Analysis of promising methods of irrigation and melioration techniques of crops in arid climate

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Abstract. The paper discusses the problems of optimal regulation of soil water regime under crops. In particular, the water regime of the soil and the experience of irrigation of crops in the conditions of the arid climate of the Lower Volga region are analyzed and promising methods of irrigation and irrigation techniques of crops, including potatoes, are also considered. The conducted research allows us to analyze and summarize the accumulated experience of growing potatoes under irrigation conditions, as well as formulate a number of General provisions for improving the efficiency of reclamation in a dry climate. In addition, studies have shown that despite the high price of irrigation systems, the use of sprinkling is cost-effective in the Southern regions of Russia, where the temperature factor is one of the reasons for the decline in the potato crop. In contrast to mobile machines, stationary sprinkler irrigation systems provide flexible regulation of the irrigation rate and optimal watering frequency. It is noted that another important advantage of sprinkler irrigation is the possibility of using it for processing crops with direct and systemic pesticides. Observations made in experiments have shown that the use of pesticides and sprinkler irrigation makes it possible to virtually eliminate the possibility of various diseases in plants.

1. Introduction

Optimal regulation of soil water regime under agricultural crops in most regions of Russia is associated with the need for irrigation reclamation. At present one of the promising trends of enhancing a set of service properties of such bronzes is alloying them with superdispersed powders (SDP). Introduction of their small amount into the melt before a crystallization process allows increasing strength propeties of castings [1, 2]. But a mechanism of interaction with lead-tin-based bronzes, as well as the process regularities of such modification, is not studied profoundly. However, such modification of copper alloys is promising from several points of view.

This paper presents an investigation the problems of optimal regulation of water regime of soil under agricultural crops.
2. Materials and methods

Russian researchers [3-5], based on the experience of potato cultivation in a temperate climate, also made a clear conclusion about the prospects of irrigation of potato crops and formulated the basic conditions for irrigation efficiency:

- do not carry out watering before the formation of flower buds;
- practice intensive irrigation from the beginning of the flower;
- continue irrigation after flowering, but reduce water supply regime.

Of course, in the conditions of unstable and insufficient moisture characteristic of the Lower Volga region, these recommendations are not fully acceptable. The acute shortage of natural moisture supply of the territory makes it impossible here to effectively cultivate potatoes without situational irrigation in the initial periods of growth and development. It should be recognized that the recommendations of foreign colleagues have a certain physiological justification. In particular, precipitation in the first half of the growing season increases the growth of tops, during budding-increase the number of tubers in the Bush, in the second half of the growing season – a positive impact on the growth of tubers, determining the overall productivity and yield of commercial tubers.

Of great practical importance is also the presence of a dynamic relationship between the conditions of water supply and the temperature optimum of tuber formation. In the literature it is noted that with an increase in the content of productive moisture in the soil, the temperature optimum of tuber formation increases significantly. This is especially important to consider when cultivating potatoes in the hot climate of southern Russia.

The results of studies conducted in the conditions of the dry-steppe zone allowed one to recommend the authors to carry out vegetation watering of potatoes from the moment of appearance of inputs and to pump the irrigation season 1-2 weeks before harvesting. It is pointed out that it is necessary to reduce the soil temperature during tuber formation and maintain it at the level of 18-22°C, which is possible due to frequent watering with small irrigation norms.

In experiments conducted with potatoes in the Lower Volga region, watering was also carried out throughout the growing season. The research sets 2 options with a constant during the vegetation period threshold pre-irrigation soil moisture - 75-80% NV and 80-85% NV and 1 option with differentiated irrigation regime - 70-85-70% NV. Studies have revealed an undeniable advantage of the differentiated regime of potato irrigation: the yield of commercial tubers obtained in this variant reached 28.8 t/ha against 23.6-26.1 t/ha in the areas of the first two variants. Specific water expenses for yield formation of potato during irrigation in the differential scheme does not exceed 82 m³/ha, while maintaining a constant pre-irrigation threshold was increased to 95-106 m³/ha.

One of the key parameters of potato irrigation technology, as well as any agricultural crop, is a properly established irrigation rate. In the published literature, referring to long-term experimental data, it is recommended to limit the irrigation rate of 20-30 mm, focusing primarily on the biology of the potato plant. Experiments, laid down and implemented in the Volgograd region, the study raised questions related to the possibility of establishing irrigation norms by calculation, and the admissibility of changes in the calculated irrigation in production conditions. The highest yield of potatoes, 36.2-37.9 t/ha, was obtained in variants where irrigation by the sprinkler machine "Fregat" was carried out by the calculated norm. At the same time, it was noted that the increase in the calculated irrigation rate by 20% did not provide an increase in potato yield, and with a decrease in the irrigation rate by 20%, the yield of commodity tubers decreased by 4.0 - 6.0%.

Experiments, conducted on the basis of farms of the Volgograd region, established the possibility of obtaining a potato crop without irrigation. However, the yield of marketable tubers did not exceed 10.7 tons/ha. In addition, we studied the effectiveness of water-saving method of application of irrigation land reclamation (with holding irrigation only in the phase of budding and flowering of potato) and intensive irrigation (with holding irrigation during the vegetation period). The highest yield of commercial tubers, 24.8 t/ha, was obtained in variants with intensive irrigation. The irrigation rate was 1680 m³/ha, and during the growing season 4 irrigations of 420 m³/ha were carried out.

Experiments conducted in the dry-steppe zone of light chestnut soils of the Lower Volga region
confirmed the effectiveness of drip irrigation for watering potato crops. The highest yields were obtained when carrying out irrigation, focused on the hydration of 0.4-metre layer of the soil and the maintenance of the differentiated pre-irrigation moisture threshold scheme: 60-65% NV – to the phase of budding plants, 85-90 % of the HB in the period of budding and flowering, 70-75% NV – after flowering, before harvest.

In most literature sources there is information about the use of the following methods for watering potatoes:
- surface, mainly furrow irrigation;
- sprinkler irrigation method;
- use for irrigation drip irrigation.

3. Results
In the South of Russia potato irrigation sprinkling is widely used with the use of sprinkler machines and installations of different designs.

On light chestnut soils of the Volgograd region during sprinkling potato, yield reached 25-35 t/ha while maintaining stable yields over the years of research [6].

The main advantage of potato irrigation with the use of sprinkler machines and installations is the use of simulation of rain, that is, natural conditions for plants. In contrast to furrow irrigation, irrigation water costs are significantly reduced, the irrigated area is wetted more evenly, surface water runoff is minimized when optimizing irrigation techniques. The modern world market of sprinkler equipment is represented by a wide range of technical solutions and brands. From domestic machines innovative technological solutions are implemented in models of raincoats of the Kuban – LK1 brand, DMFE «Fregat» and «Fregat – N». In international models of innovation policy is most successfully implemented in the irrigation machines Valley family and Valley Rainger, Lindsay, Bauer (Centerliner, Monostar BMS-100, Linestar), Reinke, IRRIFRANCE, Urapivot. While maintaining the general trends and dynamics of development of technical structures in each segment of the production of sprinkler machines offers unique design solutions that provide advantages in operation and increase the range of adjustment modes of irrigation equipment.

Modern structural changes in the agricultural system of Russia are accompanied by an increase in the role of relatively small-sized irrigation sites equipped with mobile water supply facilities and small pumping stations. One of the promising solutions to the problem of irrigation of small areas is the use of mobile sprinkler strip type.

The general scheme of drip irrigation systems consists of a hydraulically connected source of irrigation water (open or closed type, pressure or non-pressure), a pumping station (in the case of a non-pressure water source), a filtration system (including coarse and fine filters in various configurations), an installation for preparing a solution of mineral fertilizers, trunk, distribution and irrigation pipelines and drip irrigation outlets. Regulation of irrigation water supply is carried out by means of a system including shut-off and control valves.

In our opinion, the advantages of drip irrigation are to reduce the zone of soil moisture in the irrigated area, which reduces the unproductive costs of water for physical evaporation, the possibility of irrigation under intense wind conditions, the possibility of irrigation on slope lands or in areas with complex topographic structure, the possibility of reducing irrigation norms to a level at which there is virtually no intra-soil water discharge for infiltration, the exclusion of water losses to surface runoff. We provide a supply of mineral fertilizers with irrigation water or organization fertilizing irrigation, in suppressing the development of weeds in the dry aisles to improve water-air regime of soils, accompanied by the increase of crop yield with the cumulative reduction of water use for crop production.

The disadvantages of drip irrigation include pulling salts from the underlying horizons into the upper fertile soil layer, the inability to regulate air humidity in the plant environment, the inability to use for anti-frost irrigation, the inability to use irrigation to cool the soil at high air temperatures and intense solar insolation.
Sprinkler irrigation, which is gaining popularity today, is a promising solution for irrigation of most crops. According to the method of irrigation, this is also sprinkling, but unlike sprinkler machines, sprinkling is low-intensity (water consumption for irrigation is approximately equal to water consumption for drip irrigation), and rain covers the entire area of the irrigated area. According to the advantages of sprinkler irrigation are high uniformity of water distribution, reducing the impact of drops on the soil and plants, low intensity of sprinkling, high quality of rain, the possibility of organizing short irrigation cycles. High uniformity of water distribution is achieved due to 100% overlap of the rain flares from the nozzles (outlets from each other are placed at a distance half the width of the sprinkler). This also ensures high stability of the rain cloud formation to the wind. The low intensity of sprinkling excludes the formation of surface runoff in micro-depressions, which makes it possible to operate the haymaking area for a long period without planning [7].

Unlike drip irrigation, the main advantages of sprinklers is that when they are used, they not only compensate for the lack of soil moisture, but also increase the humidity in the surface layer, as well as contribute to a significant decrease in soil temperature. The latter is especially important in the period of potato tuber formation [8-10].

It is noted that another important advantage of sprinkler irrigation is the possibility of using it for treatment of crops with pesticides of direct and systemic action. Conducted in experiments observed that the use of pesticides and sprinkler irrigation can virtually eliminate the possibility of the emergence of the potato plants to late blight, early blight, Rhizoctonia, scab, macrosporiosis of the Colorado potato beetle and aphids.

4. Conclusion
Generalization and analysis of the accumulated experience of potato irrigation allow us to formulate a number of general provisions to improve the efficiency of irrigation reclamation in drought conditions:
- the presence of a dynamic relationship between soil moisture and the optimum temperature of tuber formation allows you to adjust the level of the latter by carrying out vegetation watering;
- the presence of a general tendency to reduce irrigation norms and increase the frequency of irrigation, providing an increase in the efficiency of water consumption for the formation of the crop, which is manifested, inter alia, in the active development of drip irrigation method;
- the need to take into account the features of different methods of irrigation in the development of optimal, climate-based, irrigation regimes of potatoes, including when cultivating in early culture.

In addition, the studies found that despite the high price of the system (which is 100 thousand rubles/ha and more), sprinkler irrigation is economically justified in the southern regions of Russia, where the temperature factor is one of the reasons for the decline in the potato crop. Unlike mobile machines, stationary sprinkler irrigation systems provide flexible regulation of the irrigation rate and optimal frequency of irrigation. Unlike most drip irrigation systems, the lifetime of sprinklers is more than 10 years.

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References
[1] Kruzhilin I P, Ovchinnikov A S, Kuznetsova N V, Kozinskaya O V, Fomin S D, Bocharkov V S and Vorontsova E S 2018 Water pressure monitoring in irrigation piping as quality management tools of sprinkler irrigation ARPN J. of Engineering and Applied Sciences 13(13) 4181–4184
[2] Kruzhilin I P, Dubenok N N, Ganiev M A, Ovchinnikov A S, Melikhov V V, Abdou N M and Rodin K A 2017 Mode of rice drip irrigation ARPN J. of Engineering and Applied Sciences 12(24) 7118–7123
[3] Ovchinnikov A S, Kuznetsov N G, Nekhoroshev D D, Gapich D S, Nekhoroshev D A, Fomin S
D, Zagorodskikh B P, Slavutsky V M, Shaprov M N, Ryadnov A I and Tseplyaev A N 2018 Some ways to reduce the dynamic loads of agricultural machine-tractor aggregates ARPN J. of Engineering and Applied Sciences 13(22) 8776–8779

[4] Timoshenko M A, Rogachev A F, Medvedeva L N and Tokarev K E 2019 Analysis and support of decision making with the use of latest information and communication technologies for development of social and economic area with regard to capabilities of different categories of population The Leading Practice of Decision Making in Modern Business Systems: Innovative Technologies and Perspectives of Optimization 9 87–98

[5] Ovchinnikov A S, Bocharkov V S, Skorobogatченко D A and Borisenko I B 2018 The optimum geometrical form modeling of the "Striegel" type harrow ARPN J. of Engineering and Applied Sciences 13(23) 9138–9144

[6] Ovchinnikov A S and Bocharkov V S 2012 New technical solutions improve the efficiency of resource-saving irrigation methods Proc. of Lower Volga Agrouniv. Complex: Sci. and Higher Vocational Educ. 1(25) 119–124

[7] Tokarev K E, Rogachev A F, Pleschenko T V, Rudenko A Yu and Kuzmin V A 2019 Economic and mathematical modelling of regional market of grain crops IOP Conf. Series: Earth and Environmental Science 341(2019) 012212

[8] Yurchenko I F 2018 Information support for decision making on dispatching control of water distribution in irrigation Journal of Physics: Conference Series 1015(4) 042063

[9] Bandurin M A, Yurchenko I F and Volosukhin V A 2018 Remote monitoring of reliability for water conveyance hydraulic structures Ecology and Industry of Russia [in Russian – Ekologiya i promyshlennost Rossii] 931 209–213

[10] Skiter N N 2017 Modeling of eco-economic security with the use of tax instrumentarium Contributions to Economics 9783319454610 121–131

[11] Tokarev K E, Orlova Yu A, Rogachev A F, Kuzmin V A and Yu M Tokareva 2020 Crops reclamation management based on hybrid neuro-fuzzy systems IOP Conf. Series: Earth and Environmental Science 421(2020) 042015