METER
ENVIRONMENT

WATER POTENTIAL INSTRUMENTS USED TO DETERMINE WHERE ALKALI BEE LARVAE GET THEIR WATER

Alkali bee beds are maintained by farmers near Touchet, Washington to pollinate fields of alfalfa, grown there for seed. The beds are typically a few acres in size and provide a nesting place for the bees, which can increase seed production by as much as 70 percent. Alkali bees are better than honeybees for pollinating alfalfa, as they don't mind the explosive pollen release of the alfalfa flower.

USDA-ARS entomologist, Dr. Jim Cane, is trying to understand optimal bee-soil-water relations to ensure the bees will happily reproduce next year's pollinators. Dr. Gaylon S. Campbell recently worked with Dr. Cane to measure water relations in bee nesting beds. Here's what they found out:

WHY WATER RELATIONS MATTER

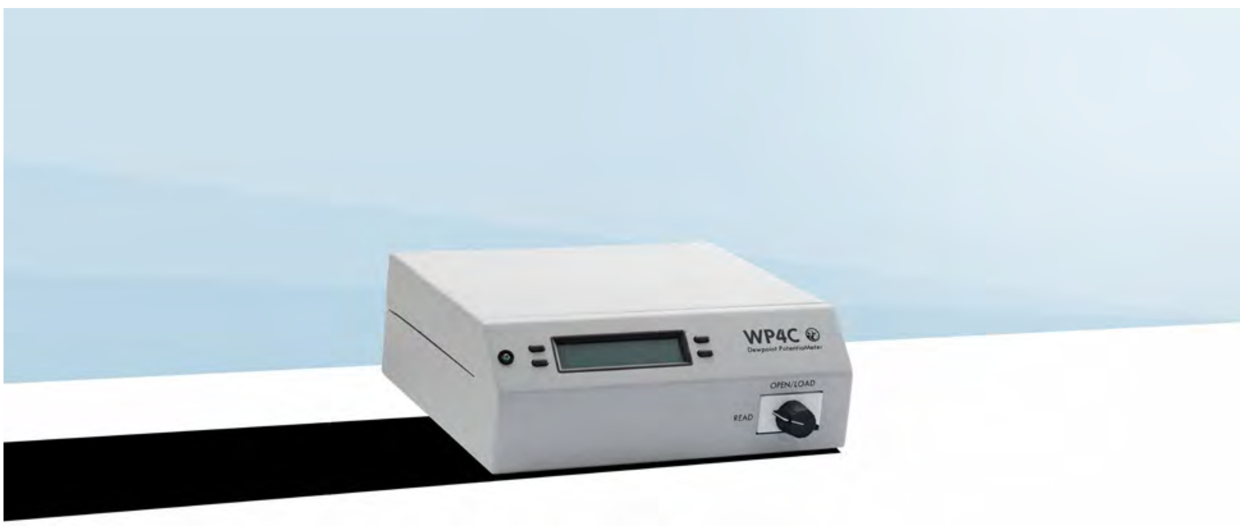
Alkali bees nest underground. They prefer salty soil surfaces which retard evaporation and discourage plant growth. The soil has to be the right texture, density, and have the correct moisture levels for successful nesting. In addition, the water potential of the larval food provision mass has to be low so it does not mold. Growers apply high levels of sodium chloride to the bee bed surface, and the soil is sub-irrigated to keep the salt near the surface and the subsurface soil moist.

The female digs a tunnel down to a favorable depth, typically 15 to 20 cm or more, hollows out a spheroidal-shaped cell around 1 cm diameter, and carefully coats the inside of the cell with a special secretion that appears to form a hydraulic and vapor barrier between the soil and the nest contents. She then builds a provision mass from pollen and nectar, shaped like an oblate spheroid with major axis around 6 mm and minor axis 3 to 4 mm. One egg is laid on the provision mass (which provides food for the larva), and the mother bee then seals up the entrance to the cell and moves on to the next one. The female coats the inside of the cell with a special secretion that appears to form a hydraulic and vapor barrier between the soil and the nest contents.

SPECIALIZED INSTRUMENTS FOR EACH MEASUREMENT

In order to understand moisture relations between the soil, the larva, and the food provision mass, Dr. Cane carefully excavated three soil blocks from one of the bee beds, dissected them to find nests, and Dr. Campbell helped measure water potentials of the eggs, larvae, and provision masses. They also measured matric and total water potentials of bee bed soils.

A sample chamber psychrometer is the only water potential device with a small enough sample chamber to be able to measure individual eggs and early-stage larvae, which it did. The provision masses were too dry to measure with the psychrometer, so several provisions were combined (to provide sufficient sample size) and measured in a WP4C Dew Point Potentiameter, along with the soil samples. Dr. Campbell measured matric potential of the highly saline soils using a METER tensiometer.



WP4C hygrometer

WATER POTENTIAL SEEMS IMPORTANT TO THE BEES

Dr. Campbell thinks matric potential is important in determining physical condition of the soil (how easy it is for the bees to dig and paint the inside of the nest), but probably has little to do with bee or larva water relations. The water potentials of the eggs and larvae were low (dry), but within the range one sees in living organisms. There was a consistent pattern of larva water potential decreasing with larval growth.

The exciting part of this experiment was the provision mass water potentials, which were so low that it is more convenient to talk about them in terms of water activity (another measure of the energy state of water in a system, widely used by food scientists). The intact provision masses were drier than any of the soil water potentials and not in equilibrium with the soil. Dr. Campbell says, “It’s interesting that all the provision masses were at water activities that would make them immune to degradation by almost all microbes, both bacteria and fungi.”

ANOTHER INTERESTING OBSERVATION

Dr. Cane found one provision mass covered with mold. Soil and plants are full of inoculum, so it is unlikely that the other provision masses lacked spores, but this one was wet enough to be compromised, and the others apparently weren’t. Dr. Campbell says, “There are two possibilities. Either it was put up too wet, or it got wet in the nest. The really interesting question is why all of them don’t get that wet. I think the hydrophobic coating of the nest eliminates all hydraulic contact from the soil to the provision mass, thus eliminating any liquid water flow, which would almost immediately wet the pollen balls. I think it also drastically reduces the vapor conductance from the soil to the ball, making water uptake through the vapor phase slow enough that the provision mass can usually be consumed before its water activity gets high enough for mold to grow.”

HOW DO LARVAE STAY HYDRATED?

The water activity of the larvae were around 0.99, much higher than either the soil or the provision mass, inspiring the scientists to wonder how they stay hydrated. Dr. Campbell speculates, “They have a water source from their metabolism, since water is a byproduct of respiration (Campbell and Norman, p. 205). It is also possible for biological systems to take up water against a potential gradient by expending energy. There are reports of a beetle which can take up water from a drop of saturated NaCl (water activity 0.75), so it is possible that the larva gets water from the environment that way. There appears to be no shortage of energy available. On the other hand, it would seem like the larval cuticle would need to be pretty impermeable to maintain water balance since the salty soil, and especially the provision mass, are so much drier than the larva.” Dr. Cane notes that, ”For a few exemplar bee species, mature larvae weigh 30 to 40% more than the provision they ate, with the possibility that the provision undergoes a controlled hydration by the soil atmosphere through the uncoated soil cap of the nest cell.”

In the future, Dr. Campbell is hoping to see more experiments that will answer some of the questions raised, such as measuring individual provision masses to determine why there is some variation in water potential. Dr. Cane will be undertaking experiments to measure moisture weight gain of new provisions exposed to the soil atmosphere of the Touchet nest bed soil.

REFERENCES

Campbell, G. S. 1985. Soil Physics with BASIC: Transport Models for Soil-Plant Systems. Elsevier, New York.

Campbell, G. S. and J. M. Norman. 1998. An Introduction to Environmental Biophysics. Springer Verlag, N. Y.

Rawlins, S. L. and G. S. Campbell. 1986. Water potential: thermocouple psychrometry. In Methods of Soil Analysis, Part 1. Physical and Mineralogical Methods – Agronomy Monograph 9, 2nd edition.