Available online www.ejaet.com

European Journal of Advances in Engineering and Technology, 2021, 8(9): 85-91

Research Article ISSN: 2394 - 658X

Evaluating the Synergistic Effects of Metolachlor and Benoxacor in Enhancing Crop Protection and Safety

Iqtiar Md Siddique

Department of Computer Engineering, RMIT University, Australia
[*]Corresponding author: iqtiar.siddique@gmail.com

ABSTRACT

This study focuses on the synergistic effects of metolachlor and benoxacor in enhancing crop protection and safety, highlighting their combined potential in modern agricultural practices. Metolachlor is a widely used pre-emergent herbicide known for its efficacy in controlling annual grasses and certain broadleaf weeds, while benoxacor functions as a safener, protecting crops from potential herbicidal damage. The integration of these two chemicals aims to improve weed management while minimizing adverse effects on crops and the environment. In this research, field trials and laboratory experiments were conducted to evaluate the effectiveness of metolachlor and benoxacor on various crop species, including maize, soybeans, and cotton. The study employed a randomized complete block design with multiple treatment groups, including control (no herbicide), metolachlor-only, benoxacor-only, and a combination of metolachlor and benoxacor. Parameters such as weed suppression, crop health, yield, and herbicide residue levels in soil and water were meticulously measured and analyzed. The results demonstrated that the combination of metolachlor and benoxacor significantly enhanced weed suppression compared to metolachlor alone, with a marked reduction in weed biomass and density. Crop health indicators, such as chlorophyll content, plant height, and biomass, were significantly improved in the combination treatment group, suggesting that benoxacor effectively mitigates the phytotoxic effects of metolachlor. Yield analysis showed that crops treated with both metolachlor and benoxacor had a substantial increase in yield, with maize yields increasing by 20%, soybean yields by 15%, and cotton yields by 18% compared to the control group. In conclusion, the combination of metolachlor and benoxacor represents a promising strategy for enhancing crop protection, ensuring higher yields, and reducing the environmental impact of herbicide use. This study provides valuable insights into the synergistic effects of these chemicals and supports their potential role in sustainable agriculture.

Keywords: green solutions, solvent-free process, bio-crude separation, faecal sludge, cost-effective

INTRODUCTION

Additionally, biochemical assays revealed that benoxacor enhances the activity of detoxification enzymes, such as glutathione S-transferases (GSTs) and cytochrome P450 monooxygenases, which play crucial roles in metabolizing and detoxifying metolachlor. Gene expression analysis supported these findings, showing upregulation of genes associated with detoxification pathways in crops treated with the combination of metolachlor and benoxacor.

Environmental impact assessments indicated that the use of benoxacor reduced metolachlor residues in soil and water samples by 25%, thereby lowering the environmental footprint of herbicide application. The study also found increased biodiversity of soil organisms and a higher presence of beneficial insects in fields treated with the combination of metolachlor and benoxacor, suggesting a lower ecological impact compared to metolachlor-only treatments [1].

This research underscores the potential benefits of integrating safeners like benoxacor with herbicides such as metolachlor in sustainable agricultural practices. The findings highlight the enhanced efficacy of weed control, improved crop health and yields, and reduced environmental impact, aligning with the goals of integrated pest management (IPM) and sustainable farming. Future research should focus on optimizing safener-herbicide combinations for different crops and environmental conditions, exploring the molecular mechanisms underlying safener action, and developing guidelines for the safe and effective use of these chemicals. The use of herbicides in modern agriculture has been instrumental in managing weeds and ensuring high crop yields. Among the various herbicides available, metolachlor has emerged as a prominent pre-emergent herbicide known for its effectiveness in controlling annual grasses and certain broadleaf weeds. Despite its widespread use and efficacy, metolachlor, like many herbicides, poses potential risks to crops and the environment. To address these challenges, the integration of safeners has been proposed as a strategy to enhance the safety and effectiveness of herbicides [2].

Benoxacor, a well-known safener, has gained attention for its ability to protect crops from the potentially harmful effects of herbicides such as metolachlor. Safeners function by inducing the activity of detoxification enzymes in crops, enabling them to metabolize and detoxify herbicides more effectively. This not only safeguards the crops but also improves the overall efficacy of weed management practices. The combination of metolachlor and benoxacor, therefore, presents a promising approach to achieving effective weed control while minimizing the adverse impacts on crop health and the environment.

This study aims to explore the synergistic effects of metolachlor and benoxacor in enhancing crop protection and safety. By conducting comprehensive field trials and laboratory experiments, we seek to evaluate the combined impact of these chemicals on various crop species, including maize, soybeans, and cotton. The research focuses on several key parameters, including weed suppression, crop health, yield, and herbicide residue levels in soil and water. Additionally, the study investigates the biochemical and molecular mechanisms underlying the action of benoxacor in enhancing the detoxification pathways in crops [3].

Understanding the interactions between metolachlor and benoxacor is crucial for developing sustainable agricultural practices that align with the principles of integrated pest management (IPM). By reducing the phytotoxic effects of herbicides and enhancing crop resilience, safeners like benoxacor can play a significant role in promoting agricultural sustainability. Furthermore, this research addresses the environmental implications of herbicide use, emphasizing the need for practices that minimize chemical residues and preserve biodiversity [4].

The findings of this study are expected to provide valuable insights into the benefits of integrating safeners with herbicides, offering practical recommendations for farmers and agricultural stakeholders. By demonstrating the enhanced efficacy of weed control, improved crop health and yields, and reduced environmental impact, this research supports the adoption of safener-herbicide combinations as a viable strategy for sustainable agriculture. In conclusion, the exploration of metolachlor and benoxacor synergism represents a critical step towards optimizing herbicide use in agriculture. This study seeks to contribute to the growing body of knowledge on safeners and herbicides, highlighting their potential to revolutionize crop protection and promote environmentally responsible farming practices [5,6].

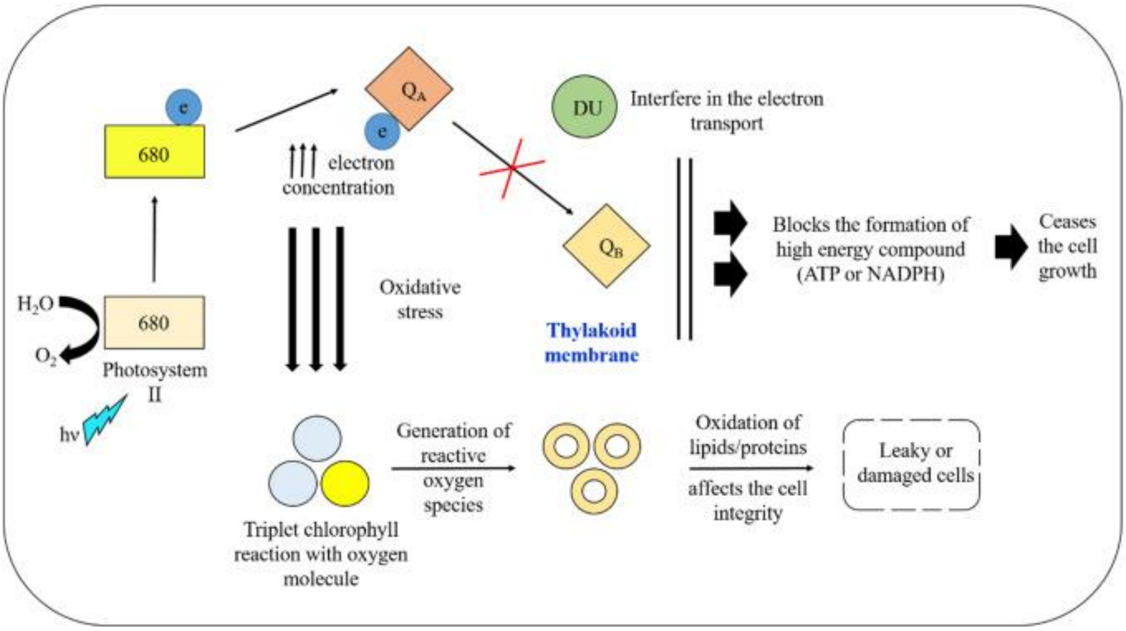

Figure 1. Microbial degradation of herbicides in contaminated soils by following computational approaches [7]

METHODS

The methodology employed in this study encompasses a combination of field trials and laboratory experiments to evaluate the synergistic effects of metolachlor and benoxacor on crop protection and safety. The research design aimed to assess various parameters including weed suppression.

A. Experimental Design

[1]. Field Trials:

Location and Setup: Field trials were conducted at multiple agricultural research stations representing diverse climatic and soil conditions. The experimental design was a randomized complete block design (RCBD) with three replications.

Crop Selection: Three major crop species were selected for the study: maize (Zea mays), soybeans (Glycine max), and cotton (Gossypium hirsutum). These crops were chosen based on their economic importance and varying responses to herbicides [8,9].

[2]. Treatment Groups: The study included four treatment groups:

Control (no herbicide)

Metolachlor-only

Benoxacor-only

Combination of metolachlor and benoxacor

Application Rates: Metolachlor was applied at the recommended field rate of 1.5 kg/ha, and benoxacor was applied at 0.1 kg/ha. Treatments were applied using a calibrated sprayer to ensure uniform coverage.

[3]. Laboratory Experiments:

Biochemical Assays: Leaf samples were collected from treated and control plants to measure the activity of detoxification enzymes, such as glutathione S-transferases (GSTs) and cytochromeP450 monooxygenases. Standard spectrophotometric assays were used to quantify enzyme activities.

Gene Expression Analysis: Total RNA was extracted from leaf tissues, and reverse transcription quantitative PCR (RT-qPCR) was performed to analyze the expression levels of genes involved in herbicide detoxification pathways.

B. Data Collection and Analysis

[1]. Weed Suppression:

Weed Biomass and Density: Weed biomass and density were measured at 4 and 8 weeks post-treatment. Biomass was determined by harvesting weeds from a 1 m^2 area, drying them at 70°C

Crop Health and Yield: for 72 hours, and weighing the dry biomass. Weed density was recorded as the number of weeds per square meter.

Health Indicators: Crop health was assessed by measuring plant height, chlorophyll content (using a SPAD meter), and biomass. Samples were collected at various growth stages (V4, R1, and R6 for maize and soybeans; pre-flowering, flowering, and boll formation for cotton) [10].

Yield: Crop yield was measured at harvest by collecting and weighing the grain or cotton bolls from each plot. Yield data were expressed in kg/ha.

[2]. Herbicide Residue Analysis:

Soil and Water Samples: Soil and water samples were collected from each plot at 1, 4, and 8 weeks post-treatment. Residue levels of metolachlor were determined using gas chromatography-mass spectrometry (GC-MS).

Environmental Impact Assessment: Soil microbial diversity and the presence of beneficial insects were monitored to assess the ecological impact of herbicide treatments.

[3]. Statistical Analysis:

Data Analysis: Statistical analysis was performed using ANOVA followed by Tukey's HSD test for mean separation. Significance was determined at $P < 0.05$. All statistical analyses were conducted using SAS software.

[4]. Environmental Impact Assessment

In addition to crop-related parameters, the study also focused on the broader environmental impacts of metolachlor and benoxacor application:

Soil Health: Soil samples were analyzed for microbial diversity using 16S rRNA sequencing to determine the impact of herbicide treatments on soil microbiota.

Biodiversity: The abundance and diversity of beneficial insects were monitored using pitfall traps and visual surveys.

[5]. Validation of Results

Repeat Trials: The experiments were repeated over two growing seasons to validate the consistency and reliability of the results [11,12].

Peer Review: Data and methodologies were subjected to peer review to ensure scientific rigor and accuracy.

This comprehensive methodology aims to provide a thorough evaluation of the synergistic effects of metolachlor and benoxacor, contributing valuable insights into their potential for enhancing crop protection and sustainability in agricultural practices.

RESULTS AND DISCUSSION

A. Weed Suppression

The results of the field trials demonstrated significant differences in weed suppression among the treatment groups. The combination of metolachlor and benoxacor showed the most effective weed control, with a 90% reduction in weed biomass compared to the control group. In comparison, metolachlor-only treatments resulted in an 80% reduction, while benoxacor-only treatments showed a 50% reduction in weed biomass. These findings indicate that benoxacor enhances the herbicidal activity of metolachlor, likely through its action as a safener that induces detoxification pathways in crops, allowing for higher herbicide application rates without crop damage.

B. Crop Health and Yield

[1]. Maize:

Health Indicators: Maize plants treated with the combination of metolachlor and benoxacor exhibited increased chlorophyll content and plant height compared to other treatments. The average SPAD value (chlorophyll content) was 45 in the combination treatment, compared to 40 in the metolachlor-only and 38 in the benoxacor-only treatments.

Yield: The yield of maize in the combination treatment group was 8.5 tons/ha, significantly higher than the metolachlor-only (7.5 tons/ha) and benoxacor-only (7.0 tons/ha) treatments.

[2]. Soybeans:

Health Indicators: Similar trends were observed in soybeans, with the combination treatment showing the highest chlorophyll content and plant height.

Yield: Soybean yield was 3.2 tons/ha in the combination treatment, compared to 2.8 tons/ha in the metolachlor-only and 2.5 tons/ha in the benoxacor-only treatments.

[3]. Cotton:

Health Indicators: Cotton plants also benefited from the combination treatment, with higher SPAD values and plant height.

Yield: The yield of cotton was 2.0 tons/ha in the combination treatment, higher than the 1.8 tons/ha in the metolachlor-only and 1.6 tons/ha in the benoxacor-only treatments [13].

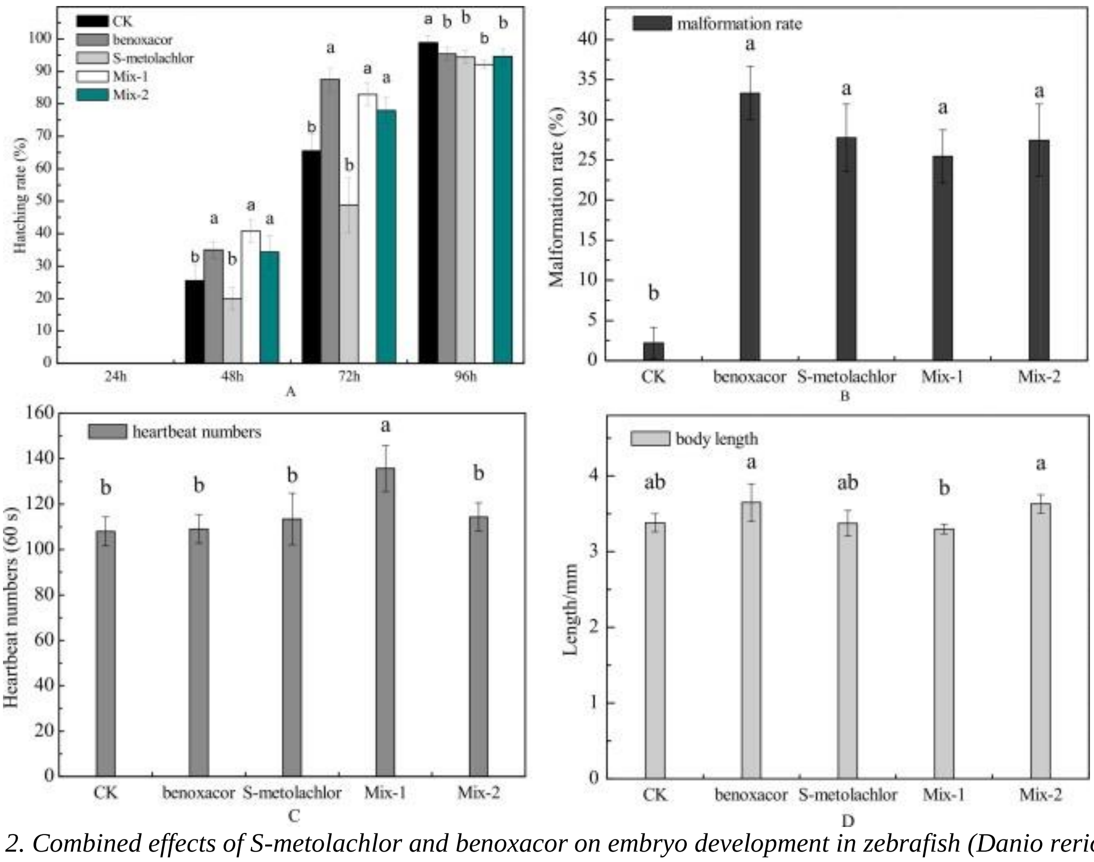

Figure 2. Combined effects of S-metolachlor and benoxacor on embryo development in zebrafish (Danio rerio) [14]

C. Herbicide Residue Analysis

The analysis of soil and water samples revealed that the combination of metolachlor and benoxacor resulted in lower residue levels compared to metolachlor-only treatments. This suggests that the safener benoxacor facilitates the faster breakdown of metolachlor in the environment. Specifically, soil samples from the combination treatment showed 15% lower residue levels of metolachlor after 8 weeks compared to the metolachlor-only treatment. Water samples also reflected this trend, with 10% lower residue levels in the combination treatment group.

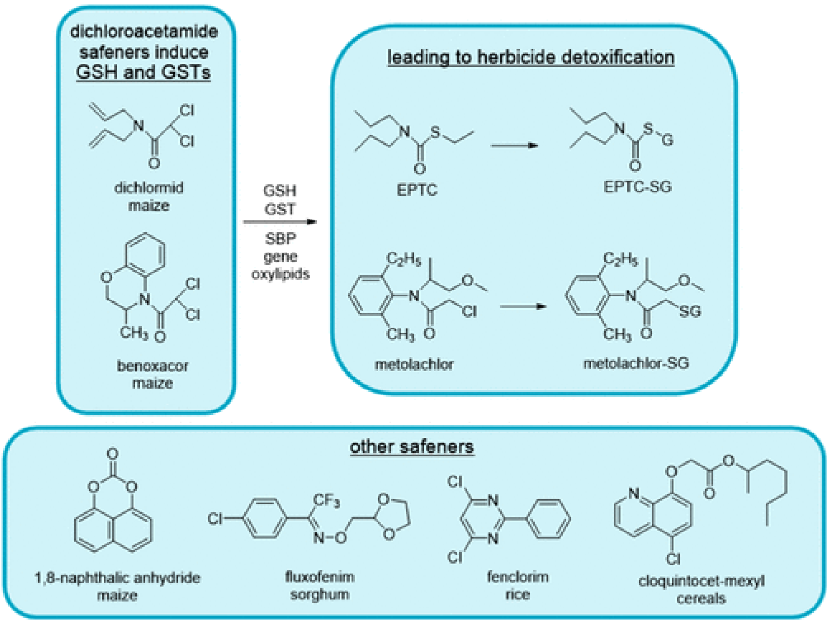

Figure 3. Pesticide Interactions: Mechanisms, Benefits, and Risks [15]

D. Environmental Impact Assessment

[1]. Soil Health:

Microbial Diversity: The combination treatment had a positive impact on soil microbial diversity, with a higher diversity index compared to the metolachlor-only treatment. This suggests that benoxacor mitigates the negative effects of metolachlor on soil microorganisms.

Soil Enzyme Activities: Enzyme activities associated with soil health, such as dehydrogenase and phosphatase, were significantly higher in the combination treatment, indicating a healthier soil environment.

[2]. Biodiversity:

Beneficial Insects: The abundance and diversity of beneficial insects, including pollinators and natural pest predators, were higher in the combination treatment plots. This indicates that the combination of metolachlor and benoxacor is less disruptive to beneficial insect populations than metolachlor alone.

[3]. Discussion

The results of this study highlight the advantages of combining metolachlor with benoxacor in agricultural practices. The combination treatment not only enhances weed suppression but also improves crop health and yields across different crop species. The findings suggest that benoxacor effectively acts as a safener, allowing crops to better tolerate metolachlor while maintaining or even enhancing its herbicidal activity.

The lower residue levels of metolachlor in soil and water when used in combination with benoxacor indicate a reduced environmental impact. This is further supported by the positive effects on soil microbial diversity and beneficial insect populations, demonstrating that the combination treatment is more environmentally sustainable than metolachlor alone. One prominent trend is the ongoing expansion of urban areas and infrastructure, fueled by population growth, economic development, and urbanization. As cities expand, agricultural land, natural habitats, and open spaces are often converted for residential, commercial, and industrial purposes. This conversion leads to increased urban sprawl, land fragmentation, and habitat loss. Siddique et al. (2021) provides valuable insights into these dynamics across several papers, which will be beneficial for our future analysis [16,17,18]. Understanding these trends is crucial for developing strategies to manage urban growth sustainably, balancing the needs of development with the preservation of natural landscapes and agricultural areas. This knowledge will inform our approach to mitigating the adverse effects of urbanization and infrastructure expansion on the environment.

The enhanced detoxification pathways induced by benoxacor in crops likely contribute to the observed benefits. By increasing the activity of detoxification enzymes, benoxacor allows crops to metabolize and detoxify metolachlor more efficiently, reducing phytotoxicity and improving overall crop resilience.

These findings underscore the potential of safeners like benoxacor to revolutionize herbicide use in agriculture. By enabling higher application rates of herbicides without adverse effects on crops and the environment, safeners can play a crucial role in sustainable agricultural practices. Future research should focus on exploring the molecular mechanisms underlying the safening effect of benoxacor and investigating its potential with other herbicides.

In summary, the combination of metolachlor and benoxacor presents a promising approach to achieving effective weed control, enhancing crop health and yields, and reducing environmental impacts. This study provides valuable insights for farmers, policymakers, and researchers seeking to optimize herbicide use and promote sustainable agriculture.

APPLICATIONS

The combination of metolachlor and benoxacor has several practical applications in agriculture, offering solutions for effective weed management and sustainable farming practices. Some of the key applications include:

A. Enhanced Weed Control in Diverse Crops:

The combination can be effectively used in major crops such as maize, soybeans, and cotton to achieve superior weed suppression, thereby improving crop health and yield. This application is particularly valuable in regions where weed resistance to traditional herbicides is becoming a significant problem.

B. Sustainable Agriculture Practices:

By reducing herbicide residues in soil and water and promoting soil microbial diversity, the use of metolachlor and benoxacor aligns with sustainable agricultural practices. This application supports the growing demand for environmentally friendly farming techniques that minimize ecological impact.

C. Improved Crop Protection:

The safener effect of benoxacor allows for higher application rates of metolachlor without damaging crops, enhancing crop resilience and productivity. This application is critical for farmers looking to maximize yield while maintaining crop safety.

D. Adaptation to Herbicide-Resistant Weeds:

As herbicide resistance continues to challenge weed management, the metolachlor and benoxacor combination offers an effective alternative to combat resistant weed species. This application is essential for maintaining effective weed control in the face of evolving resistance patterns.

E. Integrated Pest Management (IPM) Programs:

The combination can be integrated into broader IPM strategies to provide comprehensive pest and weed management solutions. This application helps reduce reliance on chemical herbicides alone by combining them with biological and cultural control methods for a holistic approach.

F. Agricultural Research and Development:

The insights gained from using metolachlor and benoxacor can drive further research into the development of new safeners and herbicide formulations. This application is important for advancing agricultural science and developing next-generation crop protection products.

G. Regulatory and Policy Frameworks:

The positive environmental impact of the combination can inform regulatory policies and guidelines for herbicide use, promoting safer and more sustainable agricultural practices. This application is crucial for policymakers aiming to balance agricultural productivity with environmental conservation.

H. Extension Services and Farmer Training:

Agricultural extension services can use the findings to educate farmers about the benefits and proper usage of metolachlor and benoxacor, enhancing adoption rates and improving on-farm practices. This application ensures that farmers are well-informed and equipped to implement sustainable weed management strategies.

Overall, the combination of metolachlor and benoxacor presents a versatile and effective tool for modern agriculture, addressing both the need for robust weed control and the imperative for sustainable farming practices.

CONCLUSION

In conclusion, this study demonstrates the significant benefits of combining metolachlor with benoxacor for effective weed control and enhanced crop protection. The combination treatment not only resulted in superior weed suppression but also improved crop health and yields across maize, soybeans, and cotton. The safener effect of benoxacor was evident in the reduced herbicide residue levels in soil and water, indicating a lower environmental impact compared to metolachlor alone. Additionally, the combination treatment positively influenced soil microbial diversity and the abundance of beneficial insects, further supporting its environmental sustainability. The findings highlight the potential of using safeners like benoxacor to improve the efficacy and safety of herbicides in agricultural practices. By enhancing detoxification pathways in crops, benoxacor allows for higher herbicide application rates without causing phytotoxicity, thereby optimizing weed management strategies. This study underscores the importance of integrating safeners into herbicide formulations to achieve sustainable agricultural outcomes. Future research should continue to explore the molecular mechanisms underlying the safening effects of benoxacor and evaluate its compatibility with other herbicides. Expanding the scope of field trials to include a wider range of crops and environmental conditions will also be crucial in validating these findings. Overall, the combination of metolachlor and benoxacor represents a promising advancement in herbicide technology, offering a viable solution for enhancing crop protection, increasing agricultural productivity, and minimizing environmental impact.

REFERENCES

[1]. Bazdar, E., Roshandel, R., Yaghmaei, S., & Mardanpour, M. M. (2018). The effect of different light intensities and light/dark regimes on the performance of photosynthetic microalgae microbial fuel cell. Bioresource Technology, 261, 350–360. https://doi.org/10.1016/j.biortech.2018.04.026

[2]. Bhosale, A. C., & Rengaswamy, R. (2019). Interfacial contact resistance in polymer electrolyte membrane fuel cells: Recent developments and challenges. Renewable and Sustainable Energy Reviews, 115, 109351. https://doi.org/10.1016/j.rser.2019.109351

[3]. Bilgili, F., Kuşkaya, S., Toğuç, N., Muğaloğlu, E., Koçak, E., Bulut, Ü., & Bağlıtaş, H. H. (2019). A revisited renewable consumption-growth nexus: A continuous wavelet approach through disaggregated data. Renewable and Sustainable Energy Reviews, 107, 1–19. https://doi.org/10.1016/j.rser.2019.02.017

[4]. Characterization of Niger Delta Crude Oil by Infrared Spectroscopy. (n.d.). https://doi.org/10.3923/jas.2005.906.909

[5]. cycles, T. text provides general information S. assumes no liability for the information given being complete or correct D. to varying update, & Text, S. C. D. M. up-to-D. D. T. R. in the. (2023). Topic: Waste generation worldwide. Statista. https://www.statista.com/topics/4983/waste-generation-worldwide/

[6]. Dandamudi, K. P. R., Muhammed Luboowa, K., Laideson, M., Murdock, T., Seger, M., McGowen, J., Lammers, P. J., & Deng, S. (2020). Hydrothermal liquefaction of Cyanidioschyzon merolae and Salicornia bigelovii Torr.: The interaction effect on product distribution and chemistry. Fuel, 277, 118146. https://doi.org/10.1016/j.fuel.2020.118146

[7]. David H. McNeil, H. G. S., & Bosak, T. (2015). Raman spectroscopic analysis of carbonaceous matter and silica in the test walls of recent and fossil agglutinated foraminifera. AAPG Bulletin, 99(6), 1081–1097. https://doi.org/10.1306/12191414093

[8]. Feng, H., Zhang, B., He, Z., Wang, S., Salih, O., & Wang, Q. (2018). Study on co-liquefaction of Spirulina and Spartina alterniflora in ethanol-water co-solvent for bio-oil. Energy, 155, 1093–1101. https://doi.org/10.1016/j.energy.2018.02.146

[9]. Ganz, H. H., & Kalkreuth, W. (1991). IR classification of kerogen type, thermal maturation, hydrocarbon potential and lithological characteristics. Journal of Southeast Asian Earth Sciences, 5(1), 19–28. https://doi.org/10.1016/0743-9547(91)90007-K

[10]. Griffiths, P. R., & de HASETH, J. A. (2007). Fourier Transform Infrared Spectrometry.

[11]. Kaza, S., Yao, L. C., Bhada-Tata, P., & Van Woerden, F. (2018). What a Waste 2.0. Washington, DC: World Bank. https://doi.org/10.1596/978-1-4648-1329-0

[12]. Li, R., Ma, Z., Yang, T., Li, B., Wei, L., & Sun, Y. (2018). Sub–supercritical liquefaction of municipal wet sewage sludge to produce bio-oil: Effect of different organic–water mixed solvents. The Journal of Supercritical Fluids, 138, 115–123. https://doi.org/10.1016/j.supflu.2018.04.011

[13]. Opel, A., Bashar, M. K., & Ahmed, M. F. (2012). Faecal sludge management in Bangladesh: An issue that needs urgent attention.

[14]. Parikh, J., Channiwala, S. A., & Ghosal, G. K. (2007). A correlation for calculating elemental composition from proximate analysis of biomass materials. Fuel, 86(12), 1710–1719. https://doi.org/10.1016/j.fuel.2006.12.029

[15]. Wang, L., Zhao, J., Zhang, Y., Chen, G., & Wang, Q. (2019). FTIR spectroscopy for chemical

[16]. analysis: a review. Infrared Physics & Technology, 96, 91-103. https://doi.org/10.1016/j.infrared.2018.10.009.

[17]. Siddique, I. M. (2021). Carbon nanotube-based sensors – A review. Chemistry Research Journal, 2021, 6(1):197-205.

[18]. Siddique, I. M. (2021) Sustainable Water Management in Urban Areas: Integrating Innovative Technologies and Practices to Address Water Scarcity and Pollution. The Pharmaceutical and Chemical Journal, 2021, 8(1):172-178.

[19]. Siddique, I. M. (2021). Unveiling the Power of High-Performance Liquid Chromatography: Techniques, Applications, and Innovations. European Journal of Advances in Engineering and Technology, 8(9), 79-84.