Evaluation of corn crops drip irrigation quality at different versions of the tillering zone

M I Lamskova¹, A E Novikov², S V Borodychev² and M I Filimonov²

¹ Department of Processes and devices of chemical and food industry, Volgograd State Technical University, 28 Lenin Avenue, Volgograd, 400005, Russia
² Laboratory of Irrigation and Reclamation, All-Russian Research Institute of Irrigated Agriculture, 9 Timiryazev Street, Volgograd, 400002, Russia

E-mail: lamskov@yandex.ru

Abstract. Presents results of a study of the uniformity of distribution of irrigation water along the length of the drip lines at its pre-treatment in sand gravel and disc filters (typical) and hydrocyclone installation (experimental version) and the efficiency of water technology in the cultivation of corn. It was found that when using a sand-gravel and disc filter as a water treatment unit on a drip irrigation system, the coefficient of effective irrigation was 0.635, insufficient irrigation - 0.240, and excessive irrigation - 0.125. The use of hydrocyclone installation for water treatment, which combines the processes of capture of dispersed particles by the method of sedimentation in a centrifugal field and the filtration method provides an increase of the coefficient of effective irrigation to 0.715 and reduce the rates of under- and over-irrigation, respectively, to 0.20 and 0.085. Thus, increasing the uniformity of the distribution of irrigation water along the length of the drip lines ensures the regulation of irrigation of agricultural crops. In field experiments on corn cultivation with drip irrigation, an increase in grain yield was achieved by 9% when using an experimental version of the water treatment unit instead of the standard one on the irrigation system.

1. Introduction

In modern conditions, increasing the yield and quality of agricultural products are the most important problems of the agricultural sector of the economy. Sufficient and sustainable yield under the conditions of hydrothermal loads characteristic of regions with arid climates depends on the provision of cultivated crops with an optimal irrigation regime [1].

In this regard, drip irrigation is of particular interest, since it meets the requirements of rational and efficient use of moisture and obtaining stable yields. The use of this method of irrigation allows to significantly reduce the consumption of water and mineral fertilizers, including by automating the irrigation process with the introduction of liquid complex fertilizers, to minimize the likelihood of the development of irrigation and erosion processes in the soil. As the result, the yield of agricultural crops increases by 20-50%, compared with sprinkling and surface irrigation [2, 3]. The reliability of the drip system depends on the quality of water, and, accordingly, on the efficiency of water treatment equipment and technology.

In the water treatment units of drip irrigation systems, bulk sand and gravel filters are used for coarse cleaning, and disc filters are used for fine cleaning. The filtration method provides a high quality of water treatment, however, the operation of this equipment has technological and technical
difficulties. In particular, high resource costs for periodic backwash, selection, cleaning, sorting and laying of multi-layer sand and gravel backfill, regeneration or disposal of filtration materials, and their purchase [4, 5].

It is possible to reduce material costs for the purchase, operation and maintenance of equipment for water treatment units by using modern designs of hydrocyclones that meet the requirements of energy efficiency and provide high rates of water purification from various types of impurities [6, 7, 8]. Of particular interest is a hydrocyclone installation with a filter drain pipe (Figure 1) [9].

![Figure 1. Hydrocyclone irrigation water treatment plant: 1, 2, 3 - gate valves; 4 - feed pipe; 5 - hydrocyclone; 6 - sand nozzle; 7 - sludge collector; 8 - filter drain pipe.](image)

The water treatment technology in such an installation is implemented as follows. When water is supplied for drip irrigation on water pipes, gate valves 1 and 2 are open, and gate valve 3 is closed. Water through the feed pipe 4 tangentially enters the hydrocyclone 5. From the swirling water flow descending along the periphery of the hydrocyclone body, dispersed particles of heavy fractions are deposited on the walls under the action of centrifugal force and, descending along them, are removed through the sand nozzle 6 to the sludge collector 7. Further, the ascending central water flow, passing through the side surface of the filter drain pipe 8, on which dispersed particles of light fractions are captured, is diverted to the distribution water supply. When flushing the reverse current of water hydrocyclone installation in the supply and distribution pipelines, valves 1 and 2 are closed, and the washing water valve 3 is open. In this mode of operation, water is transported through the flushing and distribution water pipes, flushes the filter drain pipe, the body of the hydrocyclone and the sludge collector.

The analysis of the results of field experiments on the use of a hydrocyclone installation (Figure 1) on a drip irrigation system in comparison with a serial hydrocyclone (with a solid drain pipe) shows the decrease in the amount of suspended substances by 67.5%, turbidity by 55%, color by 29%, and the total iron content by 58% (gross forms) and 35% (dissolved forms) [10, 11]. In continuation of these studies, the purpose of this work was to assess the quality of the drip irrigation method for various versions of the water treatment unit on the example of corn cultivation for grain.
2. Materials and methods
Field experiments were carried out at the Federal State Unitary Enterprise "Irrigated" in Volgograd region and included the study of the uniformity of the flow of irrigation water along the length of the drip lines at its pre-treatment in sand gravel and disc filters (typical variant) and hydrocyclone installation (experimental version), as well as evaluating the efficiency of water technology in the cultivation of corn. We used a tall, medium-early hybrid "Volga 89MV" with a vegetation period of 110-115 days.

The quality of water treatment was assessed indirectly through the provision of regulations for watering corn with a differentiated moisture regime according to the depth of the soaked soil layer and the phases of growth and development of the crop, as well as the yield.

The study of the uniformity of water distribution by drip lines was carried out on a plot of 100 m during one hour. The line was conditionally divided into segments of 25 m, at the beginning of each section at the length of one meter, measuring tanks in the amount of 10 pcs were installed under the water outlets. The uniformity of the distribution was estimated statistically as the arithmetic mean of the raindrop intensities at the points of the irrigation area by constructing a frequency graph. At the same time, the coefficients of effective K1, insufficient K2, and excessive K3 wetting were calculated by using the formulas [12]:

\[
K_1 = \frac{S_1}{S_L} = \frac{n_1}{n_L}; \quad (1)
\]

\[
K_2 = \frac{S_2}{S_L} = \frac{n_2}{n_L}; \quad (2)
\]

\[
K_3 = \frac{S_3}{S_L} = \frac{n_3}{n_L}, \quad (3)
\]

where \(S_1\), \(S_2\), \(S_3\) is the area of effective, insufficient and excessive irrigation, hectares or \(m^2\); \(n_1\), \(n_2\), \(n_3\) is the number of cases of effective, insufficient and excessive watering; \(S_L = S_1 + S_2 + S_3\) is the total irrigated area, ha or \(m^2\); \(n_L = n_1 + n_2 + n_3\) is the total number of cases.

3. Results and discussion
The use of drip irrigation method in the cultivation of corn for grain in comparison with traditional sprinkling is characterized by more economical water consumption to obtain the planned crop, high technological efficiency of production and significantly less erosion and irrigation load on the soil.

The technology of maize cultivation consisted of traditional measures for the conditions of the Volgograd region and the use of serial agricultural machinery and equipment for this technology. Wide-row sowing with a row spacing of 0.8 m and a standing density of 75-80 thousand plants per hectare was carried out when the soil was warmed 10-12 °C. To obtain a crop at the level of 7 thousand feed units, nitrogen 75 kg · ha\(^{-1}\), phosphorus 90 kg · ha\(^{-1}\) and potassium 70 kg · ha\(^{-1}\) were added to the main tillage. When sowing, the doses of nitrogen, phosphorus and potassium were 75, 30 and 20 kg · ha\(^{-1}\) in the active substance, respectively. From germination to the onset phase of 13 leaves, the humidity in the soil layer of 0.4 m was maintained at 70% of minimum water capacity, from the phase of 13 leaves until the end of flowering, the humidity in the soil layer of 0.7 m was maintained at 80% of minimum water capacity, and after flowering - at 70% of minimum water capacity. The weighted average irrigation rate during the observation period was 2850 m\(^3\) · ha\(^{-1}\). During the growing season of corn, the necessary measures were taken to care for the crops, and when the technical ripeness of the cobs was reached, cleaning was carried out.

The frequency graph of the distribution of raindrops along the length of the drop line was constructed as follows. The x-axis caused the intensity of the raindrops \(p_i\) (1 · h\(^{-1}\)), and y-axis put the number of cases \(n\) corresponding to the intensities (Figure 2). The graph below \(n = f(p_i)\) indicated the average intensity of rain \(p\) and it is within ± 25%, that is to the left (0.75 \(p_i\)) and right (1.25 \(p_i\)), we determined the area of efficient irrigation \(S_i\). Accordingly, the left is square lack of irrigation \(S_L\), and the right is a square excess watering \(S_E\) [12, 13].
To measure the areas of effective, insufficient and excessive irrigation, limited by the abscissa axis and the intensity curve of raindrops, a planimeter is most often used. In a numerical experiment, one can also use numerical integration methods, in particular the Newton-Leibniz formula in the following interpretation:

\[
S_i = \int_{\rho_1}^{\rho_2} f(\rho)d\rho = F(\rho_2) - F(\rho_1),
\]

(4)

\[
S_\Sigma = \sum_{i=1}^{n} S_i,
\]

(5)

Here \(S\) is the local area of the curvilinear trapezoid is limited by schedule \(n = f(\rho)\) on the interval intensities from \(\rho_1\) to \(\rho_2\), the x-axis and straight \(\rho = \rho_1\) and \(\rho = \rho_2\).

4. Conclusion

According to the results of field and numerical experiments to determine the uniformity of the distribution of raindrops along the length of the drip line, for a typical version of the water treatment unit on the drip irrigation system, the values of the coefficients were established: effective irrigation is 0.635, insufficient irrigation is 0.24, excessive irrigation is 0.125. In the variant in which an experimental hydrocyclone installation was used as a water treatment unit on a drip irrigation system, the following coefficients were obtained by constructing a frequency graph and determining the areas of effective, insufficient and excessive irrigation by numerical integration: effective irrigation - 0.715, insufficient irrigation - 0.20, excess irrigation - 0.085. The data analysis proves the high efficiency of the hydrocyclone installation with a filter drain pipe when cleaning water from dispersed particles of heavy and light fractions, which helps to reduce the cases of blockage of water outlets of drip lines and increase the uniformity of irrigation water flow along their length, compliance with the regulations for irrigation of agricultural crops. As the result, in field experiments on corn cultivation with drip irrigation, the increase in grain yield was achieved by 9%, 8.7 against 7.9 t · ha\(^{-1}\). The achieved increase in grain is explained by the creation of an optimal water-heat regime in corn crops, which ensures active growth and development of plants, full-fledged formation of cobs.
5. Acknowledgments
The publication was prepared with the support of the grant of the President of the Russian Federation MK-2289.2020.8.

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