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Sustainable Management of Rose Growing in Greenhouse Heated by Geothermal Water at Kuju, Japan

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ABSTRACT

Hand Flower Producing Union has been growing roses for cut flowers in 20 green houses in Kuju, Oita, Japan, for more than 10 years since 1991. The union consists of 10 farmers and grows roses in the green houses that have been partly heated with geothermal water produced from a 550 m depth well. A submersible pump has been installed and produces 1.7 kg/s of geothermal water at 106 °C. The water is then mixed with the heat-depleted water flowing out of the houses to make 70 to 75 °C water. This water flows through finned tubes in the green houses for heating. The annual product of roses reaches 1.6 million stems and all the roses are shipped to Tokyo where good prices of flowers can be realized. The basic design of the heating system and of the growing system of roses is introduced as an example of sustainable management of green house farming.

1. INTRODUCTION

One of the direct heat uses of geothermal energy is heating greenhouses for growing flowers and vegetables. For sustainable management to grow agricultural products in greenhouses, it is required to design an appropriate heat supply system, a growing system of flowers and vegetables, and to carry out a market survey.

Geothermal heat use for farming in Japan is popular in Kyushu and Hokkaido where geothermal resources are rich (Shibata, 1982). Vegetable farming in Hokkaido has advantages, as domestic demands for them are large as this island is located in the north where vegetable production is very low in winter and early spring. There is a large scale greenhouse farming at Nigorikawa, Hokkaido, where a part of the separated water from the Mori geothermal power plant passes through heat exchangers and is sent to 69 greenhouses of total area 31000 m^2 (Japan Geothermal Energy Association, 2000). On the other hand, flower farming is more popular in Kyushu where green house heating has a long history and farmers seek more valuable products. There are various kinds of flowers grown in greenhouse such as chrysanthemum, carnation and rose for the cut flower market, and orchid for the potted flower market.

Hand Flower Producing Union located in Kuju, 2km to the northeast of the Otake geothermal power plant, has been growing roses for cut flower in green houses for the last 13 years. The houses are heated with geothermal water as well as with oil burning boilers when temperatures become low in winter. The arching method for growing roses is used for high quality flowers. Statistics of the annual production of roses and of total sales are summarized for information of sustainable management of green house farming.

2. HEATING SYSTEM OF GREEN HOUSES

2.1 Climate at Kuju

The average yearly temperature in Kuju is 13.3 °C. As the green house is located 860 m above sea level, temperatures during winter drop down as low as -15 °C. Temperatures during summer rise up to 30 °C in daytime. Humidity is basically low compared with the flatland areas. This is one of the climatic advantages for growing roses as low humidity can help flowers from suffering diseases. However, controlling low humidity by heating is required even in warm wet seasons to avoid disease. Therefore, geothermal water provides a base load of heating. Heat supplied by geothermal water is not sufficient during winter when ambient temperatures become low. Thus, additional heating with boilers is necessary to keep temperatures high enough for roses in the greenhouse, which must be 15 °C at the lowest. Cooling is not necessary even in summer when temperatures in the house go up to 30 °C. During summer time, roof windows automatically open when indoor temperature rises above 20 °C and the plastic sidewall is opened manually to introduce the breeze. Shades are also set below the glass roof to avoid strong sun light.

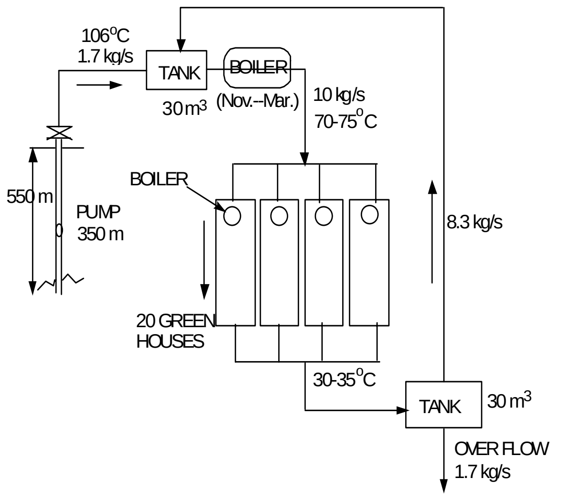

Fig.1 Schematic of heating and flow system of geothermal water at Handa Rose Garden, Kuju, Japan.

2.2 FACILITIES FOR HEATING

Figure 1 represents a schematic diagram of the heating system of the farm. It consists of a geothermal well, submersible pump, mixing tank, main boiler and warm air boilers. A 35 horse power submersible pump has been installed at a depth of 350 m and pumps water at a rate of 1.7 kg/s. The pumped water flows down to the 30 m^3 storage tank located at the edge of the property of green houses through a pipe line of 1000 m long. The straight distance between the well and the storage tank is about 600m. Measured temperature of the geothermal water at the inlet of the tank is 106 ^oC, which is above the saturation temperature under atmospheric pressure of 860 m elevation. The pump is thermal resistant up to 250 ^oC, and has had no failure due to temperature.

The water is mixed with the returned water in the tank to adjust its temperature to 70-75 ^oC. The mixed water then flows in finned tubes through the greenhouses and the exhausted water temperature decreases to 30 to 35 ^oC, and a part of the water overflows at a rate of 1.7 kg/s. Other water is pumped up to the tank at 8.3 kg/s. The houses are constructed on a gently inclined slope at the foot of Mt. Sensui, thus the water flows down naturally.

The houses are divided into four groups, five houses per group, and the pipeline is designed such that the mixed water flows at the same rate to each group. As there is no flow rate control system, fine adjustment is conducted by manual operation of valves installed at the inlet of the houses. The finned tube for heat radiation is set in the greenhouse to obtain homogeneous heating, placed along the wall and the middle of the house (Fig.2). The length of the tube in the house is about 170 m.

During wintertime, the temperature of the exhausted water drops below 30 ^oC and then the main boiler starts to operate to increase the mixed water temperature up to 80 ^oC. Additional heating is also achieved by small boilers with heat supply capacity of 40000 kcal/h installed in each of the greenhouses for warming air in that greenhouse.

2.3 Temperature measurement

Figure 3 shows temperatures of water at the inlet and the outlet of the greenhouse for two days in February 2004. The temperatures of the outdoors and of the water tank into which heat-depleted water from greenhouses flows are also presented. The inlet temperature ranges from 40 to 50 ^oC, which is lower than the specified values. This is because the geothermal water distribution system had some breakdown and leakage. Outlet water temperature varies from 25 to 40 ^oC. The lowest indoor temperature of about 15 ^oC was recorded at night even though outdoor temperature went down below 0 ^oC in the morning of February 18.

2.4 Chemistry of geothermal water

Geothermal water is slightly alkaline with pH 8.1 (20^oC) and is of the sodium chloride-sulfate type. Concentrations of major ions are Na=526 ppm, K=71.8 ppm, Ca=74.4 ppm, Cl=620 ppm, SO_4=472 ppm, HCO_3 =287 ppm, and SiO_2 =85 ppm.

3. GROWING SYSTEM OF FLOWERS AND PRODUCTS

The arching cultivation method is used for growing roses in the greenhouse (Fig.4). This method was developed by Japanese rose producers in the late 1980s (Ohkawa and Suematsu, 1999). This method is characterized by the use of rockwool as substrate and of benches as shown in Fig.5. The basal shoots appearing in the early stage of growth are bent down in an arch, and the subsequent basal shoots are cut at their base when grown up. The arched shoot plays a role of taking up nourishment whereas basal shoots are used for cut flowers. The number of stems for cut flowers per unit area is smaller than a conventional growing system.

Fig.2 Finned tube set along sidewall of the house.

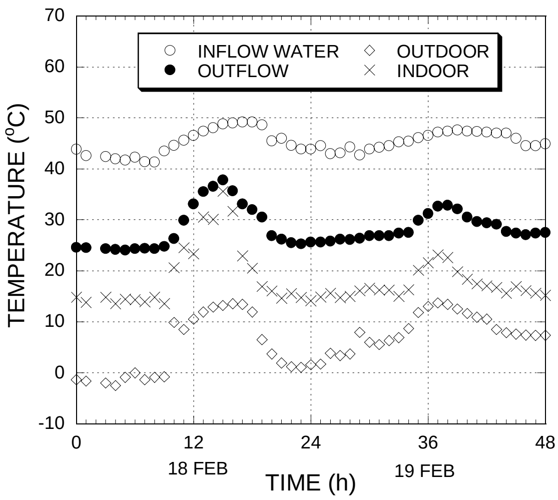

Fig.3 Measured temperature of geothermal water at the inlet and the outlet, and of indoor of the greenhouse, and of the outdoor.

Fig.4 Roses on ridge.

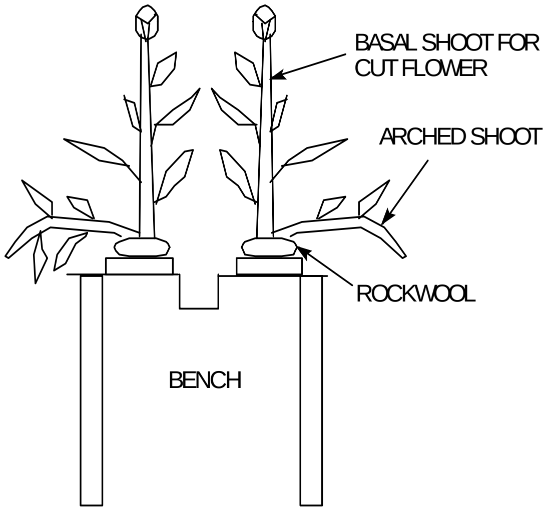

Fig.5 Bench and arched growing system.

However, high quality flowers with long stems are more available as they can be cut at the base. Furthermore, the height of the bench where rockwool is placed is about waist-high, and this makes maintenance and harvesting work more comfortable for the farmers who need not bent down. There are 14 ridges each of 40.5 m long in the greenhouse. 500 roots are planted per ridge in the rockwool substrate. Thus, the total number of roots per greenhouse is 7000. The substrates planted with roots are replaced every four years, but some last up to ten years.

Twenty rose species are grown in the greenhouses. Two kinds of roses, *Roterose* (dark red) and *Pineke* (white), have been grown since the start of farming in 1991. Another 18 kinds of roses, mainly in different colors, have been placed using newly supplied species. There are a couple of species that have large demand depending on season, for example red roses are very popular in December, and roses of pale color such as white are popular during Autumn when weddings are in high season. Consumer preferences for roses are collected at retail flower shops and then information on those preferences is fed back to the union. Then, good selling species will replace less popular and unsalable roses. This is one of the advantages running flower farming through the union.

Figure 6 shows monthly data of total amount of shipped stems and an average price per stem. The largest number of stems can be shipped in July when roses grow quickly: one month for a rose to grow for cut flower. However, the lowest number ranges from 34000 to 50000 stems in January or February when flowers grow slowly: two months required for cut flower growth. The average price of a stem is highest in September and October during the bridal season. Accordingly, net income is highest during these two months.

The total number of stems per year ranges from 1.26 to 1.91 million with an average 1.48 million as shown in Fig. 7. Both values have decreased continuously with time. One of the reasons for this decrease is that more roses are grown elsewhere in Japan and shipped to the market. Another reason is the import of roses with lower price. The average wholesale price of an imported rose is 39 Yen whereas the domestic rose is 68 Yen according to the 2002 Statistics of Agriculture, Forestry and Fisheries. The average price of rose of the union in 2002 is about 83 Yen, which is higher than the average wholesale price of domestic roses in Japan. This implies that roses grown at the farm have higher quality.

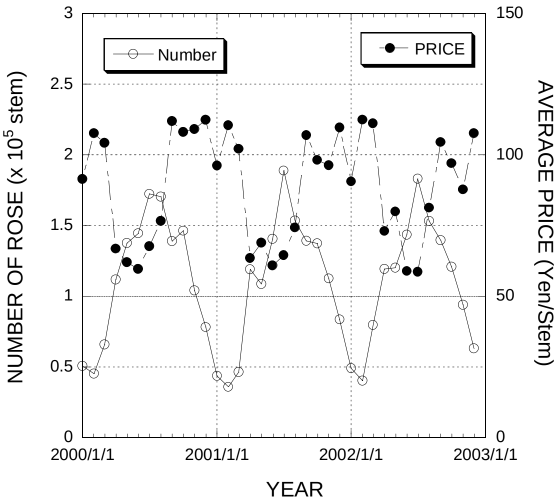

Fig.6 Monthly data of the number of stems shipped out and the average price per stem from 2000 to 2002.

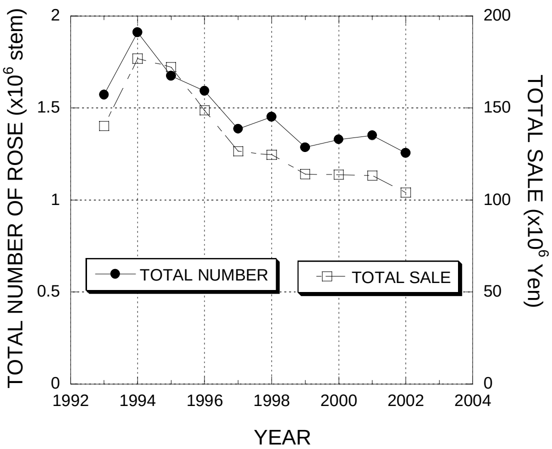

Fig.7 Total number of rose stems shipped out and total sale of each year from 1993 to 2002.

4.COST PERFORMANCE

4.1 Initial Investment

The total amount of investment was 0.811 billion Yen (7.37 million US$ with 110 Yen/US$) in 1991. Investment for the greenhouses occupied 63% of the total cost. This is because of the use of glass. Glass greenhouses have advantages such as they last longer and need less maintenance compared with the plastic houses. Costs for drilling the well and for the heating system (finned tube and boilers) were about 13% of the total. Property of 3.5 ha for green houses and other facilities came to 15%, and the shipping facility was 5.4%. Half of the total cost was covered by the grant from the government, but the other half was on loan from banks. Members of the union, however, can not make sufficient income from their share of the union, thus each of them operate two additional green houses of the same size at their own properties. They send cut flowers to the shipping house of the union.

4.2 Managing Cost

Figure 8 represents the annual expenditure of the union as of 2002. The cost for shipping and packaging, and that for fuel are similar. The high shipping cost is because all the cut flowers are shipped by air cargo to the wholesale markets in Tokyo where top quality flowers can sell at a good price. Power cost for the submersible pump is about 4%. Fuel cost was reduced by 30% by using geothermal water for heating. The contribution of geothermal heat use in the total cost is not so high, but the advantages of using geothermal heat are the low environmental impact, homogeneous heating in the house, and low humidity. In particular, controlling humidity to be low during summer can be an appreciable contribution to rose farming as high humidity definitely causes disease of the flowers and a change in the colors of the petals. This results in lower quality of the flower, and sometimes it may lose its commercial value.

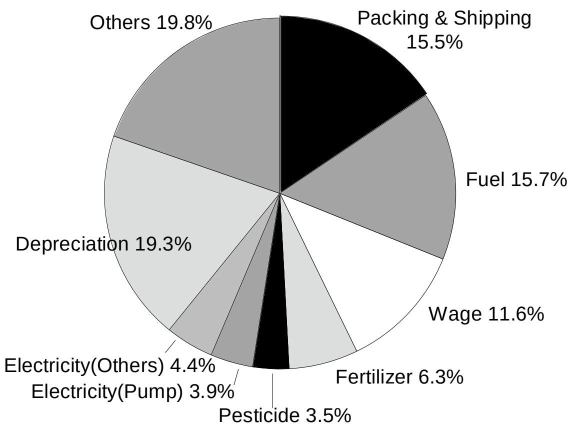

Fig.8 Percentages of annual expenditure as of 2002.

4.3 Sustainable Management

For sustainable management of rose farming, the following improvement and information are crucial.

1) More use of geothermal heat by introducing a heat exchange system rather than a once-through system. A closed system coupled with a heat exchanger was realized in direct heat use for farming in Iceland and found to be easier to control (Ragnarsson, 2000).

2) The advantages and disadvantages of flower growing in a high elevation area. Additional heating is required in the greenhouse during winter because of cold weather, and this causes additional cost for fuel oil. However, low humidity from spring to autumn when flatland farming suffers from high humidity provides ideal conditions for growing high quality roses.

3) Information of consumer preference through retail flower shops is important to compete with other rose-growing farmers.

5.CONCLUSIONS

Direct heat use for rose growing at Kuju was introduced with particular interests in cost and in sustainable management. Use of geothermal water can save fuel cost by thirty percent, but cold weather during winter requires the use of additional heating by oil-burning boilers. The advantages of rose growing at this high elevation of 860 m above sea level can be the natural conditions such as low humidity during summer and the introduction of the arching cultivation method. Retail shop information also helps farmers to select preferable species to grow to meet consumer’s taste. However, the heat exchange system is not well configured to achieve optimal performance. Improvements to this system are required to achieve better cost effectiveness.

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