19th International Conference on Food Industry Sciences, Organic Farming and Food Security
نوزدهمین کنفرانس بین المللی علوم صنایع غذایی، کشاورزی ارگانیک و امنیت غذایی | گرجستان
Event Place: Tbilisi,Georgia
www.fsaconf.ir
19th International Conference on Food Industry Sciences,Organic Farming and Food Security
مجلات معتبر بین المللی

Electromagnetic waves and their application in precision agriculture

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Abstract

Modern agriculture is a new approach based on the use of advanced technologies and new techniques to optimize food production processes, reduce costs and increase productivity. This type of agriculture seeks to use natural resources more efficiently and minimize environmental impact through the use of modern machinery and tools. Awareness of new plant cultivation technologies and their acceptance by farmers leads to freedom from climatic constraints and to sustainable agricultural, economic and ecological development. Electromagnetic waves are one of the most widespread and fascinating concepts in physics that play an important role in our daily lives. These waves move through space and have the ability to transmit energy. Electromagnetic waves are referred to by different names depending on their frequency: Radio waves, microwaves, infrared, visible light, ultraviolet, X-rays and gamma rays. Modern agriculture leverages science and technology to boost crop production and sustainability. One such innovation is the use of electromagnetic waves. the most important applications of electromagnetic waves in modern agriculture are soil analysis, remote sensing, pest control, irrigation management, precision agriculture, inspection and storage of food and agricultural products, and livestock monitoring.

Keywords: Electromagnetic waves, irrigation, modern agriculture, pest control, soil analysis

Introduction

The Earth is facing significant challenges due to harsh environmental conditions resulting from global climate change. These issues are exacerbated by a growing population and its increasing demands for food, water, housing, and energy, complicating the situation even further. The competition for vital resources among various communities threatens the stability of human civilization (FAO, ٢٠٢٣). At the same time, agriculture is crucial in tackling these issues, even though it also contributes to significant challenges. A key challenge posed by global population growth is achieving food security. A fundamental strategy for ensuring food security involves the development and management of agricultural systems, as well as the preservation of water and soil resources (Johnson, ٢٠٢٤). The quantity and quality of agricultural production can differ greatly, primarily due to the influence of management techniques and environmental conditions. Climate change presents a significant risk to global agricultural sustainability. Agriculture plays a crucial role in the gross domestic product of developing nations. The various effects of climate change on agriculture include extreme weather events like droughts, heatwaves, irregular rainfall, storms, floods, and new pest and diseases outbreaks, all of which are hindering agricultural output. Farmers' socioeconomic conditions are especially susceptible to these climatic extremes, with future forecasts suggesting a notable rise in temperatures and unpredictable, heavy rainfall. Traditionally, agriculture has depended on the widespread use of synthetic fertilizers, herbicides, and insecticides, along with improvements in irrigation and biotechnology to enhance productivity (Verma *et al*., ٢٠٢٤). Agricultural management plays a crucial role in the practices and processes associated with farming. The introduction of advanced technology and modern management techniques provides a fresh perspective on agricultural production, which could significantly impact the environment. These innovative management strategies can be seen as essential solutions for conserving natural resources, ensuring food security, and enhancing community dynamics (Liang *et al*., ٢٠٢١; Khan *et al*., ٢٠٢١; Reddy, ٢٠٢٢). Modern (precision) agriculture uses innovative technologies and methods to improve food production, reduce costs and increase efficiency. This approach focuses on using natural resources more effectively while reducing the impact on the environment through the use of modern machinery and equipment. In modern agriculture, advanced technologies are widely used to optimize agricultural processes. These technologies include drones, smart sensors, agricultural robots, data management systems, the use

of nanotechnology and the use of electromagnetic waves to help farmers increase their productivity and use resources more efficiently (Yimer *et al.*, ۲۰۱۹; Júnior *et al.*, ۲۰۲٤). Systematically observing, measuring, and responding to temporal and spatial variability within agricultural systems, precision agriculture utilizes advanced technologies, sophisticated data analysis techniques, and cutting-edge tools like variable rate technology (VRT), automation, and decision support systems (DSS). A novel method in precision agriculture involves utilizing electromagnetic waves to address agricultural issues. Electromagnetic waves are a prevalent and intriguing phenomenon in physics, capable of traveling through space and transmitting energy. The use of electromagnetic fields (EMF) such as radiation, microwaves and infrared in precision agriculture holds great potential for improving resource utilization, environmental protection and system resilience. The technology has already shown promising results in various physiological and biochemical aspects of plant growth and development. However, the underlying mechanisms for the stimulating effects of EMF are not yet fully understood. Further studies are needed to explore biochemical and molecular aspects and to determine the appropriate doses and exposure levels for different plant species, as higher doses and long-term exposure to radiation can have detrimental effects. Numerous reports on the irradiation of seeds or plants with UV radiation, gamma rays, ultrasound and ionizing radiation have shown significant effects on the growth and development of plants. However, defining treatments and replicating results are critical to developing reliable and cost-effective tools for collecting information on plant responses to electromagnetic radiation. It is important to be cautious when researching EMFson EMF in agriculture as biological systems are susceptible to radiation. Preventive measures must be taken to ensure the safety and well-being of plants and the environment (Kouzmanova et al., ۲۰۲٤; Cama-Pinto et al., ۲۰۲۱; Said *et al.*, ۲۰۲٤). In this short review article, we will try to mention the main applications of electromagnetic waves in precision agriculture and give brief explanations of their mechanism and use.

Types of electromagnetic field radiation

Electromagnetic radiation consists of synchronized oscillations of electric and magnetic fields perpendicular to each other and the direction of energy and wave propagation. These propagate as electromagnetic waves. Electromagnetic radiation can be visible light, radio waves, microwaves, and X-rays (Figure ۱) (Chen *et al.*, ۲۰۲٤; Polo & Lakhtakia, ۲۰۱۱). It can travel through space and can even penetrate solid objects. Electromagnetic radiation is also used in many applications,

such as communication, medical diagnostics and therapies, and imaging. Electromagnetic radiation comprises various frequencies and wavelengths that make up the electromagnetic spectrum (Ishimaru, ۲۰۱۷). This spectrum begins with longer wavelengths of non-ionized radiation with low energy, such as radio waves and microwaves, continues through infrared and visible light, and extends to shorter wavelengths of radiation with higher energy, such as ultraviolet, X-rays and gamma rays (Kouzmanova *et al.*, ۲۰۲٤).

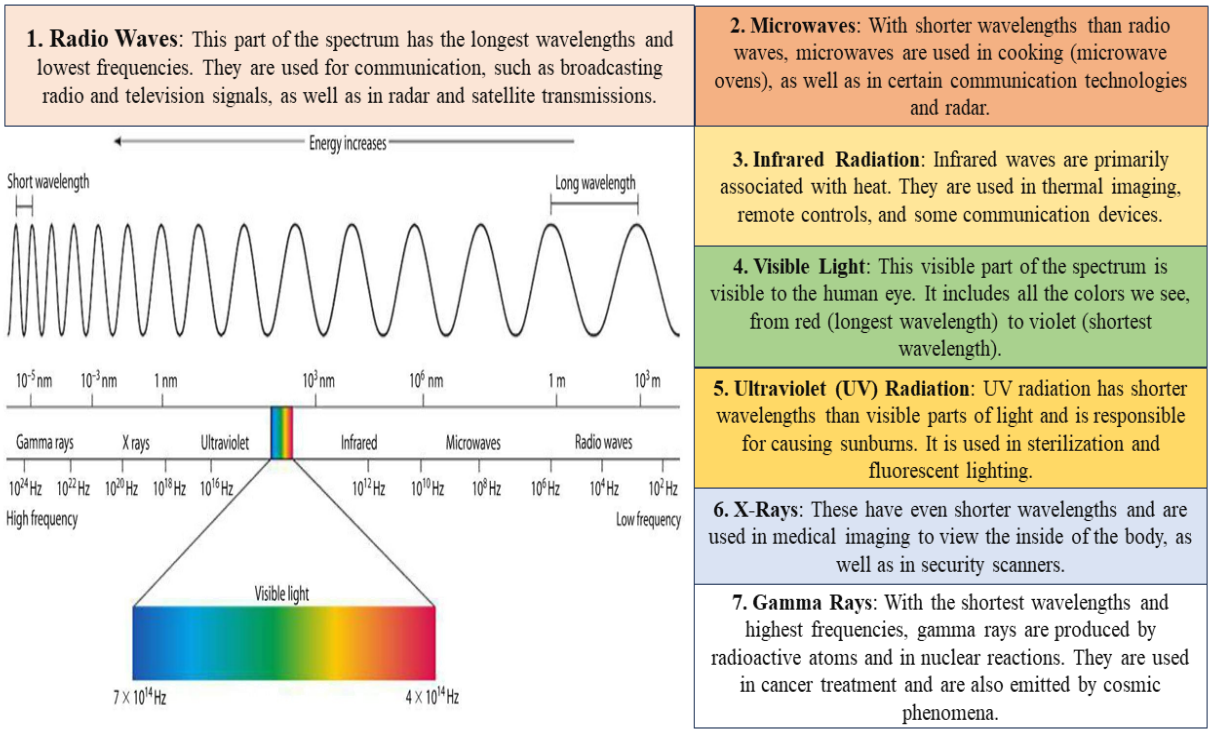

Figure ۱. Schematic representation of the electromagnetic spectrum with the different segments of the spectrum: γ-rays, X-rays, ultraviolet, visible light, infrared, microwaves and radio waves.

Microwaves are mainly used for high bandwidth communication systems, while radio waves are used for cellular communication. Radio-frequency electromagnetic fields (RF-EMFs) are man-made, non-ionizing radiations that do not occur in nature, with the exception of very high frequency, low amplitude cosmic rays. RF EMFs have frequencies from ۳۰۰ MHz to ۳ GHz and wavelengths from ۱ m to ۱۰ cm. These fields are used in wireless technology applications such as cell phones and Wi-Fi devices. The widespread use of wireless telecommunications leads to electromagnetic pollution in urban and rural areas (Amineh, ۲۰۲۰).

Applications of Electromagnetic Waves in Agriculture

Electromagnetic waves have been utilized in agriculture for various purposes, including remote sensing, imaging, quality assessment, and dielectric heating during both pre-harvest and post-harvest stages. This discussion will focus on applications that specifically involve the warming effect of electromagnetic waves. Among the various methods used in agriculture, Radio Frequency (RF) power is recognized as a physical (non-chemical) thermal technique. This method operates on the same principle as heating food to eliminate bacteria and can be employed to disinfect a range of food and non-food items, including soil. Additionally, RF technology can also be applied to assess soil parameters and measure soil salinity. Contemporary farming utilizes scientific advancements and technology to enhance crop yield and sustainability. One notable innovation involves the application of electromagnetic waves. Let's examine the seven primary uses of this technology in agriculture (Manickavasagan & Jayasuriya, ٢٠١٤; Popescu & Safta, ٢٠٢١; Zeng *et al.*, ٢٠٢٢).

Figure ١. Schematic representation of the Applications of Electromagnetic Waves in Agriculture

Remote sensing relies on the interaction between different phenomena and electromagnetic waves. This interaction can be characterized by the ratio of wave absorption to reflection. The way electromagnetic waves are absorbed and reflected across various spectral ranges is referred to as spectral behavior. This spectral behavior can be illustrated through a spectral diagram, which is a two-dimensional vector with a horizontal axis for wavelength and a vertical axis for reflection intensity. Knowing and understanding spectral behavior helps to gain the following information: ١- Understanding how different phenomena are represented in satellite images ٢- Selecting the optimal bands when processing satellite images ٣- Understanding the performance of bands in spectral indices ٤- Designing new spectral indices ٥- Predicting the performance of spectral indices (Popescu & Safta, ٢٠٢١). Remote sensing employs electromagnetic waves to detect and measure characteristics of agricultural fields from a distance. These data are crucial for crop forecasting, assessing drought conditions, and monitoring overall crop health. Certainly, recognizing, understanding and analyzing these spectra in the agricultural ecosystem can play an important role in improving plant performance and behavior. Soil analysis is a process that uses various chemical

reactions to examine the chemical, physical and biological properties of the soil, which benefits plant nutrition and soil health. Soil analysis can determine the amount of chemicals such as nitrogen (N), phosphorus, potassium, organic matter, carbon content, sulfur content, lime content as well as the physical properties of the soil such as color, structure, water holding capacity, permeability, density and pH (Sparks *et al*., ۲۰۲۰). Electromagnetic waves can be used in soil analysis to gauge soil properties like moisture content, nutrient levels, and salinity. Through this information, farmers can tailor their cultivation practices to suit the specific soil conditions, increasing productivity. Chemical pest control and the use of poisons have been practised for more than half a century. The excessive use of these poisons has led to numerous human diseases, environmental pollution and increased resistance of pests to this type of control. Today, the ban on the use of these substances is on the global agenda, so the importance of non-chemical and non-destructive pest control methods has increased. The goals of non-chemical pest control include striving for sustainable agricultural development, reducing the possibility of resistance development in target pests, reducing pesticide residues and the harmful effects of chemicals on products and the natural environment, reducing health and medical costs to society, enabling the production of healthy and organic products and much more. This includes the use of several areas of electromagnetic waves that have been targeted by researchers and scientists (Abd El-Ghany *et al*., ۲۰۲۰; Balmori, ۲۰۲۱). Using specific frequency ranges, electromagnetic waves can serve as an effective method of pest control. These frequencies can deter pests or disrupt their life cycles, minimizing crop loss without the use of harmful chemicals (Costa & Marra, ۲۰۲٤). The effect of magnetism on water was observed by chance by Russian scientists. The movement of water in the pipes leads to the deposition of salts on the walls of the pipes, which reduces the cross-sectional area of the pipes and increases the loss of energy, so that the flow of water in the pipes is disturbed. They found that magnetized water cleans the mass inside the pipes and prevents it from redepositing on the walls of the pipes. It was thus observed that by applying magnetic energy, normal water can be transformed into a liquid with specific chemical effects, so that the physical properties of the magnetized water, including temperature, specific gravity, surface tension, viscosity and electrical conductivity, change. One of the changes that occur in magnetized water is the arrangement of the electrical charges of the water molecules. As a result, the electronic charge of the water molecules in these conditions will be different from that of ordinary water and,

in addition to forming smaller molecules than water, it increases the number of water molecules per unit volume and also increases the solubility of water. In other words, a normal water molecule is left-handed and becomes right-handed. Through the application of electromagnetic waves, irrigation management can be optimized. It allows farmers to determine the moisture content of the soil accurately, thereby helping to prevent over or under-watering of crops (Terlizzi *et al*., ٢٠٢٤; Ignatov *et al*., ٢٠٢٤). Precision agriculture or smart agriculture is a type of calculated agricultural management that, using accurate and calculated information and employing modern agricultural tools, can produce the highest yield with the least cost and environmental damage. Today, the most fundamental issues to be examined in precision agriculture are GPS positioning systems, remote control, smart irrigation systems, crop yield zoning and soil type zoning, soil testing, geographic and climate information zoning systems, seed testing, remote sensing, and the consequences and effects of precision agriculture. Although precision agriculture usually has a high initial investment cost, increasing crop production, reducing water consumption and pesticide and fertilizer inputs, as well as reducing human costs, will make this technology widespread and sustainable in the near future. Electromagnetic waves are integral to precision agriculture, providing real-time information about the condition of crops and fields. (Shafi *et al*., ٢٠٢٩; Cisternas *et al*., ٢٠٢٠). Developing the agricultural sector based on self-reliance and improving the quality of food products requires conducting scientific research and using modern technologies. The quality and health of agricultural products is a result of the condition and quality of soil, water, inputs, living organisms, the harvesting process, processing, and supply of products. Under proper management, it can be improved, and even the production of certified products is considered an important step in this area. One of the important issues in the quality of agricultural products is providing modern, healthy, and accurate methods for analyzing the quality of food and agricultural products. Food quality assessment often involves electromagnetic waves to determine properties like water content, sugar levels, and ripeness. This non-destructive method helps ensure quality and safety (Ling *et al*., ٢٠٢٠; Akhila *et al*., ٢٠٢١). Livestock monitoring using electromagnetic waves helps farmers to track the health and well-being of their animals, aiding in the early detection of diseases and improving animal welfare. Magnetic and electromagnetic fields also inactivate bacteria in the water, which in turn reduces disease and consequently Livestock mortality (Aleluia *et al*., ٢٠٢٢; Henry *et al*., ٢٠١٨).

Conclusion and future perspectives

Modern agricultural methods are measures and technologies that aim to increase productivity, reduce negative effects on the environment, increase agricultural production and improve the living conditions of farmers. Electromagnetic waves are undoubtedly one of the highly efficient new methods in agriculture that can be used effectively in the near future in the areas of management and increasing the quantity and quality of agricultural products. Establishing chairs for the application of magnetic sciences in agriculture in universities, expanding research in this field, providing the necessary resources and facilities, and encouraging researchers to study the application of these waves in agriculture can play an effective role in increasing the quantity and quality of agricultural products and the economic and political dimensions of society.

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