REPUBLIC OF AZERBAIJAN

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IRRIGATION OF ALFALFA IN ABSHERON CONDITIONS BY DISPERSION (AEROSOL) METHOD

Speciality: **3103.02-Development, recultivation and conservation**
Field of science: **Agrarian sciences**

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ABSTRACT

of the dissertation for the degree of Doctor of Philosophy

BAKU-2025

The dissertation work was carried out in the laboratory "Irrigation" of the Azerbaijan Hydrotechnics and Melioration Scientific and Production Union (AzH&M SSU).

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INTRODUCTION

Topicality and degree of using of the theme. As a result of the global climate changes and anthropogenic impacts on the environment, the serious water problem has arisen on the Earth as a result of an increase in temperature and a decrease in precipitation, their uneven distribution by regions, as well as a change in the nature of precipitation. According to the data provided by the United Nations experts, 5 thousand people die in one day due to lack of drinking water. The expansion of irrigated areas, the growth of the population, the continuous development of industry, energy and other sectors of the economy, the demand for fresh water is increasing every year. According to the experts, the reserves of fresh water in Azerbaijan are very limited. Depending on the water content of the year, the reserve for river waters is about 20-32 billion m^3, the reserve of groundwater with a degree of mineralization up to 3 g/l ranges from 4.4 to 8.5 billion m^3 and the water reserve of freshwater lakes ranges from 0.3 to 0.9 billion m^3.Every year, about 10-16 billion m^3 of water is taken from water sources and supplied to the economy areas. On average, 50-70% of the water taken from the sources is used for irrigation of agricultural crops and 30-40% of the water taken from sources goes to losses.

The analyses show that water losses occur due to seepage from soil irrigation channels, evaporation from the water surface, non-use of progressive irrigation methods and irrigation techniques, as well as due to improper leveling of irrigated areas and the absence of field forest belts to protect the fields. Among these mentioned reasons, one of the leading and main places is occupied by the non-application of progressive irrigation methods and techniques and their poor application.

It should also be noted that not every agricultural plant can be watered with known irrigation methods and techniques. For example, it is impossible to irrigate the plants such as alfalfa, barley, wheat and others with the drip method. Therefore, choosing the method and technique of watering, the type of plants should be taken into account. The plant alfalfa plays an exceptional role in the creation of the feed base of livestock and its development. However, this plant has a greater demand for water compared to other plants and it requires the frequent watering. Currently, the plant alfalfa is irrigated using the submergence method and the irrigation rate during the growing season varies between 6,000-10,000 m^3/ha, depending on the climatic conditions. In conditions of water scarcity, the supply of so much water to irrigation creates the serious difficulties in the water balance of the country.

In order to use the surface and underground water resources of the country more efficiently and economically, the "National Strategy for the efficient use of Water Resources" was approved by the Order of the President of the Republic of Azerbaijan on October 10, 2024.

Thus, taking into account the above mentioned, there is a serious need to create progressive and water-saving irrigation methods and techniques in order to use irrigation water more efficiently and economically and to obtain high yields of agricultural crops. This problem, which is of exceptional importance, is considered one of the most actual problems of the day.

One of the progressive methods that allows to save up to twice on irrigation water and get a high yield from the plant alfalfa is aerosol irrigation method. However, this method is one of the least studied in irrigation agriculture. For the first time in Azerbaijan, the experiments were carried out in 1981 to study the method of dispersion (aerosol) irrigation at the tea plantation in Zagatala region. The experiments were continued until 1986 by the scientists of the Scientific Research Institute of Water and Reclamation (former Azerbaijan Hydraulic Engineering and Reclamation Scientific Research Institute) and were not returned to these studies until later.

Only since 2013 till nowadays studies on the irrigation of alfalfa by dispersion irrigation have been carried out by us.

The aims and objectives of the research. The main aim of the work is to use water resources efficiently and economically; to improve the existing dispersion irrigation method and irrigation technique in order to achieve the sustainable and high productivity of agricultural crops, to determine its feasibility and most favorable parameters for irrigation of the most water-demanding alfalfa plant, as well as to substantiate its application scientifically and practically.

To achieve the aim, the following tasks were set before the study:

1. Study of the natural and economic conditions of the Absheron Peninsula;
2. Preparation of an overview of irrigation methods and techniques;
3. Analysis of the current state of irrigation in Absheron, selection of the area of expertise and determination of its typicality for the region;
4. Preparation of hydraulic reporting method of dispersion irrigation system;
5. Study of the effectiveness of dispersion irrigation method and determination of its economic efficiency;
6. Assessment of the environmental impact of dispersion irrigation;
7. The study of the effect of dispersion irrigation on the yield of clover and the development of its irrigation regime.

Object and method of research. The object of the research was dispersion irrigation method and clover plant, the experiments were carried out in the territory of Absheron Experimental-Research Station (former Absheron Irrigation and Mechanization Experimental-Research Station) of the Scientific Research Institute of Water and Reclamation. Each issue was tested and solved on the basis of generally accepted methods, the essence and description of the used methods were interpreted in the text of the dissertation work. The effectiveness of the dispersion irrigation method was studied on the basis of field experiments carried out over three years in three variants and with three repetitions. The hydraulic calculation method for designing the dispersion irrigation network was developed by collecting, studying, analyzing and systematizing information provided in literature and internet resources. In general, the systematic approach was used in the study.

The main provisions for defense:

- more efficient and economical use of irrigation water in conditions of water shortage;
- the scientific and practical basis of using dispersion irrigation method in combination with free and other irrigation methods;
- the dispersion irrigation network and its design method;
- impact of dispersion irrigation on alfalfa crop productivity and environment in Absheron Peninsula;
- the effectiveness of the dispersion irrigation method and the factors affecting it;
- the economic benefits obtained during the application of the dispersion irrigation method.

Scientific novelty of the research:

1. For the first time, the effectiveness of the dispersion irrigation method was studied in Azerbaijan in the conditions of the Absheron Peninsula and the possibility of using it in a free and combined form was proved.
2. Dispersion irrigation has been found to be effective and efficient to combat the complications caused by climate change and to eliminate water shortages.
3. For the first time, the impact of dispersion irrigation on the productivity of alfalfa plants and the environment were determined.
4. To design the dispersion irrigation network, its hydraulic calculation method has been developed.
5. A summary of irrigation methods and irrigation techniques was made and a review was prepared.
6. A system of requirements for the application of the dispersion irrigation method has been developed.

7. Applying the dispersion irrigation method, the irrigation regime (irrigation norm and irrigation times) of clover plants was worked out.

8. The instructions for the operation and maintenance of dispersion irrigation equipment have been developed.

Theoretical and practical significance of the research. The obtained results allow theoretically and practically to substantiate measures for the efficient and economical use of water resources, to develop and correct irrigation regimes for agricultural crops. The proposed hydraulic calculation method and data can be used in the preparation of projects. The information provided on the methods and techniques of dispersion irrigation can be used as the information sources in educational institutions and state organizations. The application of the dispersion irrigation method allows to obtain stable and high yields of agricultural crops, save irrigation water by more than 1.5-7 times and create a favorable microclimate and ecological balance in the environment.

Approbation and application of the research. The main results and scientific provisions of the dissertation work were reported and discussed at the International Scientific-Practical Conference on "Water management, modern problems of engineering comminution systems and ecology" (Baku, 2014),at the International Scientific Conference "The role of young scientists in agriculture: problems and opportunities" (Baku, 2014), "At the XXXIII International Scientific and Practical Conference "Russian science in the modern world" (Moscow, 2020)" and "The Scientific Council of the Scientific-Research Institute of Water and Reclamation" (Baku, 2013-2014). "Proposal on dispersion irrigation of alfalfa fields planted in the territory of the Republic "was submitted to the Institute for the design of the Water and Reclamation complex (formerly "Azerbaijan State Water Org.Pr. Institute) for use in the preparation of projects and was accepted".

The name of the organization in which the reserach work is performed. The research work was carried out at the Scientific-

Research Institute of Water and Reclamation (former Azerbaijan Hydraulic Engineering and Reclamation scientific-Production Association).

Published works. 13 articles on the dissertation, including 9 articles were published in periodical scientific publications of the Republic of Azerbaijan and 4 articles in foreign countries.

The total volume of the research work with a sign indicating the volume of the structural parts of the dissertation separately. The dissertation work consists of 6 parts, conclusion, recommendation for production and list of literature. The work included 15 pictures, 4 graphs and 23 tables. The first part was 13, the second part was 33, the third part was 12, the fourth part was 17, the fifth part was 35 and the sixth part was 7 pages, the total volume of the dissertation is 194 371 signs with 139 pages.

GENERAL CHARACTERISTICS OF THE WORK
CHAPTER I. NATURAL AND ECONOMIC CONDITIONS OF THE ABSHERON PENINSULA

Absheron Peninsula is located in the southern part of the Greater Caucasus Mountains, in the eastern part of Azerbaijan. On average, it was 28 km wide and 73 km long and its relief is complex.The relief of most of the territory consists of mountainous and gently undulating plains and a small part consists of coastal plains. The lowest point in the region is 28 m below sea level and the highest point is the peak of Mount Dubrar (2205 m) located in the northwest. The soil-forming rocks are formed of the ancient sediments of the third-fourth period and the Caspian Sea. In the process of soil formation, the presence of dark black clay shales of the lower jurassic, gray-brown clay or sandy loam of the middle jurassic, as well as gray and red-green clays with mergels is observed.Here the soils are mostly non-salinated and have an alkaline environment. The soil-climatic conditions of Absheron region are characterized by the influence of the Caspian Sea surrounding it on three sides and the mountains of the Greater Caucasus.The average annual wind speed on the peninsula is 4-8 m/sec, with a maximum speed of 30 m/sec during the winter months and in some cases reaching 40 m/sec, and the number of sunny days is 230.

The types and subtypes of gray and gray-brown soils are widespread on the Absheron Peninsula, accounting for 55.3% of the total land reserve of the region. In this type of soil the rot layer is very thin and the humus content in it varies from 1.0 to 1.5%.The Absheron natural-economic-geographical region is one of the most developed economic regions of the republic and its area is 381,776 ha, which constitutes 4.4% of the total territory of the republic, of which 175,661 ha are suitable for agriculture, while only 19,127 ha are irrigated areas.The irrigated land accounts for 5.0% of the total land fund of the region and 10.9% of agricultural land. In 3.3 thousand hectares of irrigated lands, the degree of mineralization of groundwater is less than 1.0 g/l, in 5.3 thousand hectares it varies between 1.0-3.0 g/l and in 10.5 thousand hectares it is >3 g/l.

The Absheron region, where the experiment was conducted, falls within the temperate, hot semi-desert and dry subtropical climate zone with dry summers. Here the average annual temperature reaches 12.4^{0}C. The average winter temperature ranges from 0.0-4.6^{0}C and the average monthly summer temperature ranges from 20.7-29.7^{0}C. The amount of precipitation falling in the plain part of Absheron, which ranges from 144-218 mm per year, is unevenly distributed across the seasons and its maximum amount falls in the spring and autumn months.

The number of frost-free days is 278. The sum of temperatures above 10^{0}C during the year is 4192 degrees and the sum of temperatures below 10^{0}C is 2300 degrees.The period of development and yield of most agricultural crops coincides with the period of temperature above 10^{0}C in the soil.In winter, the average monthly temperature on the soil surface is 6^{0}C and in summer this indicator rises to 29.7^{0}C.

The annual amount of evaporation from the Earth's surface reaches 1119 mm. This is 5.1-7.8 times more than the annual amount of precipitation. Therefore, it is impossible to develop agriculture in the region without intensive irrigation. The natural conditions, soil cover and relief of Absheron are considered favorable for the irrigation by the method of precipitation and dispersion.

CHAPTER II. ABOUT IRRIGATION, IRRIGATION METHODS AND IRRIGATION TECHNIQUES

This chapter contains a review on irrigation, types of irrigation, water requirements of plants, irrigation regime, irrigation methods and techniques, as well as dispersion (aerosol) formation process, classification of dispersion liquid droplets, dispersion irrigation system (network) and devices, experiments with dispersion method in the world and water saving.

The irrigation from primitive times to the present arid (in zones where precipitation is many times less than evaporation) has been the only means for the production of agricultural products and for meeting the needs of plants for water and an integral part of human economic activity. Azerbaijan is a country with the oldest culture of irrigation agriculture in the world and its history goes back to more ancient times. Irrigation is divided into the types such as arat, moisturizing, fertilizing, heating, pre-sowing, post-sowing refreshing and provoking.Each type of irrigation is applied according to its purpose and their main purpose is to obtain high yields from plants and meet the needs of plants for water. The water requirement of plants is the amount of water spent on their development and production during the growing season. The demand of plants for water is regulated and ensured by the irrigation regime, depending on numerous factors.The irrigation regime includes when, for what time and in what norm to supply water to plants during the growing season. According to the experiments carried out, literature sources[1], the demand of plants for water during the growing season is called the norm of vegetation irrigation and is determined by the following formula:

$$\mathrm{M} = \boldsymbol{E} - \boldsymbol{P}_0 - \Delta\boldsymbol{W} + \boldsymbol{K} \qquad (1)$$

Here M is the vegetation irrigation rate; E is the sum of evapotranspiration or the water transpired by plants and physical evaporation from the soil layer ($E=T_p+U$); P_0 – amount of atmospheric precipitation falling during the growing season; ΔW – at the beginning of the growing season (W_1) and at the end (W_2) moisture in the soil layer ($\Delta W=W_1-W_2$); K – is the amount of water used by plants from groundwater due to capillary rise.

The unit of measurement for all quantities in the formula is expressed in m^3/ha.The rate (amount) of water supplied for irrigation each time during the vegetation period is called the periodic irrigation rate (m) and is calculated using the following formula:

$$\mathrm{m}100 = \alpha\boldsymbol{h}\left(\rho_{\boldsymbol{HNT}} - \beta_1\right), \qquad (2)$$

Here α- is the soil volume mass, *ton/m*^{3} or *q/sm*^{3}, h – the depth of the reporting layer of the soil, *m*; β_{HTNT}-soil moisture capacity with a net, %; β_f - isthe actual moisture in the soil before irrigation, %.

On the base of the analysis of the statement (1) it was determined that with the help of progressive irrigation methods and appropriate agrotechnical measures, irrigation rates can be reduced many times and thus save water.However, the analysis of formula (2) shows that it is possible to change the depth of the soil's reporting layer by taking into account the development of the root system of

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[1] Kostyakov A.N. Fundamentals of land reclamation. Moscow: Selkhozgiz, 1960, 622 p.

the plants. In this case, it is possible to adjust the periodic irrigation rates and reduce its amount at different times. This creates the opportunity to significantly save irrigation water.

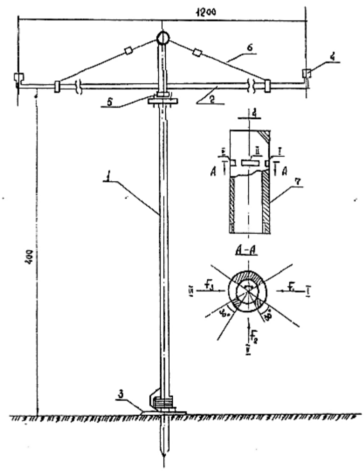
Irrigation is a method of delivering water to the soil and plants. Irrigation methods play a crucial role in using water resources more efficiently and economically. Based on the science of land reclamation and systematization of information, more than 10 irrigation methods are known, including self-flow irrigation, sprinkling, rainfall, drip, dispersion (aerosol), underground, subirrigation, injection, burial (port), combined and other irrigation methods.

To carry out each irrigation method, appropriate and special irrigation techniques are used. The explanatory information about these irrigation methods and techniques, as well as the least studied dispersion (aerosol) irrigation method and the irrigation techniques (devices) that implement it, the dispersion (aerosol) formation process, the classification of dispersed droplets and experiments conducted with the dispersion method is given in the research work.

The essence of the dispersion irrigation method is to separate the irrigation water into aerosol particles (droplets) with the help of special devices and to create fog and light rain in the air layer of the plants [1-3]. At this time, the air temperature in the environment decreases, the relative humidity of the air increases and the leaves and stems of plants get wet, as well as moisture appears in the soil. As a result, photosynthesis depression of plants is prevented, the amount of water spent on evapotranspiration and water losses are reduced.At the same time, it becomes easier to fight pests [5,7,8,9]. With the help of dispersion generating devices and their fog and rain generating devices, it is possible to create water droplets (particles) from 0.5 to 1000 mkm. The dispersion devices, which have different construction and principle of operation, are known[2].One of the

[2] Bogatov V.M. Study of experimental installation of fine-dispersed sprinkling, new in irrigation technique and technology. Moscow: VNIIGiM, 1977, issue 10, pp. 94-100

facilities with an advanced design was created at the Water and Reclamation Research Institute (formerly the Azerbaijan Hydro-technical and Reclamation Research Institute)[3]. “This device, called “the flat torch dispersion device”, consists of a stand, a collector, a slotted insert at the base of the stand, rotating and retaining cables (picture 1). In general, there is no mass production of dispersive devices. Therefore, to conduct the experiments, we used the Volzhanka-type rain machine and for this purpose its rain-making working body (apparatus) was replaced with an aerosol-generating insert”.



Picture 1. Flat-flare dispersion device: 1-support; 2-collector; 3-support base; 4- slotted insert; 5-rotor; 6-retaining cable; 7-body (dimensions are given in cm).

This insertion was created at the Research Institute of Water and Reclamation. In the world the experiments were carried out on various agricultural crops by the dispersion method.It has been determined that when irrigating with the dispersion method, water is

[3] Bashirov N.B., Akhmedov F.A. New installation for aerosol irrigation // Information leaflet. Agriculture, No. 67, Baku: AzNIINTI, 1989, pp. 1-4.

saved 1.5-1.9 times, depending on natural and climatic conditions and the plant productivity increases 1.1-5 times.Operating at the pressure of 2-5 atmospheres, the nozzle sprays water powder into the air with a diameter of 6 m, creating fog and light rain in the air. Based on the information we analyzed, almost no experiments have been conducted on alfalfa using the dispersion method.

CHAPTER III. CURRENT STATUS OF IRRIGATION IN ABSERON, SELECTION OF EXPERIMENTAL FIELD AND METHODOLOGY OF CONDUCTING RESEARCH

In this part the current state of irrigation on the Absheron Peninsula, the composition of the study and the used methodology are described. Taking into account the soil and relief conditions in Absheron, agricultural crops were and are currently irrigated using the rain-fed method. Until the collapse of the Soviet Uniothe brands such as KDY, Volzhanka, Kuban, Fregat, DDA-100M, DDA-100MA and other rain-making machines and units were used here. However, most of those machines and units were later dismantled and destroyed. The irrigation systems that once operated suffered the same fate. After the land was transferred to private ownership, the purpose of the land was changed in most areas.The Absheron main canal was reconstructed and its drainage capacity was increased from 9 m^3/sec. to 15 m^3/sec. The water from this canal has made it possible to fully supply 22,500 hectares of cultivated land with irrigation water. Farmers and private farms have begun to take advantage of this opportunity. A number of farms have begun implementing modern irrigation methods and techniques.

The methods for conducting research in desert conditions have been systematized and with their help, the water-physical properties of Absheron soils, including soil bulk density and volume, maximum field moisture capacity, soil porosity, soil water absorption capacity were determined, as well as the dynamics of soil moisture, seasonal and vegetation irrigation norms, air temperature regime, total evaporation, biological curvature coefficient, plant productivity, irrigation regime and other necessary issues are studied.

CHAPTER IV. NATURAL-SOIL CONDITIONS OF THE EXPERIMENTAL FIELD, DISPERSION IRRIGATION SYSTEM AND ITS HYDRAULIC CALCULATION

In this chapter the natural-soil conditions of the experimental area is briefly described, the actual values of the water-physical properties of the soils defined on the basis of experiments are provided, the typicality of the selected experimental area for the Absheron region and the degree of soil salinity are determined, the hydraulic calculation method of the dispersion irrigation network is also explained.

The selected experimental area is located south of Pirshaghi settlement, between the Baku-Sumgayit railway and the Absheron main canal. The soil cover is gray-brown, sandy in granulometric composition up to a depth of 1 m and is not saline. Here, groundwater is located deep and its mineralization rate varies between 1-2 g/l.The fertile soil layer is quite thin. However, due to fertilizers and cultivation, the fertile soil layer gradually thickens and its structure improves. The average annual temperature changes between 12.4-14.4^{0}C, in winter the temperature drops to 0-4.6^{0}C, in summer the average monthly temperature is 21-30^{0}C. The amount of annual evaporation is 1100-1200 mm, but the amount of precipitation changes between 144-218 mm. The total number of temperatures above 10^{0C} is 4192 degrees, the number of frost-free days is 278 [2]. The amount of precipitation is 5.1-7.8 times greater than evaporation. Therefore, it is impossible to develop agriculture here without irrigation. According to the experiments conducted with three replicates, the soil has the bulk density of 1.59 g/cm^3, the density of 2.69 g/cm^3, the porosity of 41%, and the maximum field moisture capacity of 16.8%.The amount of physical clay (<0.01 mm) in a one-meter soil layer changes between 7-16%. The amount of harmful salts in the soils of the experimental site is very low and the degree of salinity is 0.05-0.10% (based on dry matter).The amount of harmful salts in the soils of the experimental area is very low and the salinity level is 0.05-0.10% (based on dry matter).

Due to the experiments carried out in three replicates at three sites, the rate of water absorption into the soil changes between 97-134 mm/min. in the first hours, and 5.0-5.4 mm/min. or 7.2-7.8 m/day in the steady state. The analyses show that soils in the Absheron region have a very high water absorption capacity and low moisture capacity. Therefore, using the runoff irrigation method here is not considered advisable.This leads to a large amount of water losses. Therefore, water-saving and progressive irrigation methods should be used in Absheron lands.

The typicality of the selected experimental area for the Absheron region was determined based on nine characteristics using probability theory[4] such as air temperature (P_1) and humidity (P_2), wind speed (P_3), soil moisture capacity (P_4), precipitation amount (P_5), soil bulk density (P_6), porosity (P_7) and density (P_8), as well as the amount of evaporation (P_9).

For this purpose, a block-scheme of the location of elements on reliability was built, taking into account their sequential and parallel combinations by dividing the signs (indicators) into degrees. The reliability model was compiled on the base of block-scheme:

$$P = P_k[1-\prod_{i=1}^{n}(1-P_i)][1-\prod_{t=1}^{m}(1-P_t)], \qquad (3)$$

Here P_k- probability of reliability of first-order features; P_i and P_t - respectively probability of reliability of second and third order signs; n and m – are the number of second and third degree signs.

[4]Ventzel E.S. Probability theory. Moscow: Nauka, 1969, 576 p.

According to the actual data and expression (3), the probability of coincidence of the features is 0.76. It mentions that the typicality of the experimental area is 76% for the region.

The calculation method was prepared to carry out the hydraulic report of the dispersion irrigation network. For this purpose, hydraulic principles were used[5].

The hydraulic report of the network starts from the field distribution pipeline and ends at the irrigation (main) pipeline [4].

The diameter of each field distribution pipeline is determined by the following formulas:

$$d_i = (0{,}75 \div 1{,}2)\sqrt{q_i}\ , \tag{4}$$

The average speed of water in the pipe:

$$v_1 = q_1 / 0{,}785\, d_i^2 \ ; \tag{5}$$

The longitudinal pressure loss:

$$h_{uz} = \lambda \frac{l_i}{d_i} \frac{v^2}{2g}\ ; \tag{6}$$

The coefficient of friction:

$$\lambda = \frac{0{,}2017}{R_c^{0{,}2}}\ ; \tag{7}$$

Reynolds number:

$$R_c = \frac{v_i d_i}{\upsilon}\ ; \tag{8}$$

Local losses:

$$h_{yer} = 0{,}05\ h_{uz}; \tag{9}$$

In formulas q_i - water consumption in the field distribution pipeline, m^3/sec; l- pipeline length, m; g=9,81 m/sec^2 - free fall emergency. The names of other symbols are given at the beginning of the formulas.The hydraulic reporting of distribution pipelines is

[5] Uginchus A.A., Chugaeva E.A. Hydraulics. Leningrad: Stroyizdat, 1971.351 p.

carried out in the same way as for the field distribution pipeline. However, these formulas assume $q_i=\Sigma Q_i$ (here Q_i is the flow rate of each of the distribution pipelines, m^3/sec).

The hydraulic analysis of the main pipeline is also carried out using formulas (4)÷(9). However, in these formulas, the water consumption in the pipeline is assumed to be equal to the total consumption of the distribution pipelines, i.e. $q_i=Q_{gb}=\Sigma Q_{pb}$. This proposed calculation method allows for the design of the dispersion irrigation network.

CHAPTER V. EXPERIMENTS ON IRRIGATION OF ALFA BY DISPERSION METHOD AND THEIR RESULTS

In this part the field experiments carried out in various variants, their results, soil moisture dynamics, the effect of dispersion irrigation on total evaporation (evapotranspiration) and alfalfa productivity, determination of the biological curvature coefficient, accuracy of experiments, definition of the amount of water used for unit crop production, dispersion irrigation regime and the impact of dispersion irrigation on the environment are studied.

The experiments were carried out in three variants:

Variant I – irrigation of alfalfa by the rain method (control);

Variant II – irrigation of alfalfa by the dispersion method in combination with rainfall;

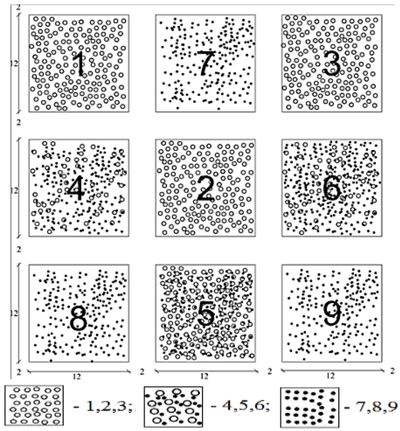
Variant III – irrigation by the dispersion method.

Each variant was implemented with three replications and the variants were placed in the experimental area using a randomization method[6] (picture 2).

In all variants, while keeping the agrotechnical measures the same, the effectiveness of irrigation methods was studied in terms of

[6] Dospekhov B.A. Methods of field experiment. Moscow: Kolos, 1978, p.416.

the total amount of water spent on alfalfa irrigation during the vegetation period (vegetation irrigation rate), productivity, the amount of water spent on the production of a single crop (1 quintal of alfalfa) (water consumption), and the value of the biological curvature coefficient [5, 6, 7, 8].



Picture 2. Scheme of the experiments: 1, 2, 3 - Areas irrigated by rain-fed methods – variant I; 4, 5, 6 - Areas irrigated by combined application of the precipitation method and dispersion method – variant II; 7, 8, 9 - Areas irrigated by dispersion method – variant III.

In variant I the irrigation was carried out 8-9 times during the vegetation period using the rain-fed irrigation method, the average irrigation rate during the period was 715 m^3/ha, the vegetation (total) irrigation rate was 6190 m^3/ha, the average yield of alfalfa was 168 sen/ha. About 33 m^3 of water was used to produce a single crop (1 quintal of alfalfa), the value of the biological curvature coefficient changed among 0.69-0.76 (table).

In variant II the combined application of dispersion method and rainfall irrigation was carried out 73-83 times during the vegetation period and 3-4 times using the rainfall method.In the dispersion irrigation method the aerosol mist was created in the air layer above the plants with an irrigation rate of 34 m^3/ha. Each time 737 m^3/ha of water was applied to the alfalfa plant using the sprinkler method.In this variant the three-year average yield was 263 sen/ha. 19 m^3/sen of water was used for unit crop production. Comparing to the variant I the yield in variant II was 75 sen/ha higher. The value of the biological skewness coefficient changed among 0.48-0.68 (Table).

In the variant II the irrigation water was saved by 20% compared to the variant I.

In variant III the fog was created 77-86 times during the vegetation period using dispersion irrigation, with a rate of 31 m^3/ha in the air layer above the plants. To create the moisture reserve in the topsoil, the plowing operation was carried out at the beginning of the vegetation period with the help of the rain-fed machine at the rate of 665 m^3/ha. The total average irrigation rate was 3355 m^3/ha. The three-year average yield of alfalfa was 174 sen/ha, 19 m^3/sen of water was used for unit crop production, the value of the biological curvature coefficient varied among 0.41-0.51.Compared to the variant I the yield in the variant III was approximately 14 sen/ha less (Table). The partial decrease in productivity is due to the lack of sufficient moisture in the soil layer during the growing season. However, due to the small diameter of aerosol particles in the dispersion irrigation method, water droplets falling on the root system of plants have not created sufficient moisture in the lower layers of the soil.

In order to overcome this shortcoming of the dispersion method, the two-phase generation of aerosol mist has been proposed by us. For this purpose, water particles with a diameter of 40 μm to 600 μm are sprayed into the air.At this time, water particles with a diameter of 40-100 μm form a moist fog suspended in the air, the water particles with a diameter of 100-600 μm form light rain.Fog prevents photosynthesis depression in plants and lowers air temperature. Light rain, penetrates the soil layer, soaking the plant and creating the necessary moisture there.

Table.

Average indicators of three-year experiences according to the variants

Experience variants	Number of irrigation	Periodic irrigation rates (amount of water supplied per irrigation) *m*, m^3/ha	Vegetation irrigation rate (general irrigation rate) M, m^3/ha	Evapotranspiration (total evaporation) E, m^3/ha	The amount of water used to produce a unit of output (water consumption coefficient) ε_y, m^3/ha	Alfalfa productivity S, *sen/ha*	Yield increase (+) and decrease (-) compared to the control variant	The value of the biological skewness coefficient,*kb*	Water savings compared to the variant I, %
Variant I (control) – irrigation by the rain method	8-9	715	6190	6598	33	188	-	0,59	-
Variant II – Irrigation with the combined application of dispersion and rainfall methods: - by dispersion method - by rainfall method	73-83 3-4	34 737	2519 2450 Σ4969	6337	19	263	+75	0,48-068	20
Variant III – Irrigation by dispersion method:	77-86 1	31 665	2690 665 Σ3355	6381	19	174	-14	0,41-0,51	46

In dispersion irrigation the irrigation water was saved by 45% compared to the rainfall method, by 32% compared to the variant II. The lowest value of the biological curvature coefficient (0.41-0.51), which characterizes the ratio of total evaporation to the deficient air moisture, was observed when irrigation was carried out using the dispersion method (Table). It shows that during dispersion irrigation, the lack of moisture in the air is eliminated and the relative humidity increases.

Of course, it leads to a decrease in the amount of evaporation from the soil and transpiration by plants [9, 10, 12]. Based on the experiments it has been determined that when the air temperature is higher than 28°C and the relative humidity is less than 45%, the respiratory pores in clover leaves gradually close, making the respiration of the plant difficult and even stopping.At this time, the process of photosynthesis depression occurs, as a result, the process of crop formation is disrupted and slowed down. In dispersion irrigation, this process is eliminated because the leaves of the plant are continuously moistened with water particles.

The accuracy of the experiments in terms of productivity was verified with the help of mathematical statistics.The average error of the experiments was 0.28-0.91 sen/ha, with a relative error of 0.28-0.58%, that is, many times less than the acceptable limit. The dispersion irrigation method has a very favorable effect on the environment and during the hottest times of the day (from 1:00 PM to 4:00 PM), it lowers the air temperature by 6°C or more, increases the relative humidity of the air by 25-40%, and finally creates a microclimate in the environment.

According to the experiments carried out on soil moisture dynamics, it has been determined that when irrigation is carried out using the dispersion method, the decrease in soil moisture reserves is observed at the end of the vegetation period. This process is due to the fact that aerosol fog at accepted levels does not provide the soil layer with sufficient water. Therefore, aerosol fog, as we propose, should be created in two-phase forms - light rain and fog.

On the basis of the studies the irrigation regime was developed for the dispersion method. Unlike the traditional irrigation regime, in the dispersion irrigation method the irrigation begins when the air temperature is above 28^0C.During the day from 13:00 to 16:00 1-3 times with the help of a dispersion device, water in the amount of 19-33 m^3 per hectare is sprayed into the air in the form of the light rain fog within 10-15 minutes.Every ten days the moisture is determined in the 0-20 cm layer of soil. If the soil moisture level is below 70-75% of the field moisture capacity, then light rain is created in the field by reducing the working pressure of the dispersion device.

PART VI. ECONOMIC EFFICIENCY OF THE DISPERSION IRRIGATION METHOD

The economic efficiency of dispersion irrigation was determined based on the comparison of the economic indicators of the base and new techniques (technology).Irrigation by rain-fed method was adopted as the base option. Economic efficiency (in the form of net income) was calculated based on the costs of basic and new equipment (technology), the value of the product obtained, production costs, water and land use factors. Compared to the base option, the net income obtained when using the combined (related) application of dispersion and rainfall methods is 4362 man/ha, while the net income from using dispersion irrigation only is 3719 man/ha.The payback period for investments in dispersion irrigation is 0.18 years, the payback period for investments in the combined application of dispersion and rainfall methods is 0.16 years.

CONCLUSION

1. Fresh water resources in Azerbaijan are very limited and there is a gradual decline in water resources due to climate

changes.About 50-70% of the water taken from the water sources is used in irrigation. But 30-40% of the water taken from the sources is spent on leakage and evaporation losses.Therefore, in order to use the available water resources economically and efficiently, it is required to develop appropriate agrotechnical measures.The main place among these measures is the development of progressive water-saving irrigation methods and techniques, the study of their effectiveness and application to production.

2. Livestock farming plays an exceptional role in agriculture and ensuring the food security of the country. To ensure the sustainable development of livestock farming, it is necessary to strengthen its feed base.The plant alfalfa occupies one of the leading places in the creation of the feed base for livestock.However, the plant alfalfa requires a lot of water during the growing season, and using traditional irrigation methods the vegetation irrigation rate is 6,000-10,000 m^3/ha or more. In the water shortage situation, diverting so much water for irrigation creates serious difficulties in the water balance of the country. The carried out researches and analysis show that dispersion (aerosol) irrigation can be used to save and use irrigation water efficiently.
3. On the basis of multi-variant experiments carried out on the Absheron Peninsula for a long time, it was established that dispersion irrigation method is considered quite effective and efficient in arid, as well as fodder crops with high water permeability, hot climate and very low atmospheric precipitation.
4. The dispersion irrigation method can be used both independently and in combination with other irrigation methods.During combined (connected) with the dispersion method, irrigation water is saved 1.25 times compared to the rainfall method, which is considered the most advanced irrigation method, and when the dispersion method is applied

independently, water is saved approximately 3 times compared to the rainfall method.

5. Irrigation using the dispersion method allows to lower the air temperature by 4-6^{0}C and increase the relative humidity by 25-40%.Therefore, the process of photosynthesis depression in plants is eliminated, transpiration by plants and evaporation from the soil surface are prevented, and the favorable microclimate is created in the environment.
6. It has been determined that when the dispersion irrigation method is applied independently or in combination, the amount of water used to produce a single crop (1 quintal) or the water consumption coefficient is reduced by 1.8 times compared to the rain irrigation method.Thus, the amount of water used to produce one quintal of alfalfa is 33 m^3 with sprinkler irrigation and 19 m^3 with dispersion irrigation.
7. Analysis of the results of the conducted experiments shows that, despite the fact that the dispersion irrigation method has the same agrotechnical background and high technical-economic indicators, when applied independently, the yield of alfalfa is partially reduced compared to other methods. In the experiments the alfalfa yield decreased by approximately 7% compared to the rainfed method, but when the dispersion method was used in combination with the rainfed method, yield increased by 75 sen/ha or 40%. This is explained by the fact that when using the dispersion irrigation method in free form, the soil layer is not moistened sufficiently. Therefore, in order to increase the effectiveness of this method, it should be applied either in combination with other irrigation methods, or the dimensions of the aerosol particles should be relatively enlarged.
8. The irrigation regime in the dispersion irrigation method differs sharply from the irrigation regime used in other irrigation methods. Watering during the growing season is carried out when the process of depression occurs in plants,

that is, when the air temperature is above 28 and the moisture content in the upper layer of the soil decreases to 70-75% of the field moisture capacity.Irrigation begins at 1:00 PM in Absheron conditions and continues until 4:00 PM. At this time, the irrigation rate changesamong 29-33 m^3/ha, but the number of irrigations during the vegetation period changesamong 73-86. Each irrigation rate is sprayed into the air for 10-15 minutes and is repeated 1-3 times a day.

9. The dispersion irrigation method is considered a very economically efficient method, and appling independently, the economic efficiency is 3179 man/ha, but appling together with the rain irrigation method, it is 4362 man/ha.

PRODUCTION RECOMMENDATIONS

To save irrigation water, it is advisable to use the dispersion irrigation method, which creates fog and rain above the planting field. The dispersion irrigation method can be applied independently or in combination with other irrigation methods.Applying the dispersion irrigation method independently, aerosol water particles are sprayed into the air in mixed sizes (from 40 mkm to 600 mkm in diameter).

The small water particles remain suspended in the air, creating fog, while larger particles create light rain.When the dispersion irrigation method is applied in combination with other irrigation methods, one or two irrigations are carried out using the usual method (run-off, rainfall, burial, etc.) during the growing season. Subsequent irrigation is carried out by the dispersion method.

Irrigation by dispersion method is carried out if the air temperature is higher than 28^0C. During the day from 13.00 to 16.00 1-3 times with the help of a dispersion generating device, water in the amount of 19-33 m^3 per hectare is sprayed into the air within 10-15 minutes.Every 10 days, moisture is measured in a 0-20 cm layer of soil. If the humidity limit is less than 70-75% of the field moisture capacity, then the working pressure of the dispersion generating unit is reduced and light rain is created.

In the absence of the dispersion generating device, all types of rain-applied, medium and long-range sprinklers and other irrigation devices in the farm can be used.For this purpose, some of the working devices of sprinkler machines are replaced with aerosol-generating attachments, or aerosol-generating attachments are installed in addition to these machines.During the irrigation season, the working parts of rain-making machines and devices are started and stopped alternately.

The main conclusions and innovations of the dissertation are reflected in the following works of the author:

1. Irrigation by dispersion (aerosol) method and its effect-tiveness // Collection of Scientific Works of the AzH&M EIB, Baku: Elm, 2013, volume XXXIII, pp. 173-177.
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6. Irrigation of alfalfa by dispersion (aerosol) method in Absheron conditions // Collection of Scientific Works of the AzH&M EIB, Baku: Elm, 2016, vol. XXXV, pp. 164-179 (co-authors: N.B. Bashirov).
7. Determination of transpiration intensity and relative transpiration in alfalfa under different irrigation methods in Absheron conditions // Collection of scientific papers dedicated to the 60th anniversary of the Honored Inventor of the USSR, Laureate of the USSR Council of Ministers Prize, Academician of the Russian Academy of Natural Sciences Fakhraddin Hasan oglu Gabibov. Geomechanics, Geotechnics, Geoecology, Hydraulic engineering. Baku: AzIMETI, 2016, pp. 299-302 (co-authors: N.B. Bashirov, R.G. Ibragimov, S.M. Shakhmaliyeva).
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11. Methodology for determining water demand and irrigation regimes of agricultural crops in the Talysh agro-climatic region //Collection of Scientific Works of the AzH&M EIB, Baku: Science, 2022, vol. XLIII, pp. 150-156 (co-authors: S.M.Shahmaliyeva, E.I.Rufullayev, Z.A.Mammadov, R.H.Ibrahimov, Sh.T.Aghammadov).

12. Optimal irrigation regimes of agricultural crops cultivated in the Republic under conditions of global climate change // Collection of Scientific Works of the Scientific Research Institute of Land Reclamation LLC, Baku: Science, 2023, vol. XLIV, pp. 159-169 (co-authors: E.I. Rufullayev, S.M. Shahmaliyeva, R.H. Ibrahimov, Sh.T. Aghammadov).
13. Scientific basis for adjusting irrigation regimes of agricultural crops in the Kur-Araz agroclimatic region of Azerbaijan taking into account global climate change //Collection of Scientific Works of the Scientific Research Institute of Land Reclamation LLC. Baku: Elm, 2023, vol. XLIV, pp. 185-190 (co-authors: R.G. Ibrahimov).

The defense of the dissertation will be held on 31 oktober 2025 at 14:00 at the meeting of the Dissertation Council FD 1.32 operating under the Azerbaijan Republic Ministry of Science Education, Institute of Soil Science and Agrochemistry.

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The dissertation is available at the Library of the AR MSE Institute of Soil and Agrochemistry.

Electronic versions of the dissertation and abstract are posted on the official website of the AR MSE Institute of Soil and Agrochemistrywww.tai.az

The abstract was sent to the necessary addresses on 30 september 2025.

Signed for publication: ___________
Paper format: 60x84/ 1/16
Volume: 40000
Issue: 1000