Science-based regimes of corn irrigation for grain in the reclaimed lands of Rostov region

I V Gurina, N V Mikheev and A I Shcherenko

Novocherkassk Engineering and Land Reclamation Institute named after A K Kortunov Branch of the Federal State Educational Institution of Higher Education “Don State Agrarian University”, 111, Pushkinskaya Street, Novocherkassk, Rostov region, Russia

E-mail: i-gurina@mail.ru

Abstract. The purpose of the studies conducted in 2013-2015 was to develop scientifically grounded regimes of corn irrigation for grain during sprinkler irrigation with the use of wide-capacity sprinklers. Field research was carried out at the pilot site in LLC Svetlagorskoye, Bagaevsky District, Rostov Region. As a result, it was established that during the dry growing season (at HTC = 0.59) to maintain the specified thresholds of soil moisture 7 growing season irrigations by irrigation rates from 240 to 500 m$^3$/ha were carried out. The irrigation rate was 3040 m$^3$/ha.

At HTC = 0.50, 6 vegetative waterings were carried out according to the norms from 300 to 500 m$^3$/ha. The irrigation rate was 2400 m$^3$/ha.

At HTC = 0.58 8 vegetation irrigation with irrigation rates from 350 to 450 m$^3$/ha was carried out, irrigation rate was 3400 m$^3$/ha.

In our studies also determined the total water consumption by the water balance method. The analysis of the total water consumption structure allowed establishing that the main share in the structure (up to 70%) was the irrigation rate, then precipitation and productive moisture reserves used by plants.

1. Introduction

Studies conducted in different regions have shown that irrigation significantly increases crop yields, in particular, corn for grain. However, it is important to observe a complex of effective agrotechnical measures and to apply science-based irrigation regimes [1-4].

Irrigation regime should meet the water requirements of plants in each phase of their development, provide regulation of nutritious, air and heat regimes of soil, improve the fertility of irrigated lands, as well as ensure stable crop yields. Also, the irrigation regime is influenced by the applied method and technique of irrigation, water availability, natural and climatic conditions, applied agricultural machinery, labor availability and other factors.

In this connection, the aim of the research was to develop scientifically grounded regimes of corn irrigation for grain during sprinkling with the use of wide-capacity sprinklers.

2. Materials and methods

Research on the development of corn grain irrigation regimes was carried out in 2013-2015 at a pilot site in LLC Svetlagorskoye, Bagaevsky District, Rostov Region.
Soils of the experimental site are represented by ordinary black soils with high water-holding capacity: the lowest moisture capacity in the layer of 0.6 m was 28.1%, density - 1.25 g/cm$^3$, the total load factor in the layer of 0-100 cm - 48%, maximum hygroscopicity - 10.8%. The content of mobile phosphorus in the soil layer of 0-40 cm was 31.0 mg/kg, available potassium - 490.0 mg/kg. The availability of mobile phosphorus is medium, and the potassium available is high. Soils are resistant to salting, as the absorbing complex is saturated with calcium (0.70 mg-eq.). The analysis of water extraction has shown that there is no excess salt in the soil and it is suitable for cultivation of agricultural crops, including corn for grain.

Ground waters on the pilot plot were found at depths of more than 5 m. Their chemical composition is hydrocarbonate-sulfate-calcium. They did not influence the growth and development of agricultural crops.

Corn was irrigated with a frontal sprinkler Reinke-A-100.

Field studies were conducted in accordance with generally accepted methodological guidelines [5-7].

3. Results and Discussion
Establishment of the irrigation regime begins with determining the values of irrigation rates, the number of irrigations and the timing of their implementation. The irrigation rate depends on the water-physical properties of the soil and the depth of the calculated (active) layer, which is the main mass of the root system of irrigated crops [8]. The main mass of the root system of corn, cultivated on grain, during sprinkling irrigation is concentrated in a layer of 0-60 cm, and this layer is considered active, and when calculating the irrigation rate - the calculated [9, 10].

Irrigation is carried out with the aim of creating a favorable water regime in the active soil layer during the period of growth and development of agricultural crops. There are various methods of establishing the timing of irrigation of crops. In our studies we used the method of assigning the next irrigation period by soil moisture. It is important to correctly determine the lower humidification threshold, which requires another watering. It is expressed as a percentage of the lowest moisture capacity (LH). It is known that the highest productivity of corn for grain is achieved at the pre-irrigation
threshold of soil moisture of 60-75% of NV in the active layer [9, 10]. Further reduction of soil moisture leads to low yields.

Natural water availability, i.e. the amount of precipitation has a huge impact on the irrigation regime and the irrigation rate. Meteorological conditions had a significant impact on the irrigation regimes of the studied crop (Table 1).

Table 1. Meteorological indicators in comparison with average annual data, m/s Semikarakorsk

| Climatic parameters | Year | Month | Average for vegetation period |
|---------------------|------|-------|-----------------------------|
| Daily average air temperature, °C | Year | 04 | 05 | 06 | 07 | 08 | 09 | |
| | 2013 | 12.1 | 21.1 | 23.0 | 24.3 | 24.6 | 14.9 | 20.0 |
| | 2014 | 9.7 | 19.1 | 20.8 | 24.4 | 25.0 | 17.4 | 19.4 |
| | 2015 | 9.8 | 16.2 | 23.0 | 24.4 | 24.3 | 21.2 | 20.0 |
| Average annual data | | 10.2 | 16.5 | 20.5 | 23.5 | 22.6 | 16.4 | 18.3 |
| Precipitation, mm. | Year | 2013 | 2014 | 2015 |
| | Average annual data | 33.0 | 37.0 | 45.0 | 41.0 | 0.5 | 21.0 | 177.5 |
| | 2013 | 10.5 | 1.5 | 36.0 | 29.7 | 34.4 | 98.8 | 210.9 |
| | 2014 | 33.0 | 37.0 | 45.0 | 41.0 | 0.5 | 21.0 | 177.5 |
| | 2015 | 52.0 | 71.0 | 34.0 | 21.0 | 20.0 | 7.0 | 205.0 |
| Average annual data | | 33.0 | 37.0 | 45.0 | 38.0 | 36.0 | 29.0 | 218.0 |
| Relative air humidity, % | Year | 2013 | 2014 | 2015 |
| | Average annual data | 67 | 59 | 56 | 53 | 54 | 59 | 58 |
| | 2013 | 63 | 54 | 53 | 48 | 50 | 77 | 58 |
| | 2014 | 66 | 65 | 57 | 48 | 46 | 54 | 56 |
| | 2015 | 65 | 67 | 59 | 51 | 38 | 49 | 55 |

Assessment of the degree of moisture content in the territory was carried out using the hydrothermal coefficient (HTC). The growing season of 2013 can be characterized as very dry. HTC this year amounted to 0.59. The value of HTC in 2014 was 0.5, which indicates that the vegetation period of this year is very dry. The growing season of 2015 was also very dry, as the HTC was 0.58.

The developed modes of corn for grain irrigation are presented in Table 2.

Table 2. Corn crop irrigation regimes, 2013-2015

| Irrigation order number | Date of execution | Irrigation rate, m³/ha. | Date of execution | Irrigation rate, m³/ha. | Date of execution | Irrigation rate, m³/ha. |
|------------------------|-------------------|------------------------|-------------------|------------------------|-------------------|------------------------|
| 1                      | 15.05             | 240                    | 04.06             | 500                    | 4.06              | 350                    |
| 2                      | 27.05             | 400                    | 16.06             | 300                    | 10.06             | 400                    |
| 3                      | 04.05             | 400                    | 26.06             | 400                    | 17.06             | 400                    |
| 4                      | 15.06             | 500                    | 05.07             | 400                    | 2.07              | 450                    |
| 5                      | 27.06             | 500                    | 16.07             | 400                    | 13.07             | 450                    |
| 6                      | 05.07             | 500                    | 24.07             | 400                    | 21.07             | 450                    |
| 7                      | 16.07             | 500                    | -                 | -                      | 30.07             | 450                    |
| 8                      | -                 | -                      | -                 | -                      | 8.08              | 450                    |
| Nop                    | -                 | 3040                   | -                 | 2400                   | -                 | 3400                   |

In our studies, the pre-irrigation threshold of soil moisture on corn grain sowings in the 0-60 cm layer was maintained at least 70-75% HB. During dry vegetation periods (at HTC = 0.59) 7 vegetation water applications with irrigation rates from 240 to 500 m³/ha were carried out to maintain the given
thresholds of soil moisture. The irrigation rate was 3040 m$^3$/ha. At HTC = 0.50, 6 vegetative waterings were carried out according to the norms from 300 to 500 m$^3$/ha. The irrigation rate was 2400 m$^3$/ha. At HTC = 0.58, 8 vegetation irrigation with irrigation rates from 350 to 450 m$^3$/ha was carried out, irrigation rate was 3400 m$^3$/ha.

At appointment of terms of carrying out of vegetative waterings the approach of the basic phases of vegetation of corn for grain was considered (table 3). High demand for moisture in this crop is noted in the phase “7-9 sheets”, 7-8 days before the phase of “ejection of the panicle” and continues until the end of flowering. The critical period with respect to moisture is also observed in the grain filling phase [9, 10]. In this regard, during these periods of growth and development of culture it is necessary to carry out irrigation. The water regime forming on crops influenced the terms of the main phases of corn vegetation for grain.

| Vegetation phases         | Dates of the vegetation phases |
|---------------------------|--------------------------------|
|                           | 2013  | 2014  | 2015  |
| Sowing                   | 19.04 | 23.04 | 3.05  |
| Shoots                   | 4.05  | 03.05 | 14.05 |
| 3d leaf                  | 15.05 | 13.05 | 25.05 |
| 6-7th leaf               | 25.05 | 03.06 | 12.06 |
| 8-9th leaf               | 5.06  | 19.06 | 17.06 |
| 10th leaf                | 9.06  | 01.07 | 27.06 |
| Ejection of the panicle  | 28.06 | 10.07 | 6.07  |
| Blossoming               | 5.07  | 18.07 | 13.07 |
| Full ripeness            | 15.07 | 27.07 | 20.07 |
| Wax ripeness             | 7.08  | 07.08 | 11.08 |
| Full ripeness            | 23.08 | 23.08 | 25.08 |
| Harvesting               | 28.08 | 29.08 | 9.09  |
| Vegetation period, 24h   | 114   | 116   | 119   |

On corn sowings at the beginning of vegetation humidity of soil was maintained at the level of 80 % HB, from a phase "6-7 leaves" up to a phase "milk ripeness" - 75-80 % HB that has allowed to receive the following yielding capacity of grain: 2013 – 7.9 t/ha, 2014 – 10.1 t/ha, 2015 – 11.4 t/ha.

In our studies, total water consumption was determined, which gives a concrete idea of the crop's water requirements to create a certain yield. Calculation of total maize grain water consumption was carried out using the water balance method [11]. The results of the calculation are presented in Table 4.

| Table 4. Total water consumption of corn for grain, 2013-2015 |
|---------------------------------------------------------------|
| The moisture content of the soil used, m$^3$/ha | Precipitation, m$^3$/ha | The irrigation rate, m$^3$/ha | Total water consumption, m$^3$/ha | Yielding capacity, t/ha | Water consumption ratio, m$^3$/t |
|---------------------------------------------------------------|
| 1046                           | 180                    | 3040                        | 4266                        | 7.9                       | 540                            |
| 268                            | 839                    | 2400                        | 3507                        | 10.1                      | 347                            |
| 1536                           | 1717                   | 3400                        | 6680                        | 11.4                      | 586                            |
Analysis of the total water consumption structure allowed establishing that the main share in the structure (up to 70 %) was the irrigation rate, then precipitation and the reserves of productive soil moisture used by plants.

4. Conclusion
Science-based maize irrigation regimes have been developed, the application of which in the arid conditions of the South of Russia during frontal irrigation with Reinke-A-100 sprinklers allows to obtain a sufficiently high grain yielding capacity.

The results of the field research allowed determining the expediency of corn production on reclaimed lands using scientifically grounded irrigation regimes.

References
[1] Kireicheva L V, Karpenko N P 2015 Evaluation of the efficiency of irrigation in a zonal soil sequence Eurasian Soil Sci. 48(5) 524–532
[2] Dubenok N N 2013 Land reclamation - the basis of successful development of agro-industrial complex Land Reclamation and Water Management. 3 7–9
[3] Cassman K G 1999 Ecological intensification of cereal production systems: Yield potential, soil quality, and precision agriculture Proc. of the National Academy of Sciences of the United States of America. 96(11) 5952–5959
[4] Stricevic R J, Stojakovic N, Vujadinovic-Mandic M, Todorovic M 2018 Impact of climate change on yield, irrigation requirements and water productivity of maize cultivated under the moderate continental climate of Bosnia and Herzegovina J. of Agricultural Sci. 156(5) 618-627
[5] Shevchenko P D, Olgarenko G V, Ivanova N A 2001 Practical guidance on the methodology of experiments in steppe agrolandscapes. (Novocherkassk) p. 114
[6] Goryanskiy M M 1970 Methodology of field experiments on irrigated lands. (Moscow: Yield) p. 172
[7] Pleshakov V N 1983 Methodology of the field experiment under irrigation conditions (Volgograd) p. 147
[8] Ivanova N A, Gurina I V, Shemet S F, Gurin K G, Oleinikova M F 2010 Methodical guidelines for calculation of optimal water regime of root-inhabited soil layer during cultivation of agricultural crops on irrigated lands. (Novocherkassk) p. 26
[9] Melikhov V V, Kruzhilin I P, Kuznetsova N V 2003 Guidelines for the cultivation of corn on grain (in Russian) (Volgograd: Publisher) p. 88
[10] Balakai G T 2007 Irrigated corn for grain: recommendations (Novocherkassk: Gelikon) p. 16
[11] Shtoyko D A 1968 Water consumption and crop irrigation regime Irrigated agriculture in Ukraine. pp. 147–170