

Case 24

Uncoupling Proteins in Plants

Last modified 19 March 2004, K. Cornely, Providence College

Focus concept

Uncoupling proteins in plants uncouple oxidative phosphorylation in order to generate heat in the developing plant.

Prerequisites

- C Electron transport and oxidative phosphorylation.
- C Mechanisms of uncoupling agents, such as 2,4-dinitrophenol.

Background

In mammals, body temperature can be regulated by uncoupling proteins which act by uncoupling electron transport and oxidative phosphorylation. Two such uncoupling proteins have been identified which have been named UCP1 and UCP2. UCP1 is believed to be involved in heat production, whereas UCP2 might be involved in obesity in humans.

The mechanism of thermogenesis in plants is not as well understood. Several studies have been carried out which indicate that thermogenesis is an important process in the developing plant. For example, the Eastern skunk cabbage has the ability to maintain the temperature of the plant 15-35 °C higher than ambient temperatures during the months of February and March where ambient temperatures range from -15 to +15°C. Thermogenesis in the skunk cabbage is critical to the survival of the plant since the spadix tissue is not frost-resistant. The skunk cabbage may be unique in its ability to carry out thermogenesis for longer than just a few hours.

Thermoregulation has also been studied in lotus flowers. Investigators in Australia noted that the temperature of the lotus flower receptacle rises one or two days before the flower opens. Temperatures fall only after the flower is completely opened. The investigators speculated that heat production in the lotus flower serves to enhance evaporation of the floral scent that attracts pollinating insects. Noting that many pollinating insects require a thoracic temperature of 30 °C or higher to initiate flight, the investigators hypothesized that heat production in the lotus flower would assist the departure of the insects from the flower.

Although observations of temperature and oxygen utilization in the skunk cabbage and lotus flower implicated an uncoupler, an uncoupling protein was not isolated until fairly recently. A research team in France recently reported that they had identified an uncoupling protein in potatoes (*Solanum tuberosum*) that is involved in thermoregulation in plants in a manner similar to the *brown fat* uncoupling proteins in mammals. The uncoupling protein is named StUCP and its synthesis is induced by cold temperatures. The authors note that heat production concomitant with a “burst of respiration” occurs during plant flowering and fruit ripening.

Questions

1. Explain how uncoupling agents work and how an uncoupling agent acts to bring about an increase in temperature.
2. In the skunk cabbage, the site of thermogenesis is the spadix. However, the spadix tissue does not store starch in its tissues. Instead, the spadix relies on the massive root system in the skunk cabbage which stores appreciable quantities of starch. The large quantity of starch available may explain why the skunk cabbage is able to carry out thermogenesis in weeks rather than hours. Why is starch required for thermogenesis?
3. Oxygen consumption by the skunk cabbage increases as temperature decreases. The rate of oxygen consumption nearly doubles with every 10 °C drop in ambient temperature. Similarly, in the lotus flower, the receptacle temperature is maintained between 30 and 35 °C for a two day period during flower opening. The ambient air temperature during this two-day period may fluctuate between 10 and 30 °C. Oxygen consumption was observed to decrease during the day when temperatures were close to 30 °C. Explain the biochemical mechanism for these observations.

4. In the skunk cabbage, lotus flower, and the potato, thermogenesis occurs because of the action of an uncoupling protein. The gene that codes for the uncoupling protein in potatoes was recently isolated. The results from one of the experiments is shown in Figure 24.1. What is your interpretation of these results? How is the production of the uncoupling protein regulated?

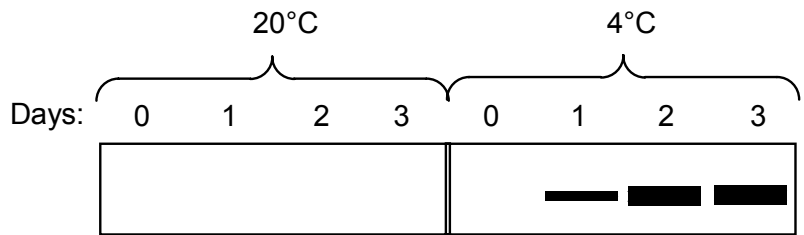


Figure 24.1: Northern blot analysis of the uncoupling protein from potatoes at 20°C and 4°C. Northern blots detect levels of mRNA. (Based on Laloi, *et al.*, 1997.)

References

Laloi, M., Klein, M., Riesmeier, Müller-Röber, B., Fleury, C, Bouillaud and Ricquier, D. (1997) *Nature* **389**, pp. 135-136.

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