amount of mineral fertilizers applied to get the expected sugar sorghum fresh yield. During the research work, it was revealed that doses of mineral fertilizers applied for sugar sorghum growing should be defined taking into account the expected fresh yield and yield removal rates. According to the result of the studies, the highest fresh yield of 65.0 t/ha was received from Seville sugar sorghum during the second sowing period (21-30 of May). $N_{85}P_{37}K_{39}$ rate of mineral fertilizers applied to get the expected harvest contributed to the yield increase by 166.4% in comparison with the control rate and yielded 40.6 t/ha.

Key words: Characteristics of sorghum varieties, sugar sorghum, sorghum durra, sorghum-sudangrass hybrids, soil treatment, application of fertilizers, efficiency.

Introduction

Sorghum is known to be a food, fodder and industrial plant. Its global planting acreage is 44 million hectares (ha). In many African and Asian countries as well as in some countries of Central Asia, sorghum is the most important cereal crop. Sorghum is used for alcohol and starch production (Ermakov et al., 2017; Zayneb et al., 2015). Sugar sorghum culms are used to make sugar syrup. Sorghum is a more productive crop in comparison to corn. It has a better growth at high temperatures and low water supply. The average sorghum yield capacity is 20-25 centners per ha and 45-60 centners per ha when applying farming techniques. The seeds contain up to 70 % of starch, which is rich in lysin and 3.5 % of fat. Sorghum is widely used for feed-stuff purposes.

Fresh yield capacity is 200-300 centners per hectare and from 800 to 1,000 centners per hectare during irrigation (Nafikov et al., 2019).

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The area of sorghum cultivation in the Russian Federation is 250,000 ha including 75,000 ha where the grain is grown. This crop is mainly used for feed stuff purposes (Araslanbaev, 2007; Muratova et al., 2015). There are 23.5 feed units of herbage, 22 feed units of silage and 49.2 ha feed units in 100 kg of sorghum.

Sorghum has high plasticity. It easily adapts to different soil and climatic conditions (Ahmed et al., 2014). Thus, this crop finds wide application.

The birthplace of sorghum is Equatorial Africa. But, it is also widely used in India and China. In India, sorghum has been grown since 3000 BC, and in China and Egypt, since 2000 BC. In the 15th century, sorghum was delivered to Europe, and in the 17th century to America. Moench sorghum variety belongs to the *Poaceae* family (Poaceae Bernh) and includes 60-70 species of cultivated sorghum and a group of wild and semi-wild plants. The sorghum growth period is 120-130 days. It's a cross fertilization crop (Hammer et al., 2014; Khaibullin and Avsakhov, 2016; Nafikov et al., 2018).

A special feature of sorghum is low intensity during the early growth period. This crop can also stop growing under poor conditions and stay in anabiotic state until the conditions get better (de Souza Miranda et al., 2016). Sorghum plants have the following special features: high drought tolerance, high necessity for warmth and light (Hammer et al., 2014), salt-tolerance, low growth during the early vegetation period, high sensitivity to weed plants and to sowing time and high seed propagation coefficient.

The sorghum crop has been studied rather poorly. Thus, the aim of our research work was to determine optimum sowing time, and reveal the influence of the amount of mineral fertilizers to be applied on the expected yield capacity of sorghum grown in the conditions of the southern forest-steppe zone of the Republic of Bashkortostan.

Materials and Methods

Field experiments were conducted in the Scientific Training center of Bashkir State Agrarian university in 2016-2018 to determine optimum amount of mineral fertilizers to be applied to get sorghum fresh yield in the conditions of the forest-steppe zone of the Republic of Bashkortostan. The experiments were carried out on Sevilla sugar sorghum variety grown in the conditions of the forest-stepp zone of the Republic of Bashkortostan.

To make a more fundamental study of the influence of the amount of mineral fertilizers, the experiments were conducted taking into account the sorghum sowing time and fertilizing norms necessary to obtain the expected sorghum fresh yield capacity. A two-step experiment was carried out according to the following scheme: factor A - degree of ground fertilization: A_1 - without fertilizers; A_2 - N85P37K39, factor B - sowing time: B_1 - on May 15, B_2 - on May 25, B_3 - on June 5. The total plot area is 108 m^2, the record plot area is 50 m^2. The experiment was repeated according to the scheme three times. The sample taken for the study is a Sevilla sugar sorghum variety.

Basic and secondary tillage were typical for the southern forest-steppe zone of the Republic of Bashkortostan. Sorghum was sowed using CH-1.8 sowing-machine with a seed application rate is 1.82 million pieces per ha. A typical sowing technique was applied. The sowing depth was 4-5 cm.

Results and Discussion

When sowing sorghum after crops, which are harvested early (spiked cereals, grain legume crops) on fields polluted by rootstock and offset weeds, it is necessary to combine the elements of classical soil treatment: primary tillage to provoke weeds sprouting, application of contact herbicides and subsoiling using such tillagers as Leader - 4, Leader - 8.5 or ST (sowing tillager) - 4 and ST - 7.4.

In early spring, during the period of soil workability (SW), farmers cultivate the fields where sorghum will be grown using SCB-1.0 (Speed Crust Buster) or ASCB-1.0 (Average Speed Crust Buster) field drags in two rows to decrease moisture evaporation and to level the field land. Two cultivationsare performed with harrowing: the first one to the depth of 8-10 cm, and the second to the seed depth which is 5-6 cm. After the last cultivation, the field should be levelled with ring rollers. Complete cultivation is carried out across the field land or at an angle to it. The second cultivation is performed across the direction of the first cultivation (Holou et al., 2014). The cultivation of plots with well-marked contours is carried out across the slope or in horizontal direction (Aipov et al., 2018).

Natural field emergence is commonly lower than laboratorial. This should be taken into consideration during sorghum sowing. There are no special seeding machines for sorghum durra sowing. All-crop Pneumatic Intergral planter (APISM)-8 as well as the new generation seeding machines such as Presicion Seed planter (PSP)-108, PSP-109, PSP-112and others are used for row-crop planting.

Seed-Fertilizer planter (SFP)-3,6, Seed-Fertilizer Press planter (SFPP)-3,6 A, Plow planter (PP) and other seeding machines are used for a regular row planting (space between rows being 15 and 30 cm) of sorghum durra resistant to overcrowding (Nafikov et al., 2018; Nafikov et al., 2019).

The quality of commercial sorghum seeds should meet the requirements of the Russian National Standard (GOST R) 5?2325-2005 (State Commission, 2019).

In order to increase the fresh yield, bursting between rows and culture feeding with N30 should be made after the first mowing to withold water evaporation from soil. In this case, rationing happens faster (Khaibullin and Avsakhov, 2016). The precipation months of August and September are useful for the growth of sprouts.

Unlike experiments with other cultures, which showed a positive effect of fertilizers on field emergence of seeds, the experiment with sorghum showed a significant decrease in field emergence of seeds in the variant with fertilizer (according to sowing time of 9.8; 15.6; 10.4%) (Table 1). However, the percentage of plants preserved during the growing season did not decrease. On the fertilized variant, strong and well-watered plants were grown, and sowing in general provided the expected yield of green mass with a high proportion of grain.

Sorghum, which is mowed many times is used for green feed, hay and haylage. But the crop should be gathered depending on its ripe rate 45-55 days later after sprouting, i.e., 10-12 days before sorghum tasseling. At the same time, a high yield of mass is combined with an increased content of protein (up to 16-18%), carotene, a low content of fiber and a high digestibility. The aftergrowth is removed 30 days after the first cut under favourable weather conditions and it is then used as soiling food for grazing.

Fertilizers increases leaf area and leaf photosynthetic potential (LPP) (Table 2). The LPP of the first sowing period is 2.7 million m^2day/ha, with fertilizers-4.1, on the second-3.2 and 4.9 million m^2 day/ha.

The data in Table 3 show that fertilizers significantly increase the fresh yield of sorghum and provide an

Table 1: Field emergence of seeds and preservation of sugar sorghum plants before harvesting at different sowing periods and nutrition status

Amount of fertilizers	*Number of sproutings, pcs/m²*				*Field emergence, %*	*Amount of plants before harvesting, pcs/m²*				*Preservation of plants, %*
	2016	*2017*	*2018*	*Average*		*2016*	*2017*	*2018*	*Average*	
Without fertilizers	188	184	187	186	62	154	163	150	155	84
NPK/60 t	162	158	151	157	52	132	142	149	138	88
Without fertilizers	218	224	232	225	75	202	211	226	213	95
NPK/60 t	174	182	179	178	59	263	174	173	170	96
Without fertilizers	192	198	204	198	66	187	193	198	193	98
NPK/60 t	168	173	159	167	56	165	168	151	161	97

Table 2: Dynamics of changes in the area of leaves and leaf photosynthetic potential (LPP) of sugar sorghum (average 2016-2018)

No.	*Amount of fertilizers*	*Area of leaves, thousand m²/ha*					*LPP per vegetation, million m²/ha*
		Tillering	*Shooting*	*Heading*	*Flowering*	*Milky-wax ripeness*	
				May 15			
1.	Without fertilizers	14	19	23	46	43	2.7
2.	NPK/60 t	18	25	49	62	59	4.1
				May 25			
1.	Without fertilizers	17	31	42	58	45	3.2
2.	NPK/60 t	23	36	59	75	72	4.9
				June 5			
1.	Without fertilizers	16	27	38	52	47	2.6
2.	NPK/60 t	19	34	57	69	68	3.5

expected yield during first and second sowing periods. The increase in fresh yield during the first sowing period was 32.7 t/ha, 40.6 during the second and 23.3 t/ha during the third sowing periods, respectively. Each kilogram of the active substance of tuks was paid by 1.8 kg of food units in the first sowing period, 2.3 kg-in the second, 1.3 kg-in the third. May 25 was observed as the optimal date for sowing sorgum.

Fertilizers increased the efficiency factor of photosynthetic active radiation (PAR) at first and third sowing periods by 2.1-2.3 times. The best indicator was observed in the second sowing period, where it increased by 2.7 times (Table 3).

Unfortunately, at present there are no soil herbicides that control the destruction caused by annual weeds (prickly grass, bristle grass, etc.) in sorghum crops. They have to be dealt by using agrotechnical methods. Offset weeds and annual dicotyledonous weeds are destroyed successfully by Aminobolic and Lineplant herbicides (Table. 4).

Effective cultivation of sorghum largely depends on a clear and high-quality implementation of techniques for crop care (Ableeva et al., 2019). Scientists using their knowledge and practice have developed a set of techniques to combat weeds, preserve moisture, improve aeration of the root system, etc. (Lukianova and Araslanbaev, 2019). It includes seed rolling, harrowing before and after shoots, row-to-row treatment of wide-row crops and implementation of herbicides.

Table 3: Effect of nutrient status on the sorgum fresh yield depending on different sowing dates

Amount of fertilizers	*Fresh yield, t/ha*				*Increase caused by fertilizers*		*Yield plan completion, %*	*The yield of dry matter, t/ha (2016-2018)*	*PAR efficiency factor, %*
	2016	*2017*	*2018*	*Average*	*t/ha*	*%*			
May 15									
Without fertilizers	21.8	23.2	25.1	23.4	-	-	-	5.9	1.6
NPK/60 t	54.2	56.0	58.1	56.1	32.7	140	94	14.0	3.7
May 25									
Without fertilizers	22.8	23.6	26.8	24.4	-	-	-	6.1	1.6
NPK	61.4	64.2	69.1	65.0	40.6	166	108	16.3	4.3
June 5									
Without fertilizers	22.1	22.9	23.5	22.8	-	-	-	5.7	1.5
NPK/60 t	41.7	44.5	52.0	46.1	23.3	102	77	11.5	3.1

Table 4: Sorghum protection system against weeds

Group, name, preparative form, active substance content	*Application norms (l/ha, kg/ha)*	*Harmful object*	*Way, time and special application features of treatment*
2,4-D (dimethylamine salt) (P) Aminopelik, BP (600 g/l, 2,4-D acid)	1.0-1.3	Annual dicotyledonous weeds	Spraying of seeding and crop leaves in stage 3-6. Operating fluid consumption – 200-300 l/rha
2-methyl-4-chlorophenoxyacetic acid (dimethylamine salt+potassium salt+sodium salt, mixture) (P) Lintaplant, BK (500 g/l 2-methyl-4-chlorophenoxyacetic acid)	0.7-1.2	Same	Same

Conclusions

If sorghum is cultivated with the use of intensive technology, which is aimed at obtaining the maximum yield, then the norms and types of fertilizers are established based on the agrochemical passport of the field, expected yield, the removal of nutrients and moisture supply.

In modern economic conditions of agrarian complex functioning, not all farms can apply appropriate amount of fertilizers to grow sorghum cultures. Thus, it is cheaper to apply mineral fertilizers during sowing (nitrophosca and ammophos) in an amount of 15-20 kg of active substance per 1 ha and once more in the form of foliar dressing when applying herbicides to fight against weeds. It is possible to use biological growth regulators, which differ with the lowest production cost.

In favourable climatic conditions, during 2018 in "Bazy" agricultural production cooperative (APC) of Chekmagush district of the Republic of Bashkortostan 273 centner/ha of fresh yield was obtained from 1 ha of sugar sorghum sowing field. In 2017, in the scientific training centre of Bashkortostan agrarian university Ufa district of the Republic of Bashkortostan, Kinelskoye, four variety of sugar sorghum formed 292 kg/ha of fresh yield.

Sorghum culture is economically more efficient compared to other grain crops. The high fodder value of the by-product – leaf-stem mass has relatively low seeding rate (8-10 kg/ha), 1 kg of which contains an average of 0.4 fodder units and 28 g of digestible protein. This allows us to consider grain and sugar sorghum as a valuable fodder crop.

Application of calculated amounts of mineral fertilizers per 60 t/ha of fresh yield increases the yield of sorghum by 2-2.7 times. During the second sowing period, optimal external conditions are created, ensuring the greatest efficiency of fertilizers.

Increasing the sorghum production area in southern region farms of the Republic to Bashkortostan for fodder purposes has a very important prospect.

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