Bio-Resonance Feedback for Plant's Diagnostics and Optimized Growth

White paper

Introduction

Biophoton Subtle Energy Technology is aimed to help farmers grow more resilient and productive plants. This technology optimizes the growth of plants based on intrinsic and induced ultraweak biophoton emission from plants in the red and near-infrared regions of the optical spectrum. Characteristics of the plants' well-being identified by evaluating the spectral and delayed fluorescent parameters of their biophoton emission are used to generate an electrical feedback signal as a frequency-modulated current in industrial LED light grow system, thus helping indoor farmers increase the yield of their crops and reduce their costs. This technology can detect and diagnose diseases in plants, allowing farmers to better manage their crops and reduce the use of pesticides and other chemicals, resulting in a reduction in environmental pollution.

The Customer. The expected customer for Biophoton Subtle Energy Technology is any individual or organization that grows plants in bulk, such as commercial growers, greenhouses, and indoor farms that use hydropriming and biopriming techniques, which seeks to increase the health and productivity of their crop yields. This technology addresses the need for a comprehensive, non-invasive way to measure the health of plants and seeds in real time. It also enhances the growth potential of plants by allowing the optimization of the environment and nutrient inputs to the plants.

The Customer Benefits. The benefits to the customer of the proposed technology include but are not limited to, 1) Faster and more accurate assessment of plant and seeds health and nutrition needs, giving customers the assurance that their plants are getting the nutrients they need efficiently; 2) Improved plant yields: the technology can help customers optimize the yield of their crops, ensuring that they get the maximum return on investment; 3) Reduced cost of crop production, by eliminating the need for costly manual testing and assessment; and 4) Enhanced environmental sustainability by maximizing plant growth while minimizing energy input and waste.

The proposed technology uses biophoton resonance feedback from a plant to provide a rapid, non-invasive, and cost-effective comprehensive real-time assessment of the plant's health and stress level. Besides plants' health monitoring capabilities, the benefits of this technology include its adaptability to specific environmental needs by providing adequate current-modulating patterns to be used by farmers' LED light grow systems and affecting the plants in the desired way. The proposed approach is easily scalable and can meet the needs of indoor farming and hydroponic farms.

The Innovation. Stress-induced changes in plants have predominantly been detected through invasive mechanical sampling, followed by biochemical and molecular analysis. Methods that can detect levels of oxidative stress before the emergence of visible symptoms and the establishment of adverse effects are of great value. The proposed ultra-weak biophoton emission recording setup that uses integrated biophoton imaging and delayed fluorescence is a competitive innovation beneficial for crop yield management. While this technology is currently limited to laboratory conditions, research has suggested that the physiological and chemical changes caused by various types of environmental stress can be captured and assessed in the field through the analysis of ultra-weak biophoton emission, statistics, and image patterns. The proposed technology can then optimize growth of the plants from seedlings to harvesting stages through continuous monitoring.

The Commercial Opportunity. According to the preliminary tests, other benefits may include:

- Increased yield by 20-40% with no extra fertilizers or nutrition and beneficial changes in the micro components of the plant, leading to increased environmental sustainability by preserving land and plant resources without extra chemical pressure on soil, water, or plants.

- Increased productivity by improving germination rates and survival rates of early crop development.
- Increased soil and plant sustainability by implementing ecologically friendly biophoton-modulated LED light treatment.
- Uncomplicated equipment installation and operation suitable for small family farms and indoor farming, which is relatively non-expensive, with the total cost of this innovation around $500.00 per small family-size farm or indoor farm.

Biophoton Subtle Energy Technology facilitates the creation of a library of biophoton signature patterns that make it possible to electronically process various aqueous solutions, including fertilizers, to increase their effectiveness and consequently use them in smaller amounts, which prevents the excessive abuse of the soil ecology, and saves the area for crop production.

The $1.3B (2020) worldwide market of LED lighting is expected to increase to about $12B by 2030, reflecting the exponential growth of indoor horticulture as a way of increasing the overall sustainability of food production affected by adverse environmental conditions. To meet the challenge of limited space, artificial light agriculture must be highly efficient while minimizing the need for extra fertilizers or nutrition. Proposed technology addresses the above needs by devising plant species-specific biophoton-modulated patterns, making it attractive for both manufacturers of LED lighting and agricultural users.

Art-Energy LLC plans to use these established marketing channels to introduce time/frequency optimized LED illumination sources. This business approach would demonstrate the benefits of the biophoton-modulated light to existing indoor lighting customers, so they can offer it as a part of an option for their LED products. The optimized patterns can then be licensed to manufacturers. For the existing indoor agricultural facilities, LED-modulating hardware can be offered as a part of an efficiency package that would provide a higher crop yield at reduced fertilizer expense.

The market includes:

- Indoor vertical farms, greenhouses, experimental facilities, and plant labs with climate chambers and containers.
- Seeds storage and improving germination facilities.
- Companies that use hydropriming and biopriming techniques.

Future experiments using Biophoton Subtle Energy Technology might include:

- Investigation of the effect of technology on fertilizers, insecticides, and fungicides.
- Use of biophoton-modulated water and lighting as a part of the aeroponic and hydroponic systems to increase crop yields in indoor farming.
- Use of the proposed technology with the scaling greenhouses technologies.

The Technical Solution

The innovative approach is suggested for treating seeds, seedlings, and plants using their innate *biophoton feedback* as a baseline for further modification. The biophoton feedback is recorded with the assistance of photon-counting equipment; then it is electronically transformed and delivered back to the plants using light-emitting diode (LED) illumination systems. Biophoton Subtle Energy Technology approach offers a unique opportunity to evaluate in “real-time” the impact of various environmental factors on the plants’ well-being by analyzing biophoton feedback without referring to biochemical analysis or long-time observation of noticeable changes. Different impacting factors can be introduced, then rapidly evaluated. The system implementation requires minimal modifications to any indoor/greenhouse plant growing facilities that use artificial light, stationary or portable.

Plants' emission of biophotons is the extremely weak radiation flux (several hundred photons per second per cm^2) in the optical range of the spectrum. This emission is observed in all living cells of plants, animals, and humans (Popp, 2003; Van Wijk, 2001; Bischof, 2005; Bajpai, 2003). According to the contemporary theory (Bischop, 2005; Bajpai, 2003; Popp et al., 1984; Popp and Li, 1993), biophotons are constantly released and absorbed by the cell's DNA, cells, and tissues, thus creating a communication network that connects all life processes in the plant or living organism. In addition, part of the biophoton flux emitted externally indicates the state of the plant's well-being. This flux is more intense in a healthy growing plant and gets weaker and less coherent in a plant that is diseased or subjected to stressful environmental conditions, such as dehydration or undernourishment (Floryszak-Wieczorek, 2011; Oros, 2018).

In its combined form, biophoton flux is recorded and analyzed using currently available, highly sensitive detectors, such as single photon counters or hyper-sensitive photomultipliers. The intensity of the biophoton flux, as well as a degree of its coherence, can be manipulated and adjusted by external conditions such as, for example, the LED illumination (the biophoton measurements are done after the illumination is seized) or use of different color filters (Oros, 2018).

The proposed technology is based on the initial finding that plants react to variations in the external LED system's light modulation, typically in the 10 to 100 kHz range. Further exploration of these light frequencies through the biophoton flux feedback would enable responsive modulation of the LED illumination light to create the most favorable growing conditions for seedlings and plants. Similarly, the light electromagnetic spectra of the LED illumination can also be optimized using this feedback mechanism. Such a customized, plant-tailored LED illumination system can create an optimized environment for indoor gardens, and vertical and hydroponics farming.

The proposed approach is fully scalable and promises an increase in productivity by improving germination rates and survival of early crop development in any seeds storage and/or during the priming process. It can also induce beneficial changes in the micro components of the plant without extra fertilizers or nutrition, enhancing environmental sustainability by preserving plant resources.

We expect the following key technical challenges and risks in bringing Biophoton Subtle Energy Technology to market:

1. Establishing the feasibility of the technology to ensure that the portable field detection device can be built and can perform its intended functions. The feasibility must also be shown in a cost-effective manner.
2. Ensuring the reliability of the technology—it must be reliable in different environments and must meet safety requirements. This requires testing, validation, and certification processes.
3. Securing intellectual property—the innovation must be protected through means such as patents, trademarks, and copyrights.

Technical Discussion

Biofield and Biophotons

Conventional biology is based on biochemical interactions and macromolecules such as DNA and RNA. Organismal biology still relies on the reductionist approach of understanding the whole organism by analyzing its parts. These approaches, although very successful in some scientific applications, do not address phenomena that need to be explained from a whole organism context (Kafatos et al, 2015). During the last 70 years, an experimental and theoretical basis for defining and confirming the existence of a coherent quantum system in living objects has been developed (Popp et al, 1984; Popp et al, 2002; Sun et al, 2010; Creath and Schwartz, 2005; Kaznacheyev and Mikhailova, 1981; Volodyaev and Beloussov, 2015; Zhao and Zhan, 2012). These findings profoundly influenced the development of Biophoton Resonance Feedback (BRF) technology, which uses plant's biofield as a reference point and a feedback mechanism. The US National Institutes of Health defines biofield as "the endogenous, *complex dynamic electromagnetic field* resulting from the superposition of component electromagnetic fields of the organism that are proposed to be involved in self-organization and bioregulation of the organisms." (Hubacher, 2015)

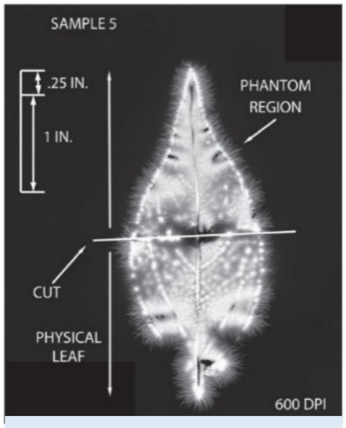

Figure 1. Example of the phantom leaf effect from Hubacher (Hubacher, 2015)

According to the contemporary theory, this "*complex dynamic electromagnetic field*" is synchronized via biophotons—the extremely weak emission of the electromagnetic waves (Figure 1). The word "*biophoton"* is used to represent a permanent spontaneous photon emission from all living systems within the spectral range of 260-800 nanometers.

Biophotons are held within the cells of a living organism, primarily within the DNA molecules of the nucleus. A constant exchange of biophotons between the DNA molecules is thought to facilitate communication between cellular organelles, cells, tissues, and organs. This light emission is believed to signal the functional state of the organism and may serve as the primary regulator of all life processes (Bischof, 2005; Popp et al, 1984; Popp and Li, 1993).

Biophotons are observed in all living cells of plants, animals, and human beings. The biophoton flux cannot be seen by the naked eye, but can be measured and recorded by special equipment that is sensitive enough to register 10-1000 photons per second. It has been observed that biophotons serve as a driving force for all biochemical reactions (Popp, 2003; Van Wijk, 2001). The delayed luminescence of biological tissues, referring to the long-term and ultra-weak re-emission of biophotons following exposure to light illumination, is tightly correlated with the excited states of the biophoton field. The physical properties show biophotons originate from fully coherent and sometimes even "squeezed" states (Popp et al, 2002).

Properties of Biophotons and Mechanism of their Action

Coherence is a characteristic of a system whereby the components of the system interact cooperatively. Coherence is established when the agents of cooperation are readily identifiable; otherwise, it may reveal quantum coherence. Both stimulated and spontaneous biophoton signals show properties that can be attributed to the cooperative actions of many photon-emitting units. But the agents accountable for the cooperative actions of units have not been discovered (Bajpai, 2003). It is speculated that an *in vivo* nucleic acid molecule is a congregation of unbalanced quantum patches that emits biophoton in quantum transitions. This might suggest that the distributions of quantum patches and their lifetimes determine the general features of biophoton signals so that the coherence of biophotons is simply a manifestation of the coherence of living systems (Beloussov, 2007; Pradhan, 2020) The ultraweak intensity of the biophoton emission due to the generation of free radicals may contribute to background biophotons. Further, the maintenance of background biophoton emissions may play a role in biophoton energy storage in particular molecules, such as proteins, that may be involved in biophoton signal transmission (Sun et al., 2010).

Another underlying mechanism that would bring biochemistry and nuclear diagnostic applications together would be the understanding of how resonance applies to biological systems. After discovering biophotons in the living cells, Popp et al. discovered that DNA is the source of biophoton emissions. He found that DNA sends out a large range of frequencies, where certain frequencies were linked to certain functions (Popp, 2003; Popp et al, 1984). It is speculated that once energy reaches a specific threshold, molecules vibrate in unison until they reach a level of coherence. The moment molecules reach this state of coherence, they take on quantum-like qualities, including nonlocality, where they operate in tandem (Hammerschlag et al, 2015; Travis et al., 2022).

Experimental Findings

Biophotons have been observed and measured since the 1970s, starting with the pioneering studies of biophysicist Fritz-Albert Popp. Since that time, over a hundred peer-reviewed academic research papers on biophotons have been published in publicly indexed scientific journals. Larger progress started in 1991, when Inaba's research group developed the first photon-counting device for measuring spontaneous ultraweak photon emission from the surface of the human body (Cohen and Popp, 1997). In the USSR, Kaznacheyev V. conducted thousands of experiments over twenty years that are in his book published in 1981 (Kaznacheyev and Mikhailova,1981). These experiments have shown that cellular information can be transmitted and induced in target cells via electromagnetically absorbed photon radiation.

Interest in biophotons started with the works of Gurwitsch, who conducted a famous experiment in 1923 on a "non-chemical external impulse" with two onions (the "emitter" and the "recipient"), which were placed perpendicular to each other. The authors calculated the number of mitotic figures in the "recipient" root in the exposed and non-exposed halves of the root. The exposed side possessed a significantly higher proportion of cells in mitosis than the non-exposed side. This phenomenon was named the "mitogenic effect" (MGE). MGE was also detected if a quartz plate was fixed between the two roots but was not detected if the roots were separated with glass. Based on these and other data, the acting factor was concluded to be ultraweak photon emission and was called "mitogenic radiation" (Zhao and Zhan, 2012).

The phenomenon by which irradiated organisms, including cells *in vitro,* communicate with unirradiated neighbors is well established in biology as the radiation-induced bystander effect. The exact mechanism is not yet known, but researchers have evidence that physical signals like biophotons impacting cellular photoreceptors may be involved. Communication between cells is thought to possess a protective and adaptive purpose, which is a widely preserved evolutionary trait allowing for quick responses to environmental stressors.

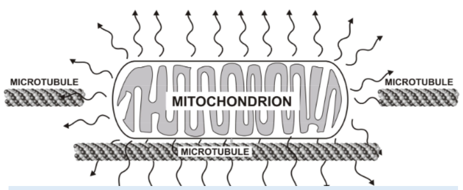

Figure 2. Biophotons produced by mitochondria; and the interaction of biophotons with microtubules.

Biofield interactions could also be responsible for the organization of cellular microtubular networks (Figure 2) and biological regulation processes that have been shown to occur via endogenous electromagnetic fields within microtubular cytoskeletons such as regulating the dynamics of mitosis and meiosis, chromosome packing during the mitotic phase of the cell cycle, and interactions between ion channel activities (Zhao and Zhan, 2012; Jibu et al, 1994; Rahnama et al, 2011).

Influence of the Environmental Pollution

The increasing presence of environmental pollutants has been disrupting bio-photonic communication in all living organisms, leading to detrimental effects on health. To combat this, it is imperative to reduce the levels of environmental pollutants and toxins resulting from agriculture to safeguard the health of plants and consumers. The ability of plants to absorb chemical components from the soil and nutrients is also decreasing, resulting in diminished agricultural yields and reduced nutritional value of the produce. BFR technology can successfully capture the biophoton patterns of healthy plants, and then deliver the holographic biophoton image to the target plants, enabling their optimal growth. The damaging effect of

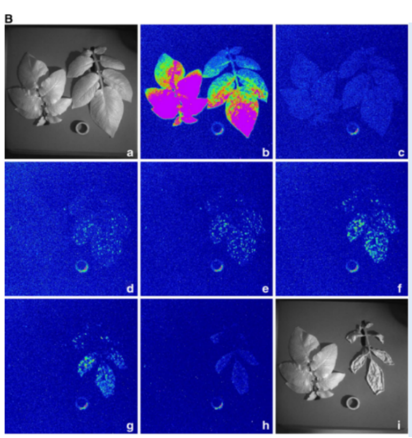

Figure 3. Imaging of biophoton generation from potato leaves during late blight (*Phytophthora infestans*) development.
a) The first panel provides a starting photo of inoculated potato leaves—*P. infestans* resistant cv. Bzura (left) and susceptible cv. Bintje (right).
b) The second panel shows quenching of leaf autofluorescence.
c–h) The sequence of images presents a pattern of biophoton generation in the dark for 1, 24, 48, 72, 96 and 120 hours after inoculation.
i) The last panel provides a photo of infected leaves of both cultivars at 120 hours after *P. infestans* inoculation.

environmental pollutants on the well-being of plants is shown in Figure 3, which illustrates the diminishing biophoton emission from the leaves affected by the fungal infection (Floryszak-Wieczorek et al., 2011).

Biophoton Emission Kinetics

In the proposed approach, biophoton emission is utilized to show a natural and lasting photon emission connected to oxidative activities in cells and appears to be ubiquitous ***in all*** living systems due to the formation of reactive oxygen species (ROS) that are developed under tension conditions. Measuring this biophoton emission provides a non-invasive way of monitoring the phenological phases throughout plant growth, which has direct applicability in agricultural studies (Prasad et al, 2020).

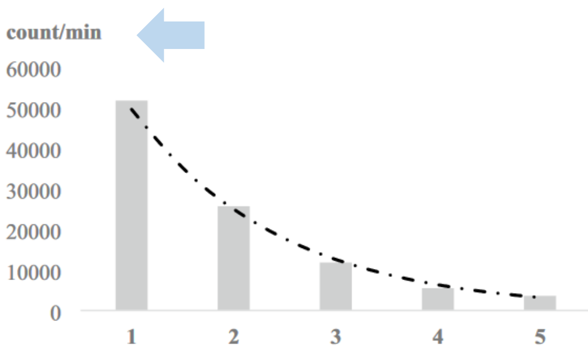

Figure 4. An example of a biophoton emission intensity decay with fitted exponential regression curve from the control group, leaf A, R2=0.9912.

Experimental results showed (Ponya and Somfalfi-Toth, 2022) that the biophoton emission signal (Figure 4) decayed exponentially with distinctive dynamics that seem to reflect the different physiological states triggered by stress. The signal decay varied depending on the type of stress (biotic or water) applied, suggesting a possible connection between the kinetic features of the signal intensity decay and stress. This implies that although stress brings about intricate and complicated changes in the oxidative metabolism of biological systems, biophoton imaging may be used to noninvasively monitor the oxidative processes spurred by stress with various applications, especially in nutrient-targeted agriculture.

The potential of the proposed research is based on the observation that ultra-weak biophoton emission is linked to metabolic processes, especially with the production of reactive oxygen species (ROS). This type of emission is between 200 to 800 nm (Slawinski and Popp, 1987) and its intensity is several orders of magnitude below the sensitivity of the human eye, with values between a few and a few hundred photons per second per square centimeter. It has been noted that a change in the kinetics of biophoton emission (for example, delayed fluorescence) reflects a change in physiological conditions due to stress, as the energy necessary for auto luminescence appears to come from the transition of excited biological molecules during relaxation to a lower energy state (Popp, 2003; Popp, 1994). Considering that an increase in ROS triggers an augmented biophoton emission, it was observed that stress applied to test plants induced biophoton emission with different kinetics depending on the induced type of stress (Popp, 2003).

In another study, the molecular mechanism underlying biophotons production by living cells was explored via an analysis of the biophoton spectra in the human skin following ultraviolet irradiation (Tsuchida and Kobayashi, 2020). The results revealed that the spectral patterns were distinct for various biomolecules and differed from those of the skin tissue. This indicated that biophotons generated from the skin tissue represent a collection of light emitted by biomolecules. Tsuchida and Kobayashi believed that this biophoton flux forms through a photosensitization reaction in energy transfer. The specific biophoton spectrum that was identified could potentially be used to explain ultra-violet-radiation-induced oxidative stress in the skin and may have applications for the prevention of skin diseases.

A recent study highlighted distinctions in the spectral profiles of biophoton flux from the body surface of human breast cancer-bearing nude mice and healthy control mice (Zhao et al, 2017).

These findings underscore the importance of spectral analysis in biophoton emission research and lay a basis for the experimental setup used in the proposed biophoton resonance feedback approach.

Three-Stage Biophoton Subtle Energy Technology Experimental Setup

Biophoton Subtle Energy Technology can create specific plant-oriented signals, based on their bio-photonic network characteristics, and then transmit them to the targeted plants using various ways of delivery. The process involves three stages.

In Stage I a hologram, resulting from the interference of high-frequency generator and the plant fluorescence emission, is captured by the charged-couple device (CCD). The signal from the CCD is evaluated by the spectrum analyzer, where it is transformed into a digital signal suitable to be used by LEDs in the next stage.

Stage II is based on the photon detection unit, a single photon counting setup designed for registering low light emissions without special tuning. This system allows for registering biophoton flux from a sample while it is illuminated by different LEDs. A digital spectrum signature created in the previous stage is used for LEDs modulation.

After illuminating a biological test sample with this modulated emission, a delayed fluorescence intensity is recorded. In this way, different modulation patterns can be evaluated by comparing the fluorescent intensity of the plant sample before and after LED light processing with the help of Light Technology MIG.

As soon as the favorable digital spectrum signature is chosen, it is transported to Stage III of the technology where the test plants are grown in a controlled environment while illuminated by LED light electronically processed with the chosen modulation pattern.

After the growing cycle for the test plant is finished, the plant is evaluated for biochemical, genetic, and physical changes.

Commercial LED Lighting Modification for Biophoton Subtle Energy Technology

LED illuminating systems have various advantages over traditional lighting for indoor farming. They are more energy efficient and provide a more even distribution of light, which can be tailored to the specific needs of the plants. LED systems produce very little heat, reducing the load on cooling and ventilation systems, as well as minimizing the risk of overheating the plants. LED systems also last much longer than traditional lighting systems and are more resistant to water damage, so they do not need as frequent repair or replacement. They can produce more intense light than traditional lighting systems, which can help increase crop yields.

LED lamps are available in a variety of power and provide aimed spectrums that can be beneficial for certain plants. The most suitable LED system for the suggested Biophoton Subtle Energy Technology research is the Spider Farmer G8600 LED Grow Light Full Spectrum Commercial Grow CO2 Indoor system. The G8600 has a unique 8-bar LED grow light design (Figure 5) that provides more uniform and comprehensive canopy coverage, especially at the edges of cultivated areas. With 2968 Bridgelux diodes, the G8600 plant growing light can reach 860 watts of power, achieving an impressive PPE of 2.8 μmol/J, and covering 4×4 feet of commercial full cycle growth. The full spectrum LED lights (3200-4200K, 4800-5000K, 650-665 nm) provide different wavelengths of light ideal for every stage of plant growth from seed to harvest. The dimmable LED grow lights are ideal for growers to adjust the light intensity for different growth stages and save on growing costs. Spider Farmer G8600 LED Grow Light is designed specifically for indoor farming, offering a high level of energy efficiency and adjustable spectral output. It is suitable for starting seedlings but also provides enough light for vegetative and flowering stages.

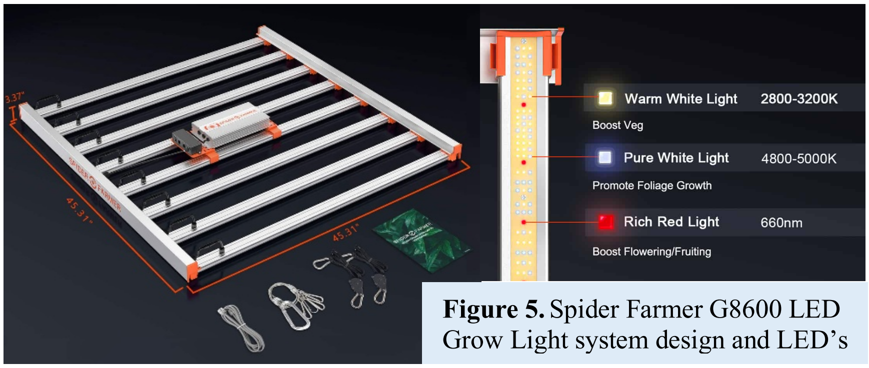

Figure 5. Spider Farmer G8600 LED Grow Light system design and LED's

The design of this light system (Figure 5) allows for an easy installation of the additional standard RJ11 data cable that will transfer electrical signal modulations (formed at Stage I of the technology—Figure 5) to the dimming unit Spider via Farmer LED Grow Light Controller handling the light system.

In time, it is hoped that more statistical data on different plants and the variety of their strains will be collected for the creation of a database, allowing for more targeted recommendations regarding the biophotonic spectrum patterns to be used, as well as how to reduce overall water and fertilizer consumption and target nutrients of interest.

R&D Plan

The key objectives to be accomplished during research, besides research and scientific experimental data collected during the testing stages outlined in the previous chapter, include:

1. *Technical feasibility*: This includes determining the technical requirements for Biophoton Subtle Energy Technology to match agricultural standards, assessing the availability of necessary resources for the technology development, and gauging the complexity and cost of developing and delivering the proposed approach.
2. *Identifying and validating the target market*: This includes understanding the needs of the target market, which is at this stage is focused on agriculture, assessing farmers and growers' willingness to pay for the proposed technology, and evaluating the size of the addressable market.
3. *Commercialization*: This includes analyzing the competitive areas in the agricultural market, assessing the potential for farmers to adopt this technology and improve adoption rates, and evaluating the profitability of the technology if accepted by 10% of the potential customers.

Broader Impacts

Biophoton Subtle Energy Technology is an innovative approach that deals with the interaction of light and biological systems. It is a non-invasive, low-cost method of diagnosing and treating a variety of agricultural products, resulting in better quality food capable of mitigating the detrimental effects of environmental toxins, such as heavy metals, which are now ubiquitous in our food and other consumables.

Biophoton Subtle Energy Technology can also improve the efficiency of food production, reduce waste, and reduce the environmental impacts associated with agricultural practices. Additionally, the technology has the potential to facilitate the development of precision agriculture, which can enable farmers to use the best practices to optimize crop yields, while also reducing the amount of water, fertilizer, and energy resources used in the production process. Finally, this technology can monitor the health of crops, which can help to detect and prevent disease outbreaks.

Biophoton Subtle Energy Technology offers the potential for broader societal and economic benefits by improving the health and welfare of the American public, offering them less expensive yet more potent produce, and enhancing partnerships between academia and agriculture in the United States.

Biophoton Subtle Energy Technology can provide a broad range of economic and societal benefits, including an increase in the economic competitiveness of the United States. To realize these outcomes, a comprehensive implementation plan must be developed. The first step in the implementation plan should be the identification of relevant metrics and the associated measurement plan. The next step should be to identify potential partners to enhance the likelihood of success.

Overall, the Biophoton Subtle Energy Technology has the potential to deliver broad-ranging benefits to society, the economy, and the environment. By working with partners across multiple sectors, MIG-Tech Lab team is poised to make significant advances in this exciting and promising field.