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Design of a Fuzzy Mamdani Control System for Root-Zone Optimization in NFT Lettuce Cultivation

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**ABSTRACT**

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**Keywords**: Enter keywords or phrases in alphabetical order, separated by commas. The number of keywords must distinguish between 3-5 words.

# Introduction

H

ydropnic cultivation is increasingly recognized as a viable substitute for traditional farming, given its lower water consumption, reduced environmental impact, and capacity to produce large quantities of crops in confined urban settings [1]. A commonly used method within hydroponics is the Nutrient Film Technique (NFT), which is especially effective for growing leafy greens such as lettuce. This technique involves continuously flowing a shallow stream of nutrient solution over the plant roots, promoting consistent nutrient uptake and enhanced oxygen access [2][3]. Lettuce (Lactuca sativa) is particularly well-suited to NFT systems because it matures quickly and responds sensitively to changes in its surroundings, requiring careful management of the root environment to achieve the best possible growth and quality [4][5].

Nevertheless, NFT systems are prone to instability in critical root-zone variables, including pH, electrical conductivity (EC), temperature, dissolved oxygen, and nutrient concentration. Such fluctuations can hinder nutrient absorption and negatively affect crop development if not properly managed [6][7]. Research has shown that maintaining stable root-zone conditions is crucial for optimizing lettuce yield, physiological health, and phytochemical content in NFT setups [8][9]. As a result, there is a need for systems that can continuously monitor and automatically adjust nutrient solution parameters, particularly in response to varying greenhouse or climatic conditions.

Traditional control methods, which often rely on fixed thresholds and ON/OFF operation, tend to be inadequate for hydroponic systems due to their nonlinear and unpredictable behavior [10]. Alternatively, fuzzy logic control offers a more flexible and intelligent approach, capable of managing uncertainties in sensor data and environmental shifts [11]. The Mamdani-type Fuzzy Inference System (FIS) is especially suitable for agricultural applications because of its transparent rule structure and effectiveness in dealing with nonlinear processes [12][13]. Previous applications of fuzzy logic in hydroponics have shown improved control over pH, EC, and nutrient delivery, outperforming conventional techniques [14].

However, a review of current research indicates that there are still few studies that implement a Mamdani-type fuzzy controller specifically designed for multi-parameter root-zone management in NFT lettuce production, incorporating real-time monitoring and automated adjustments [15]. Many existing systems focus on regulating individual parameters, have not been tested in continuous NFT operations, or fail to address root-zone dynamics in an integrated manner. To address this limitation, the present study develops and assesses a Mamdani fuzzy logic control system aimed at stabilizing essential root-zone parameters in NFT lettuce cultivation, with the objective of enhancing growth uniformity, nutrient use efficiency, and final crop productivity.

Table 1

Unit For Magnetic Properties

|  |  |  |
| --- | --- | --- |
| Symbol | Quantity | Convert from Gaussian and CGS EMU to SI a |
| Φ | magnetic flux | 1 Mx → 10−8 Wb = 10−8 V·s |
| *B* | magnetic flux density,  magnetic induction | 1 G → 10−4 T = 10−4 Wb/m2 |
| *H* | magnetic field strength | 1 Oe → 103/(4π) A/m |
| *m* | magnetic moment | 1 erg/G = 1 emu  → 10−3 A·m2 = 10−3 J/T |
| *M* | magnetization | 1 erg/(G·cm3) = 1 emu/cm3  → 103 A/m |
| 4π*M* | magnetization | 1 G → 103/(4π) A/m |
| σ | specific magnetization | 1 erg/(G·g) = 1 emu/g → 1 A·m2/kg |
| *j* | magnetic dipole  moment | 1 erg/G = 1 emu  → 4π × 10−10 Wb·m |
| *J* | magnetic polarization | 1 erg/(G·cm3) = 1 emu/cm3  → 4π × 10−4 T |
| χ*,* κ | susceptibility | 1 → 4π |
| χρ | mass susceptibility | 1 cm3/g → 4π × 10−3 m3/kg |
| μ | permeability | 1 → 4π × 10−7 H/m  = 4π × 10−7 Wb/(A·m) |
| μr | relative permeability | μ → μr |
| *w, W* | energy density | 1 erg/cm3 → 10−1 J/m3 |
| *N, D* | demagnetizing factor | 1 → 1/(4π) |

Vertical lines are optional in the table.

# Research Method

The articles must consist of at least eight pages. Do not change the font size or line spacing to insert more text on a limited number of pages. Use italics for emphasis; do not use underscores.

To insert an image in Word, place the cursor at the insertion location and use Insert | Picture | From file or copy the image into the Windows clipboard and select Edit | Paste Special | Picture (with the "float over text" option unselected). The editorial team of the Jurnal ELTIKOM will make the final editing for your article.

## The body of The Paper

Abstracts should be explained at the beginning of the manuscript. The abstract section must clearly state the research's background, problems, objectives, results, and conclusions. The Introduction section must explicitly state the problem, update, and research objectives. The introduction must also be equipped with state-of-the-art research accompanied by the latest primary library sources. The Research Methods section contains a detailed description of the research carried out. Readers are expected to be able to replicate the research conducted by the author. The Results and Discussion section can be divided into two subsections: the Results subsection and the Discussion subsection. The Results subsection only displays the results of the evaluation or tests performed. The Discussion sub-section contains a discussion of the results of the tests. The discussion can contain the test's impact or the test's findings, comparison with other studies, and so on. The conclusion contains whether the research objectives were achieved and other important matters. In addition, the conclusions must provide suggestions for future research on sustainability.

If you write an original research paper, the main body of the paper should be numbered in consecutive order as follow: I. Introduction, II. Research Method, III. Result and Discussion, IV. Conclusion, Acknowledgment, and References. You may present the result and discussion (analysis) as a separate sub-section. The Acknowledgment section is optional. The minimum number of references is 15 references.

If you write a review paper, the main body of the paper should be numbered in consecutive order as follow: I. Introduction, II. Related/Previous Work, III. Research Method, VI. Findings, V. Discussion, VI. Conclusion, Acknowledgment, and References. The Research Method section should describe (and not be limited to) review objectives and research questions, search strategy and criteria, data collection and selection, and methodological quality assessment. The Acknowledgment section is optional. The minimum number of references is 60 references.

## Abbreviations and Acronyms

Define abbreviations and acronyms when first used in the content, although it has been defined in the abstract. Common abbreviations such as IEEE, SI, AC, and DC do not need to be defined. The abbreviation that uses a dot should not be given space: write "C.N.R.S.," not "C. N. R. S. " Do not use the abbreviation in the title of the article unless it cannot be avoided (for example, "ELTIKOM" in the title of this article).

## Other Recommendation

Use one space after a dot and comma. Separate the complex modifier with a connecting sign: "Zero-Field-Cooled Magnetization." Avoid using ambiguous sentences, such as, "Using (1), the final value has been calculated." [It is not clear who or what uses (1).] It is better to write down, "The final value is calculated using (1)," or "using (1), we calculate the final value."

Use a dot as a decimal separation: "0.25" and not "0,25". Use "cm3," not "cc." Moderate the sample dimension as "0.1 cm × 0.2 cm," not "0,1 × 0,2 cm2." When writing the range of values, write down "7 to 9" or "7-9," not "7 ~ 9.

The statement in the brackets is given a dot outside the closing brackets (like this). (A dot). Serial commas are more recommended: "A, B, and C" and not "A, B, and C."

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| μr | relative permeability | μ → μr |
| *w, W* | energy density | 1 erg/cm3 → 10−1 J/m3 |
| *N, D* | demagnetizing factor | 1 → 1/(4π) |

Vertical lines are optional in the table.

If you use Word, use Microsoft Equation Editor or Mathtype (http://www.mathtype.com) to write the similarities in your article. Make sure the "Float Over Text" format is not selected.

## Equation

The equations are an exception to the prescribed specifications of this template. You will need to determine whether or not your equation should be typed using either the Times New Roman or the Symbol font (please, no other font). Treating the equation as a graphic may be necessary to create multileveled equations and insert them into the text after your paper is styled.

Number equations consecutively. Equation numbers, within parentheses, are to position flush right, as in (1), using a right tab stop. To make your equations more compact, you may use the solidus ( / ), the exp function, or appropriate exponents—Italicize Roman symbols for quantities and variables, but not Greek symbols. Use a long dash rather than a hyphen for a minus sign.

|  |  |
| --- | --- |
|  | (1) |

Ensure that the equation's symbol has been defined before the equation is written or immediately after the equation. Make sure the symbol is tilted in a paragraph. Refer with "(1)," not "EQ. (1) "or" Equation (1), "except at the beginning of the sentence:" Equation (1) is .... ".

# Figure and Table

## Figure

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The figure can use any color, but it is more advised to use grayscale. The recommended color range is grayscale, RGB (red/green/blue), and CMYK (Cyan/Magenta/Yellow/Black). RGB is usually used for graphics on the screen, whereas CMYK is used for printing purposes. All color images must be made in RGB or CMYK format. Grayscale images must be inserted in the form of grayscale.

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The maximum figure size is the same as the width of the page.

### Resolution

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### Label

The label is at the bottom of the figure—the number of sequential figures from 1 according to the example in Figure 1. Use the "Times New Roman" font with the size of 8 pt.

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### Font in figure

If the figure has text, the author needs to use "Times New Roman" with adjusted fonts (8-11 pt).

## Table

### Size on page

The maximum Table size is the same as the width of the page.

### Label

The label is at the top of the table. The number of sequential tables from 1 according to the example in Table 1. Use the "Times New Roman" font with the size of 8 pt.

### Laying Tables

The table must be placed at the top or bottom of the page. The table is not allowed to be placed in the middle of the page.

### Reference Table

When referring to a table in the article, use "Table 1". Tables must be given a number with Arabic numbering.

### Font in Table

The author needs to use "Times New Roman" with adjusted fonts (8 pt).

# Conclusion

The conclusion summarizes the article's main points but does not copy the abstract as a conclusion. A conclusion might emphasize the importance of work results or suggestions for further development.

Attachment

Attachment, if necessary, can be displayed before Acknowledgement.

Acknowledgment

Acknowledgments are also a part that is not mandatory. If outsiders are involved in making this article, then it can be written in this section.

References

The reference source written in the Bibliography must be cited in the content. 80% of the references must consist of primary references from the last ten years. We strongly recommend using reference management applications such as Mendeley, Endnotes, Zootero, and others. We use the IEEE format as the reference format.

1. G. Eason, B. Noble, and I. N. Sneddon, "On certain integrals of Lipschitz-Hankel type involving products of Bessel functions," Phil. Trans. Roy. Soc. London, vol. A247, pp. 529–551, April 1955. *(references)*
2. J. Clerk Maxwell, A Treatise on Electricity and Magnetism, 3rd ed., vol. 2. Oxford: Clarendon, 1892, pp.68–73.
3. I. S. Jacobs and C. P. Bean, "Fine particles, thin films and exchange anisotropy," in Magnetism, vol. III, G. T. Rado and H. Suhl, Eds. New York: Academic, 1963, pp. 271–350.
4. K. Elissa, "Title of paper if known," unpublished.
5. R. Nicole, "Title of paper with only first word capitalized," J. Name Stand. Abbrev., in press.
6. Y. Yorozu, M. Hirano, K. Oka, and Y. Tagawa, "Electron spectroscopy studies on magneto-optical media and plastic substrate interface," IEEE Transl. J. Magn. Japan, vol. 2, pp. 740–741, August 1987 [Digests 9th Annual Conf. Magnetics Japan, p. 301, 1982].
7. M. Young, The Technical Writer's Handbook. Mill Valley, CA: University Science, 1989.