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IRRIGATION PARAMETERS OF SEA BUCKTHORN OF VARIOUS PLANTING DENSITY DEPENDING ON WEATHER CONDITIONS

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Moisture and heat are the main factors limiting the yield of sea buckthorn. The research aims to assess the moisture regime of chernozem under sea buckthorn plantations of various planting densities and to calculate irrigation rates. In the spring of 2007, the water regime in the soil profile under the sea buckthorn plantations according to the (4x1) m scheme turned out to be very favorable until June. The need for irrigation arose due to the lack of soil moisture, which reached a maximum in early August and lasted until autumn. In the summer of 2008, there was a lack of available moisture in the humus layer of chernozem. In the second half of the summer period, irrigation rates increased to 460 t/ha and practically did not decrease until the end of August. Useful moisture reserves in May 2007 under the sea buckthorn plantations according to the scheme (4x2) m turned out to be low. Over the next months, the lack of moisture could be compensated by irrigation with irrigation rates of 300 to 500 t/ha. In 2008, the beginning of May was marked by high reserves of productive moisture. During all other months of summer, the water regime of the soil was characterized by a significant moisture deficit. Thus, the spring moisture reserve in the chernozem profile until July ensures the growth and development of plants. In the second half of summer, productive moisture reserves are intensively spent on transpiration and desuction from the soil surface. At the same time, atmospheric precipitation moistens only the humus horizon; therefore, irrigation reclamation is necessary to ensure the high productivity of sea buckthorn.

Keywords: *sea buckthorn; chernozem; moisture; water regime; irrigation; wilting moisture; lowest moisture capacity; moisture deficit; irrigation rate*

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ПАРАМЕТРЫ ОРОШЕНИЯ ОБЛЕПИХИ РАЗЛИЧНОЙ ПЛОТНОСТИ ПОСАДКИ В ЗАВИСИМОСТИ ОТ ПОГОДНЫХ УСЛОВИЙ

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Влага и тепло являются основными факторами, лимитирующими урожайность облепихи. Целью исследований являлась оценка режима увлажнения чернозема под облепиховыми насаждениями различной плотности посадки и расчет поливных норм. Весной 2007 года водный режим в почвенном профиле под насаждениями облепихи по схеме (4х1) м оказался весьма благоприятным вплоть до июня. Необходимость орошения возникла в связи с дефицитом почвенной влаги, который достигал максимума в начале августа и сохранялся до осени. Летом 2008 года наблюдался недостаток доступной влаги в гумусовом слое чернозема. Во второй половине летнего периода поливные нормы возросли до 460 т/га и практически не снижались вплоть до конца августа. Полезные запасы влаги в мае 2007 года под насаждениями облепихи по схеме (4х2) м оказались низкими. В течение последующих месяцев недостаток влаги можно было компенсировать орошением поливными нормами от 300 до 500 т/га. В 2008 году начало мая было отмечено высокими запасами продуктивной влаги. В течение всех остальных месяцев лета водный режим почвы характеризовался значительным дефицитом влаги. Таким образом, весенний запас влаги в профиле чернозема до июля обеспечивает рост и развитие растений. Во второй половине лета продуктивные запасы влаги интенсивно расходуются на транспирацию и десукцию с поверхности почвы. При этом атмосферные осадки увлажняют только гумусовый горизонт, поэтому для обеспечения высокой продуктивности облепихи необходимы оросительные мелиорации.

Ключевые слова: *облепиха; чернозем; влажность; водный режим; орошение; влажность завядания; наименьшая влагоемкость; дефицит влаги; поливная норма*

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Introduction

One of the limiting factors of crop productivity in the Altai Ob region is moisture, which is one of the irreplaceable factors of plant life. Therefore, information about the moisture content of the soil, the patterns of its formation and changes over time are important. Since the soil moisture reserves accumulated due to the cold period of the year in the forest-steppe zone on the left bank of the Ob River is sufficient, as a rule only until July, the question of their replenishment through irrigation is urgently raised [21].

Of the horticultural crops, one of the most popular in Siberian horticulture is sea buckthorn, which realizes its productivity potential only with sufficient moisture supply [12]. The sea buckthorn plant (*Hippophae ramnoides L.)* is a shrub with a wide distribution area in Russia. Sea buckthorn is one of the species of the oleaster family (Elegnacae). The crown of the bush is formed by branches of various ages. Sea buckthorn roots are located in the surface layer of the soil. At a depth of 0–10 cm, they are concentrated up to 25% of the total mass. The main amount of the root system (up to 77%) is located in the humus-accumulative horizon, and only a few reach a depth of 1.5–2.0 m. Most roots reach up to 1.3 mm in diameter. The root system is formed around the stem within a radius of up to one meter [5; 8; 13; 16].

Plants develop best on sandy loam or light loamy, water and air permeable soils enriched with mobile phosphorus [12]. At the same time, moisture content and heat are the main limiting factors of productivity [15; 18].

Since the culture of sea buckthorn is photophilous, it does not tolerate shading. The annual high productivity of sea buckthorn in the conditions of Western Siberia requires reliable protection by garden forest belts from harmful dry winds that often blow in the steppe zone. They optimize the heating conditions for the soil and reduce the loss of soil moisture as a result of physical evaporation and transpiration.

The improvement of the design of the sea buckthorn garden represents significant reserves for increasing its yield [19; 20]. The issue of thickening of sea buckthorn plantings has not been fully studied, and therefore there is a need to assess the reaction of sea buckthorn to the implementation of dense placement schemes and study the patterns of formation and manifestation of water properties in the soil profile. The scientific novelty of the research lies in the fact that we established deficiencies in the moisture content of chernozem for different planting densities of sea buckthorn during the growing season and determined the necessary irrigation norms to replenish the moisture reserve.

Materials and methods

The objects of research are chernozems leached under the plantings of sea buckthorn. The research aims to assess the regime of moistening of chernozem under sea buckthorn plantations of various planting densities and determine irrigation rates during the growing season. The tasks included the following questions: (1) to determine the basic water-physical properties of the studied chernozem; (2) to establish the reserves of soil moisture and its deficiency during the growing season at different densities of seabuckthorn planting; (3) calculate irrigation rates depending on the conditions of soil moisture. The research was carried out in 2006–2008 at the production sites of the M. A. Lisavenko Scientific-Research Institute of Horticulture of Siberia located in the area of Barnaul.

The methods generally accepted in land reclamation and agricultural soil science for determining soil moisture, density and its water-physical constants were used [1; 10].

Results

The profile of chernozem leached under sea buckthorn plantations has its own characteristics, which can be represented by the following expression: Ap (arable surface humus horizon 0–23 cm thick) + AB (eluvial horizon 23–34 cm thick) + B (illuvial, 34–60 cm) + BCk (transitional to horizon C, carbonate, 60–75 cm thick) + Ck (mother rock located at a depth of > 75 cm). At the same time, the Ap horizon is black-gray when dry and black when wet. It is light loamy, permeated with roots, loose.

The transitional layer AB has a brown hue, light loamy and loose. Illuvial horizon B is light brown, compacted, belongs to medium loam. Carbonates in the form of mycelium are present in the transitional horizon BCk. It is of a fawn shade, dense, and there are humus streaks, loamy. The mother rock is yellow-fawn, dense, homogeneous, has inclusions of carbonates, light loamy.

Thus, the studied soil is a leached low-humus chernozem with a complex granulometric composition from light to medium loam. The density of the genetic horizons increases with depth from 1080 kg/m^3 in the arable layer to 1,429 kg/m^3 in the underlying rock. The wilting moisture (WM) in the chernozem profile varies within 7.5%–8.5% of the dry soil mass, and the lowest moisture capacity (LMC) is from 32.6% in Ap to 20.1% in the Ck horizon. The average values of general physical and water-physical indicators for one-meter soil thickness are presented in Table 1.

Table 1.

General physical and water-physical indicators of leached chernozem (2007)

Depth (h), cm	Bulk density (ρ), kg/m ^{3}	Wilting moisture (WM), %/mm	Lowest moisture capacity (LMC),%/mm	Total porosity (P), %	Aeration porosity (Pae),%
0–20	1,144	8.4/18.5	32.0/70.4	55.7	24.7
0–100	1,264	8.1/102.1	25.3/319.0	52.3	29.0

We have assessed the parameters of the water regime of the soil under rainfed conditions to determine the moisture deficit and irrigation rates. With an accurate calculation, for example, WM and LMC, values are obtained equal to 104.7 mm and 304.0 mm, respectively. The average values presented in Table 1 are 102.1 mm and 319.0 mm, respectively. This indicates that the relative error does not exceed 2.5% for WM and 4.9% for LMC, which is much less than the error allowed in field experiments, which is more than 10%.

It should be noted that the moisture content in the chernozem profile and the humus-accumulative horizons under the sea buckthorn plantations is mainly determined by meteorological conditions during the growing season. They include precipitation and air temperature. In this regard, it is necessary to give a brief analysis of the weather conditions during the years of research.

The winter of 2006–2007 was abnormally warm; the height of the snow cover in the middle of winter reached 61 cm, which prevented deep freezing of the soil. The air temperature in May averaged 12.6°C. June 2007 was 1.8 °C colder than the average climatic norm, and July was warmer by 1.6°C. April 2007 was dry, and there was practically no precipitation. However, there were intense rains in May, which lasted until mid-June. During the second half of the growing season, the weather was dry until the beginning of August. In general, during the time when the air temperature was more than 10°C, the amount of precipitation reached 247 mm.

The beginning of spring 2008 was very warm. Already in March, the maximum temperature was + 13.5°C (March 23). April was characterized by unstable weather with much precipitation. In general, precipitation in the form of snow and rain exceeded the norm by 25 mm, the monthly sum of temperatures was 108 °C above the norm. The moisture content in the profile of the chernozem was provided mainly by snow and rainfall since snowmelt water was insufficient due to a winter with little snow. Meteorological conditions in June for berry crops were characterized as favorable. A deficit of available moisture in the soil was observed only at the end of July due to the absence of atmospheric precipitation and the onset of drought [4].

In 2007–2008, we performed observations of the soil moisture regime at a different planting pattern for sea buckthorn plants. Moistening of the soil profile was studied when the culture was placed in the classical way (4x2) m and compacted (4x1) m. The research results are presented in Tables 2 and 3.

Table 2.

Total (TMR – numerator) and productive (PMR – denominator) moisture reserves, as well as a shortage of available water in the arable layer and a meter soil layer (mm) with a sea buckthorn planting scheme (4x1) m

2007							
May 8	May 31	June 12	June 21	June 30	July 10	July 31	August 21
0–20 cm							
80.1/61.6	53.6/35.1	50.4/31.,9	48.1/29.6	60.4/41.9	36.7/18.2	35.8/17.2	44.7/26.2
Deficiency of available moisture							
8.8	35.3	38.5	40.8	28.5	52.2	53.2	44.2
0–100 cm							
254.5/152.4	260.8/158.7	252.0/149.9	236.2/134.1	262.1/160.0	199.1/97.0	173.9/71.8	189.0/86.9
Deficiency of available moisture							
166.6	160.3	169.1	184.9	159.0	222.0	247.2	232.1
2008							
May 10	May 29	June 12	June 23	June 30	July 13	July 27	August 18
0–20 cm							
60.6/42.1	44.0/25.5	52.0/33.5	56.5/38.0	42.0/23.5	45.4/26.9	48.6/30.1	32.6/14.1
Deficiency of available moisture							
28.3	44.9	36.9	31.4	46.9	43.5	40.3	56.3
0–100 cm							
298.6/198.4	243.2/141.1	235.6/133.5	277.2/175.1	218.0/116.2	224.3/122.2	235.6/132.5	184.0/82.3
Deficiency of available moisture							
100.2	177.9	185.3	143.9	202.8	196.8	186.5	236.7

Table 3.

Total (TMR – numerator) and productive (PMR – denominator) moisture reserves, as well as a shortage of available water in the arable layer and a meter soil layer (mm) with a sea buckthorn planting scheme (4x2) m

2007							
May 8	May 31	June 12	June 21	June 30	July 10	July 31	August 21
0–20 cm							
51.5/33.0	45.4/26.9	56.8/38.3	44.7/26.2	57.5/39.0	44.5/26.0	33.7/15.2	37.2/18.7

End of Table 3.

Deficiency of available moisture							
37.4	43.5	32.1	44.2	31.4	44.4	55.2	51.7
0–100 cm							
255.8 153.7	230.6 128.5	270.9 169.8	223.0 121.1	260.8 159.7	226.8 124.7	160.0 58.2	195.3 93.2
Deficiency of available moisture							
165.3	190.5	149.2	197.9	159.3	194.3	260.8	225.8
2008							
May 10	May 29	June 12	June 23	June 30	July 13	July 27	August 18
0–20 cm							
61.8 43.3	44.9 26.4	47.4 28.9	61.8 43.3	43.3 24.8	39.2 20.7	39.7 21.2	34.9 16.4
Deficiency of available moisture							
27.1	44.0	41.5	27.1	45.6	49.7	49.2	54.0
0–100 cm							
287.3 175.2	236.9 134.8	223.0 121.1	277.2 175.1	229.3 127.2	210.4 108.6	216.7 114.6	186.5 84.3
Deficiency of available moisture							
143.8	184.2	197.9	143.9	191.8	210.4	204.4	234.7

Discussion

At the beginning of May 2007, quite favorable water conditions were formed in the soil profile under the seabuckthorn plantations according to the scheme (4x1) m. In the plowed layer, the TMR was 80.1 mm, and the PMR was 61.6 mm. This corresponded to the classification of A.F. Vadyunina, a very good moisture level, at which the moisture deficit was extremely small (8.8 mm). Water availability was similar in the one-meter layer of chernozem when the PMR reached 198.4 mm. However, by the beginning of June, the water regime of the soil had changed dramatically. Thus, the productive moisture reserves decreased by the 12th of June in the 0–20 cm layer to 31.9 mm, and the water deficit increased to 35.3 mm. To obtain a high yield of sea buckthorn, it became necessary to irrigate with an irrigation rate of 350 t/ha. The maximum deficit of available moisture appeared in early August and persisted until autumn, reaching 53 mm, which corresponded to irrigation of 530 t/ha, which could be divided into two irrigations of 250–260 t/ha with a difference of 3–5 days. In the meter layer of soil, there was also a significant lack of productive moisture exceeding 200 mm. The moisture deficit in the one-meter stratum existed throughout the growing season, but there was no need to wet it since the bulk of the roots of the sea buckthorn plant is concentrated in the humus-accumulative horizons.

In the spring of 2008, the one-meter soil thickness turned out to be more wetted, especially in its lower part, where ELVs exceeded 198 mm, which characterized them as excellent. On May 10, the PMR in the arable layer was 42.1 mm, which corresponded to a good level of moisture. However, already at the end of spring, the situation began to change since hot weather came and the sum of temperatures for the month was more than in 2007 by 108°C. Therefore, during the entire growing season, there was a significant deficit of available moisture in the humus horizon, which was not noted in the lower part of the profile.

In the second half of summer, the PMR value decreased, which caused an increase in moisture deficit, at which irrigation rates increased to 460 t/ha by the beginning of July and practically did not decrease until the end of August. At the same time, the moisture deficit in the underlying horizons in 2008 was less than in 2007.

Consider the moisture content in the soil under the sea buckthorn plantings according to the scheme (4x2) m. The productive amount of moisture in May 2007 was low. Thus, the moisture deficit in the arable layer was equal to 37–43 mm, and the level of PMR averaged 30 mm, which can be characterized as satisfactory. Over the next months, the lack of moisture fluctuated within 44–55 mm, with the exception of June 30, when it dropped to 31 mm as a result of atmospheric precipitation the day before.

In the one-meter soil layer from May to early June, PMR corresponded to the optimal level but then decreased to 58.2 mm at the end of June and did not exceed 93.2 mm in August. The upper root-inhabited layer of chernozem needed irrigation during the growing season with rates from 300 to 500 t/ha.

In 2008, the beginning of May was marked by high reserves of productive moisture. During the entire summer period, there was a significant shortage of productive water in the amount of 40 to 50 mm, which determined the irrigation rate in the amount of 400–500 t/ha. Only on June 23, under the influence of the past rains, PMR was equal to 43.3 mm with a moisture deficit of 27.1 mm.

At the same time, the moisture reserves in the one-meter layer of chernozem were very good throughout the summer, with the exception of August, when they dropped to 84.3 mm. Taking into account the location of the bulk of the sea buckthorn roots in the humus-accumulative horizons, we should note that in the summer of 2008, the water supply to plants was more intense than in the previous year.

The regularities revealed by us in the formation of the water regime of the soil are consistent with the previously obtained results of V.P. Panfilov [9], I.A. Trunov [14], S.N. Khabarov [18], and N.V. Mikhailova [5]. S.N. Khabarov pointed to the peculiarities of the seasonal rhythms of the moisture content of soil horizons in the gardens of the forest-steppe zone on the left bank of the Ob River. He noted that the depth of soaking of chernozem by summer precipitation ranges from 8 to 35cm. Therefore, during dry years, the water regime in the first half of the growing season is determined by winter moisture reserves in the form of snow and spring rains. In addition, the degree of humidification of humus-accumulative horizons of chernozem in the hot season of June-August depends only on meteorological conditions, which are temperature and amount of precipitation. N. V. Mikhailova concludes that the growing season is divided into two parts. In spring, the moisture reserve in the chernozem profile ensures the growth and development of plants under the influence of late autumn precipitation and meltwater. Then the productive reserves of moisture are intensively consumed by plants against the background of physical evaporation from the soil surface. Atmospheric precipitation moistens only the humus horizon. Therefore, irrigation reclamation is necessary to ensure the high productivity of sea buckthorn. Other researchers have expressed a similar opinion [2; 3; 15].

The results of such studies can be extrapolated and useful for farmers in countries with similar environmental conditions [7; 22]; and they also may be required when planning irrigation reclamation [9].

Conclusion

The studied soil is leached chernozem, low-humus, medium loamy, well structured, highly water-absorbing, poorly consolidated.

A seasonal mode of soil profile moistening was established. There was a wetting of a meter-long soil layer in spring due to winter precipitation, then intensive drying of the upper soil horizons in May-June and the formation of a deep water depression in July and August.

The moisture deficit in the soil under the sea buckthorn plantations must be replenished with certain irrigation rates, on which its productivity depends. In 2007, in the soil profile with a compacted seabuckthorn planting scheme (4x1) m, a moisture deficit was observed since June and to obtain a high yield of fruits, irrigation rates of 350 t/ha were required to wet the upper soil horizons, in July and August the recommended irrigation rates increased to 530 t/ha and 440 t/ha, respectively. Under the plantations of sea buckthorn according to the scheme (4x2) m, the moisture deficit in spring occurred earlier, and the volumes of irrigation rates were comparable, from 300 to 500 t/ha during the growing season.

In 2008, water deficiency in the 0–20cm soil layer under the sea buckthorn plantations according to the planting pattern (4x1) m occurred at the end of May. Recommended irrigation rates for all sea buckthorn planting schemes were as follows: May – 280–450 t/ha; June – up to 470 t/ha; July – 400 t/ha; August – up to 500 t/ha.

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