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What Biophoton Images of Plants Can Tell Us about Biofields and Healing

KATHERINE CREATH[a,b,c] AND GARY E. SCHWARTZ[b,c]

[a]*College of Optical Sciences Center, University of Arizona*
1630 E. University Blvd
Tucson, AZ, USA 85721-0094
e-mail: kcreath@ieee.org

[b]*Center for Frontier Medicine in Biofield Science, University of Arizona*
1601 N. Tucson Blvd., Suite 17
Tucson, AZ, USA 85719

[c]*Biofield Optics, LLC*
2247 E. La Mirada St.
Tucson, AZ, USA 85719

Abstract—Monitoring biofields around living organisms can provide information about the system, its state of health and how it is healing. Experimental evidence gathered by various researchers since the 1920s indicates that biophotonic emission (light) plays an important role in certain biological functions and processes. Advances in low-noise, cooled, highly-sensitive CCD (charge-coupled device) cameras essentially able to count photons over thousands to millions of pixels have made it possible to image biophoton emission in completely darkened chambers. Images of biofields can now be recorded and changes can be monitored over time. This paper reviews 2-1/2 years of research studies we have performed to develop biophoton imaging instrumentation for monitoring biofields around living organisms yielding quantitative information about their state of health and how they are healing. All but one of the experiments presented in this paper involves plants as subjects enabling a much larger subject sample and the ability to carefully test instrumentation and methodology. Because it is possible to pinpoint an area in an image and quantify the biophoton emission using the techniques presented in this paper, it is possible to create assays using plants to aid in determining healer efficacy and potentially to determine dosage.

Keywords: biophoton emission—biophoton imaging—biological chemiluminescence—bio-communication

Introduction

Biofields are fields surrounding living biological objects (Rubik, 2002). They can have photonic, thermal, magnetic and electromagnetic components (Oschman, 2000). The research presented in this paper has grown out of an intention to develop instrumentation to measure these fields from and around living objects to support research in energy healing and complementary and alternative medicine (CAM) (Hintz et al., 2003). In particular, our interest has

been to develop techniques to detect subtle changes in biofields that can be linked to state of health in humans and to develop quantitative measures of healer efficacy and healing energy dosage for energy healing. This paper presents a review of two and a half years of studies measuring biophoton emission (BE) using highly sensitive imaging techniques.

Up until a few years ago it was not possible to create images of BE from a biological system. The first images presented in the literature utilized multichannel photomultiplier tubes (PMTs) or multianode PMTs and only had a few pixels of resolution in each direction (Ichimura et al., 1989; Schauf et al., 1992; Scott et al., 1987; Scott & Usa, 1988; Scott et al., 1989). Only recently have high-resolution low-noise super-cooled CCD arrays been available at a reasonable price. Cameras originally developed 10–20 years ago for long exposure images through telescopes have proven to be very useful in studying biophoton emission (Creath & Schwartz, 2003a,b,c; Flor-Henry et al., 2004).

Over the past 2-1/2 years we have observed BE patterns produced by various plant parts such as leaves and vegetables as a function of time and noted that injury (such as cutting) and unhealthy tissue is associated with clearly visible increased biophoton emission (Creath & Schwartz, 2003a,b,c, 2004a). As we studied the thousands of images recorded, we observed there were also patterns in the ''noise'' surrounding the plant parts. It appeared as if not only did the biophoton patterns extended beyond the plants, but that patterns were strengthened between plants when they were in close proximity. In this paper we will present some of these images and show measurements of biofields from and surrounding plant parts as well as human hands. We will begin with a review of research studies describing mechanisms of BE, then we will describe the imaging system and present ways in which these patterns can be utilized.

Background

Research of the ''biophoton'' phenomenon has been abundant. There are hundreds of published papers describing this emission in plants, bacteria, and animals—including humans (reviews include Popp et al., 1988; Van Wijk, 2001; Van Wijk et al., 1992). It is well-known that all living organisms emit low-intensity chemiluminescence as part of their metabolic processes (Ruth, 1989; Slawinska & Slawinski, 1983). When electrons move between energy states during chemical reactions as part of metabolic processes, photons may either be absorbed or emitted. A major source of photons is the breaking down of larger molecules into smaller ones resulting in the chemical byproducts of the reaction as well as emitted photons. (The opposite can also be observed in the example of photosynthesis where smaller molecules are combined with the absorption of photons from sunlight to create larger molecules; see, for example, Hader & Tevini, 1987; Wolken, 1986.)

Early research in this area by Gurwitsch (A. A. Gurwitsch, 1988; A. G. Gurwitsch, 1925) created such excitement that within 12 years more than 600 studies had been published (Hollaender & Claus, 1937). Since this radiation is

not visible to the naked eye, and photon-counting detectors had not yet been developed, these studies relied upon difficult to use "biological detectors" measuring cell growth as an indirect means of quantifying light emission. Optical detectors sensitive enough to measure this radiation were not developed until the late 1940s with the advent of PMTs (Engstrom, 1947; Morton & Mitchell, 1948; Westoo & Wiedling, 1949). In the 1950s Strehler and Arnold (1951) showed that low-level emission from plants was related to chlorophyll and that the emissions had peaks in the vicinity of 400 nm (deep blue/near ultraviolet) and 700 nm (near infrared). This is now common knowledge. Colli et al. were the first to present measurements of this spontaneous emission from a number of different plants (Colli & Facchini, 1954; Colli et al., 1955). They found that beans cut into pieces emitted 2–3 times as much light as whole beans. This is the first indication in the literature that mechanical injury is a mechanism that leads to more photon emission from plants.

In our studies we have found that 89% of the emission we detect from plant leaves is between 600–1000 nm putting it in the deep red and near infrared (IR) portion of the spectrum. (Our detector is not sensitive to emissions from the shorter wavelength ultraviolet peak). In plants, it is well-known that reactions relating to chlorophyll are a major contributor to emission in the red and near IR (Hideg et al., 1989). Experimental evidence points to chemical reactions involved in the production of singlet oxygen and other oxygen derivatives (free radicals) as the source of this emission (Slawinska, 1978). The work of Hideg and colleagues also points to similar reactions in mitochondria as another mechanism for emission peaking in the red and near IR present after many hours in darkness (Hideg, 1993; Hideg et al., 1991). Both chlorophyll and mitochondria are fundamental to cellular energy metabolism in plants.

A common link between plants, animals and humans is that emission has been measured from isolated plant, animal and human mitochondria (Cercek & Cercek, 1979; Hideg, 1993; Hideg et al., 1991; Meduski et al., 1974). Mitochondria serve a vital role in the healthy functioning of cells and energy metabolism. Another link among plant, animal and human cells is a correlation between singlet oxygen production not related to chlorophyll or mitrochondria and increased photon emission (Slawinska, 1978; Slawinski et al., 1978; Tilbury & Quickenden, 1988; Voeikov et al., 1999). Recent research indicates that the presence of free radicals, reactive oxygen species and singlet oxygen is associated with weakened immune function and various diseases (Ames, 2003; Bernardi et al., 1999; Chinnery & Schon, 2003). Thus, an advantage of developing a biophoton measurement (biological chemiluminescence) model is that studies beginning with plants can be easily extended to animals and humans.

It is well-known and well-documented in the literature that cells of all kinds under stress (Boveris et al., 1983; Gu & Popp, 1992; Hideg & Bjorn, 1996; Iyozumi et al., 2001; Nagl & Popp, 1987; Slawinska et al., 1992; Slawinski et al., 1992; Van Wijk et al., 1992) or that have been injured (Salin & Bridges, 1981; Slawinska et al., 1992) emit more photons than healthy cells. Examples where more radiation is emitted from stressed than healthy cells include

mechanically wounded plant parts (Salin & Bridges, 1981; Slawinska et al., 1992), algae stressed with poison (Gu & Popp, 1992), non-tolerant plants stressed by chilling (Hideg & Bjorn, 1996), seedlings stressed with salt (Ohya et al., 2000) or drought (Ohya et al., 2002; Xing et al., 1999), and cancerous human cells compared to normal cells (Nagl & Popp, 1987). Not only have biophoton emissions been correlated with chemical byproducts, they have also been correlated with physiological measures (Usa et al., 1989).

There are similarities between emissions from mechanically injured plant and root tissue and emission from leukocytes in animals (Salin & Bridges, 1981). Common links include increased emission with increased oxygen free radical concentration, an increase of emission with the presence of oxygen, a decrease of emission in a nitrogen environment and the implication of peroxidase in plant tissue (myeloperoxidase in leukocytes). This is consistent with the increased oxidative metabolism of wounded tissue as the tissue responds to the injury. It has been hypothesized that this is part of a defense response to seal off a wounded area and generate new tissue.

Some recent theories of biophoton emission consider the possibility that this radiation helps regulate biological and biochemical functions within and between cells (Van Wijk 2001). Other researchers postulate that biophoton emission may be a potential mechanism responsible for intra- and intercellular communication (Popp, 1999).

Initial research studies of biophoton emission were performed using biological detectors and later optical detectors such as PMTs that were not position sensitive. PMTs are single-pixel detectors generally used to measure emission over large sample areas (Inaba, 1988, 1997). Since the development of multichannel plates and position sensitive photon-counting detectors (such as PMT arrays), low resolution imaging has enabled studying the localization of BE (Ichimura et al., 1989; Schauf et al., 1992; Scott et al., 1987; Scott & Usa, 1988; Scott et al., 1989). Imaging with high resolution signal-limited detectors such as the one used in these studies additionally enables the quantization of biophoton emission from specific areas on a sample so that areas and samples can be directly compared.

As outlined above, photonic emission (biophoton output) is a correlate of physiological change in a biological system. It is also an indicator of oxidative metabolic processes and energy transfer within an organism as well as between organisms. Using a highly sensitive imaging array the emission can be quantified in different areas of an object as well as around and between objects to study the behavior of the emission as a function of time. In the rest of this paper we discuss the imaging system and show example images of emission from plant parts as well as the interaction between plant parts.

Biophoton Camera and Imaging Method

The imaging system used for these studies was a Princeton Instruments VersArray 1300B low-noise high-performance CCD, manufactured by Roper Scientific (2002). The system includes a camera head containing the sensor and

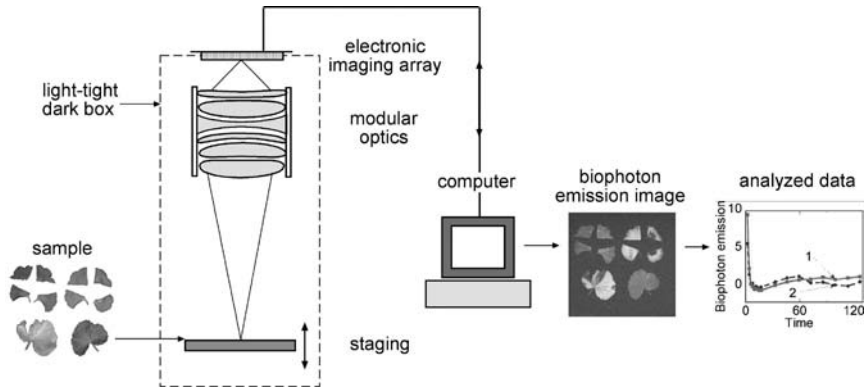

Fig. 1. Schematic of biophoton imaging system.

readout electronics, an electronics box to get images into a computer, a CryoTiger cryogenic cooler, and software for controlling the camera and acquiring images. The camera is mounted on top of a dark box that is as light tight as possible (see Figure 1). The sensor is a back-illuminated silicon CCD with 20 μm × 20 μm pixels (E2V CCD36-40, grade 1) digitized to 16 bits yielding 65,536 gray scale levels (GSLs). It is cooled to reduce thermal and readout noise. For optimal exposures, the sensor is cooled to a temperature of –80 to –100°C using the CryoTiger. The response of this sensor spans from 350–1000 nm with the maximum response between 400 and 800 nm (see Figure 2).

Much of what this sensor detects is in the range of human vision; however, it is much more sensitive to low light levels than human vision, and can see things that the human eye cannot. The output of this sensor is directly proportional to the number of photons incident at each pixel. Using the specifications provided by Roper Scientific (2002) when operating the camera in low-noise mode with a gain of 4 × and assuming an average quantum efficiency of 0.8, there are approximately 1.6 photons per GSL. This camera is essentially close to counting photons.

A standard Nikon F/1.2 50 mm lens set at F/1.2 is used as the imaging lens. The field of view (FOV) at the closest focal distance (CFD) is 220 mm wide. Objects to be imaged are placed on a black or non-fluorescing piece of paper on top of a focusing stage at the CFD. Because nothing is truly light tight and there are always some ambient photons present even in the darkest room and the darkest enclosure, the imaging system is placed within a darkened room and baseline images are monitored before and after each imaging session to determine if there has been a light leak. Baseline images are taken without the presence of objects and have the same exposure time as the regular images in order to determine noise background levels.

The necessary operating temperature of the sensor was determined by taking images at different sensor temperatures with no object present. As shown in

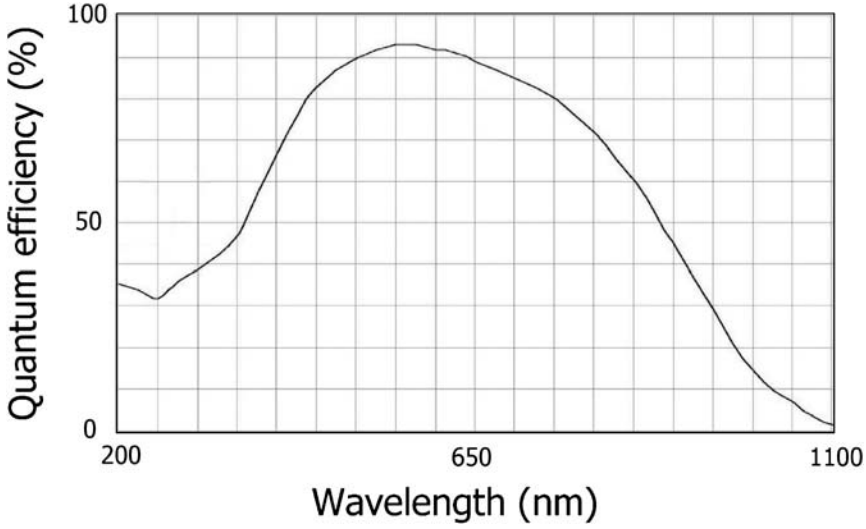

Fig. 2. Camera sensitivity.

Figure 3A the background noise minimizes when operating the CryoTiger at least as cold as –80°C with 1-minute exposure times. The background levels are shown as number of GSLs. ''1×1'' refers to reading out every pixel, while 3×3 is the combining the charge collected over groups of pixels 3 pixels wide and 3 pixels high in hardware and reading out this 9-pixel unit as a single pixel (also known as hardware ''binning''). When hardware binning is used the resolution of the sensor is decreased. For 3×3 binning each image element is now 60×60 μm instead of the 20×20 μm for 1×1 binning. Binning effectively enables increasing the signal-to-noise level (SNL) because the system is essentially background limited. Figure 3B shows signals from plant leaves compared to background levels with no object present for different settings of hardware

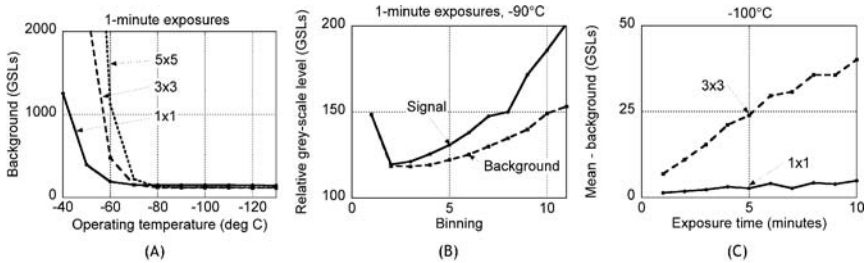

Fig. 3. (A) Mean gray scale level (GSL) for different operating temperatures and hardware binning levels for 1-minute exposures. (B) Relative GSLs for signal from a geranium leaf and background with no object as a function of hardware binning level. (C) Mean GSLs as a function of exposure time for two different hardware binning levels.

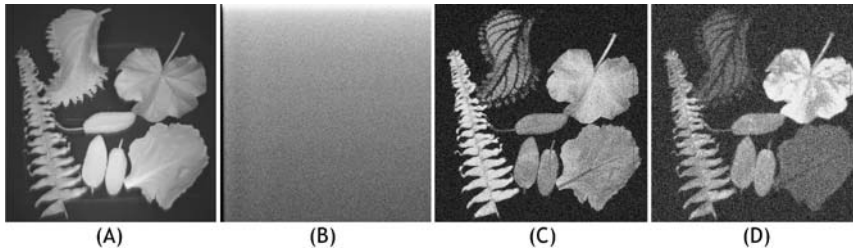

Fig. 4. Clockwise from left: Boston fern, coleus, geranium, blooming cabbage, purple sage on a black background. (A) Leaves with white light illumination. (B)–(D) Leaves in total darkness with (B) 100 ms exposure, (C) 1-minute exposure showing chlorophyll fluorescence, and (D) 10-minute exposure showing biophoton emission. Gray scales have been adjusted to enhance contrast.

binning. Figure 3C shows how binning can help increase the signal level as a function of time. Most of the measurements taken for this study utilize 2×2 binning, which increases the SNL by a factor of four, but only decreases the image resolution by a factor of two.

Biophoton Imaging

Types of Images

Figure 4 shows examples of images taken with this system. Figure 4A is a 100 ms white light image of a group of different plant leaves. When the white light is turned off and the chamber is sealed no image can be seen in this light-tight chamber with a 100 ms exposure (Figure 4B). A one-minute exposure in the dark taken immediately after turning off the light and closing the chamber is shown in Figure 4C. This image illustrates the fluorescence of chlorophyll that will decay over 10–20 minutes. After the chlorophyll fluorescence has decayed there remains a persistent ultraweak biological chemiluminescence generally referred to as biophoton emission (Figure 4D).

Image Irradiance Over Time

The chlorophyll fluorescence is many times brighter than the biophoton emission as can be seen in Figure 5A. This plot shows the mean levels averaged over areas of geranium leaves with 1-minute exposures taken over a 3-hour long time period. Once the initial fluorescence has decayed, the biophoton emission persists and even slightly increases with time as the leaves are drying out. The emission from geranium leaves is predominantly in the red and near-infrared parts of the spectrum (see Figure 5B). Further analysis of the data show that approximately 89% of the emission we detect from plant leaves is between 600–1000 nm (Creath & Schwartz, 2003a). In plants, it is well-known that reactions relating to chlorophyll are a major contributor to emission in the red and near IR

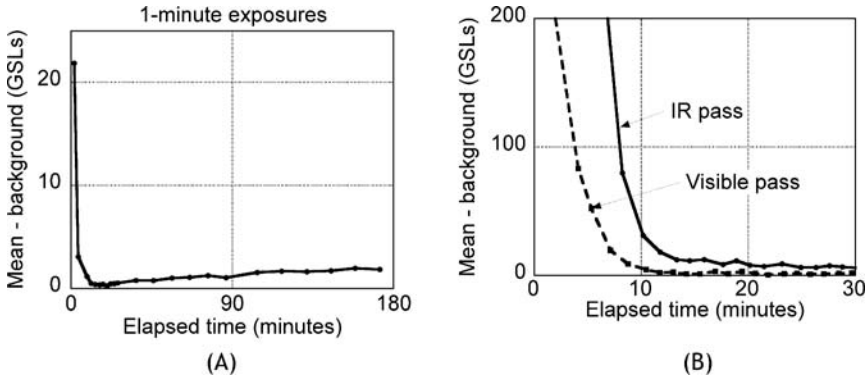

Fig. 5. (A) Average biophoton emission for geranium leaves with 1-minute exposures with background signal subtracted. (B) Emission of geranium leaves as a function of time with visible pass (380–670 nm) and IR pass (>720 nm) filters on camera lens. Scales of (A) and (B) are relative and of different sets of leaves and therefore cannot be directly compared to one another.

(Hideg et al., 1989). This affirms the published experimental evidence pointing to chemical reactions involved in the production of singlet oxygen and other oxygen derivatives (free radicals) as the source of this emission (Slawinska, 1978). The work of Hideg and colleagues also points to similar reactions in mitochondria as another mechanism for emission peaking in the red and near IR present after many hours in darkness (Hideg, 1993; Hideg et al., 1991). Both chlorophyll and mitochondria are fundamental to cellular energy metabolism in plants.

Artifact Removal

Figure 6A shows a cut and slightly wilted geranium leaf with browned edges taken in white light with a conventional Canon digital camera. Figure 6B shows a one-minute chlorophyll fluorescence image immediately after the light-tight chamber is darkened. Figure 6C shows a two-hour long biophoton emission image begun after the leaf had been in total darkness for 5 hours. Note that the biophoton emission persists and that some areas are brighter than other areas. Also note that details in the leaf such as veins are easily visible. The bright spots all over the image are due to high-energy rays such as stray gamma rays and other ‘‘cosmic’’ rays or particles that expose pixels of the array. These spots have much higher values than the surrounding pixels and can be removed using a median filter as shown in Figure 6D that utilized a 5×5 median filter. Removing these ‘‘cosmic’’ rays enables more precise determination of biophoton emission in areas of plant parts. The downside of median filtering is that it reduces the resolution of the image (smears it slightly) so that the details are not quite as visible.

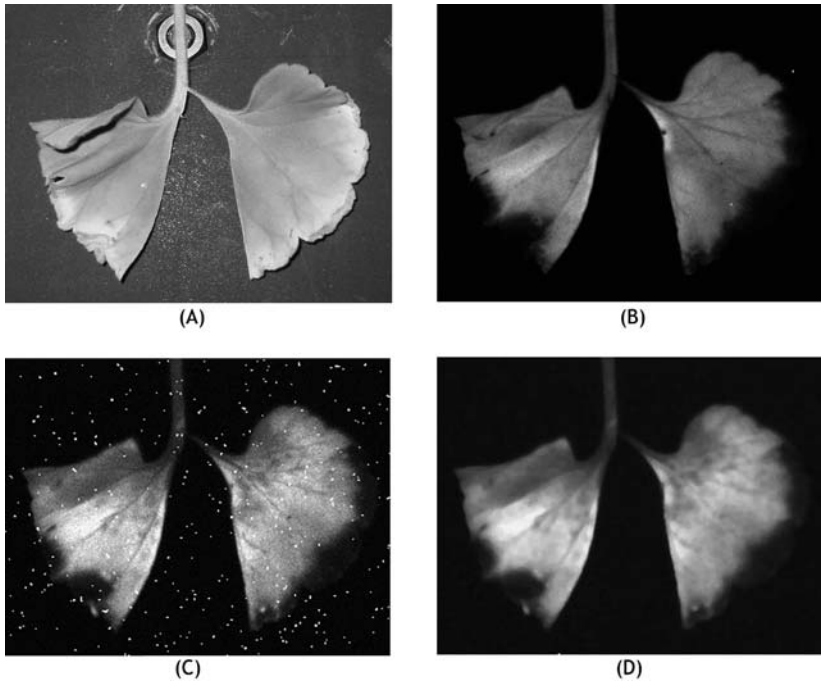

Fig. 6. Cut geranium leaf on black stage platform. (A) White light image. (B) Chlorophyll fluorescence image. 1-minute exposure in total darkness. (C) Two-hour biophoton image after five hours in total darkness, Bright spots are high-energy "cosmic" ray hits. (D) Biophoton image (C) after a 5×5 median filter to remove cosmic rays.

Applications

Assessing State of Health

Biophoton imaging can reveal information about the state of health of a biological object. When plant parts are used as objects, unhealthy and injured (cut) areas will have more emission than healthy and uninjured (uncut) areas. However, there is a point where a portion of the plant part may be unable to emit biophotons when it no longer has metabolic processes functioning such as in a brown spot on a leaf. Although some of these variations are clearly visible to the naked eye, areas may show stress through biophoton emission before it is clearly visible to the naked eye (Chaerle et al., 1999).

Similarly sized healthy and unhealthy leaves from a single geranium plant are compared in Figure 7. Figure 7A shows a color image of the leaves taken with a Canon digital camera. The unhealthy leaf on the left is yellowish green with brown spots, while the healthy leaf on the right is deep green. Figure 7B is a 1-minute exposure taken with the VersArray camera showing the chlorophyll

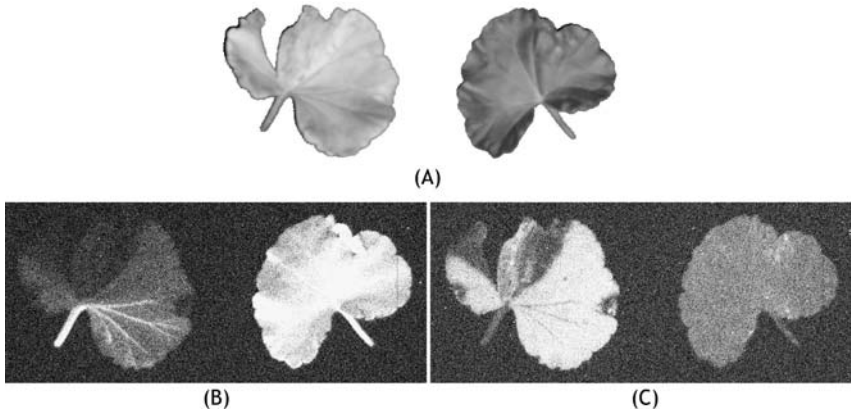

Fig. 7. Unhealthy (left) and healthy (right) geranium leaves. (A) Digital camera photograph. (B) Chlorophyll fluorescence (1-minute exposure) in darkness. (C) Biophoton image (10-minute exposure) after 27 minutes in darkness.

fluorescence in total darkness. Figure 7C shows a 10-minute exposure after 27 minutes in complete darkness. For comparison Figures 7B and C have been scaled the same. Note that while the healthy leaf fluoresces more, the unhealthy leaf has a greater BE.

Assessing Response to Injury

Figure 8 shows a geranium leaf cut into 4 sections using a blunt edge and severely injured with a hammer blow in the middle of the right side showing noticeable damage. The chlorophyll fluorescence image (Figure 8B) indicates noticeably more activity along the edges of the leaf. With time the BE activity apparently moves to different parts of the leaf sections as can be seen by comparing Figures 8C and D. There is more BE in the less traumatized left half of the leaf. In the right half of the leaf the activity migrates more to the edges over time. These images illustrate that activity increases as a result of a cut injury. With time the leaf focuses its energy where it needs it most at the edges of the severe trauma wounds leaving less activity in adjacent areas.

The BE in two areas of the lower right leaf section of Figure 8 is tracked over time in Figure 9. These plots show the average BE with background levels subtracted for a series of interleaved 1-minute (Figure 9A) and 10-minute (Figure 9B) exposures taken over a 130-minute period in total darkness. The analysis areas containing 440 pixels each are shown in Figure 9C. Background levels were determined by taking an exposure without the leaves present for the same length of time and averaging over the same pixel window area in the image. Note that after the chlorophyll fluorescence fades, the BE at both locations increases with more activity near the center than the edge. An hour after injury the BE activity appears greater at the edge than at the center and this

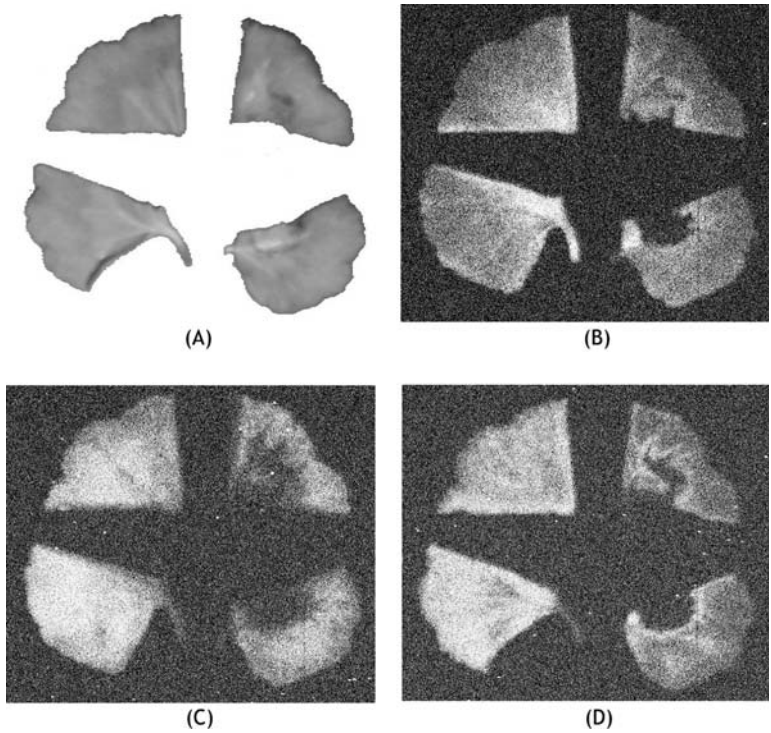

Fig. 8. Geranium leaf injured with a hammer blow and cut with a blunt edge into 4 sections. (A) Digital camera photograph. (B) Chlorophyll fluorescence (1-minute exposure). Biophoton images (10-minute exposures) after (C) 22 minutes and (D) 116 minutes in total darkness.

continues for the rest of the series. Activity near the edges is a response to injury as the leaf begins sealing off the damaged edges.

Emission from Human Subjects

The human body emits light as well as thermal radiation as part of basic metabolic processes. Biophoton emission from hands and other body parts have been measured with PMTs by many researchers (Choi et al., 2002; Cohen & Popp, 1997). The results of Cohen and Popp (1997) show that the emission varies depending upon state of health, position on the body, time of day, and time of the year. Because of the nature of PMTs, images cannot be obtained. However, detailed images of biophoton emission can be obtained utilizing cooled, low-noise CCD cameras with exposure times on the order of minutes (Creath & Schwartz, 2004a).

Figure 10 shows images of the first author's hands taken by the second author using a cooled, highly sensitive silicon CCD camera with 10-minute exposures in total darkness. The bottom two images were taken in white light, while the top

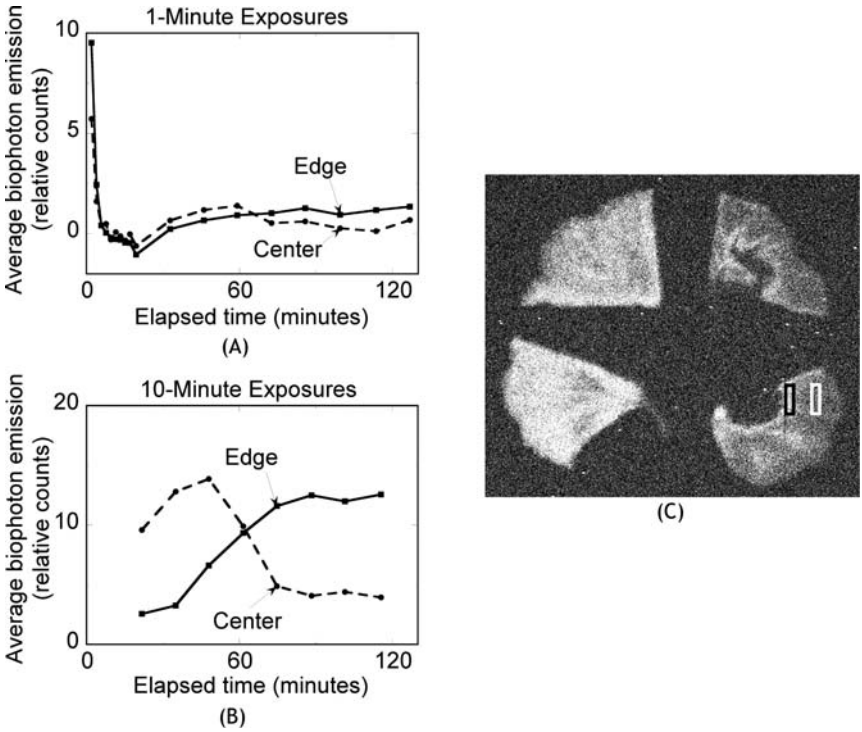

Fig. 9. Plots of average BE for 440-pixel areas within lower right section of leaf in Figure 8. (A) 1-minute exposures with corresponding background levels subtracted. (B) 10-minute exposures with background levels subtracted. (C) The black rectangle is the edge area and the white rectangle is the center area.

two images are biophoton images taken in total darkness. The Princeton Instruments VersArray 1300B camera was hardware binned providing 67×65 pixels with each pixel having a 400 μm square sensing area. Note that the fingertips emit more biophotons than the back of the hands, and the palms of the hands are in between. These images show great detail, but they do not enable us to look at dynamic changes on shorter time scales.

Measuring Healer Efficacy

To determine if energy healers could affect the metabolism of a biological organism, we designed a study to test their effectiveness on the biophoton emission of geranium leaves (Creath & Schwartz, 2004c). We compared effects of treated leaves to untreated control leaves by utilizing two similarly-sized leaves from a single geranium plant that were each cut into 4 sections. Sections from one leaf were treated for 10–15 minutes with a healing intention using an energy healing technique. Sections from the untreated second leaf were placed in similar lighting conditions to act as a control. Practitioner's hands were posi-

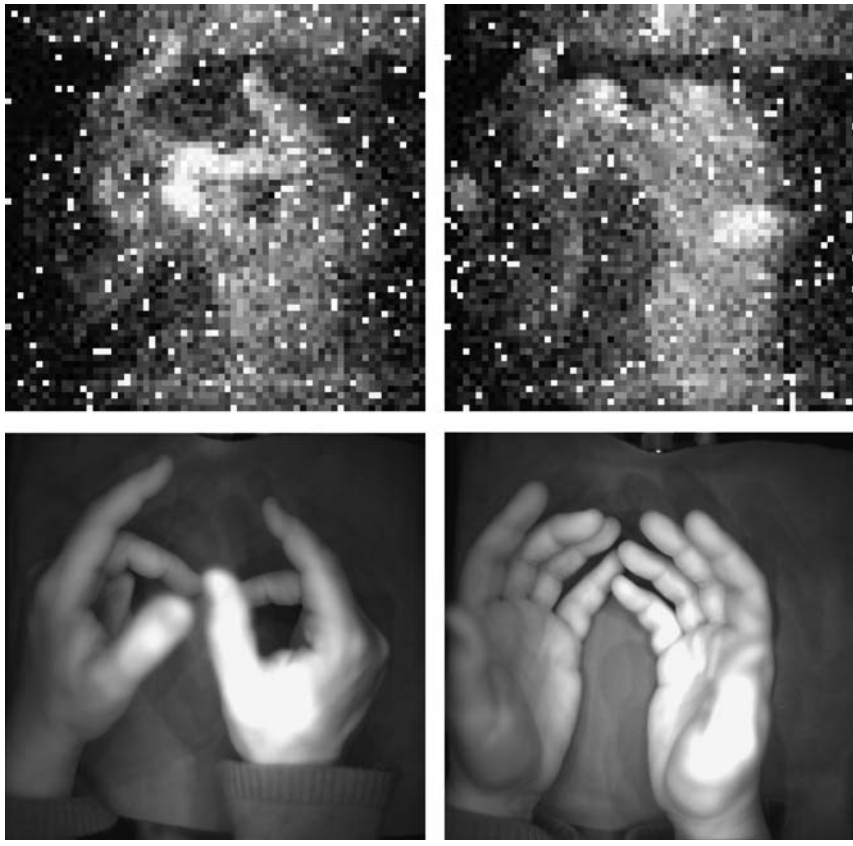

Fig. 10. Top images are 10-minute exposures taken in total darkness using 20 × 20 binning with a Princeton Instruments VersArray 1300B camera cooled to –100°C. Bottom images are 10 ms exposures taken with white-light illumination.

tioned 3 inches from the leaves for the first trial and 6–10 inches from the leaves for the subsequent 3 trials. Hands were positioned not to block direct light from an overhead light fixture. Positions on the imaging platen for different conditions were varied between trials. The trials involved 3 different energy-healing modalities, each with a different practitioner. Modalities utilized were VortexHealing (VH), Reiki, and Barbara Brennan training.

Figure 11A shows leaf sections treated with VH for 15 minutes (right) compared to untreated leaf sections (left). The untreated leaf sections have greater photon activity near the injured edges as well as noticeable clumping of the emission. The treated leaf sections have noticeably less BE, and there are fewer clumps with less activity near the edges. Figure 11B shows a plot of the relative BE for the leaf sections in Figure 11A averaged over 1200-point windows at similar places in each leaf section placed as far from the injury as

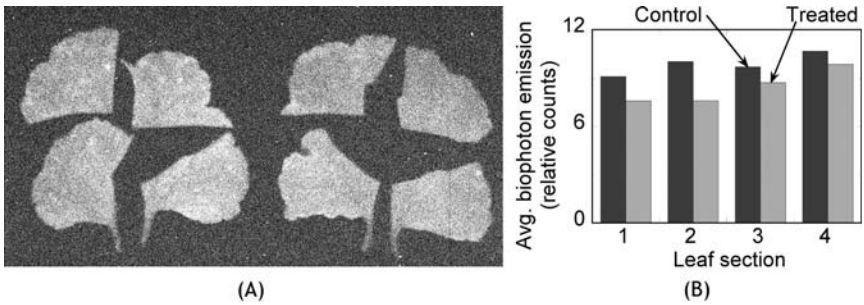

Fig. 11. (A) Biophoton image (10-minute exposure) of geranium leaves in darkness for control (left) and VH treatment (right). (B) Comparison of average relative gray scale levels in each leaf section.

possible. Analysis of these data shows the effect is statistically significant ($T = 3.953$, $p < 0.03$).

We have consistently seen similar effects with an overall reduced BE effect for trials using different energy healing modalities and different practitioners. This protocol has been extended to include trials with either a healing intention or a glowing intention and is being used by at the University of Arizona as one measure of healer efficacy (Connor & Schwartz, in press).

Biophoton Interaction

In our experiments, initially we placed the plant parts on a black background that absorbs light. To look more closely at the patterns around and between plant parts, we found that placing the plants on a white background (that did not itself fluoresce nor glow in the dark) could enhance the ability to detect light patterns around the plants and potentially between them. Since the white background reflected and scattered light emitted from the plant parts, we were able to see more emission around the edges and between plant parts (Creath & Schwartz, 2004b, in press). This is analogous to energy workers who often report that they see human auras more readily when people are near white walls.

Figure 12A shows a two-hour biophoton image of geranium leaves with the gray scale scaled as a photograph. The leaves on the left side of the image are on non-fluorescing white paper to enhance the light around and between the leaves while those on the right side of the image are on black paper. The white paper reflects and scatters the biophotons emitted from the leaves so we can more easily see what is in the areas around and between the leaves. Figure 12B was enhanced in software by stretching the gray scale. This enables seeing areas between and around the leaves more clearly. This scaling shows that more light can be seen in the areas between and around the leaves on the white paper than those on the black paper. Figure 12C is an enlargement of the lower left quadrant of the middle image. Close inspection of this image shows a ‘‘halo-like’’ pattern

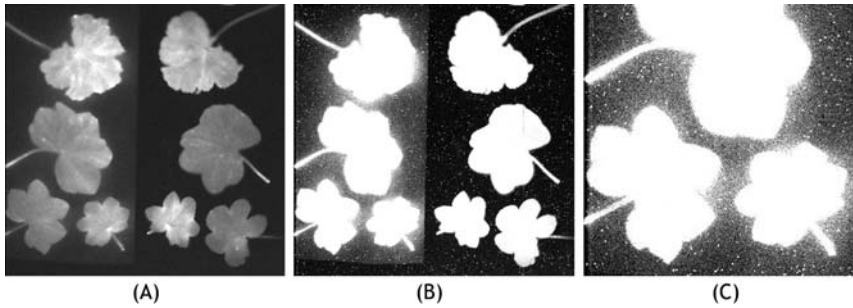

Fig. 12. (A) Biophoton image of geranium leaves taken as a two-hour exposure in total darkness inside a light-tight chamber. Leaves on the left side of the image are on non-fluorescing white paper and those on the right are on black paper. (B) Same biophoton image rescaled in software to enhance the area between the leaves. (C) Enlargement of lower left quadrant of (B).

around the leaves (i.e. an ''aura''). Furthermore there is noticeably more light between adjacent leaves than around leaf edges without an adjacent leaf and this signal is stronger when leaves are closer together.

Figures 13A and B show two images from an experiment we performed studying effects of distance between plant parts. Sections of string beans were pinned in place a known distance apart in millimeters on non-fluorescing paper and a series of one-hour biophoton images were taken (Creath & Schwartz, 2005). As expected, the bean sections were brighter in the first hour than in the fourth hour. When the gray scales are enhanced as shown in Figures 8C and D the amount of light between the sections falls off with their separation and as a function of time. It can be seen that the closer the cut pieces of beans are, the brighter the emission between them.

Discussion

These experiments illustrate that biophoton imaging can quantitatively and locally monitor physiological processes such as response to injury. The average BE in a given area yields indications about localized metabolic processes and the functional state of health of the living system as it is tracked with time. The quantitative nature of BE enables it to be a baseline measurement correlated to state of health that can be used as a measured outcome to determine efficacy of any therapeutic modality (i.e. energy healing, herbs, drugs, etc.). The results we have presented here show a variety of applications utilizing plants as subjects and detectors of energy.

The images in Figures 6 through 8 illustrate the details that can be gleaned using a state-of-the-art cooled CCD camera. The patterns on the leaves can be correlated with physiology as well as metabolic function. Areas on the subject can be quantitatively compared and tracked with time as shown in Figure 9. The sensitivity as well as the flexibility of the system are such that images can also

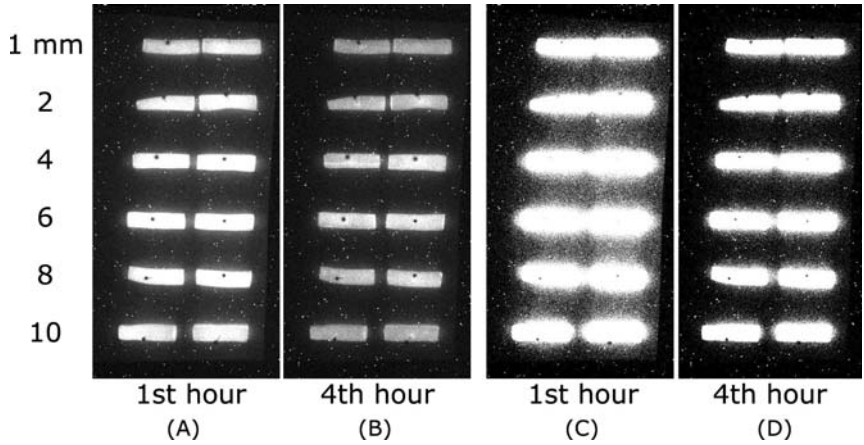

Fig. 13. One-hour biophoton images of string bean sections on non-fluorescing white paper. Distances between bean sections indicated in millimeters. (A) First hour in total darkness scaled as a normal photograph. (B) Fourth hour in total darkness with gray scale the same as (A). (C) Image of (A) with gray scale stretched in software to enhance the area between bean sections. (D) Image of (B) scaled the same as (C).

be made of human biophoton emission. Although the spatial resolution of Figure 10 is much less than that of the leaves, and the signal is about 10 times as weak, yet location on the hands is still obvious.

When used as a bioassay, subtle differences in biophoton emission can be detected between treated and control conditions as shown in Figure 11. A healer can send healing energy to a leaf or have it be the detector as healing energy is sent to a third party. Because a healthier state corresponds to fewer biophotons we would anticipate seeing a lower biophoton emission as shown in Figure 11. When a healer consciously connects to a leaf and has a focused intention for the leaf to glow more we see consistently higher output from the treated leaf than from the control over a period of time. One of our colleagues is utilizing this bioassay as one type of assessment for healers (Connor & Schwartz, in press). Another of our colleagues has found that the mood and state of being of the healer can be one potential indicator of whether the healer can affect a biological system (Rubik et al., in press). Results of these studies will be published in future papers.

The images in Figures 12 and 13 show that we can see light emission beyond the edges of the plant parts. More light is seen when the plant parts are on a white non-fluorescing background than when they are on a black background. The white background enables scattering and reflecting of the light emitted from the edges as well as the unseen portions of the plant parts. This scattered and reflected light around the edges is analogous to what often is called an ''aura.'' It should be noted that this effect can also be seen on black backgrounds but it is more often than not much closer to the background noise level than it is with a white background.

Another aspect of the effects we are seeing is that when the plant parts are on a white background there is more light surrounding the plant part that can be absorbed as well as reflected from an adjacent plant part. We know we can only see photons that get into the camera lens. Those that are going at larger angles than the field of view are not visible in these images. Having a white textured background such as paper scatters and reflects many more photons into the lens' field of view.

When plant parts are closer together they are receiving more photons from other plant parts. These photons can be absorbed by the adjacent plant parts and cause areas closer to other plant parts to glow more. Because each plant part glows a different amount depending upon its current state of health and hydration, we can only make relative comparisons of outputs of adjacent plant parts. We can infer and hypothesize from the images shown that there is some type of dynamic feedback mechanism at work as the plant parts interact with one another over time. This dynamic feedback appears to be stronger when the plant parts are closer together. It's a process where plant part A illuminates plant part B which absorbs and re-emits a portion of the light back to A creating a mutual positive feedback loop. Photons passed back and forth between plant parts will pass energy back and forth as well as biophotonic information.

The BE effects we consistently see can be correlated with metabolic processes shown by many previous researchers. Biophoton imaging has great promise as a bioassay. Future studies to validate this bioassay include studies with leaves as well as extensions to animal and human cells and tissues. Biophoton imaging has great potential as a means of determining practitioner effectiveness as well as a means of studying mechanisms and effects of energy healing in clinical studies.

Conclusions

These images, and thousands of others recorded in our laboratory, reveal not only that plants ''glow in the dark'' but also that biophoton emission imaging provides information about metabolic functioning, state of health of the organism, and that BE appears to be able to be modulated by the intention of a healer. Moreover, the patterns of light emitted by the plants extend beyond them creating ''aura-like'' structures around them that appear stronger when the plant parts are closer together, suggesting a dynamic feedback communication process involving mutual absorption and re-emission. As more research on the bio-informational aspects of light in biological systems unfolds, we will gain a better understanding of the role the photon plays in biological functioning and a greater insight into the nature of light.

Research in biophoton phenomenon requires the collaboration and integration of multiple disciplines. There are many opportunities for research to better understand the nature and function of this radiation. Plants appear to be quite useful as test subjects for testing methodology, and they appear to be sensitive detectors of healing energy and healer intention. Potential applications in energy medicine research range from basic science experiments measuring the effec-

tiveness of healers on biological systems such as plants to measuring the light emitted from healers' hands to measuring therapeutic effects in patients.

Although the sensitive equipment required for recording biophoton imaging in total darkness is somewhat expensive ($30,000–$40,000), the potential applications to areas of research—basic and applied—in complementary and alternative medicine are sufficiently extensive and promising to justify continued development and future support. Light holds an important key in our understanding of biofields and the dynamics of energy within a biosystem. Images like these give us a window into a seemingly invisible part of the mystery of light and life. We are only beginning to see the light within.

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