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SWEET SORGHUM ROOT SYSTEM AND FEATURES OF ITS FORMATION

The research results on penetration and growth dynamics of the sweet sorghum root system, the depth of the penetration and terms of rhizomes formation are shown in the article. It was found that the overwhelming majority of sorghum roots is located in the upper (0–60 cm) soil layer and develops the strong root system that reaches two meters depth with a roots total length more than 15,000 m per plant.

Keywords: *sorghum; root system; depth; penetration; growth.*

Problem statement. In the modern conditions of agricultural production in Ukraine, the prospect of resource capabilities of sorghum crops growing becomes extremely important, as well as their production, diversity of consumption and use. The climate change tendencies that are increasingly evident in all regions of our country increase the value of sweet sorghum as a crop that will ensure the high productivity even in conditions of dry and hot weather during all growing season. Thus, sorghum has certain advantages in comparison with traditional crops of domestic field, such as wheat and barley. Yield of its green mass per hectare can reach 90 to 120 t with total sugar content in the juice up to 20%.

The high drought tolerance is a valuable biological feature of this crop. Such adaptability to environmental conditions speaks that sorghum very efficiently uses moisture per a unit mass of dry matter formation. Thus, the transpiration coefficient of sweet sorghum, i.e., the amount of water that is used to create a unit mass of dry matter an average is 300 (maize – 338, wheat – 513, barley – 365) [1–4].

The main criteria of high drought resistance of sorghum are structural features of the leaves, the presence of waxy coating that reduces the evaporation of moisture, the possibility of a longer staying in anabiosis and renewal of vegetation with the appearance of moisture. However, the most important feature of the crop is a powerful and highly developed root system, which is characterized by intensive growth already from the beginning of seed germination even at low humidity. It is penetrating into the soil to a depth of 3 m; it allows the plants to use the moisture out of the reach soil reserves. Sorghum root system, as well as other plants too, serves many functions: the absorption of water from the soil with dissolved nutrients, nucleic and amino acid synthesis, the supply of other plant organs with substances, which cause to some extent the crop drought resistance. The efficiency of its functioning is determined by the dynamics and depth of root penetration, their weight for the soil layers, the ratio between the weight of the root and aboveground mass. Essential value has also the structure and features of differentiation of roots in the place of their formation [5–7].

Analysis of recent research and publications. It should be noted that the question of root system in sorghum crops in scientific literature is less presented then other agricultural crops. However, from the information contained in some sources [8–10], you can build a clear picture of the annual sorghum root system, namely its size, growth dynamics, the nature of the spread on the soil horizons, depth of penetration, etc.

The research on the sorghum root system allows differentiating several types of roots: embryonic (primary), node (secondary), and airy. V. I Taranenko [11] and B. M. Smirnov [12] distinguish even epicotyl roots. Both embryonic and nodal roots are functioning all plant vegetation period, and we can only speak about the degree of the vital processes intensity in roots of different types over growing periods. The role of these roots, as well as the degree of their ability on different stages of growth and development is not identical. While these indicators provide answers to the relationship of the sorghum root system and its aboveground organs, in terms of features of sorghum root system development this issue is relevant.

In the literature there are data on the existence of the relationship between the intensity of tillering and plant lighting [13]. If rhizomes development is indeed a form of plants tillering, it is logical to assume that in the plants in the herbage of the second and third year of vegetation roots development will be less as the stand density increases with increasing age of grass stand.

At the same time, the scientific literature considers that fact that the nature of the growth and spread of any root crop does not depend only on its biological characteristics, but also on water, air, soil microbiological soil regimes, its mechanical composition, availability of other nutrients and other soil characteristics [9–12].

Thus in connection with the special significance of the rhizomes in sorghum plant life it is essential to study the features of their formation, in particular the timing and dynamics of formation as well as the size and depth of the roots in the soil.

Materials and methods. The research was carried out at Veselopodilska and Ivanivska Experimental Breeding Stations of the Institute of Bioenergy Crops and Sugar Beet NAAS, located in the zone of insufficient moisture in Eastern Forest-Steppe of Ukraine in 2010–2014.

Soil at Veselopodilska EBS experimental fields is typical slightly saline mid-loamy low-humus chernozem. The depth of humus horizon ranges from 35 to 45 cm, humus content 4.5 to 4.8%, pH_{sal} 7.2–7.4. The structure of the plough layer is pulverescent lumpy-granular. Soil at Ivanivska EBS is typical heavy-loamy low humus chernozem on loess. Humus content is 4.7 to 5.1%, pH_{sal} 6.2 to 6.8.

Root penetration depth and spread of in the soil profile was investigated in sweet sorghum crops by the conventional scientific and special agronomic techniques [14]. The cultural practice was typical for the area. Sweet sorghum hybrid under study was Medovyi. Sowing was carried out on 10–20 of May; seeding rate of 6.7 kg/ha with row spacing of 70 cm.

Excavations of root systems were carried out by trench method at the end of the plants growing season in the phase of wax ripeness. The number of roots and their total length were counted in layer 10×10×100 cm through center of bush. Conversion of the total length of throughout soil circle profile of 1 m diameter was performed according to the following ratio: if a layer of 10 cm depth and of 1000 cm^2 area contains X m of roots, then in the same layer of area of a circle with a radius of 50 cm there is Y m of roots.

In the research, we used the methods of quantitative and qualitative comparisons and abstract logical and analytical analysis. The results were subjected to mathematical processing.

Results and discussion. It was found that under conditions of Ivanivska and Veselopodilska Experimental Breeding stations the formation of sweet sorghum rhizomes begins at stem elongation stage (*Table 1*).

Table1

Dates of the rhizomes formation start in sweet sorghum plants (2010–2014)

Phenological phase	Veselopodilska EBS					Ivanivska EBS				
	Years									
	2010	2011	2012	2013	2014	2010	2011	2012	2013	2014
Beginning of stem elongation	16.VII	17.VII	1.VII	5.VII	1.VII	20.VII	3.VII	30.VI	1.VII	8.VII
Beginning of rhizomes formation	23.VII	24.VII	8.VII	7.VII	8.VII	26.VII	10.VII	3.VII	11.VII	17.VII

An important biological feature of sorghum as compared with the other crops is its ability to grow rapidly into the dry soil. It is known that its seeds require the minimal amounts of water for germination – 28% of its weight, whereas corn – 44%, barley – 48, rye – 58% [4].Thus, due to the intensive development of the sorghum root system the conditions for the viability are provided in the earliest period of growing season.

Examination of the depth of plant roots penetration and their spread of them on the soil horizons was carried out in sorghum crops in 2010–2014. Excavation of the plants root system was carried out by the method of trenching at the end of the growing season in the phase of wax ripeness of seed (*Table 2*).

Table 2

Length, spread over horizons and depth of sweet sorghum root penetration(2010–2014)

Soil layer, cm	Veselopodilska EBS		Ivanivska EBS	
	Total root length, m	Proportion of the total, %	Total root length, m	Proportion of the total, %
0–10	1719	11.20	2167	11.70
10–20	2114	13.80	3069	16.60
20–30	2543	16.60	3721	20.20
30–40	2025	13.20	2402	12.90
40–50	1617	10,50	2033	10.90
50–60	1429	9.60	1444	7.90
50–60	11447	74.90	14836	80.20
60–70	942	6.50	997	5.40
70–80	887	5.80	746	4.20
80–90	636	4.40	542	2.60
90–100	408	2.60	440	2.40
100–110	377	2.50	275	1.30
110–120	165	1.10	243	1.20
120–130	133	0.80	189	0.90
130–140	133	0.80	165	0.80
140–150	86	0.50	141	0.70
150–160	39	0.25	126	0.60
160–170	16	0.10	118	0.50
170–180	8	0.05	118	0.50
180–190	8	0.05	47	0.15
190–200	0	0.00	39	0.11
200–210	0	0.00	16	0.06
0–210	15285	100.0	18510	100.00

Research did not revealed distinct tiers of the root system location in the soil profile during the growing season. Thus, the general biological regularity confirmed inherent to cereal crops that the overwhelming majority of the sorghum roots, namely 74.9% (Veselopodilska EBS) and 80.2% (Ivanivska EBS), is located in the upper (0–60 cm) soil layer which contains the greatest amount of nutrients. High saturation of roots in the fertile topsoil, according to the researchers, is a prerequisite for high their productivity, as it is there are nutrients and it is this layer of soil that is moistened because of summer precipitation, which in the south do not penetrate into the deeper of soil horizons [9, 15].

However, the research results show that the depth of the roots penetration into the soil ensures the stability of sorghum plants in the period of droughts (HTC 0.8). Thus, in the initial period of the growing season they reached a depth of 1.9 m, thus being able to use the moisture reserves of two-meter layer soil. In the conditions of experimental breeding station, sorghum develops root system with a total length of 15,285–18,510 m, which indicates its good adaptation to the growth conditions. The development of root system occurs not only by increasing the depth of root penetration, but also due to the increase of their number (*Table 2*). Excavations revealed that the maximum length of the plants roots at both Veselopodilska and Ivanivska EBS is concentrated in the 30–40 cm layer. The roots of sorghum mainly grow in the enough fertile, but at the same time in the less heated soil layer in which moisture retains longer.

Research has also shown that the nodal roots in the beginning of vegetation are growing obliquely with respect to the plant, and then change the direction and grow vertically downwards. Therefore, the root system of the plants is mainly located within the projection of a circle of radius

of about 1 m. The very process of sorghum plants rhizomes formation is as follows: a part of shoots produced in the tillering node changes orthotropic growth to plagiotropny. The tip of the growing shoot is focuses not up, as usual, but to the side and down, which leads to the transformation of stem into rhizome. It should be noted that this phenomenon is quite common in the plants and is caused, according to V. V. Polevoi [16], by the change in the ratio between the growth regulators (phytohormones) inside the plant. The data are presented in *Table 3*.

Table 3

Character of sweet sorghum rhizomes spread (Veselopodilska EBS, 2010–2014)

Year/HTC at vegetation period	Indexes					
	Number of rhizomes, pcs./plant	Rhizomes total length, m/plant	Depth, cm		Distance from the tillering node, cm	
			Average	Maximum	Average	Maximum
2010/1.0	23.2	6.8	34.1	61.0	48.0	65.0
2011/1.0	24.8	6.2	39.2	55.0	44.1	80.0
2012/0.8	21.5	5.1	26.0	45.0	40.0	51.0
2013/0.9	17.7	4.8	27.0	43.0	37.0	54.0
2014/1.1	22.3	6.7	35.0	48.0	45.0	43.0
$LSD_{0.05}$	7.4	1.6	11.7	25.7	9.4	27.3

Table 3 shows that in the initial dry growing seasons of 2012–2013 (HTC 0.8 to 0.9) sorghum plants significantly (by 13.1–62.2%), reduced the number of rhizomes, as compared with 2010, 2011 and 2014 years, which were characterized with mild wet spring (HTC 1.0 to 1.1). Also decreased was the total length of roots per plant from 6.2–6.8 m to 5.1 and 4.8 m, respectively.

A similar tendency was observed regarding the depth of sorghum root. Dry weather conditions of 2012–2013 vegetative periods (HTC 0.8 to 0.9) had negative influence on the depth of root penetration into the soil. Thus, the average depth of the roots location in these years was 26 to 27 cm, the maximum 43 to 45 cm, while in the years of moderate humidity (HTC 1.0 to 1.1) this index was higher by 13–17% and 22–30%, respectively. Thus, the changes in weather conditions in the research years affected significantly the formation and development of sorghum root system.

Conclusions. 1. Sorghum plants start their rhizomes developing at the stage of stem elongation and continue until the end of growing season. Most of rhizomes are located within the projection of the bush on the ground at a depth of 30–40 cm.

2. The biggest weight of the sorghum roots (74.9 to 80.2%) is located in the upper soil layer (0–60 cm), which contains the greatest amount of nutrients.

3. Sorghum develops a strong root system and reaches a depth of two meters with a total length of roots more than 15.000 m per plant. In some dry years plants reduce the number and total length of rhizomes by13.1–62.2% and in favorable by humidity and temperature conditions years increase by 13–17%.

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Анотація

Сторожик Л. І.

Коренева система сорго цукрового та особливості її формування

У статті представлено результати досліджень проникнення та інтенсивності росту кореневої системи сорго цукрового, глибина її проникнення і строки утворення кореневищ культури. Встановлено, що переважна маса коренів сорго розташовується у верхньому (0–60 см) шарі ґрунту і розвиває потужну кореневу систему, що досягає глибини двох метрів із загальною протяжністю коренів понад 15 тис. метрів на одну рослину.

Ключові слова: *сорго, коренева система, глибина, проникнення, ріст.*

Аннотация

Сторожик Л. И.

Корневая система сорго сахарного и особенности ее формирования

В статье представлены результаты исследований проникновения и интенсивности роста корневой системы сорго сахарного, глубина ее проникновения и сроки образования корневищ культуры. Установлено, чтоподавляющая масса корней сорго располагается в верхнем (0–60 см) слое почвы и развивает мощную корневую систему, достигающую глубины двух метров с общей протяженностью корней свыше 15 тыс. метров на одно растение.

Ключевые слова: *сорго, корневая система, глубина, проникновение, рост.*

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