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A RESEARCH ON VENTILATION EFFICIENCY OF PIPED VENTILATION SYSTEMS IN GEOTHERMALLY HEATED GREENHOUSES

İbrahim Örüng*, Sedat Karaman, Ünal Sirin*****

* Atatürk University, Agricultural Faculty, Agricultural Structures and Irrigation Department, Erzurum, Turkey, E-mail: iorung@atauni.edu.tr.
** Gaziosmanpaşa University, Agricultural Faculty, Biosystems Engineering Department, 60250, Tokat, Turkey E-mail:sedat.karaman@gop.edu.tr.
*** Atatürk University, Agricultural Faculty, Agricultural Structures and Irrigation Department, Erzurum, Turkey, E-mail: unalsirin@atauni.edu.tr.

Abstract
Greenhouse play significant roles in human nutrition. Vegetable and fruit consumption at certain amounts is the basic pre-condition for a well nutrition. It is possible to produce sufficient quantities of fruits and vegetables in places with available climate conditions. However, fruits and vegetables should be grown in special buildings to have a year-long production in places without available climate conditions. These places include under-cover production facilities, greenhouses, low and high tunnel facilities.
Environmental conditions are adjusted are adjusted in greenhouses as to provide proper conditions for plant growth and development. Ventilation is used to remove excess heat, moisture and carbon dioxide from the greenhouses.
Either natural or mechanical ventilation is used in greenhouses. Mechanical ventilation systems have various advantages over natural systems. However, mostly natural ventilation systems are preferred because of their low installation and operational costs. Both systems operates based on negative pressure. Air exchange rates are usually low in winters and it is quite hard to evenly distribute cold fresh air within the greenhouse. Air inlets are usually placed over side walls and outlets are commonly placed along the ridge.
In this study an alternative natural ventilation system was proposed for more efficient ventilation of the greenhouses. In this system, fresh air gets into the greenhouse through ventilation pipes installed beneath the greenhouse floor. The incoming fresh air also heated with geothermal hot water lines, thus direct contact of cold fresh air is prevented. The design and efficiency of piped ventilation systems were provided in this paper.

Keywords: Greenhouse, ventilation, geothermal

1. INTRODUCTION

Proper greenhouse atmosphere and conditions play significant roles in improving yields levels in under-cover production activities. Stress-free environments provide great contributions to plant development and yield. Greenhouses provide a growing atmosphere for various plants and mostly valuable plants are produced in greenhouses, thus a strict attention must be paid while design and construction of such production structures (Kürklü and Çaylayan, 2005).
Economically viable and quality productions largely depend on sufficient technical characteristics of the buildings constructed for plant production purposes. Protection of plants from negative

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climate conditions is a function expected from the greenhouses. Indoor climate conditions to be considered in greenhouse design have great influences on plant yield and quality and such conditions are mostly related to indoor temperature arrangements for physiological and biological activities of the plants (Bayram, 2010).

Ventilation is a critical design component in greenhouses and proper indoor heat and humidity balance can only be supplied through a well-designed ventilation system. Natural ventilation systems are commonly used in greenhouses and the system efficiency is closely related to number, size, location and characteristics of air inlets and outlets (Çolak, 2002).

The greatest concern in winter ventilation of greenhouses is the reduction of indoor air temperature through the cold clean air inlets and direct contact of plants with this cold air flow. Such direct contacts may create negative impacts on plants (Kervankıran, 2011).

The present study was conducted to assess the potential use of a geothermal heat source trough piped ventilation system installed over the greenhouse floor as air inlets to provide a sufficient heat and relative humidity balance inside a greenhouse. Since the clean air passes through geothermally heated pipelines, air is also heated before to be blown inside the greenhouse. Then clean air will not reduce the temperature of indoor air ad plants will not be exposed to cold air flows and abrupt temperature changes will be prevented.

2. VENTILATION

Ventilation removes excess heat, relative humidity and harmful gases from the greenhouses and provides clean air to be used in plant respiration.

The basic target in ventilation is to provide clean air inside the greenhouse without creating an air current inside, to keep indoor temperature at certain level, to keep indoor relative humidity within certain limits through removing excess moisture from the greenhouse, to remove harmful organisms from the greenhouse (Figure 1) and to prevent moisture condensations (dews) over construction member surface (Gezer, 2006).

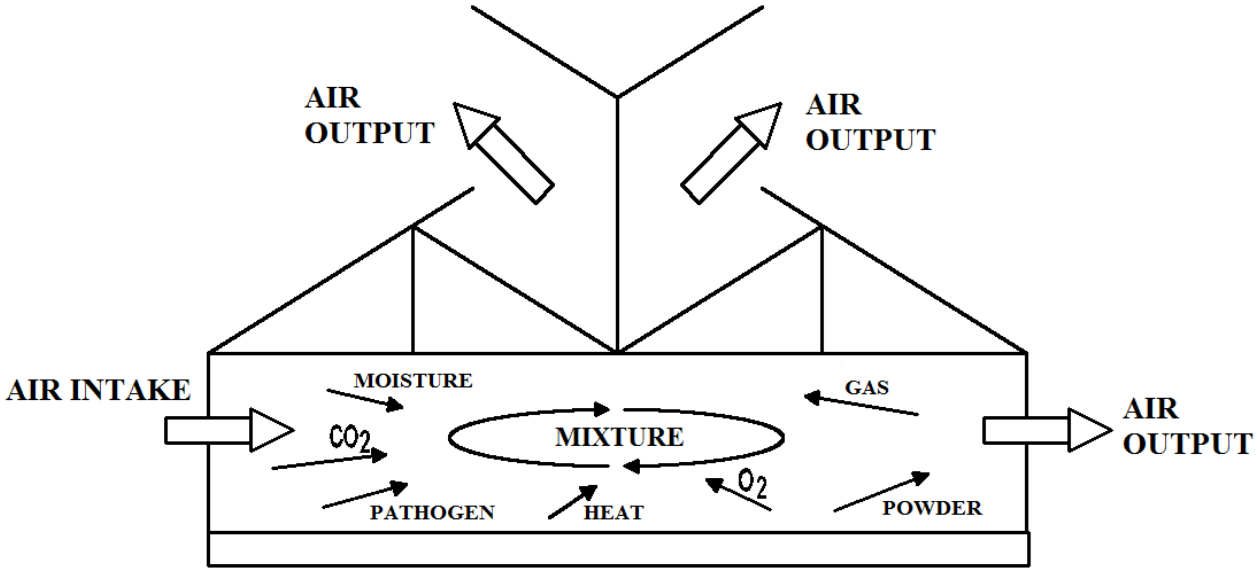

Figure 1. Greenhouse Ventilation Details

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Greenhouse indoor air is composed of a mixture of certain gases. Among them, oxygen and carbon dioxide are the two major components. Apart from them, there are some sulphur and ammonium within indoor air (Table 1).

Table 1. ppm values of gases to be harmful to humans and plants in greenhouses

Gas	SO_2	NO_2	NH_3	O_3	CH_2O	CO	C_2H_4	C_3H_6
Plant	0.2	20	10	0.2	0.7	500	0.05	50
Human	5	5	50	0.1	5	100	-	-

Concentrations of such harmful gases can only be reduced through a well-designed and operated ventilation system in greenhouses.

Natural Ventilation Systems

In greenhouses, a slight air current is desired for better plant growth. Natural ventilation systems are commonly used to provide such slight air currents. Natural ventilation is provided through air inlets together with ventilators and aspirators (Dobrolyubov, 2015).

The advantages of natural ventilation systems used in greenhouses are as follows:

- They are low-cost systems and do not require energy costs for the operation ventilation system.
- System performance does not depend on an artificial power requirement.
- Since the system does not have moving parts, there aren't any operation and maintenance costs.

Beside these advantages, natural ventilation systems have some disadvantages as such:

- It is hard to control ventilation capacity.
- Sometimes mechanical air distributors are used to provide an even air distribution.
- There is a need for large air inlet and outlets (Çanakcı and Akıncı, 2007).

Amount of natural ventilation largely depend on external air movements (winds) gravity and chimney effects through indoor-outdoor temperature differences. These factors create different pressure zones over greenhouse external walls through wind effect (Figure 2) and ultimately create an air current from high pressure to low pressure zones. Such an air current can also be provided through the air movements because of indoor and outdoor temperature differences (Göçer, 2015).

Pressure gradients are formed because of density differences between greenhouse indoor and outdoor atmospheres when the indoor and outdoor temperatures are different. In case of lower indoor temperatures, air density is lower and indoor air rises up. Such a rise is formed with a force equal to weight of outdoor air entering into the greenhouse. The case is then defined as eaves or bulking effect. While the outdoor is getting into the greenhouse, risen indoor air moves to outdoor through air outlets. Temperature difference-dependent ventilation capacity is directly proportional to vertical distance between air inlet and outlets and pressure difference between inlets and outlets. Air velocity between indoor and outdoor ambient can be calculated by using ideal gas laws (Öztürk, 2003).

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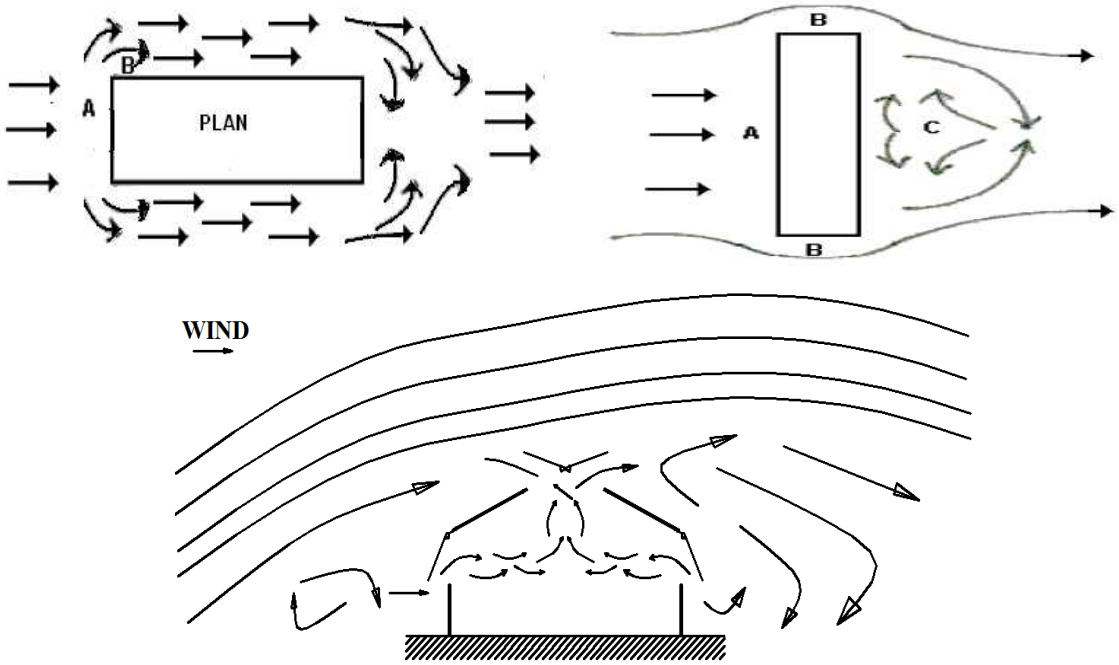
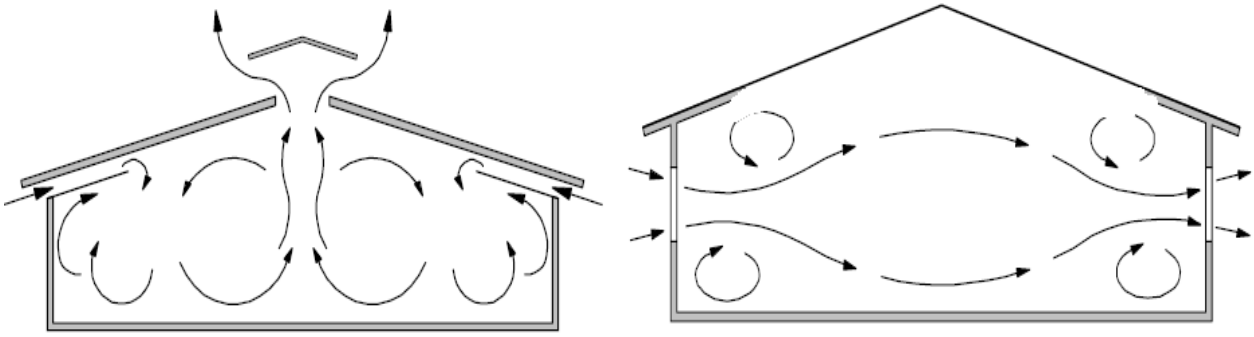


Figure 2. The motion lines of wind around the greenhouse, slowing the flow and positive pressure zone (A), flow acceleration and negative pressure areas (B, C)

3. DESIGN OF PIPED VENTILATION SYSTEM

In natural ventilation systems, windows and openings over the ridge are commonly used as air inlets (Figure 3).



(a) (b)

Figure 3. Air inlet and outlet openings used in greenhouses (a,b)

In present study, pipe system installed over the floor of a greenhouse with a floor area of 140 m^2 was used as air inlets.

Piped-type air inlet canals (Figure 4) were placed over the greenhouse floor and the air passing through these pipes is heated with the geothermal hot water lines placed underneath the greenhouse floor. Proper pipe diameters (100, 150 or 200 mm) were selected as to have sufficient strength against negative environmental conditions and to have sufficient ventilation capacities.

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For efficient natural ventilation, there should be a certain vertical distance between air inlets and outlets and there should be properly sized sufficient amount of inlets and outlets.
The air velocity between indoor and outdoor ambient can be calculated by using the following equation;

$$V = 1{,}8\sqrt{\frac{H(t_i - t_d)}{273 + t_d}}$$

Where;
V: Velocity of air removed from the greenhouse ($m.s^{-1}$),
H: Vertical distance between air inlet and outlets (m),
t_i: Indoor temperature (^0C),
t_d: Outdoor temperature (^0C) (Ekmekyapar, 2001).

The vertical distance between inlets and outlets is different in piped system and Windows system. Therefore, ventilation efficiencies will also be different in two systems. For instance, ventilation efficiencies calculated for a piped system (with a 5.0 m vertical distance) and window system (with a vertical distance of 2 and 3 m) are provided in Table 2.
It was observed based on the values provided in Table 1(based on air velocities and indoor-outdoor temperature differences) that under-floor piped ventilation system had 24% and 52% higher efficiencies than window system respectively 2 and 3 m vertical distances (Örüng et al. 2010).

Table 2. Air velocities of ventilation systems based on temperature difference and vertical distance

Indoor temperature ^{o}C	Outdoor temperature ^{o}C	Air velocity (m/s)		
		Vertical distance 5m	Vertical distance 3m	Vertical distance 2m
26	6	1.077	0.478	0.390
24	6	1.022	0.451	0.369
22	6	0.963	0.424	0.346
20	6	0.901	0.395	0.323
18	6	0.834	0.364	0.298
16	6	0.762	0.331	0.271
14	6	0.681	0.295	0.241
12	6	0.590	0.255	0.208
10	6	0.481	0.207	0.169
8	6	0.340	0.146	0.119
6	6	0	0	0

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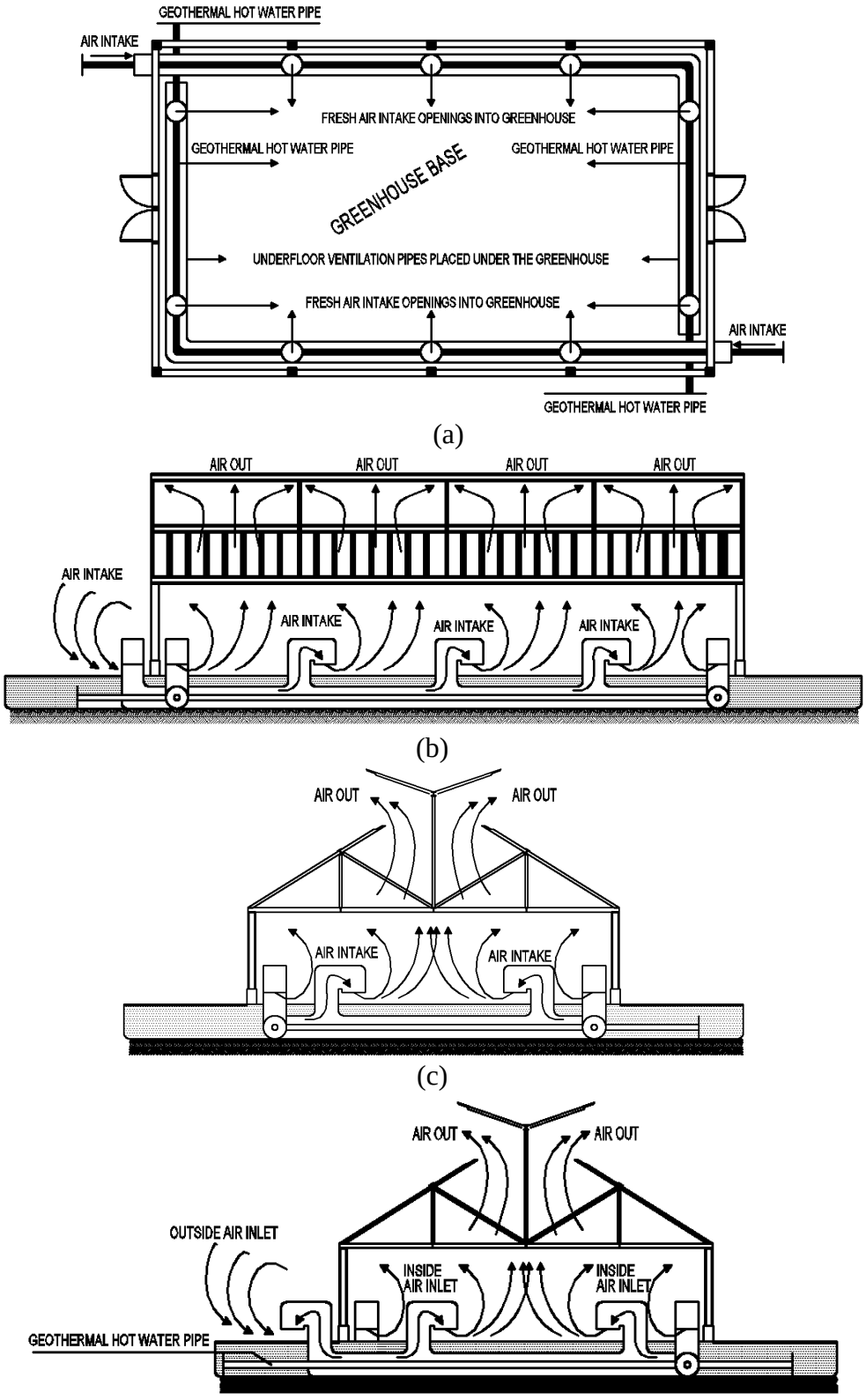

Figure 4. Details of ventilation pipes and air inlets

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4. CONCLUSION

Just because of climate conditions, a year-long vegetable and fruit culture is not possible in several parts of the world. Therefore, summer or winter vegetables and fruits are available only certain months or seasons of the year. Unavailability of fresh fruits and vegetables continuously throughout the year sometimes result in irregular or malnutrition. Greenhouses play a significant role in providing fresh vegetables and fruits all year long, thus in preserving human health.

Information was provided in this study about the significance on ventilation in greenhouses in providing proper environmental conditions and the design and efficiency of an alternative piped ventilation system used in natural ventilation of greenhouses.

The following benefits can be achieved with the piped-type natural ventilation:

- Without any extra heat source, incoming air can be heated with geothermal hot water lines and direct contact of plants with cold air is prevented,
- Ventilation efficiency can be improved through releasing fresh air from the floor of the greenhouse,
- Since the fresh air gets into the greenhouse from the floor, harmful gases can be removed easily,
- Fresh is will be available for plant respiration without much pollution,
- An efficient operation is provided through the pressure differences coming from temperature difference,
- An even air distribution can be provided with piped distribution system.

It was concluded in this study that piped ventilation system could reliably be used in natural ventilation of greenhouses with higher ventilation efficiencies.

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