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ORIGINAL RESEARCH ARTICLE

Use of fuzzy logic to optimize fertilizer application on radish

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ABSTRACT

The objective of this study was to develop a model based on fuzzy rules to evaluate the effects caused by varying the dosages of two soil fertilizers (mineral and organic) on root diameter. Fuzzy logic is a method that presents a language, more appropriate to day-to-day life, as the sky is a bit cloudy. For the input variables of this system the mineral and an organic fertilizer were used, for the output the root diameter, in cm. After optimization of the input rules, it can be seen that for the application of the fertilizers (mineral and organic) the best dosages were from 15 to 60 and 20 to 60 $g \cdot m^{-2}$, respectively. With this application of fuzzy rules in real data, it is possible to take these benefits to those involved in the production chain of radish, resulting in a reduction in the dosages of products and improving its final profitability.

Keywords: Fuzzy Logic; Mineral Fertilizer; Organic Fertilizer

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1. Introduction

The Gross Domestic Product (GDP) in 2020, showed high in all sectors of Brazilian agribusiness, even if the other sectors of this indicator showed losses with the pandemic of COVID-19[1]. Within Agribusiness one of the sectors that stood out were grains and horticulture, especially the radish[2].

The radish culture has a short cycle from planting to harvest, this in relation to other horticultural crops[3]. Therefore, the application of fertilizers both mineral and organic exert great interference in the productivity of this crop[4], because the occurrence of physiological disorders of nutritional origin are factors that significantly influence the commercial productivity of radish[5].

However, mineral and organic fertilizers are considered the highest costs in an agricultural production[6], so the optimization in the processes must be effective. The fuzzy logic is a model that can be applied in several areas, especially in agribusiness, having as main objective to optimize production processes[7].

The theories involving sets and fuzzy logic treat uncertainty and ambiguity as deterministic[8]. Where Bayesian logic researchers work with probabilities, fuzzy logic scholars visualize different amounts of pertinence to events that are not probable, but are actual events[9].

Fuzzy logic allows applying uncertainties and ambiguities in a system of rules that express a conclusion not being as true or false, but being true to a certain degree[8]. Knowing that the degree of certainty is known as the degree of pertinence, so fuzzy logic works with data and results closer to non-mathematical language, as an example, “it may rain” or

"that man is tall"[10].

Given this, this study aimed to develop a model based on fuzzy rules to evaluate the effects caused by varying the dosages of two fertilizers one mineral and one organic fertilizer on root diameter.

2. Materials and methods

The article was based on a real field experiment, where two fertilizers were applied to the soil, one mineral, the 5-10-10 fertilizer, i.e., 5% nitrogen, 10% phosphorus and 10 potassium, and an organic fertilizer, the bovine compost, was applied to the radish crop in 5 different dosages of each fertilizer. The experiment was conducted at the Adroaldo Augusto Colombo State Agricultural College. Experimental data for modeling were described by Godinho and Caneppele[11].

A system based on fuzzy rules was developed in order to find the best fertilizer dosages (mineral and organic) to obtain a high yield with an adequate financial management.

This processor has one or more inputs, known as input, and one or more outputs, where they have been defined, as shown in **Figure 1**.

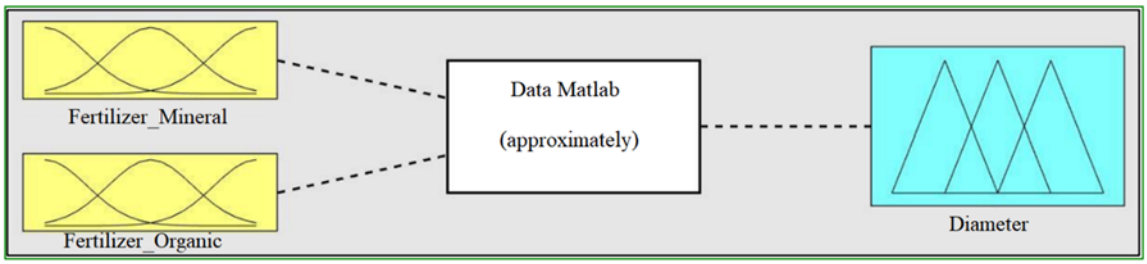

Figure 1. Fuzzy rule-based system for determining radish root diameter.
Source: Author, 2021.

In this study, a mathematical model called fuzzy logic was performed to evaluate the radish root diameter with the best fertilizer dosages (mineral and organic).

The characteristics of this mathematical modeling has a function where f: $R^2 \rightarrow R$ com $= f(\bar{x})$, where R is the set of real numbers, x_1 = *mineral fertilizer*, x_2 = *organic fertilizer* and y = *diameter*, as shown in **Figure 1**.

The input variables were mineral fertilizer (5-10-10) and organic fertilizer (bovine compost). According to Tsai[12], the most accurate model for this experiment is the trapezoidal model.

Equation 1, presents the fuzzy set of trapezoidal type, which is formed by four points (a, b, c, d). Therefore, the modeling number (x) can be contained in 3 parts of the fuzzy set. Therefore, its representation can be established as follows:

$$f(x,a,b,c,d) = \begin{cases} \dfrac{x-a}{b-a} & if \quad a \le x < b \\ 1 & if \quad b \le x \le c \\ \dfrac{d-x}{d-c} & if \quad c < x \le d \\ 0 & \text{opposite case} \end{cases} \qquad (01)$$

Figure 2a) and **2b)** show the parameter sets of the fertilizers (mineral and organic), where identical range was applied for both of [0–60] and were classified into "Low", "Medium" and "High". **Table 1** contains the points that form the relevance functions. To evaluate the radish root diameter, a mathematical model was used as previously described by Cremasco[13]. Therefore, **Figure 2c)** presents the output values for root diameter, where a range of [0–10] was established.

Table 1. Definition of relevance functions for the input variable: mineral fertilizer, organic fertilizer and output: radish root diameter

Fuzzy Set	Type	Limit
Mineral Fertilizer		
"Low" L	Trapezoidal	[-10 0 10 20]
"Medium" M	Trapezoidal	[10 20 30 40]
"High" H	Trapezoidal	[30 40 50 60]
Organic Fertilizer		
"Low" L	Trapezoidal	[-10 0 10 20]
"Medium" M	Trapezoidal	[10 20 30 40]
"High" H	Trapezoidal	[30 40 50 60]
Diameter		
"Low" L	Trapezoidal	[-1.0 0 1.0 2.0]
"Medium" M	Trapezoidal	[1.0 2.0 3.0 4.0]
"High" H	Trapezoidal	[3.0 4.0 5.0 6.0]

Source: Author, 2021.

The system was based on fuzzy computer rules

was established by the Fuzzy Logic Toolbox of MATLAB® 7.0 (MathWorks Inc. Copyright 1984–2004), coupled to the surface and the contour map.

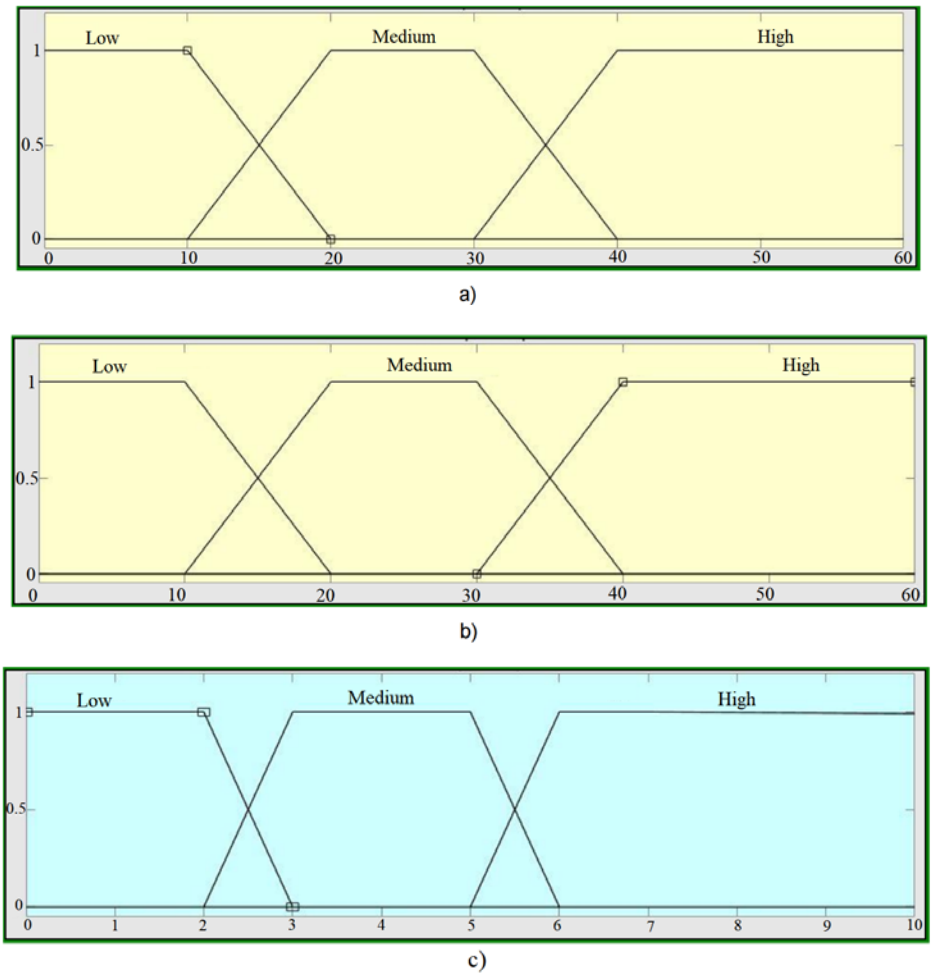

Figure 2. System parameter for determining plant diameter: **a)** mineral fertilizer; **b)** organic fertilizer; **c)** diameter.
Source: Author, 2021.

3. Results and discussion

From the field experiment with radish, it was possible to draw the base rule (**Table 2**). Thus, radish root diameter tends to respond with high yields when its fertilization is at adequate nutrient levels.

Table 2, presents the basic rules of the system, where it was elaborated from linguistic data of fuzzy logic. Being:

- If (mineral fertilizer is "L") (organic fertilizer is "L") then (diameter is "L");
- If (mineral fertilizer is "L") (organic fertilizer is "M") then (diameter is "L");
- If (mineral fertilizer is "L") (organic fertilizer is "H") then (diameter is "M");

The other lines are interpreted analogously.

From the developed model, it was possible to prepare the response surfaces for root diameter and their contour maps to verify the real inference of mineral and organic fertilizers. The model based on fuzzy rules verified all combinations between the variables, being 3 levels (L; M; H) with 2 variables (mineral fertilizer and organic fertilizer) can create a rule base with 9 combinations, being 3 × 3.

Table 2. Basic rules of the fuzzy system

Mineral Fertilizer	Organic Fertilizer	Diameter (cm)
L	L	L
L	M	L
L	H	L
M	L	L
M	M	M
M	H	H
H	L	M
H	M	H
H	H	H

L: Low; **M:** Medium; **H:** High.
Source: Author, 2021.

With this, the fuzzy response surface model in **Figure 3** was developed. In this study, a strong relationship was observed between the application of mineral fertilizer and organic fertilizer determining the root diameter of radish. In other words, radish responds well to medium to high dosage fertilizer applications for high yields, as presented in **Figure 3**.

Figure 4 is the contour map produced after applying the rule bases developed by fuzzy logic. Region **L** illustrated in **Figure 4** represents an unfavorable root diameter condition due to the low fertilizer dosage, especially for organic fertilizer, which does not provide ideal conditions for the growth and development of this particular crop. On the other hand, region **H** is characterized as an area that has medium to high rates for the mineral fertilizer and medium to high rates for the organic, providing a region condition suitable for high radish yields.

In a field experiment with different dosages of organic FO fertilizers in vegetables[14],confirmed that at high dosages of FO, vegetables in general tend to respond with greater aptitude for productivity, because these fertilizers besides having nutrients in their constitution, also have high rates of organic matter.

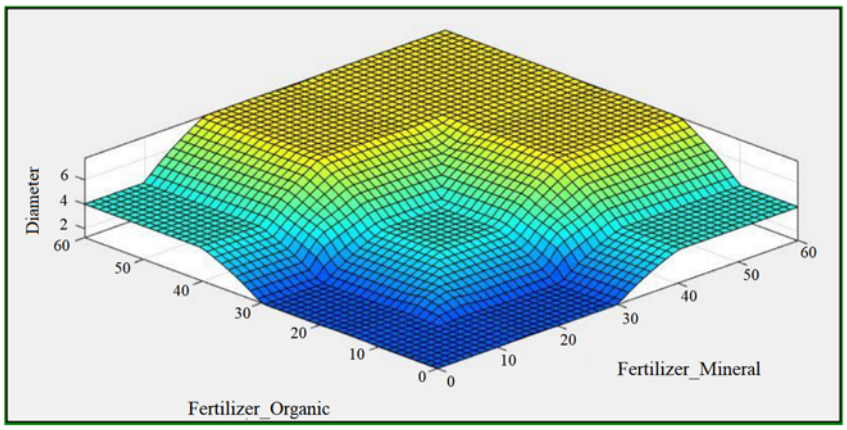

Figure 3. Response surface model of radish root diameter in response to mineral and organic fertilizers.
Source: Author, 2021.

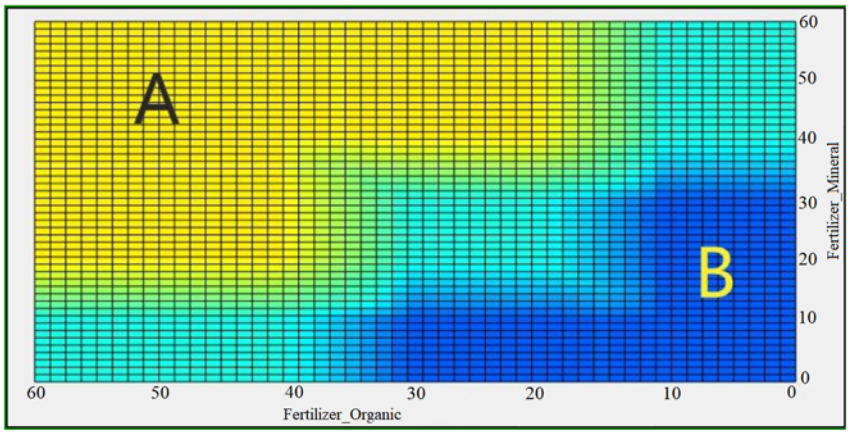

Figure 4. Contour map of radish root diameter in response to mineral and organic fertilizers.
Source: Author, 2021.

Figure 5 simulates the system based on fuzzy rules for the dosages of mineral and organic fertilizers. The point found is within an intermediate condition, which is also taken into account to determine the root diameter, given as 4.0 cm. When the analyzed degrees of association of the output variable are analyzed, it can be seen that the point has a higher degree of pertinence within the fuzzy set, as shown in **Figure 6**.

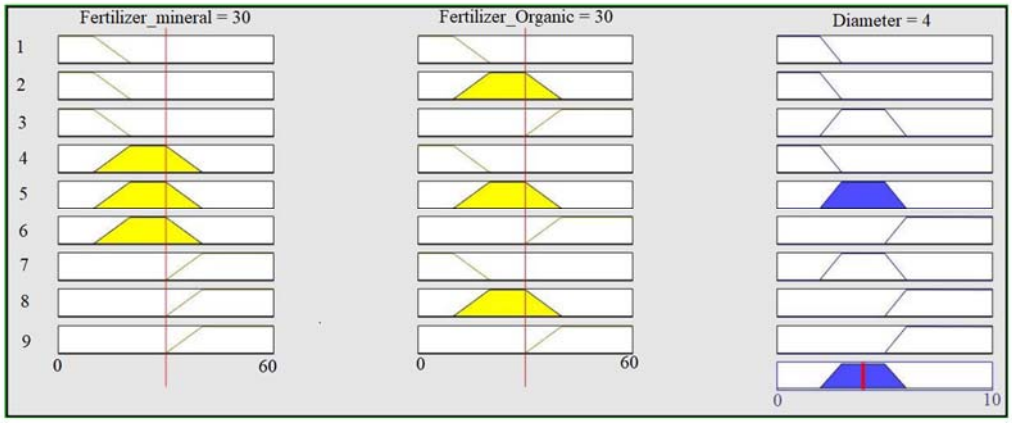

Figure 5. Mandani's inference method for mineral fertilizer = 30 g·m^{-2} and organic fertilizer = 30 g·m^{-2}, with a diffuse root diameter = 4.0.
Source: Author, 2021.

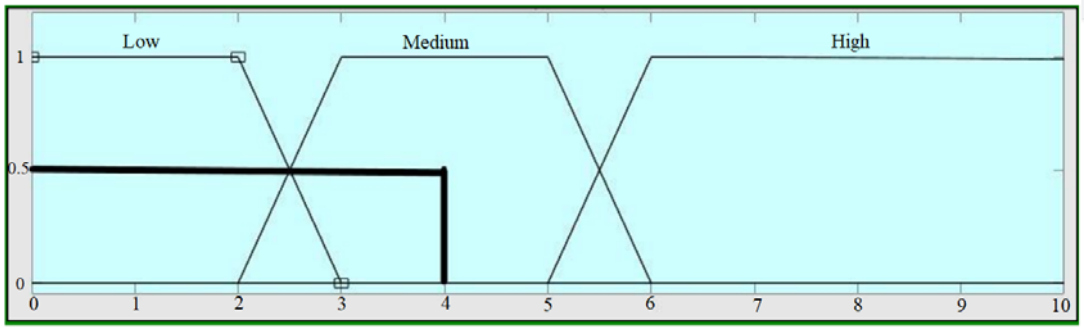

Figure 6. Indication of highest degree of pertinence for the fuzzy set, optimal point of root diameter = 4.0.
Source: Author, 2021.

4. Conclusions

The interpretation of the use of fuzzy logic in this experiment using real field data was able to optimize the best dosages of fertilizers used, being 15 to 60 and 20 to 60 g·m^{-2}, respectively of the organic fertilizer and the mineral fertilizer.

With this result, the vegetable producer, especially of radish, can optimize the dosage of fertilizers, both mineral and organic, in his beds, with greater efficiency and effectiveness, seeking greater financial profitability.

Conflict of interest

The authors declare that they have no conflict of interest.

References

1. Brasil. Produto Interno Bruto—PIB (Portuguese) [Gross Domestic Product (GDP)] [Internet]. Available from: https://www.gov.br/fazenda/pt-br/centrais-de-conteudos/publicacoes/conjuntura-economica/atividade-economica/2021/pib-brasil-4tri2020-ibge-resultados-spe.pdf.
2. CEPEA. PIB do agronegócio alcança participação de 26,6% no PIB brasileiro em 2020 (Portuguese) [Agribusiness GDP reaches 26.6% of the Brazilian GDP in 2020] [Internet]. Piracicaba: 2021. Available from: https://www.cnabrasil.org.br/boletins/pib-do-agronegocio-alcanca-participacao-de-26-6-no-pib-brasileiro-em-2020.
3. Da Silva AFA, Souza ÊGF, Barros AP, *et al.* Agronomic performance in radish fertilised with *Calotropis procera* (Ait.) R. Br. in two growing seasons. Revista Ciência Agronômica 2017; 48(2): 328–336.
4. Godinho EZ, Gasparotto HV. Response of carrotto the use of different soil fertilizers. Brazilian Journal of Development 2021; 7(3): 27052–27059. doi: 10.34117/bjdv7n3-420.
5. Ferreira RLF, Galvão RO, Miranda Junior EB, *et al.* Organic cropping of radish in no-tillage under died and live mulching. Horticultura Brasileira 2011; 29(1): 299–303.
6. Silva PP, Ferreira RS, Teodoro PE, *et al.* Response of Brachiaria brizantha at doses of poultry biofertilizers. Arquivos do Instituto Biológico 2014; 81(3): 286–289. doi: 10.1590/1808-1657001282012.
7. Godoy FO. Godinho EZ, Daltin RS, *et al.* Use of fuzzy logic applied to solar energy. Cadernos de Ciência & Tecnologia 2020; 37(2): e26663. doi: 10.35977/0104-1096.cct2020.v37.26663.
8. Caneppele FL, Godinho EZ, Zuin LFS, *et al.*

Application of fuzzy logic in strawberry development in western Paraná. Revista Sodebras 2021; 16(184): 2019–2022.
9. Chenci GP, Rignel DGS, Lucas CA. Uma introdução á lógica Fuzzy (Portuguese) [An introduction to Fuzzy logic]. Revista Eletrônica de Sistemas de Informação e Gestão Tecnológica 2011; 1(1): 17–28.
10. Putti FF, Gabriel Filho LRA, Gabriel CPC, *et al.* A Fuzzy mathematical model to estimate the effects of global warming on the vitality of Laelia purpurata orchids. Mathematical Biosciences 2017; 288: 124–129.
11. Godinho EZ, Caneppele FL. Efeito da nutrição (Portuguese) [Effect of nutrition]. Revista Cultivar Grandes Culturas 2019; 1(241): 20–23.
12. Tsai W, Lin Y, Tsai C, *et al.* Conversion of water caltrop husk into torrefied biomass by torrefaction. Energy 2020; 195: 116967.
13. Cremasco CP, Roberto L, Gabriel A. Methodology of determination of membership functions of fuzzy controllers for energy evaluation of companies of position poultry. Energia na Agricultura 2010; 25(1): 21–39. doi: 10.17224/EnergAgric.2010v25n1p21-39.
14. Godinho EZ, Santos AKO, Rockenbach B, *et al.* Beetle's response to mineral and organizational fertilizing application in summer cultivation. Revista Agropampa 2019; 2(2): 238–248.