

Growth Experiment of Subtropical Fruit Annona Cherimoya using Heating by Hot Spring in Cold Climate Regions and Regional Cooperation

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The thermal energy of the Earth's interior is not only used for geothermal power generation but also for geothermal and hot spring heat utilization systems. In Japan, which is a volcanic country, hot springs have a long history and a wide range of uses. They have been used by residents as part of daily life in hot spring towns since historical times. However, in Japan, hot springs are still primarily used for bathing. Depending on the temperature range of the hot spring water, energy loss may occur or additional energy may be needed. It is, therefore, necessary to develop methods for use of hot springs, based on the temperature of the water. The current study focused on the cultivation of tropical fruit trees using hot spring water. Cherimoya was selected as the species to be cultivated. It is native to the Andean highlands of South America. It is grown where the climate is cool, with an average annual temperature of approximately 20 °C. It is also sensitive to heat. Its growth rate becomes slower when the daily maximum temperature exceeds 30 °C. The maximum daily temperature for cultivated areas in Japan has been above 30 °C in summer. This makes cherimoya difficult and costly to cultivate, and it cannot be mass-produced. Meanwhile, the average daily maximum temperature in the Aomori Prefecture during the summer is 28.8 °C, with few days where temperatures exceed 30 °C. Temperatures in the Andean highlands are relatively constant throughout the year, with the cherimoya being able to withstand temperatures as low as -2 °C. The temperature in winter in the Aomori Prefecture is often below -2 °C. However, it is easy to raise the temperature to -2 °C by using hot spring heat. It is, therefore, possible to create an industry that takes advantage of the geographical characteristics of the Aomori Prefecture. This can be achieved by cultivating crops more efficiently than in other regions, with a cool climate in summer and using hot spring heat with no operating costs in winter under negative temperatures. In the current study, cherimoya was cultivated using hot spring heat. The cultivation methods were examined, a system for commercialization was constructed, and cost estimations were undertaken. In summer, a cultivation test site was set up using a well-ventilated mesh net, a monitoring system, and an automatic irrigation system. The system formed part of the internet of things. The fertilizer application method was examined for use with automatic irrigation. The relationships between the frequency of irrigation, irrigation, and soil moisture were explored. Once-weekly manual irrigation was used to control the amount of air in the soil and eliminate insect pests. The growth rate was determined from the length of the shoots from the pruning point of the leaf core in June. As the weather cooled, heating and insulation measures were gradually implemented in line with winter temperatures. This was implemented to prevent the temperature from dropping to -2 °C. A domed vinyl house was set up at a selected location to prevent strong winds and snow accumulation. Hot spring water was then circulated in the vinyl house, using iron pipes with high thermal conductivity. The vinyl house was double-covered. The outer vinyl was covered with a bubble buffer material, a circulator was installed, and insulation was installed between the ground surface and fruit tree body. The growth rate and extent of cherimoya growth, temperature characteristics during the summer, and heating and insulation effects during the winter were recorded. In the current study, the growth rate of the cherimoya during summer was higher than that reported in previous studies. The construction of a heating and insulation system for the winter season was also successful. In this paper, a more detailed description of

the cultivation method, results, and system is provided, and the effect, efficiency, and cost of heating and insulation in winter are discussed in detail.

Keywords: Tropical fruit, Hot spring heat use, District revitalization, Annona Cherimola