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Innovative eco-agroindustrial management with solar energy using magnetic fields to control pests

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Abstract. Introduction : Innovative eco-agroindustrial management seeks to promote effective and sustainable solutions for the control of pests, such as whiteflies (Bemisia tabaci Genn.), through the use of solar-powered magnetic fields. **Objective:** To develop and promote an electromagnetic model for pest control in agricultural crops, with emphasis on its commercial viability within the agroindustrial sector, offering an economic, efficient and environmentally friendly solution on a large scale. **Method:** The proposed system uses variable frequency magnetic fields, powered by solar energy, for the control of whiteflies in bean crops (Phaseolus vulgaris L.), guaranteeing a scalable and profitable solution for producers. **Results** : This system has proven to be effective, reducing operating costs and environmental impact, while facilitating its implementation on a large scale. **Conclusions:** The model has high commercial potential, promoting cleaner, more profitable and sustainable agriculture.
Keywords: Eco-agroindustrial, pest control, magnetic fields, solar energy, sustainable agriculture.

Gestión innovadora eco-agroindustrial con energía solar mediante campos magnéticos para controlar plagas

Resumen. Introducción: La gestión innovadora eco-agroindustrial busca promover soluciones efectivas y sostenibles para el control de plagas, como las moscas blancas (Bemisia tabaci Genn.), mediante el uso de campos magnéticos alimentados por energía solar. **Objetivo:** Desarrollar y promover un modelo electromagnético para el control de plagas en cultivos agrícolas, con énfasis en su viabilidad comercial dentro del sector agroindustrial, ofreciendo una solución económica, eficiente y respetuosa con el medio ambiente a gran escala. **Método:** El sistema propuesto utiliza campos magnéticos de frecuencia variable, alimentados por energía solar, para el control de moscas blancas en cultivos de frijol (Phaseolus vulgaris L.), garantizando una solución escalable y rentable para los productores. **Resultados**: Este sistema ha demostrado ser eficaz, reduciendo costos operativos y el impacto ambiental, a la vez que facilita su implementación a gran escala.
Conclusiones: El modelo tiene un alto potencial comercial, promoviendo una agricultura más limpia, rentable y sostenible.
Palabras clave: Eco-agroindustrial, control de plagas, campos magnéticos, energía solar, agricultura sostenible.

Gestão inovadora ecológico-agroindustrial com energia solar usando campos magnéticos para controle de pragas

Resumo. Introdução: A gestão inovadora eco-agroindustrial visa promover soluções eficazes e sustentáveis para o controle de pragas, como as moscas-brancas (Bemisia tabaci Genn.), por meio de campos magnéticos alimentados por energia solar. **Objetivo:** Desenvolver e promover um modelo eletromagnético para o controle de pragas nas culturas, com ênfase na viabilidade comercial dentro do setor agroindustrial, oferecendo uma solução econômica, eficiente e ecologicamente responsável em larga escala. **Método:** O sistema proposto utiliza campos magnéticos de frequência variável, alimentados por energia solar, para controlar as moscas-brancas nas culturas de feijão (Phaseolus vulgaris L.), garantindo uma solução escalável e rentável para os produtores. **Resultados**: Este sistema tem se mostrado eficaz, reduzindo custos operacionais e o impacto ambiental, além de facilitar a implementação em grande escala.**Conclusões:** O modelo tem grande potencial comercial, promovendo uma agricultura mais limpa, rentável e sustentável.
Palavras-chave: Eco-agroindustrial, controle de pragas, campos magnéticos, energia solar, agricultura sustentável.

1. Introduction

Innovative Pest Control Management with Eco-Friendly Solar Powered Equipment with Magnetic Fields effectively addresses several common problems in agriculture, offering a comprehensive and sustainable solution. First, it replaces the use of chemical pesticides, which can damage ecosystems. and affect human health, with a toxic-free approach. By using solar energy, the use of renewable resources is optimized, reducing operating costs and dependence on polluting energy sources.

The whitefly Bemisia tabaci (Gennadius) as a pest and virus vector in common beans is a problem that poses an urgent challenge for agriculture, requiring the development of comprehensive pest management strategies that combine biological control, the use of resistant varieties and sustainable agricultural practices. This problem is exacerbated by the following characteristics:

The high incidence of whitefly and begomovirus in strategic crops such as beans. The lack of effective and sustainable control tools , such as resistant varieties. The dependence of farmers on the use of insecticides , which generates long-term environmental and economic problems.

According to Cuéllar MA, Morales FJ (2006) The whitefly (Bemisia tabaci) , a widely distributed insect pest, represents a serious threat to agricultural production in Colombia and other tropical regions. Its effects on crops, such as the weakening of plants, the transmission of viral diseases and the proliferation of fungi, generate significant economic losses.

Begomoviruses , a group of viruses transmitted by whiteflies, are particularly damaging to crops such as beans. In Colombia, the coincidence of the arrival of the B biotype B of B. tabaci with favorable weather conditions has led to the rapid spread of these viruses.

The lack of virus-resistant varieties and poor technical assistance have forced farmers to rely heavily on the use of insecticides to control the pest. However, this practice creates environmental problems and can lead to the development of resistance in insects.

In addition, the study by Zepeda Bautista, Rosalba et al., (2019) evaluated the impact of exposure to electromagnetic fields (EMF) on corn productivity and quality. Seeds of different corn varieties were subjected to different exposure times to an EMF of 3.6 mT. The results showed a significant increase in germination and seedling establishment in seeds exposed for 24 minutes. Likewise, an increase in yield per hectare was observed in some varieties. However, the presence of fungi of the *Fusarium genus* in the grain was not consistently affected by EMF treatment. In conclusion, the results suggest that the application of electromagnetic fields before sowing can improve certain aspects of the initial development of the corn crop, but additional studies are required to determine the long-term effect and optimization of treatment parameters.

1.1. Benefits of creating and managing simple equipment to control some pests.

To develop and promote an electromagnetic model for pest control in agricultural crops, with emphasis on its commercial viability within the agro-industrial sector, offering an economical, efficient and environmentally friendly solution on a large scale; magnetic fields generated by the system are considered to alter the behavior and reproduction patterns of pests, such as whiteflies, interrupting their life cycle in a precise and controlled manner. This method minimizes damage

to crops, improves the efficiency of pest control and, at the same time, reduces the overexploitation of chemicals, promoting soil health and biodiversity.

In several countries, agriculture is dependent on the use of agrochemicals, both for nutrition and for the control of weeds, pests and plant diseases. Pest control is known to be one of the most costly issues in economic terms, and is also the origin of the largest number of restrictions on the export and consumption of agricultural products. It also has a high environmental impact, harming human health, the extinction of species of pollinating insects, such as bees and others; seriously affecting biodiversity and the environment in general in the short, medium and long term; altering not only the soil, but also the water, air quality, and biodiversity. It also affects the quality of life of human populations, without ruling out the increase in production costs that the use of agrochemicals implies (Gould, 1980).

The use of chemical pesticides in agriculture has serious implications for the quality of products, mainly in terms of requirements for human consumption and export. This also represents a high environmental and health cost in the long term, which has already generated alerts mainly in the commercial, productive, health, food and international legislation spheres, with humans being the main affected party. It is becoming increasingly necessary to seek alternatives so that agricultural production is more friendly to the environment, the health of consumers and the conservation of ecosystem services (Portilla Farfán, 2003).

The economy depends largely on agricultural production. Much of this production is based primarily on the use of agrochemicals for agricultural management. This research is proposed with the purpose of finding alternatives to reduce the environmental impacts of the use of pesticides generated when treating crop pests. The aim is to evaluate the use of photovoltaic energy for the creation of magnetic fields that generate direct insulation between the insect attack and the agricultural crop. Based on comparative studies, it has been determined that insects can be controlled by inhibiting the functioning of the locomotor system guided by their antennae through the creation of electromagnetic fields (Anderson and Vander Meer, 1993; Schiff, 1993; Vácha, 1997).

Agriculture is fundamental in most Latin American countries, which is why it is necessary to create technology that counteracts the factors that cause economic deficits in producers, such as insect attacks and crop diseases. It is established that the control of insect pests through magnetic fields would be the key point to contribute to protecting the environment and generating alternatives to avoid the use of chemical products. This article has been prepared to present the data obtained in a field experiment with favorable results that have shown the decrease in populations of *Bemisia tabaci* Genn., as a pest that affects the economic threshold on agricultural crops, especially *Phaseolus vulgaris* L.

This research aims to find solutions to reduce the use of chemical products in pest control in crops of small, medium and large producers. The aim is to establish a new form of agricultural production in the not-too-distant future, allowing production without contamination or alteration of agricultural crops, and in which an integrated pest management (IPM) approach is promoted, based on magnetic fields through an inverter based on solar radiation. This in turn will allow changing paradigms regarding agricultural production at a global level (Chirinos, *et al* ., 2020).

2. Methodology

To demonstrate the innovative management of pest control with ecological solar energy equipment with magnetic fields, the following hypothesis is proposed:

2.1. Hypothesis

Ho = All voltage levels and electromagnetic fields produce the same effect on whitefly (Bemisia tabaci Genn.) on beans (Phaseolus vulgaris L.)

Ha = At least one voltage level produces a different effect on whitefly (Bemisia tabaci Gen) in beans (Phaseolus vulgaris L.)

2.1.1. Response variable : Number of dead whitefly insects (Bemisia tabaci Genn.).

2.2. Treatments: The energy used was produced through a solar system, which fed an inverter and through a regulator the voltage for the required frequency was determined. The frequency indicated the voltage of the magnetic field generated and then the dead insects were counted.

Volt Treatments

TA.....10

TB.....15

TC..... 20

TD..... 30

To perceive the number of dead insects in the measurements, the treatments are arranged horizontally in Table 1 in the Results section.

3. Results

For Innovative Pest Control Management with Ecological Solar Energy Equipment with Magnetic Fields, in the first instance it is necessary to resort to the experimental process shown in Table 1

Table 1. Average dead insect count after 15 days.

Repeat 10 volts	15 volts 20 volts 30 volts
1	20 18 20 18
2	19 16 2214
3	17 16 2216
4	16 18 2016

Source: Own elaboration

Interpretation of Table 1: Four treatments were used for four repetitions and four readings were taken; it was inspected that in the four repetitions, for 20 volts the greatest number of dead flies was obtained with an average of 21 dead flies.

After obtaining the averages and analyzing variances, the groups with significant differences in their means are determined, then the Tukey means test is applied, shown in Table 2; that is, after knowing the measurements, the voltages and means of dead flies are arranged vertically and the

Tukey means test is applied (fundamental when performing a variance analysis with several groups, to identify the groups with significant differences in their means).

Table 2. Tukey's mean test

Treatment	Average number of dead flies	Significance
20 volts	21	A
10 volts	18	B
15 volts	17	B
30 volts	16	B

Source *:* Field work

Interpretation of Table 2. The treatment with the highest efficacy is 20 volts, as it has the highest mean population of dead flies. Measurements with the same common capital letter indicate that they are not significantly different; compared to the measurement with a different letter, they are significant with respect to the significance of 0.05.

Consequently, the null hypothesis (Ho) is rejected and the alternative hypothesis is approved: Ha = At least one voltage level produces a different effect on whitefly (Bemisia tabaci Gen) in beans (Phaseolus vulgaris L.)

That is, the effectiveness of using magnetic fields from variable frequency solar radiation to control the whitefly pest (Bemisia tabaci Genn.) in bean crops (Phaseolus vulgaris L.) is determined by applying 20 volts and the distribution of currents is produced with electrodes connected to a variable voltage system.

To show evidence of the results obtained, the installation of the equipment for the creation of an electromagnetic field with the respective solar energy inverter is presented (Figure 1.)

Figures 1. Creating an electromagnetic field with the respective solar energy inverter

Note: An electromagnetic field was created inside a glass box with its respective conductors.

3.1. Innovative Result

The use of variable-frequency solar-generated magnetic fields to control whitefly (Bemisia tabaci Genn.) pests in bean (Phaseolus vulgaris L.) crops represents a key step towards more sustainable agriculture. By applying a voltage of 20 volts through electrodes connected to a variable voltage system, this technology has been shown to effectively mitigate the pest without resorting to chemical pesticides.

The system works by using magnetic fields that alter the behavior and development of whiteflies, interrupting their reproductive and feeding cycles. This approach efficiently reduces the pest population, while minimizing the environmental risks associated with the use of chemicals. The use of solar energy as a renewable source to generate these magnetic fields reinforces sustainability and reduces operating costs, positioning itself as a key ecological alternative for pest control in various crops. This innovation opens up new possibilities for cleaner, more efficient and environmentally friendly agriculture.

Figuras 2. Visualización de moscas blancas muertas en el envés de hojas de frijol (Phaseolus vulgaris L.)

Figuras 3. Visualización de moscas blancas muertas en el haz de hojas de frijol (Phaseolus vulgaris L)

The results are evident in Figure 2 and Figure 3 with dead whiteflies on both the upper and lower surfaces of bean leaves; the simplicity and versatility of the facilities facilitate innovative pest control management with such ecological equipment using solar energy through magnetic fields.

Interpretation of the death of whiteflies (Bemisia tabaci Genn.) : With the formation of a magnetic field and contact with the insect endowed with magnetite, it is affected and causes a disorientation of locomotion. When the locomotion of an insect is inhibited by its antennae being blocked, its orientation is altered, leaving it susceptible to attacks by natural enemies, or it simply dies of starvation because it cannot move to feed. This has been demonstrated from comparative studies where insects can be controlled by inhibiting the functioning of the locomotor system.

Innovative Pest Control Management with Ecological Solar Energy Equipment using Magnetic Fields, allows the diffusion of such equipment , **to** increase agricultural productivity in a sustainable way, with a more effective and less expensive pest control, which improves both yields and crop quality. This innovative approach not only solves immediate pest control problems, but also establishes a path towards a more responsible and efficient agriculture in the long term.

4. Discussion

When an insect's locomotion is inhibited by blocking its antennae, it changes its orientation and becomes susceptible to attacks by natural enemies, or it simply dies of starvation because it cannot move to feed. This has been demonstrated by comparative studies where insects can be controlled by inhibiting the functioning of the locomotor system. oriented by their antennae through the creation of electromagnetic fields (Anderson and Vander Meer, 1993; Schiff, 1993; Vácha, 1997). The study on Technological Management on the Diffusion of Usefulness of Magnetic Fields to Control Whiteflies (Bemisia tabaci Genn.) is inserted within the growing trend of exploring alternative and sustainable methods for pest management. In this context, recent research has emphasized the use of entomopathogenic fungi and biological agents for the control of whiteflies, highlighting the relevance of non-chemical methods. For example, Bocco et al. (2021) investigated the use of the fungus Isaria javanica as an effective biological control against pests such as the green aphid, suggesting its potential to combat other pests in pepper crops. Likewise, Sani et al. (2020) have reviewed the control of Bemisia tabaci using entomopathogenic fungi, highlighting their ability to control this insect without relying on traditional pesticides. These alternatives could complement the strategy proposed in the study, which explores the application of magnetic fields, offering an innovative and environmentally sustainable route.

In turn, Murillo et al. (2020) evaluated biorational insecticides for whitefly control, focusing on methods that are effective and less damaging to the ecosystem, which is a growing trend in pest management. The importance of this line of research lies in the search for less invasive solutions that can be efficiently integrated into agroecological management. Likewise, the growing resistance of pests to traditional insecticides, as pointed out by Wang et al. (2020), underlines the need to diversify approaches, something that the study on magnetic fields could address as a complementary strategy. That is, the study on magnetic fields is in a line of research that reinforces the need to explore alternative methods for pest control, which are aligned with the principles of sustainable agriculture and the fight against pesticide resistance, following the trend set by recent research; which can serve an entire community in coordination with regional governments, as Garay Paucar et al. (2022) Their study highlights the importance of applying results-oriented management methodologies to improve the efficiency of public works, ensuring that resources are used effectively. This approach is crucial for regional development, as it allows for better planning and evaluation of the social impact of public investments.

The analysis of innovative methods for the control of Bemisia tabaci continues to gain importance, especially with regard to strategies that incorporate emerging technologies and biological solutions. More recent research (2022-2023) reinforces the trend towards the use of biological agents, such as entomopathogenic fungi, and integrated pest management in an agroecological context, which is relevant to the study on the use of magnetic fields to control whitefly. For example, Deeksha et al. (2023) conducted research on the parasitism potential of Encarsia formosa, a natural parasitoid of whitefly, under conditions in northwestern India. This study not only reinforces the importance of biological control, but also underlines the role of native species in pest management, a concept that could be complemented by magnetic field technology, whose impact still needs further validation. In connection with the work of Copa Pérez et al. (2024) The research will contribute to providing those who practice it with an Educational Hierarchy and Pedagogical-Productive Management to then put it at the service of university teachers, for the advancement of sustainability and demonstrates how the integration of clean technology can transform traditional agricultural practices.

Within the development of such innovative teams, there is a certain planning, which according to Galindo Caro et al. (2024) may be relevant given the importance of concerted local strategic planning and teacher responsibility in budget management in educational settings. Their work highlights how cooperation at the local level and accountability in the academic field can improve the efficiency and impact of budget decisions. This approach not only optimizes resources, but also promotes a more transparent education aligned with the needs of the community.

These types of biological strategies, combined with new technologies, can improve the efficiency and sustainability of pest control in agricultural systems. On the other hand, Gebremariam et al. (2022) conducted a comprehensive study on the integrated potential of microbial, botanical and chemical pesticides for the control of Bemisia tabaci in tomatoes, both in greenhouses and in the field. This multidimensional approach highlights how biological alternatives can coexist with conventional pest control methods, offering a more sustainable and less environmentally damaging alternative. The integration of these methods into integrated pest management (IPM) practices is key to reducing the dependence on synthetic pesticides, and the use of magnetic fields could be an additional strategy within this approach. Furthermore, the work of Patel et al. (2022) compared the morphological characteristics and development of B. tabaci in two important agricultural species, underlining the relevance of understanding the biology of the insect to develop more effective control strategies; In all circumstances, communications are also relevant, as Rosales Urbano et al. (2024) examine the impact of communications between educational institutions and local governments on the well-being of the population; through their research, they demonstrate that efficient and aligned communication between these key actors can have a positive effect on improving the living conditions of the community. This study highlights the relevance of inter-institutional relations in the creation of public policies that promote social well-being and sustainable development.

Consequently, the use of magnetic fields could offer a new perspective by interfering with the biological and reproductive processes of B. tabaci, complementing biological and chemical interventions with state-of-the-art technologies. Finally, the research by Walia et al. (2023) on the preference and demographic parameters of Encarsia formosa to control Trialeurodes vaporariorum reinforces the importance of biological controllers as effective tools for whitefly management. This approach demonstrates the relevance of combining different control strategies, which could include technologies such as magnetic fields, which are still in an experimental phase but present great potential as an additional tool in the pest control arsenal. That is, the most recent studies continue to reinforce the importance of biological and sustainable approaches for the management of pests such as Bemisia tabaci. Emerging technologies such as magnetic fields could complement these approaches by offering new alternatives for pest control, making their research and validation an important step for the development of integrated pest management strategies.

4.1. *In addition, the study by Zepeda Bautista, Rosalba et al., (2019)* shows some contrasts with the present study, through:

-Diversity of applications: Electromagnetic fields can have promising applications in different areas of agriculture, both to improve plant growth and to control pests.

-Need for further research: Although both studies show positive results, further research is required to fully understand the mechanisms of action of electromagnetic fields and optimize their application.

-Potential for sustainable agriculture: The use of electromagnetic fields offers a promising alternative to chemical pesticides, contributing to more sustainable agriculture.

In other words, both studies explore the potential of electromagnetic fields in agriculture, but from different perspectives. While the results are encouraging, further research is needed to develop efficient and sustainable technologies based on this technique.

The formation of a magnetic field and contact with the insect endowed with magnetite affect the insect and cause a disorientation of locomotion. When the locomotion of an insect is inhibited by blocking its antennae, its orientation changes and it is susceptible to attacks by natural enemies, or it simply dies of starvation because it cannot move to feed. This has been demonstrated from comparative studies where insects can be controlled by inhibiting the functioning of the locomotor system guided by their antennae through the creation of electromagnetic fields (Anderson and Vander Meer, 1993; Schiff, 1993; Vácha, 1997).

5. Conclusion

Statistical analysis shows that the use of variable frequency solar radiation magnetic fields is effective for pest control using 20 volts of voltage. Pest control through magnetic fields has the potential to impact agricultural production, making it more environmentally sustainable by reducing the need for chemicals for pest control. An eco-agroindustrial utility model for generating electromagnetic fields can be created from 3 solar panels of 300 W of power, including an inverter, equipment for installing wiring and the use of units to create magnetic fields. In this sense, the model has a high commercial potential, promoting a cleaner, more profitable and sustainable agriculture.

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