



Lightning Injury to Plants

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Lightning contacts planet Earth about 100 times each second, or 8 million times a day. Given so many strikes, the probability of damage to plants is very high. The heat and pressure waves generated by lightning can kill or damage plants instantaneously, causing losses in crops, forests, and landscapes.

The main challenge posed by lightning injury is to diagnosis the problem correctly. Damage from lightning such as wilting, yellowing and collapse of foliage, necrosis of foliage or vasculature, and premature fruit drop or deflation can mimic other diseases such as root rots, girdling, herbicide injury, vascular wilt, heart rots, and severe drought injury.

At first glance, lightning injury to coconut palm (*Cocos nucifera*) may resemble coconut heart rot disease (*Phytophthora katsurae*) or root rots (*Phytophthora* and *Pythium* spp.). Lightning strikes on banana (*Musa* species) may resemble Panama wilt disease (*Fusarium oxysporum* f. sp. *cubense*). Upon closer inspection, however, other unusual signs or symptoms become manifest, suggesting that the plant must have been exposed to unusually high temperatures or pressures.

This publication discusses the nature of lightning, how it strikes and damages plants, and provides photographs of lightning injury to papaya (*Carica papaya*), coconut palm, and banana in the eastern part of the island of Hawai'i.

A brief explanation of lightning

Lightning results from the buildup and discharge of electrical energy between positively and negatively charged areas. Most lightning occurs within a cloud or between a cloud and the Earth. Cloud discharges have no channel to the Earth and do not normally strike plants. Cloud-to-ground discharges have at least one channel connecting the cloud to the Earth. Plants can become part of this channel, helping to complete the electrical circuit known as lightning. In such strikes, the Earth generally carries

positive charges, while the base of the storm cloud carries the negative charges.

The action of rising and descending air within a thunderstorm separates positive and negative electrical charges within a cloud. The movement of water and ice particles also affects the distribution of electrical charge within a cloud. Positive charges typically accumulate at the top of a cloud and negative charges at the bottom. This generates an electric field between the top and bottom of a cloud. The field strength grows as the charges continue to separate within the cloud.

A cloud-to-ground lightning strike usually occurs in four steps. First, a cloud-to-ground "stepped leader" forms at base of cloud and descends toward Earth. Second, one or more ground-to-air "streamers" form at ground level and ascend toward cloud. Third, the streamer contacts the leader, creating a bright pulse of light ("lightning"). Finally, "dart leaders" and secondary "return strokes" may occur, with additional pulses of light.

Cloud-to-ground lightning can also begin as stepped leaders that are positively charged. The resulting return stroke carries a negative charge and transfers positive charge from the cloud to the ground. The combination of the leader and the return stroke is then called a positive flash.

How lightning damages plants

The most severe damage to plants by lightning may be caused by the extreme heat and shock waves generated by the current, although other damaging effects probably occur.

Heat

The return stroke propagates up the leader channel at a velocity of about $\frac{1}{10}$ the speed of light, making the trip from the ground through or around the plant and back to the cloud in about 100 millionths of a second. The energy

in this current produces temperatures in the channel greater than 50,000 degrees Fahrenheit in millionths of a second. The heat turns plant fluids into steam and burns plant cells and tissues, leading to a wilting symptom and blackened, necrotic, scorched tissues, including roots, stems, branches, and fruits.

Shock waves

The tremendous heat energy is produced in millionths of a second, which is far too quick for the air to expand gradually. The pressure produced along the channel by this intense heat is on the order of 10 to 100 times normal sea-level pressure. This high-pressure region rapidly expands *outward*, causing compression of the surrounding air. This region of compression propagates outward as a shock wave. The pressure can cause the pith of a plant stem to explode out through holes in the stem, it can cause immediate drop of all fruits (ripe or not), and it can split a tree trunk.

Indications that lightning has struck a plant

- There is rapid wilting or collapse of plants or stems, in combination with structural damage or carbonization (burning or black scorching) of the internal stem tissues, and/or browning or blackening of leaves, fruits, or stems
- Symptoms develop rapidly; they appear in days rather than weeks.
- Symptom onset coincides with recent thunderstorms.
- A circular area of plants in a field or orchard are affected, or there are other areas of the farm with similar symptoms and time of symptom onset.
- There is premature mass dropping of green fruit.
- There are burns or strange scars on plants or organs.
- Roots may be blackened or cooked.
- Interior plant tissues such as stem pith, xylem and phloem are blown out of the stem.
- For crops such as sugar beets, potatoes or sweet potatoes, underground tubers or roots are cooked.
- There is lightning damage to nearby telephone poles or transformers.

How does lightning strike plants?

Plants, as aqueous solutions of ions encased in tall vertical carbohydrate skeletons, are natural channels for the completion of the earth-to-cloud return stroke of the lightning bolt cycle.

Thus, a plant can facilitate the completion of a lightning bolt's ground-to-cloud circuit by providing

a convenient channel between the positively charged ground-to-cloud *streamer* and the negatively charged cloud-to-ground *leader*. Tall-standing, erect plants are especially ready pathways for the streaming electrons to travel from ground to cloud.

Electricity is the flow of charges. Although very pure water is a poor conductor of electricity, when salts dissolve in water, ions form and they carry or conduct charge. Fertilizer salts, soil minerals and gases readily dissolve in water. For example, roots can absorb fertilizer nutrients as charged atoms (ions) that have either a positive or a negative charge. Some important positively charged nutrient ions are magnesium (+2), potassium (+1), calcium (+2), sodium (+1); ammonium (+1), phosphates, and others. As these ionic solutions are taken up by roots, plants become standing columns of aqueous solutions of charged ions.

These ions *can move through water*. This movement carries charge. During a cloud-to-ground lightning strike, which generally occurs in the core of a thunderstorm event, many of the positively charged ions in the soil water surrounding the plant, and in the plant itself, can rise up and move through the channel of the return stroke (the ionic fluids in the stem of the plant) in milliseconds. As the lighting pulses, the charge creates burns and explosions in the plant.

How lightning can strike or affect groups of adjacent plants

It is possible for multiple ascending ground-to-cloud streamers to arise simultaneously to meet a single descending, cloud-to-ground stepped leader and to create lightning pulses. They may rise up through the adjacent plants or beside them. Or, lightning may strike the soils and heat up the soil water, affecting groups of adjacent plants.

For plants in a tight, row-cropping situation such as sugar beets or potatoes, the damage appears in the field as circular to elliptical areas of affected plants. In more open areas such as golf courses, the strikes may affect smaller clusters of plants.

Such localized destructions of plants occur because several ground-to-cloud streamers probably emerged from the Earth and completed a circuit simultaneously with the same approaching, cloud-to-ground stepped leader, not because there were several but separate lightning strikes.

Reference

NOAA National Weather Service. What is lightning?
www.crh.noaa.gov/pub/?n=/ltg/ltg_what_is_it.php

Lightning injury to papaya plants (*Carica papaya*)



Left: Collapse of papaya leaf petioles due to lightning injury. Right: A group of adjacent papaya plants with wilt symptoms suffering from lightning injury. (Photos: W. Nishijima)



Left: black necrosis of internal papaya stem caused by high temperatures associated with lightning injury. Center: blackened papaya stem after being struck by lightning. Right: Sunken, necrotic spot in papaya fruit indicates where a lightning bolt probably penetrated. (Photos: W. Nishijima)

Lightning injury to coconut palms (*Cocos nucifera*)



Nut drop associated with lightning strike. Note that the stem-ends of the coconuts are darkened, necrotic in appearance. (Photo: S. Nelson)



Collapsed and necrotic coconut foliage, a few days after a lightning strike at the Hilo Municipal Golf Course. (Photo: M. Nagao)



Burnt orange-colored pith of a coconut stem has been blown out through holes in the stem by a shock wave created by a lightning strike. (Photo: M. Nagao)

Coconut palm (*n*) an aqueous solution of positively charged ions encased in a large carbohydrate skeleton; a natural channel for an Earth-to-cloud “return stroke” of a lightning bolt.



Wilting and dying coconut trees about a week after a lightning strike at the Hilo Municipal Golf Course. Leaves are necrotic and petioles have collapsed. (Photos: S. Nelson)

Lightning injury to banana plants (*Musa species*) (Photos: S. Nelson)



Collapsed and necrotic banana plants less than a week after a lightning strike. The size of the area affected by the strike was about 400 square feet and approximately 10 plants were affected. The plant at left collapsed at the crown; the plant at center collapsed at the base; the plant at right collapsed at mid-pseudostem. The high temperature and pressure created by the strike turned the fluids in the banana plant to steam and exploded the stems.



Where petioles meet the stem, there is a scorched, blackened appearance and collapse.



Collapsed, chlorotic and necrotic banana plant less than a week after a lightning strike.