Biophoton: Collection of Photon-Images

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Biophoton emission is the ultra-weak chemiluminescence observed from many living systems. The origin of biophoton is the reactive oxygen species (ROS) produced from biochemical reactions in metabolic processes, for example, mitochondrial aerobic respiration. Usually such toxic ROS are detoxified by ROS scavengers in common living systems and almost no biophoton is detected. If a living system is in unpleasant states due to environmental changes as well as biological stresses, the concentration of ROS increases. As a result more biophoton is radiated from such living systems. In the present essay, a typical image of photon-radiation from plants is shown by using a high sensitive photo-sensor.

Key words: Biophoton Image, Stress, Infestation, Elicitor, Self-Defense Action, ROS

1. Biophoton

Bioluminescence has been a topic of interest for more than three hundred years. We can observe it in many living systems, for example, luminescence from deep-sea fishes (e.g. *Himantolophaus groenlandicus* (Chohchin-ankou in Japanese)), insects (e.g. *Luciola cruciata* (Genjibotaru)) and plants (e.g. *Mycena cyanophos* (Yakoh-dake)) as well. The intensity from many of those is however rather strong and visible by our eyes because their origin is due to reactions with specific chemicals (e.g. the luciferin-luciferase reaction). Biophoton called here is not related to such specific chemical reactions, of which intensity is extremely weak, typically 10^{-6} times weaker than in the former examples. In order to observe it, therefore, an extremely sensitive image detector such as a two-dimensional photo-multiplier array and its sufficiently long-period exposure are required in a completely dark box (Kai, 2005, 2011; Okabe and Kai, 2010). Then we can obtain images of biophoton radiation.

Here I show such an example from a root of a red bean during seedling in Fig. 1. In the cell division, mitochondria work actively and produce more excess electrons which are related to the production of the reactive oxygen species (ROS). During growth and elongation of a root in a red bean, therefore, strong biophoton is radiated. The point A in Fig. 1 shows such a location called “growing point (division area)”, which locates in a tip of the root. The colors in Fig. 1 indicate strengths of photon radiation, so that red: strong and blue: weak. From the biophoton, in other words, we can know the activity of plant cells.

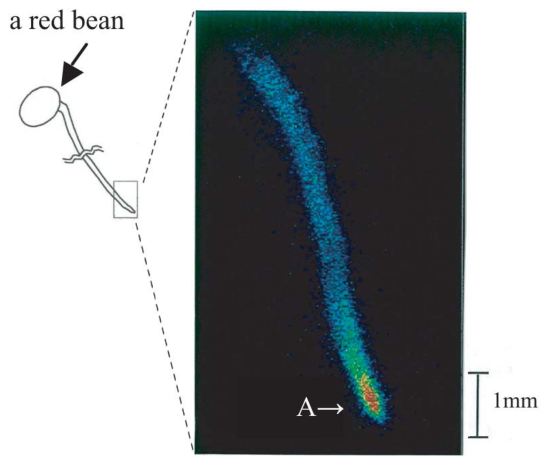

Fig. 1. Strong biophoton radiated from the growing point of a root.

2. Biophoton Due to Physiological Stresses

Due to increase of ROS induced by changes of physiological conditions, strong biophoton can be observed. Some examples of cases where plant cells become active by hormones (Kai *et al.*, 1994, 1995) and where the root of a red bean suffers damages by dry and salt stresses (Ohya *et al.*, 2000, 2002, 2003) are shown here.

Figure 2 shows that the application of a plant hormone, as an activator (gibberellins (GAs)), induces strong biophoton from the growing point. It suggests that cell divisions become more active. Contrarily, if an inhibitor is applied, they become inactive and biophoton radiation decreases.

Figure 3 shows the biophoton image of the root of a red bean, which is immersed in 0.1M-NaCl solution, of which salt concentration is weaker than the threshold for its critical damage. Before application of the salt stress no remarkable photon images is observed. After the stress, however, strong biophoton is observed in the tip (the growing point) at the beginning, and then the intensity gradually decays with time. The intensity increases later on at a different location (the elongation area) far from the tip, that is, the bright location exchanges. Such intensity changes happen

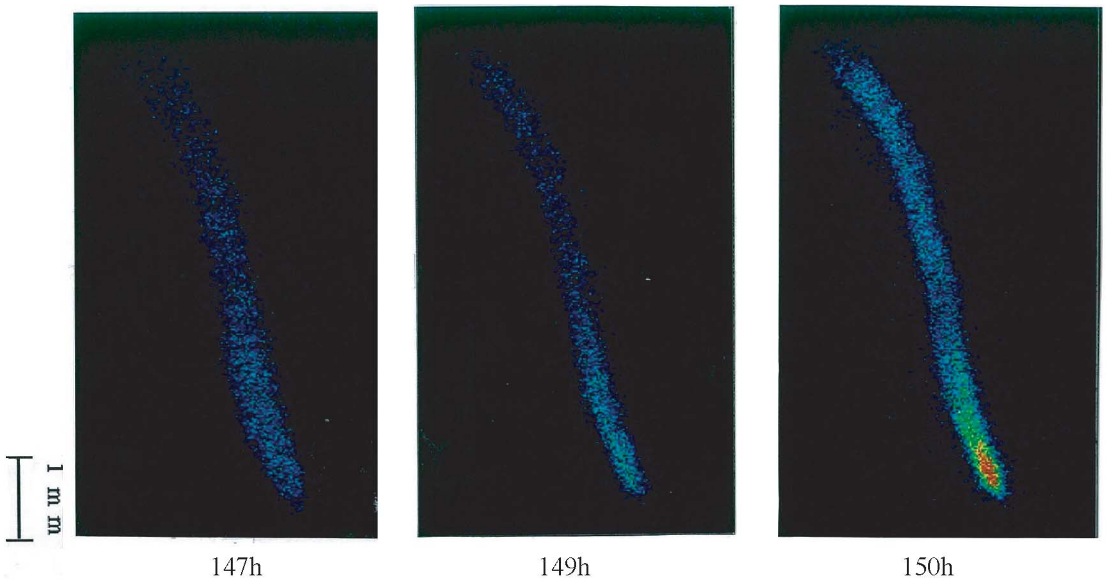

Fig. 2. Biophoton intensity change at a tip of a red bean root after application of an activator hormone (gibberellin GA_3 ~10^{-4} M/1) at 147–150 hours later from germination.

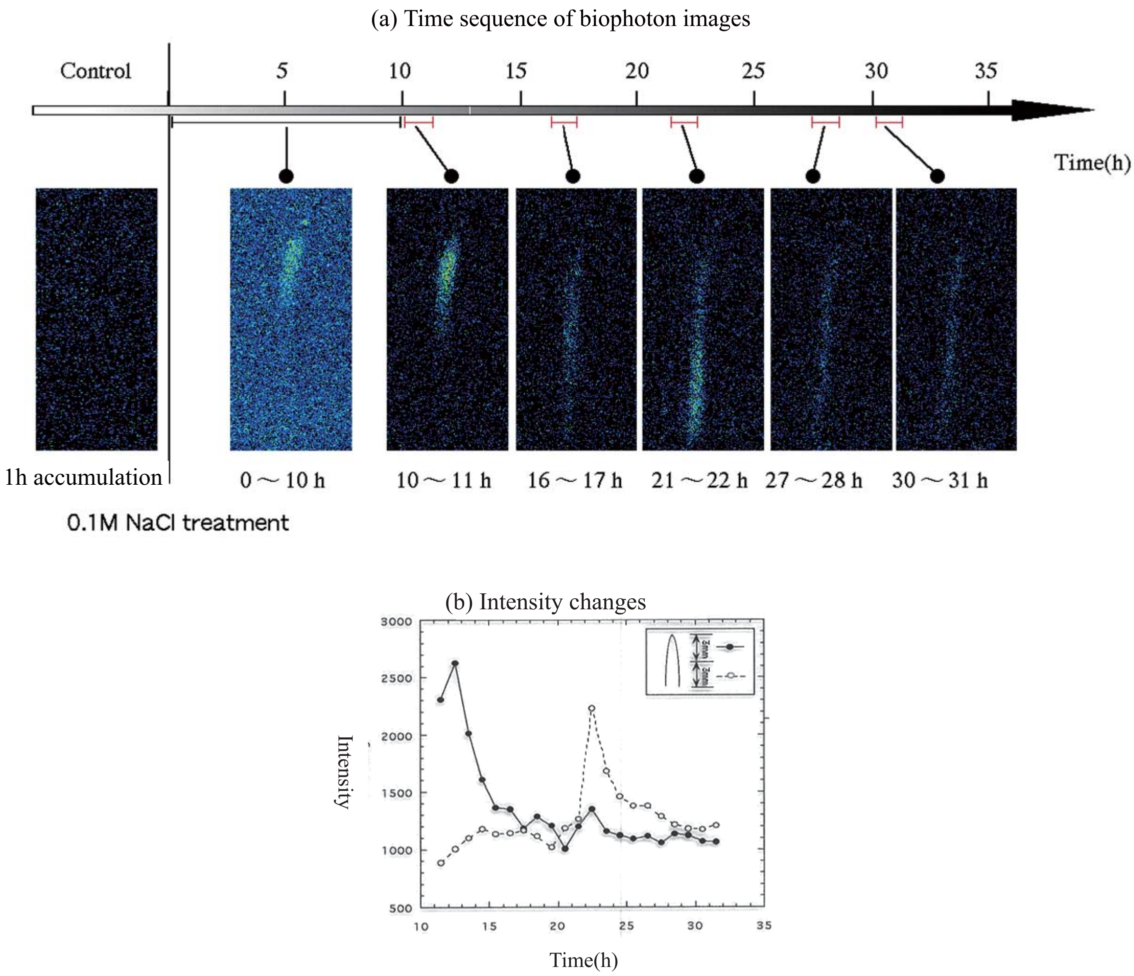

Fig. 3. (a) Photon intensity changes after weak salt stress (the images are up-side-down in this figure. The up is the tip of a root). (b) Plots of intensity from two different locations, close to a tip (the growing point) and far from it (the elongation area).

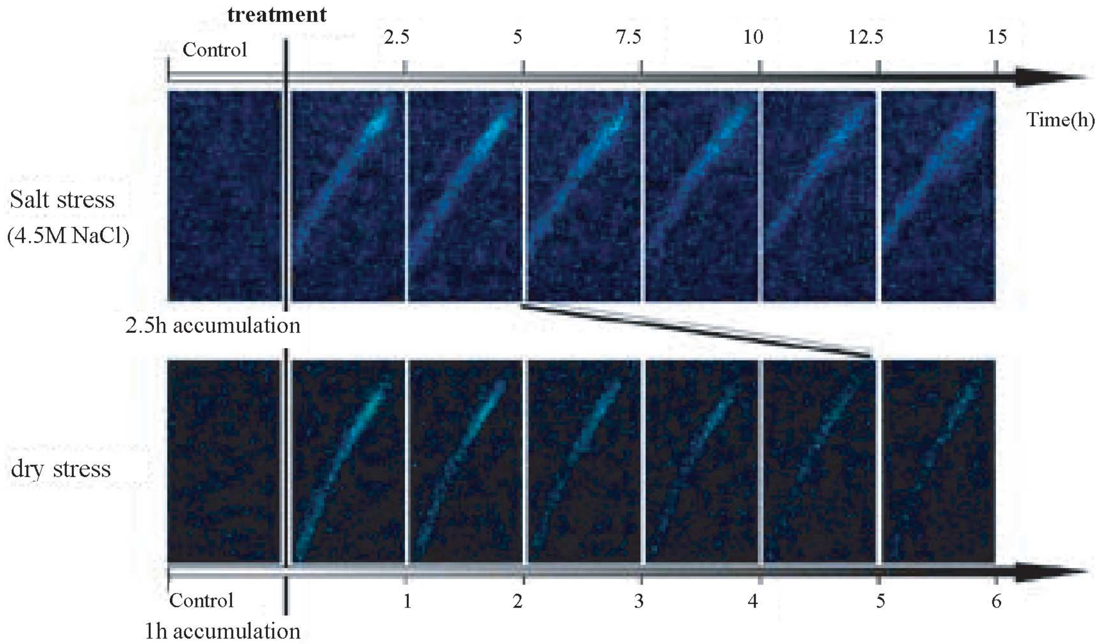

Fig. 4. Strong salt and drought stresses in a root of a red bean (the images are up-side-down in Fig. 1, and the top part is the tip of a root). For both cases the root are withered and dead. Before death, the strong biophoton is observed.

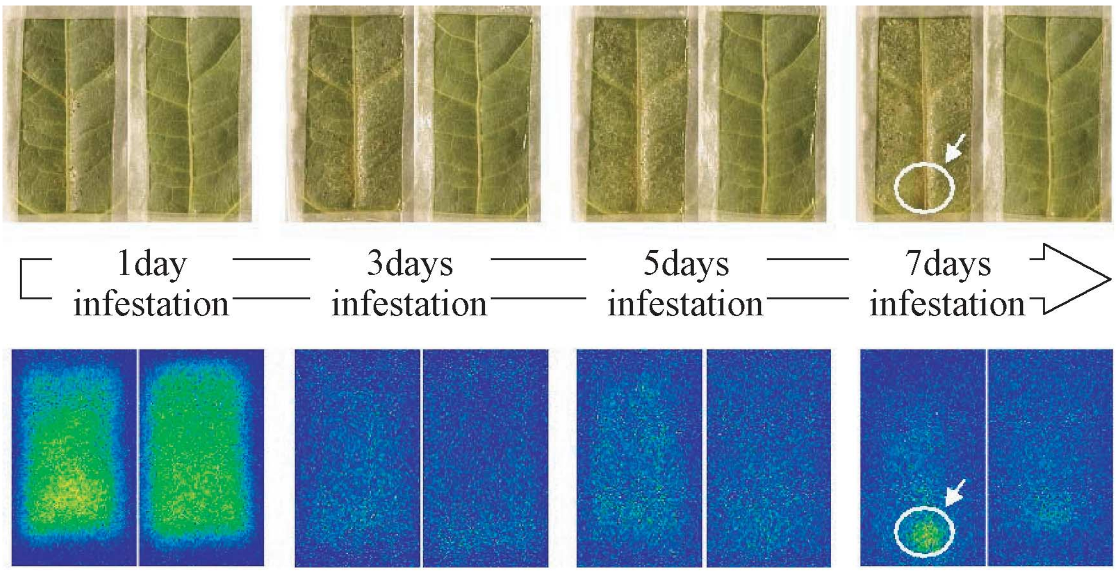

Fig. 5. Biophoton from two different leaves (upper: real images lower: biophoton images). right: control (un-infested), left: infestation of mites. After 7 days, strong radiation can be seen for an infested leaf (marked by a circle), where all mites come together.

for the two locations in time as plotted in Fig. 3. In the first image the biophoton is accumulated for 10 hours and in the others for 1 hour accumulation. For first 10 hours it is weak at the tip area as shown in Fig. 3a, but it suddenly increases and then decreases with time (see Fig. 3b for the quantitative change). On the other hand, the radiation from the elongation area suddenly increases around 23 hours later and quickly decays with a peak. Finally the radiation from both regions comes back to the standard level. The root keeps its growth in this strength of the salt stress.

For the salt and dry stresses, biophoton intensity profiles depend on the strength of the stress as well as a kind of stresses. Usually strong stresses result in the strong damage and death of plants, while so far as below the threshold they are alive.

Figure 4 shows the biophoton images due to strong salt and drought stresses in a root of a red bean. Before stress treatments almost no remarkable biophoton (too weak) is observed. Immediately after the treatments, especially salt stress, it becomes strong. For such cases the root is finally withered and dead because of serious damages beyond the corresponding thresholds.

It is quite interesting that before their death strong biophoton is always observed. Similar to these, prior to the apotosis of Hela cells, anomalous biophoton intensity changes are also observed.

3. Infestation

Regarding biological stresses, one example is shown here. The infested leaf by mites shows the strong photon radiation. The properties of biophoton such as wavelength and intensity changes in time depend on chemical nature of elicitors (some complicate chemical mixtures in mite oral secretion). As a result of the secretion, the infected plants produce several chemicals and hormones, such as salicylic acid, jasmonic acid, some amino acids (e.g. systemin) and so on. In order to protect its damage from mites a leaf collects their natural enemies to the infected leaf by releasing gas chemicals similar to a kind of pheromones for the enemies. Due to those physiological and biochemical actions, the infested leaf radiates strong biophoton.

Figure 5 shows an example of biophoton images after infestation of mites (*Tetranychus kanzawai Kishida*) (Kawabata *et al.*, 2004). In the first day, both leaves radiate strong biophoton due to photosynthesis in chlorophyll before they set in a dark box. However it quickly decays with time in the box and after 3 days almost no biophoton is observed. In 5∼7 days later it starts in the infested leaf (the left leaf) but not for the un-infested leaf (the right leaf). It shows therefore damages of the leaf by mites to radiate biophoton.

Thus from the biophoton intensity in space and in time one can know the current physiological status of living systems. That is, physiological situations can be evaluated based on biophoton measurements. The technique introduced in the present essay, therefore, may be applied to the diagnosis of living systems in the future.

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