Parameters of the system for intrasoil application of manure-containing wastewater when growing roses

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Abstract. One of the ways to utilize manure-containing milking parlor wastewater (MPW) from dairy farms is to use it as liquid fertilizer in greenhouses. Considering that there are no clear recommendations on the disposal of manure-containing milking parlor drains by application in greenhouses, the purpose of the research was to determine the main parameters of the system for subsurface application of manure-containing milking parlor drains - perforation diameter *d* (mm) and pipeline depth *h* (mm) when growing roses in the greenhouse. The main factors influencing the process of intrasoil application of manure-containing milking parlor wastewater in a greenhouse have been identified and presented in the form of an information model. A two-factor experiment was planned, the following factors were subject to variation: perforation diameter - from 2 mm to 4 mm, pipeline depth - from 50 mm to 150 mm. The length of each pipeline option is 1500 mm, the internal diameter is 16 mm, the perforation pitch is 100 mm, and a plug is installed at the end. The supply of manure-containing milking parlor wastewater from the tank to the perforated pipeline was carried out through flexible pipes by gravity at a rate of 6.5 liters per square meter. It has been established that the studied parameters have little effect on the length of rose stems, but have a greater influence on the number of flowers, and the diameter of the perforation of the subsoil pipeline has the greatest influence than its depth. As a result of the research, a mathematical model of the influence of perforation diameter and pipeline depth was obtained, the number of roses *q* was obtained, and a three-dimensional response surface was constructed. The optimal parameters for introducing manure-containing milking parlor wastewater under these conditions were perforation diameter 2 mm and pipeline depth 111 mm.

1 Introduction

When milking cows in the milking parlor, manure is removed by washing the floor and contaminated surfaces. In most farms, these operations are performed after each milking.

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Walls and floors are usually cleaned by rinsing with water using medium or high pressure hoses, combined with brushing if necessary [1]. Water contaminated with manure is milking parlor wastewater, which, as a rule, enters a manure storage facility, where it is stored (at least 6 months) before being applied to the fields. With intensive, specialized and concentrated livestock farming, there is a change in the balance between crop production and livestock production and the nutrient cycle is disrupted [2-3]. Today, one of the main problems of large livestock complexes is the lack of sufficient agricultural land to apply all the resulting organic fertilizer [4]. Manure and livestock runoff are stored in huge lagoons and reservoirs, away from large fields that could absorb and process nutrients [5].

One of the ways to utilize manure-containing wastewater from milking parlors of dairy farms is to use them as liquid fertilizers in greenhouses [6]. During the year, greenhouse plants, compared to open ground plants, produce many times higher yields, and therefore consume significantly more nutrients and water. All biological processes occurring in the soil are several times more intense than the biological processes in open ground [7]. This feature will allow the use of greenhouse soils as a utilizer of manure-containing milking parlor wastewater, based on natural biological purification by soil microorganisms and a source of nutrition for greenhouse crops. Currently, the most common and accessible organic component for soil composition is high-moor peat. Peat soils have a large absorption capacity, and their buffering capacity (the ability to withstand changes in the reaction of the soil solution) is significantly higher than the buffering capacity of artificial substrates. Therefore, the use of manure-containing milking parlor wastewater as the main nutrition and fertilizing on peat substrates gives a high effect [8]. Measuring the indicators that determine the biometric parameters and stability of plant development allows us to conclude that instead of using expensive mineral fertilizers in ground greenhouses, it is possible to use manure-containing milking parlor wastewater generated on farms in large quantities [9]. An example of a dairy farm with a greenhouse is presented in [10].

The results of experimental studies of methods for recycling manure-containing milking parlor wastewater in a greenhouse prove the effectiveness of subsoil application: in laboratory conditions, the number of peduncles increased on average by 21.4% and weight by 11.4% compared to surface application [11]; in production conditions - the collection of rose flowers increased by 18.9%, and the height by 7.2% compared to surface application and by 26.7% and 10.4%, respectively, compared to fertilizing with mineral fertilizers used in the greenhouse [7].

The introduction of manure-containing milking parlor wastewater into a greenhouse can be described in the form of an information model (Figure 1). manure-containing milking parlor effluents have an impact on the soil substrate and the plants grown in the greenhouse through the subsoil application system, the control factors of which include: pressure H of the supplied manure-containing milking parlor effluents, supply time T_p, diameter of the perforated pipeline D, its depth h, hole diameters d and perforation pitch p of the pipeline, temperature of manure-containing milking parlor wastewater t_{MPW}, composition and concentration of nutrients NPK, dry matter content C.

The other part of the input influences consists of controlled factors of the greenhouse microclimate: air temperature t_b and its humidity φ_b, illumination E. The output vector contains a criterion for assessing efficiency, namely, the maximum increase in green mass per unit of the growing season.

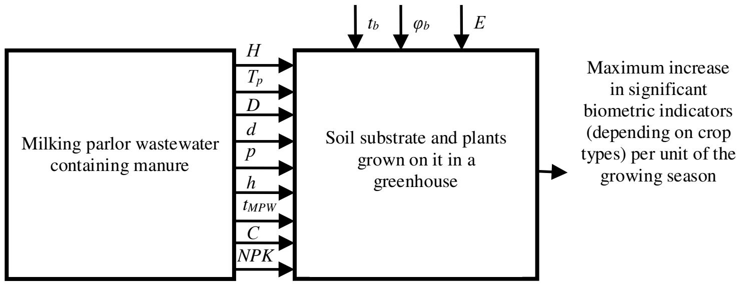


Fig. 1. Information model of subsoil application of manure-containing milking parlor wastewater in a greenhouse.

The uniformity of distribution of manure-containing milking parlor effluents along the length of the subsoil pipeline, and, consequently, the yield of grown plants, depends on the water-physical properties of the soil, design parameters of pipelines, piezometric pressure, and application rates. The components included in the composition of manure-containing milking parlor drains have the ability to improve the structure of the soil, its air and water regimes, increase the physico-chemical characteristics and level of fertility, but at the same time, suspended substances, biological and chemical pollution of manure-containing milking parlor drains have a great impact to the subsoil application system. Considering that there are no clear recommendations on the disposal of manure-containing milking parlor wastewater by application in greenhouses, a more in-depth study and research of this process is required.

The purpose of the research was to determine the main parameters of the system for intrasoil application of manure-containing milking parlor drains - perforation diameter d (mm) and pipeline depth h (mm) when growing roses in a greenhouse.

2 Materials and methods

The research was carried out on the territory of the greenhouse farm of the educational and experimental base. Manure-containing milking parlor wastewater was applied as fertilizing irrigation when growing the hybrid tea variety of rose “Cardinal”. Roses react positively to organic fertilizers by increasing the collection of flowers; moreover, this option is the safest from a sanitary point of view, because flowers are not eaten.

To assess the influence of the parameters of the intrasoil supply system of manure-containing milking parlor wastewater on the growth, development and productivity of plants, a two-factor experiment was implemented. In the study, two factors were varied: the pipeline depth h and the perforation diameter d (Figure 2). They served as controllable factors. Their limit values, levels and variation intervals (Table 1) were established as a result of laboratory studies [11] and calculations, analysis of literary sources.

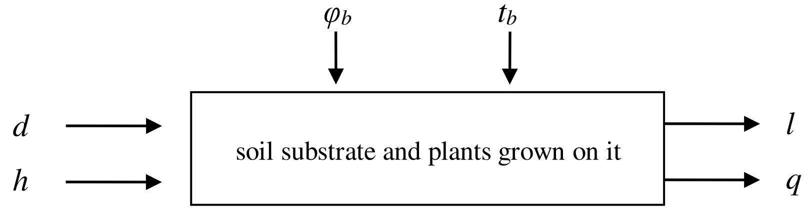


Fig. 2. Factors influencing the process.

Table 1. Levels and intervals of variation of factors in actual values.

Levels	Process factors and units of measurement	
	Perforation diameter *d*, mm	**Pipeline depth *h*, mm**
Upper	4	150
Basic	3	100
Lower	2	50
Variation interval	1	50
Code designation	x_1	x_2

The most important elements of irrigation technology, such as a single rate, the duration of its supply, the calculated specific flow rate and pressure, were determined using the methods used to determine the technological and technical parameters of subsurface irrigation systems. To calculate the design parameters of pipelines, we used well-known formulas used in hydraulics [13], taking into account the features of the hydraulic transport of wastewater through pipes [14-15].

In order to significantly reduce the number of experiments required to obtain a mathematical model of the influence of the parameters of the system for introducing manure-containing milking parlor effluents on plant productivity and to optimize the parameters of the object of study, planning of a 2-factor experiment according to a three-level plan 3^2 was applied [16]. The plan was generated using the Statgraphics Centurion XV program.

To obtain reliable mathematical models, a randomized matrix was used in the experiments.

Fertilizer irrigation of manure-containing milking parlor drains was carried out once every ten days through an intrasoil pipeline laid between two adjacent rows of plants in the middle parallel to the rows.

The length of each pipeline option is 1500 mm, the internal diameter is 16 mm, the perforation pitch is 100 mm, and a plug is installed at the end. The supply of manure-containing milking parlor wastewater from the tank to the perforated pipeline was carried out through flexible pipes by gravity at a rate of 6.5 l/m^2.

To remove suspended substances and impurities that negatively affect the flow in the irrigation system, manure-containing milking parlor drains were pre-filtered through a fine mesh, and to reduce nitrogen losses and increase the content of available phosphorus, simple superphosphate was added to the milking parlor drainage at the rate of 1 g per liter drain.

As output parameters, the number of rose flowers *q* (pieces) was calculated and, since the cost of roses depends mainly on the length of the stem, the stem length *l* (cm) was measured. The task boiled down to finding the values of the factors that give the maximum number of rose flowers *q* per cut per unit of the growing season. The adequacy of the resulting mathematical model was checked using the Fisher criterion, the significance of the regression coefficients using the Student test. The obtained data were processed using the statistical graphics program Statgraphics Centurion XV.

3 Results and Discussion

The results of measuring the number of flowers q and the length *l* of rose stems depending on the depth of the pipeline *h* and the perforation diameter *d* are presented in Table 2.

Table 2. Research results.

Plot number	Diameter of pipeline perforation *d*, mm	Pipeline depth *h*, mm	Rose accounting indicators	
			Quantity *q*, pcs.	Stem length *l*, cm
1	2	150	63	56.49
2	4	100	52	53.40
3	3	50	44	53.20
4	4	50	59	51.81
5	3	100	43	52.52
6	2	50	62	53.19
7	3	150	41	51.83
8	2	100	63	54.84
9	4	150	44	54.98

The data obtained indicate that, on average, when the pipeline depth increases from 50 to 150 mm, the number of rose flowers decreases by 10.4%, and the length of the stems increases by 3.2%. With an increase in the perforation diameter, the average productivity of roses decreases, and with a perforation diameter of 3 mm in the number of flowers by 32% and the length of stems by 4.2%, and with a perforation diameter of 4 mm by 17.6% and 2.6%, respectively. Thus, the studied parameters have little effect on the length of rose stems, but have a greater effect on the number of flowers.

In the course of multiple regression analysis on the influence of the studied factors on the number of rose flowers q, a mathematical model was obtained in coded form:

$$q = 42.667 - 5.5 \cdot x_1 - 2.8333 \cdot x_2 - 4.0 \cdot x_1 \cdot x_2 + 14.5 \cdot x_1^2, \quad R^2 = 0.992 \tag{1}$$

The significance of the equation's coefficients is determined by the Student's t-test and its P-value probability level, which must be less than a specified 0.05. The P-value for the factors presented ranges from 0.0001 to 0.0045, so the coefficients of equation (1) are statically significant.

The values of Fisher's criterion at the number of degrees of freedom of adequacy dispersion f_{ad} = 9-2-1 = 6 and the number of degrees of freedom of reproducibility dispersion f_{ad} = 9*(2-1) = 9 were found by interpolation using tabular data and obtained the value F(0.05;6;9) = 3.374. The experimental value of Fisher's F test at a 5% significance level is 1.405 for equation (1), which is less than the table value. Thus, the hypothesis about the adequacy of the description of the experimental results by the resulting equation can be considered correct with a probability of 95%.

Using the obtained regression equation, after decoding, a three-dimensional response surface and the contour of its section were constructed (Figure 3): $q=f\,(d;h)$.

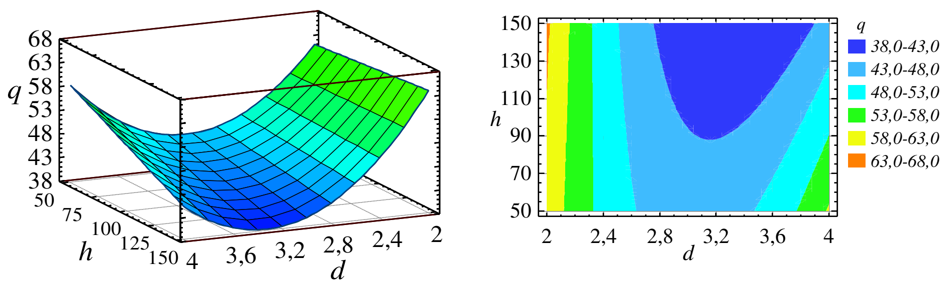


Fig. 3. Response surface and the contour of its section, showing the influence of factors *d* and *h* on the number of roses *q*.

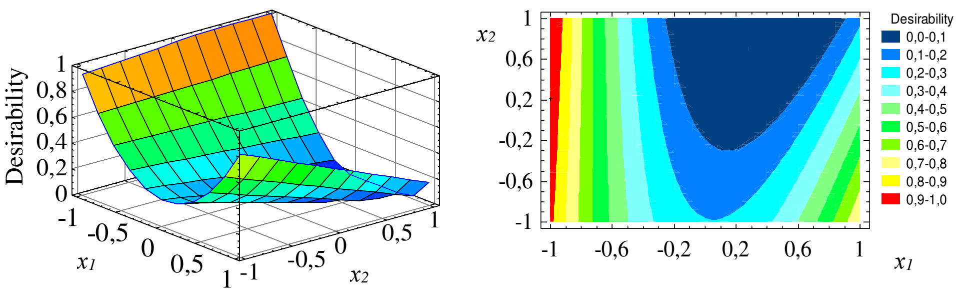
Analyzing the resulting equation (1) and the graphs (Figure 3), we can say that the number of colors q is most influenced by the diameter of the perforation of the subsoil pipeline than by its depth.

The highest yield in terms of the number and length of rose stems, with different options for the depth of the pipeline, was obtained in options with a perforation diameter of 2 mm.

To find the optimal parameters under study, nonlinear programming was used. Using the mathematical model (1), we will solve a compromise problem in which we must determine the values of the factors that give the maximum value for the number of rose flowers q. The solution to the optimization problem was carried out on a computer using the statistical graphics program Statgraphics Centurion XV and had the form:

$$q=f(x_1; x_2) \rightarrow \max; \quad -1 \leq x_1 \leq 1; \quad -1 \leq x_2 \leq -1. \tag{2}$$

Figure 4 shows the response surface and the contours of its section when solving the optimization problem.



x_1, x_2 – coded values of perforation diameter and pipeline depth

Fig. 4. Calculated response surface and contours of its section when solving an optimization problem.

Analysis of the data obtained led to the conclusion that the optimal parameters for introducing manure-containing milking parlor wastewater under these conditions were 2.002 mm in perforation diameter and 111 mm in pipeline depth.

4 Conclusion

The studied parameters have little effect on the length of rose stems, but have a greater influence on the number of flowers, and the greatest influence is exerted by the diameter of the perforation of the subsoil pipeline than by its depth. As a result of the research, a mathematical model of the influence of the perforation diameter and pipeline depth on the number of roses q was obtained, and a three-dimensional response surface was constructed. The optimal parameters for introducing manure-containing milking parlor wastewater under these conditions were perforation diameter 2 mm and pipeline depth 111 mm.

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