The effect of the sum of soil temperatures on the yield model of onion (*Allium cepa* L.) in the High Altai Prioby

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Abstract. The article presents an information-logical model of the dependence of the productivity of onion on certain meteorological and soil-physical factors. The authors conclude that meteorological factors of the growing season have a great influence on crop production, namely the hydrothermal coefficient and the sum of temperatures. Soil-physical factors (humidity and volumetric heat capacity) are also highly important.

1. Introduction

Currently, due to the intensification of agricultural production, much attention is paid to the development of the vegetable industry. As a rule, one person eats fresh vegetable products almost all year round. In addition, vegetable crops are processed, canned, dried, and frozen. One of the important problems of today’s agriculture is the production of domestic high-quality agricultural products, including vegetable products, in a volume that allows the population to completely eliminate the need for food [1].

Onion is one of the most sought after and common vegetable crops in the world. Perennial by nature, onion has gone a long way in cultivation. Currently, onions are grown under production conditions through sowing, seedlings and seeds; in winter, bulbs are used for forcing green onions.

Onions are used by peoples for food all year round in fresh and processed form. This plant is a powerful antioxidant, people know its medicinal and insecticidal properties from ancient times. In terms of its biochemical parameters, it surpasses many vegetable crops. Onions are valuable for their essential oils, flavonoids, mainly glycosides. Onions contain a large group of carbohydrates: sucrose, fructose, pectin, etc. [2, 3].

Onion is cultivated everywhere, it can be successfully cultivated in the Altai region as well. However, the onion turnip production is not debugged in the region. Up to 16 thousand tons of onion turnips are required for the population of the region annually for normal consumption. On the territory of the region, about 4.5 thousand tons are grown, the missing amount of onion comes from the southern regions of the country and the countries of the near abroad.

Climatic conditions of the Altai region are considered to be sharply continental, the duration of the growing season with favorable conditions for onions is 120-130 days on average. This time is sufficient for the formation and maturation of onion. In relation to temperature conditions, onion is a relatively cold-resistant culture. Its seeds can be grown at a soil temperature of 1 ... 20°C. An optimum temperature regime for seed germination is 20 ... 22°C; under such conditions, seedlings appear already for 6-7 days. Onion shoots are relatively easy to tolerate late spring cooling, and even short frosts up to -3 °C. The best temperature for the growth of leaves is 15-20 °C. During the bulb
formation, the outflow of nutrients comes from the leaves; consequently, the temperature of 20-25°C is necessary. It is at this temperature that the bulb successfully forms and matures [4, 5, 6, 7].

2. Materials and Methods

The studies were carried out in the conditions of stationary experience in the selection field of the laboratory of onion crops of the West Siberian Vegetable Experiment Station (a branch of the Federal Research Center for Vegetable Growing in 2004-2007). The station is located according to the climatic zoning of the region in the territory belonging to the subzone of chernozem of moderately arid and forested steppes [8]. The soil of the experimental plot is represented by leached chernozem [9].

The field production experience was laid for research. The area of the plot is 1000 m², there are two options in the experiment: 1 – a plot occupied with onion; 2 – a steam (control). Onions were cultivated through the seeding culture. Its rate was 1300-1500 kg/ha, the planting date was 5-10.05.

To determine the temperature in the soil profile under the bulb onions, we used a soil electrothermometer, which allowed to measure the temperature of the upper (0-20 cm) soil layer every 5 cm [10].

The obtained results were processed using the methods of information logical analysis [11].

3. Results

During its vegetative development, vegetable crops, including onion, are capable of forming a temperature regime with the characteristics of crops [12]. The task of our study was to identify such features under the planting of onions, formed in the conditions of high Altai Prioby.

During the growing season of onion culture plants, we observed the formation of temperature conditions in the soil under plantings and under control. The measurements were carried out in a 20 cm layer at different depths, this is the productive layer for the formation of the bulb and the location of 35-45% of the root mass of the plant.

The results of observations of the temperature in the active layer of the soil in the form of daily amounts at different depths in 2004 and 2006, as well as in 2007 are presented in Table 1 and 2.

| Depth, cm | 2004 |       |       |       |       |
|----------|------|-------|-------|-------|-------|
|          | June 9-10 | June 30 - July 1 | July 31 - August 1 |
|          | Steam Onion  Steam Onion  Steam Onion |
| 0        | 181.0 156.2 | 183.4 176.1 | 145.0 142.6 |
| 5        | 176.8 159.1 | 173.8 166.6 | 137.5 123.1 |
| 10       | 156.7 160.4 | 168.1 162.1 | 122.4 114.8 |
| 15       | 154.8 155.8 | 165.0 159.5 | 112.0 110.6 |
| 20       | 151.2 153.9 | 162.2 156.4 | 104.7 104.2 |
| Σ        | 821.5 785.4 | 852.5 820.7 | 621.6 595.4 |

| Depth, cm | 2006 |       |       |       |       |
|----------|------|-------|-------|-------|-------|
|          | June 27-28 | June 25-26 | August 8-9 |
|          | Steam Onion  Steam Onion  Steam Onion |
| 0        | 187.8 177.2 | 147.2 138.2 | 138.5 123.7 |
| 5        | 176.0 167.7 | 139.4 131.1 | 128.7 115.7 |
| 10       | 169.5 160.9 | 127.4 128.0 | 114.3 109.5 |
| 15       | 166.8 155.7 | 126.0 126.2 | 109.2 107.9 |
| 20       | 163.1 156.5 | 128.7 126.1 | 100.7 106.0 |
| Σ        | 863.2 818.0 | 668.7 649.6 | 577.4 562.8 |
Table 2. The sum of daily temperatures in the arable layer of Chernozem in 2007.

| Depth, cm | June 16th-17th | July 21st-22nd |
|-----------|----------------|----------------|
| Steam     | Onion          | Steam          | Onion          |
| 0         | 155.9          | 135.8          | 185.0          | 175.2          |
| 5         | 141.1          | 127.4          | 180.1          | 173.9          |
| 10        | 127.0          | 124.6          | 175.6          | 170.6          |
| 15        | 120.7          | 116.4          | 168.9          | 168.8          |
| 20        | 115.4          | 112.2          | 162.5          | 164.1          |
| Σ          | 660.1          | 616.4          | 872.1          | 852.6          |

The data of the sum of temperatures at a specific observation hour (13.00 hours) in a layer of 0-20 cm was obtained in the same years of observations (Tables 3, 4).

Table 3. The sum of temperatures at 13.00 in a layer of 0-20 cm (2004, 2006).

| Layer thickness, cm | 2004       | 2006       | 2004   | 2006   | 2004 | 2006 |
|---------------------|------------|------------|--------|--------|------|------|
| 0-20                | June 9th   | June 30th  | June 27th | July 25th | August 8th |
| Steam          | Onion          | Steam          | Onion          | Steam          | Onion          |
| 140.6             | 123.7        | 127.5        | 128.7        | 97.1        | 96.4 |
| 0-20                |             |             |             |             |      |
| 0-20                | 164.5        | 159.6        | 132.6        | 131.5        | 86.5 | 84.1 |

Table 4. The sum of temperatures at 13.00 in a layer of 0-20 cm (2007).

| Layer thickness, cm | Observation time        |
|---------------------|-------------------------|
| 0-20                | May 28th | June 16th | June 23rd | July 23rd | August 8th |
| steam          | onion         | steam          | onion          | steam          | onion          |
| 94.6             | 100.9        | 97.1          | 88.7          | 148.1        | 134.6 |

4. Discussion

Analyzing the data in Table 1, we can note that in 2004, the daily sum of surface temperatures of the black soil was always higher in steam than under the cover of onion. The difference in the values of the sum of temperatures was about 25°C in June, whereas it was 7°C at the end of June and 3°C at the end of July. This difference may be due to different weather conditions. Intensive warming of the air entailed a significant difference in soil temperature on the studied variants. This effect smoothed out with depth. And, in general, in the upper 20-centimeter layer in a steam, the amount of daily temperature for the growing season was more by 25-40°C than in the area occupied by onion.

Continuing to analyze Table 1, we see that during the observations in 2006, the sum of daily temperatures of the vapor field surface was higher than in 2004. At the end of June, it turned out to be 187.8°C in the first case and 183.4°C in the second case. Similar results were observed in late July and early August. Throughout the topsoil, the sum of temperatures was higher in a steam than under the onion.

In 2007, the obtained amounts of daily temperatures in the control area and under the onion indicate the trend of previous years (Table 2). So, during the growing season in a steam, they were higher as before and amounted to 660 °C and 616 °C in June. In July, the air warmed up to 30°C, this was reflected in the value of the sum of daily temperatures, making them higher than in the same periods in previous years.

Tables 3 and 4 represent the sum of temperatures of the 0-20 cm layer at 13.00 with these options in the same years of observation. Calculations showed that in 2004, the difference in the sum of temperatures in the steam and under the onion was 170°C in June, and it was practically absent in July. In 2006, the trend continues: in June is 50°C, in subsequent periods is 1-20°C. And as it turned out that in 2007, the patterns found in previous years are confirmed: the sum of temperatures in the steam and under the onion differs slightly (5-15°C).
5. Conclusion
Meteorological factors of the growing season have a great influence on crop production, namely the hydrothermal coefficient (HTC) and the sum of temperatures (\( \sum T, ^\circ C \)). Other soil-physical factors are important, such as humidity (U, %) and volumetric heat capacity (\( C_p, J / m^3 K \)).

The effect of the sum of temperatures in 0-20 cm layer on the formation of yield of onions is presented in Table 5.

Table 5. The effect of the sum of soil temperatures on the productivity of onion.

| Factor       | Condition factor | Productivity, t / ha | Yield rank |
|--------------|------------------|----------------------|------------|
| \( \sum T, ^\circ C \) | \(<90.0\)         | \(<25.0\)            | 2(3)       |
| 0-20 cm layer| 90.1-110.0       | 25.1-30.0            | 3(4)       |
| \( T=0.4775 \) | 110.1-120.0      | 30.1-35.0            | 3          |
| \( K=0.2303 \) | 120.1-140.0      | 35.1-40.0            | 3          |
|             | >140.1           | >40.1                | 2          |

Information analysis of the dependence of yield on the sum of soil temperatures showed a high reliability, which is 0.4775. A high coefficient of effectiveness of communication channels (\( K = 0.2303 \)) corresponds to the information analysis. This coefficient shows the measure of dependence between phenomena.

The most significant factors (if evaluated by the magnitude of the efficiency factor of the communication channel with the yield) can be arranged in a logical series:

\[
HTC > \sum T > U > C_p
\]

The results obtained made it possible to create an informational logical model:

\[
Y = HTC \times \sum T \times U \times C_p,
\]

where \( Y \) is the yield rank of onion crops, HTC is the yield rank, depending on the HTC, \( \sum T \) is the yield rank, depending on the amount of temperature in the 0-20 cm layer, U is the yield rank, depending on soil moisture, \( C_p \) is the rank yield, depending on the volumetric heat capacity of chernozem.

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