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The technology of fertilizing irrigation with differentiated norms using wide-reach sprinkler machines

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Abstract. Fertigation shows its high efficiency, but requires careful dosing of mineral fertilizers and irrigation water. The aim is to improve the technology of irrigation with wide-coverage sprinklers when applying fertilizers with irrigation water. The article presents the technology of differentiated irrigation with the introduction of fertilizers. A method for determining irrigation standards is given, taking into account changes in soil moisture reserves, including during reverse movement. A fertilizer dispenser is presented with the calculation of the dosage of fertilizer application in accordance with the irrigation rate. When using differentiated technologies, the yield of Moskovskaya wheat increased by 45% compared to traditional technology (uniform irrigation rate).

1 Introduction

Fertilizer irrigation creates favorable conditions for growing a wide variety of crops and can be effectively applied in various natural and climatic conditions of most regions of the Russian Federation. Fertilizing irrigation contributes to a more productive use of irrigation water and nutrients per unit of harvest. The work of many scientists is devoted to the optimization of technologies and the development of drug dispensers [1 -12].

Dispensers ensure the supply of mineral components to irrigation water with the required frequency and in the required quantities. The concentration of fertilizers in irrigation water at a watering rate of more than 500 m3/ha should not exceed 0.2-0.3% in hot periods [9].

During rainy periods, this amount increases to 0.5%. For example, with fertilizing irrigation with a norm of 300 m^3 / ha, the concentration should not exceed 0.1% (1.0 g/l). With an increase in the irrigation rate to 600 m^3/ha or more, the concentration can be increased to 0.2-0.3% (2-3 g/l) [9].

The process of complex regulation of water and food regimes of the soil using fertigation shows its high efficiency, but requires careful dosing of mineral fertilizers and irrigation water.

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The aim is to improve the technology of irrigation with wide-coverage sprinklers when applying fertilizers with irrigation water.

2 Materials and methods

Let's consider the irrigation mode when working with a wide-reach sprinkler machine. The irrigation rate, m^3 / ha, is determined by the formula [11]:

$$M = \frac{1200\, Q_{\mathrm{M}}}{RV}, \quad (1)$$

where Q_{M} – machine consumption, l/s; R – rain capture radius, m; V – the average speed of the car.

Let's determine the concentration of the mother liquor and the dosage on the dispenser to obtain, for example, a 0.05% solution for fertilizing irrigation with a norm of 300 m^3/ ha.

A liter of 0.05% solution contains 0.5 grams of fertilizers. To prepare the mother liquor for 300 grams of fertilizers, 5 liters of water are needed.

A liter of mother liquor contains 56.6 grams of fertilizers.

Knowing the required ratios, it is necessary to set the dosage percentage on the dispenser for the preparation of 0.05% solution.

To obtain the necessary 0.5 grams of fertilizers in a liter of ready-made solution, the fertilizer dispenser must supply 8.83 grams of mother liquor.

The dosage percentage is approximately 0.9%. In other words, taking into account the consumption of the matrix solution, the irrigation rate:

$$M = \frac{1200(Q_{\mathrm{B}}+Q_{\mathrm{U}})}{R\,V}, \quad (2)$$

$$Q_{\mathrm{M}} = Q_{\mathrm{B}} + Q_{\mathrm{U}}, \quad (3)$$

where Q_{B}- water consumption; Q_{U}- fertilizer consumption.

Consider the driving mode. The speed and, accordingly, the watering rate is set using a percentage timer. Let's take the example of Sprinkler machines (SM) "Kuban-LC1M" (CASCADE), table1, Figure 1.

Table 1. Operating mode of DM Kuban-LK1M (CASCADE)

SM speed, %	**Time of one pass (h/watering)**	**Irrigation rate (cubic meters/ha/watering)**	**Ratios in the irrigation rate of cubic meters/ha**	
			Water (0,99 Q_{M})	Mother liquor (0,009Q_{M})
100	23,10	117	116	1
90	25,67	130	128,5	1,3
80	28,88	145	144	1,5
70	33,00	166	165	1,7
60	38,50	194	192	2
50	46,20	233	230	2,8
40	57,75	292	289	3
30	77,00	389	385	4
20	115,50	584	578	6

Fig. 2. CASCADE Sprinkler Machine

Let's determine the required capacity of the dispenser pump per hour.

From the above ratios, it can be expressed that 1 m^3 of mother liquor should be supplied in 23.1 hours, i.e. 0.051 m^3/hour (0.01 l/s).

The developed fertilizer metering pump consists of a rotating rotor with rollers, a tube and a container with a matrix solution, Figure 2. When the rotor rotates, the rollers drive the matrix solution through the tube, feeding the required volume into the machine pipeline. The supplied volume is regulated by the rotor speed.

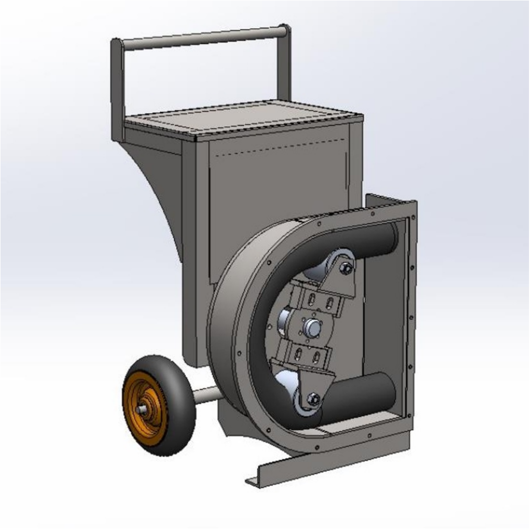

Fig. 2. Metering pump

The volume of the supplied solution is defined as the volume of the tube occupied by the solution:

$$Q_d = \mu S_T \, v_P, \tag{4}$$

where μ – consumption coefficient (0.85); S_T – the cross-sectional area of the dispenser tube, v_P – the velocity of the solution equal to the linear velocity of the roller.

$$v_P = 2 \, \pi R \, n, \tag{5}$$

where n – rotation speed, m/min.

For the D01 dispenser model:

$$v_P = 2 \cdot 3{,}14 \cdot 0{,}2 \cdot 20 = 25{,}12 \text{ m/min.}$$

Q_d = 0,85 · 0,000047 ·25,12 =0,001 m³/min =0,016 l/s.

The flow rate is regulated by the rotation frequency and the diameter of the tube.

To optimize the parameters of the dispenser, it can be calculated for different diameters of the dispenser and tubes.

When watering the sector with a machine:

$$M = 2\pi \frac{1200\, Q_M}{\ell\, V}, \tag{6}$$

where ℓ – the length of the arc of the irrigation sector.

Changing soil moisture reserves in front of the machine:

$$f_1(\alpha) = W_0 - 10Ec \int_0^{\alpha} M_1(\alpha) d\alpha, \tag{7}$$

Moisture reserves after passing the machine at time t with watering rate M_1:

$$W_1 = f_1(\alpha) + M_1(\alpha), \tag{8}$$

where α – the angle of the irrigation sector.

In case of reverse movement, moisture reserves after the passage of the machine will be determined:

$$W_2 = f_2(\alpha) + M_2(\alpha), \tag{9}$$

where $f_2(\alpha)$ – the change in moisture reserves in front of the machine during its reverse movement with watering is normal M_2.

Then the value of the irrigation rate is in the forward direction:

$$M_1(\alpha) = 2\pi \frac{1200 Q_M}{\ell V(\alpha)} \left[1 - e^{10Ec(\alpha - s)}\right], \tag{10}$$

In the reverse direction:

$$M_2(\alpha) = 2\pi \frac{1200 Q_M}{\ell V(\alpha)}\, e^{10Ec(\alpha - s)}, \tag{11}$$

s – the path passed by the last cart; E – intensity of water consumption, mm/day.

The value of c is defined as:

$$c = \frac{s}{432 \cdot 10^3 k Q_M}, \tag{12}$$

The maximum value of the path when moving in one direction is equal to the length of the arc of the cart circumference:

$$s_{MAX} = \ell = 2\pi R, \tag{13}$$

k– time utilization factor.

Thus, by setting the path that the last cart passes, it is possible to determine the optimal value of the norm during watering.

3 Results

Experimental studies were conducted when irrigating wheat for grain. The wheat variety is Moskovskaya.The soil is dark chestnut medium loamy. The yield data is presented in Table 2.

Field research was carried out with the application of fertilizers using traditional technology with a single irrigation rate and differentiated technology.

Watering with a single norm and fertilization allowed for an increase in yield of almost 45% compared to the control. When using differentiated irrigation technologies with fertilization, the yield increased by 82% compared to the control.

Table 2. Formatting sections, subsections and subsubsections.

Option	**Yield, kg/ha**	**An increase in control, %**
Control	22	-

Traditional technology	32	45
Differentiated	40	81

4 Conclusions

Fertigation creates favorable conditions for the cultivation of various crops and is effectively used in various natural and climatic conditions of most regions of the Russian Federation.

The presented method makes it possible to determine the irrigation rate taking into account changes in soil moisture reserves, including during reverse movement with the calculation of fertilizer doses in accordance with the irrigation rate.

Differentiated irrigation with fertilization allows you to get a high yield without overspending resources, which also reduces the negative impact on the environment.

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