USE OF VENTILATION EMISSIONS FROM ANIMAL BARN FOR IMPROVEMENT OF PLANT GROWTH

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Abstract. The paper presents one of the ways to utilize the nutrients from the barn ventilation emissions for additional sub-soil fertilizing of flowers grown in an indoor plant growing facility. To investigate the effect of ventilation emissions on the growth and development of floricultural crops, a barn for 160 cows was connected by an air duct with a glass house, where marigold flowers (*Tagetes*) were grown. The air from the barn (ventilation emissions) was pumped to the subsoil layer in the greenhouse. The investigation outcomes showed that the additional subsoil fertilizing of flowers with ventilation emissions from the barn under the set conditions provided in average 137 % higher number of marigold flower stalks over the reference.

Key words: livestock house, air cleaning, ecology, subsoil fertilizing, carbon dioxide fertilizing, flower crops, glasshouse, ventilation emissions.

Introduction

The key element for improving the efficiency and quality of animal husbandry is creation and maintenance of the desired indoor climate in livestock houses, where intensive processes of biochemical conversion of organic matter take place, primarily animal metabolism and decomposition of their excrements. These processes are followed by the release of harmful substances – heat, water vapors, carbon dioxide, ammonia, hydrogen sulfide and other gases, microorganisms and dust. They are removed from the livestock houses through the exchange of the inside air with the outside air, i.e., ventilation. Ventilation air continuously carries to the outer atmosphere the harmful matter generated inside, and this aggravates the ecological situation both, on local and global scale [1].

Ventilation emissions of livestock farms contain carbon dioxide (CO_2), ammonia (NH_3) and other elements, which pollute the environment.

According to the investigation data, the following amounts of microorganisms, gases and dust are released into the atmosphere from the ventilation systems of livestock farms and complexes per one hour (Table 1) [2]:

Table 1

Specific emission of cattle waste products

Per head average per hour/year	Microorganisms, pieces	Carbon dioxide, m^3	Ammonia, kg	Dust, kg
hour	$6.4 \cdot 10^6$	0.279	0.0029	0.0006
year	$2.34 \cdot 10^9$	101.8	1.06	0.2

Out of all ventilation emissions, the carbon dioxide constitutes a real danger as its high concentration in the atmosphere of the Earth results in climate warming due to the greenhouse effect.

The problem of environmental safety of animal farms should be addressed by combining the livestock production with commercial plant growing in such a way that the waste of these two inextricably linked sectors was utilized most efficiently within the closed production cycle.

Protected cropping is one of the solutions of commercial plant growing. The greenhouse area is intensively used nearly all year round. Combination of livestock houses with greenhouses may solve the problem of ventilation air cleaning from harmful substances and reduce the irrational heat loss [3; 4].

The carbon dioxide, which is released by the farm animals and emitted into the atmosphere through the ventilation system, may be used for additional fertilizing of crops in the plant growing facilities [5]. The most effective and safe way is to supply these emissions to the subsoil layer in the greenhouse adjacent to the barn [6].

The research objective was to study the effect of ventilation emissions from the barns on the growth and development of flower crops in the indoor growing facilities and to determine the optimal parameters of the subsoil system for nutrients distribution.

Materials and methods

The factors under investigation were the pipeline depth (*h*, mm), and perforation interval (*p*, mm). To study the effect of these factors on the growth, development and yield of flower crops in the indoor growing facilities, a greenhouse with the dimensions of 8000x2800x3200 mm was manufactured and placed on the farm territory close to the barn (Fig.1). The greenhouse was equipped with high-pressure sodium arc lamps providing uniform illumination inside the chambers no less than 8000 lx for 14 hours. The illumination was controlled by a programmed timer ПИК-2.

Fig. 1. **General view of the pilot greenhouse (A) and the barn (B)**

Inside the greenhouse there were the chambers with the dimensions of 700x500x900 mm with different factor variants. Each chamber was a wooden frame covered with a gas-tight screen of translucent material. On the chamber bottoms there were trays with growing gutters with the dimensions of 600x400x300 mm. Each gutter accommodated ten flower plants. In the gutters, filled with the substrate, a plastic pipeline with 20 mm diameter, perforated with 3 mm holes, was installed in the drainage layer at the fixed depth – 100, 150 or 200 mm. The control variant had different substrate depth – 100, 150 or 200 mm and no additional fertilizing by carbon dioxide. The barn was connected with the glasshouse by an air duct to pump the barn air (ventilation emissions) to the polyethylene pipelines in each greenhouse chamber. The ventilation rate was regulated with a special device on the compression pump. Gas analyzer OKA-T was used to determine the concentration of carbon dioxide, ammonia and hydrogen sulfide in the air inside the barn and greenhouse chambers. The floricultural crops grown were the seedlings of marigold flowers (*Tagetes*) as they have a short vegetation season (from seeding to abundant blooming) and this allows for a short term experiment.

During the experiment the air from a barn with 160 cows was supplied to the soil layer under the ventilation pressure of 868.7 Pa for 46 days (plant vegetation period). The barn air temperature varied from 5.4 ºC to 15.8 ºC, the moisture content was 72-99 %, ammonia content was 4-12 $mg \cdot m^{-3}$, carbon dioxide content was 0.06-0.12 %, soil layer moisture content was 63-81 %.

Experiments were carried out according to the program and procedure based on the current standards and common investigation methods, which ensure reliable results. The inaccuracy of devices was in compliance with their certificates.

Results and discussion

The investigation results are shown in Table 2 and Table 3. The experimental results were processed with the use of Statgraphics Centurion XV and the regression equations were obtained to plot the three-dimensional response surfaces (Fig. 2).

Table 2

Experimental results

Number of experiment variant	Factors		Results	
	Pipeline depth h, mm	Perforation interval p, mm	Plant height l, mm	Number of flowers q*, pieces
1	150	40	273.9	3.8
2	150	60	299.5	4.0
3	200	40	289.5	3.7
4	100	40	270.5	6.2
5	200	60	301.4	4.0
6	100	60	290.5	6.4
7	150	20	289.8	4.9
8	200	20	295.5	3.5
9	100	20	289.0	6.9
Average			288.8	4.82

*Average per growing gutter

Table 3

Investigation results (reference)

Number of experiment variant	Factor	Results	
	Soil layer depth h, mm	Plant height l, mm	Number of flowers q*, pieces
1	100	228.8	2.9
2	150	230.5	1.5
3	200	241.0	1.7
Average		233.4	2.03

*Average per growing gutter

In the multivariate regression analysis of the effect of the studied factors on the height and number of flower stalks the following mathematical models in the decoded form were derived.

- Plant height.

$$l = 27.796 + 0.606 \cdot h + 0.285 \cdot p + 1.631 \cdot p^2, \tag{1}$$

where h – pipeline depth, mm;
p – perforation interval, mm.

In this case the determination coefficient was $R^2 = 0.912$;

- Number of flower stalks.

$$q = 3.977 - 1.383 \cdot h + 0.883 \cdot h^2 + 0.25 \cdot h \cdot p + 0.383 \cdot p^2. \tag{2}$$

In this case the determination coefficient was $R^2 = 0.962$.

The investigation outcomes showed that the additional subsoil fertilizing of flowers with ventilation emissions from the barn under the set conditions provided in average 137 % higher number of marigold flower stalks over the reference, with the maximum values being registered under the pipeline depth of 100 mm and perforation interval of 20 mm; the increase of plant height by 24 % average, with the maximum values being registered under the pipeline depth of 200 mm and perforation interval of 60 mm.

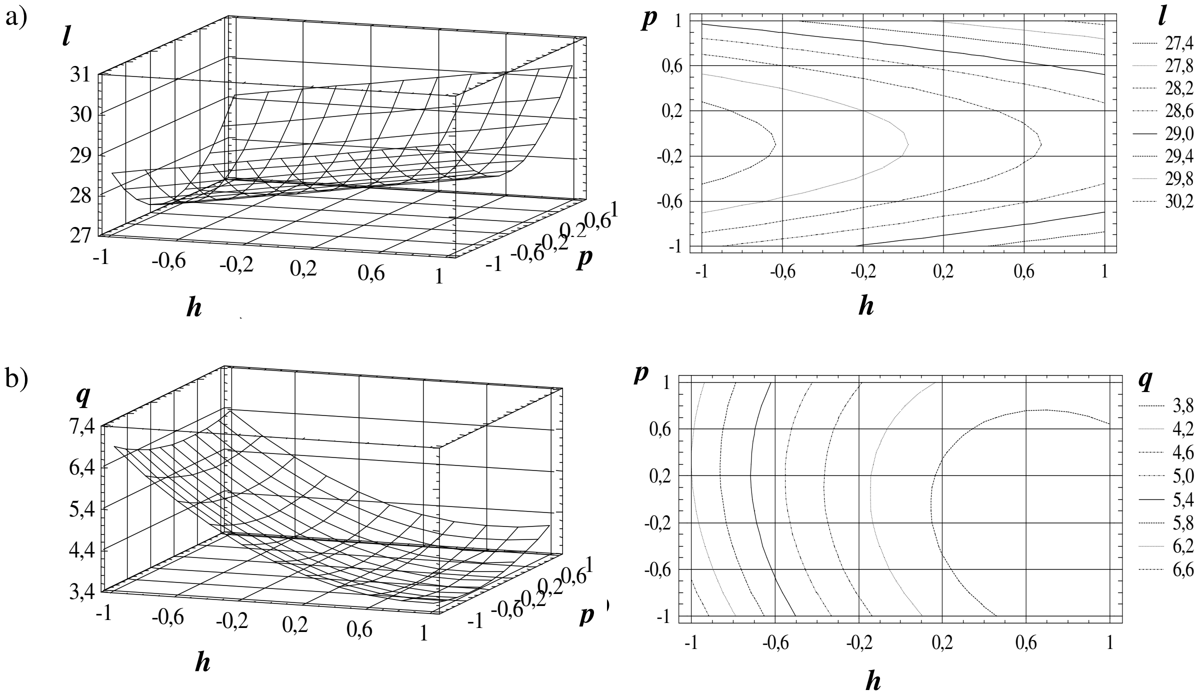

Fig. 2. **Effect of pipeline depth and perforation interval:**
a – on the plant height; b – on the number of flower stalks

Conclusions

The analysis of the mathematical models and three dimensional response surfaces allowed making a conclusion that the optimal values of the main parameters are:

- pipeline depth h = 112 mm;
- perforation interval p = 21 mm.

The use of barn ventilation emissions in the indoor plant growing facilities allows avoiding the environment pollution and has a positive effect on the plant growth and development because the required plant nutrients from the ventilation emissions are available in an easily-accessible form.

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