Electricity-Free Thermal Transfer From Rice Fields Into the Ground Using a Heat Pipe Featuring Dramatically Enhanced Water Phase-Change and Circulation

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Extreme heat days have recently become more frequent, exacerbating high-temperature damage in rice cultivation. To address this problem, in this study, we developed a heat pipe (HP) that transfers heat from the surface water layer of a rice field into the ground, containing separate evaporation and condensation sections, enabling stable downward heat transport without electricity use, through a capillary-action and siphon effect-driven water-circulation mechanism. Water is sealed in a one-meter-long aluminum pipe under reduced pressure. When the evaporator at the upper end is placed in the surface water layer, the water starts to boil at 30–40 °C, absorbing heat. The vapor moves downward and condenses in the underground condenser at 25 °C, releasing heat to the ground. The condensate returns to the evaporator through a mercerized cotton-cloth wick enclosed in a silicone tube, with a further treated upper end to esterify PVA with citric acid and glycerin, thereby enhancing the siphon effect. The pressure difference between the two sections, arising from the phase change-related vapor-pressure increase, is maintained even at temperature differences of only 5–10 °C. The HP transfers a maximum heat of 1.4 kJ/min/m, which is highly efficient. Furthermore, by integrating a horizontal HP that collects heat laterally across the field, heat could be efficiently transferred to the inverted HP. Installing an estimated 21 inverted HPs per hectare would reduce water temperature by 10 °C within 24 h, indicating strong potential in regions with limited electricity or infrastructure.

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