ISSN 1808-3765

FUZZY LOGIC TO EVALUATE VITALITY OF CATASETUM FIMBIRATUM SPECIES (Orchidacea)

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1 ABSTRACT

The fuzzy logic accepts infinite intermediate logical values between false and true. In view of this principle, a system based on fuzzy rules was established to provide the best management of Catasetum fimbriatum. For the input of the developed fuzzy system, temperature and shade variables were used, and for the output, the orchid vitality. The system may help orchid experts and amateurs to manage this species. “Low” (L), “Medium” (M) and “High” (H) were used as linguistic variables. The objective of the study was to develop a system based on fuzzy rules to improve management of the Catasetum fimbriatum species, as its production presents some difficulties, and it offers high added value.

Keywords: management, cultivar, habitat and Fuzzy systems.

PUTTI, F. F.; GABRIEL FILHO, L. R. A.; SILVA, A. O. da; LUDWIG, R.; GABRIEL, C. P. C.
APLICAÇÃO DA LÓGICA *FUZZY* PARA DETERMINAÇÃO DA VITALIDADE DA ESPÉCIE *CATASETUM FIMBIRATUM (Orchidacea)*

2 RESUMO

A lógica *fuzzy* admite infinitos valores lógicos intermediários entre o falso e o verdadeiro. Com esse princípio, foi elaborado neste trabalho um sistema baseado em regras *fuzzy*, que indica a melhor forma de manejar a espécie *Catasetum fimbriatum.* O sistema *fuzzy* desenvolvido teve como entradas as variáveis temperatura e sombreamento, e a saída à vitalidade das orquídeas, que poderá auxiliar os orquidófilos no manejo da espécie, e foram utilizadas as variáveis linguísticas “Baixo” (B), “Médio” (M) e “Alto” (A). O objetivo deste trabalho é desenvolver um sistema baseado em regras *fuzzy* para auxiliar no manejo da espécie *Catasetum fimbriatum,* pois se trata de uma espécie de difícil cultivo e de alto valor agregado.

Palavras-chave: Manejo, cultivar, habitat e sistemas *Fuzzy*

Recebido em 05/12/2012 e aprovado para publicação em 17/07/2014

3 INTRODUCTION

L.C. Richard was the first to describe the genus *Catasetum* in 1822. During the last years the genus has been focused by botanists and zoologists due to its amazing adaptation to entomophily (HOEHNE, 1938) and to its trimorphism of its flowers. The plants´ habitat is the trunk of old trees with high decomposing organic matter (HOEHNE, 1938; MACHADO, 1998). Machado (1998) and Oliveira & Sajo (2001) report on thick, well-developed pseudo-bulbs related to water storage that provides the plants´ survival during drought periods. *Catasetum fimbriatum* is an almost threatened plant due to the continuous destruction of its natural habitats and to the extraction of the plant for its high added value on the market (PEREIRA & BARRETO, 2004).

The employment of fuzzy logic in the evaluation of agrarian, biological and management phenomena is an extremely efficient and efficacious alternative in the wake of current stochastic methods. Several applications of the theory comprise power management (CREMASCO, 2008), characterization of the production environment in pregnant matrixes (PANDORFI et al., 2007), estimates on the well-being of pregnant matrixes (PEREIRA et al., 2008), determination of the ideal moment for cattle slaughter (GABRIEL FILHO et.al., 2011), use of irrigation methods (SURESH & MUJUMDAR, 2004; SARUWATARI & YOMOTA, 1995) and decision in irrigation timing and amounts (MONTAZAR et al., 2013; AL-FARAJ et al., 2001). Fuzzy logic, based on mathematical methods and computer intelligence, provides quickly and in a practical manner several decisions that should be taken in the urban and rural environment. Several meteorological variables are required to determine the environment condition patterns in which a culture adapts itself, comprising temperature and hours of light needed for its development. Agricultural zoning is one of the most precise tools to estimate adaptation involving climate (SILVA et al., 2011). However, techniques in protected culture to monitor and decide the best climate condition of the instance should be used especially when the crop is cultivated for its high economical value. In other words, fuzzy logic is a precise help when decisions have to be taken, since it warrants sure returns for the producers´ investments (HAHN, 2011).

Fuzzy logic establishes genetic algorithms which imitate a section of human reasoning. The methods are synthesized by establishing a computer program called fuzzy rules-based system (AMENDOLA et al., 2004). The theory that applies mathematics to diffused concepts was forwarded by Lotfi Asker Zadeh in 1965 and tries to approach human reasoning by fuzzy sets, also described by linguistic variables (ZADEH, 1965). A series of optimization standards is undertaken for decision taking according to planning.

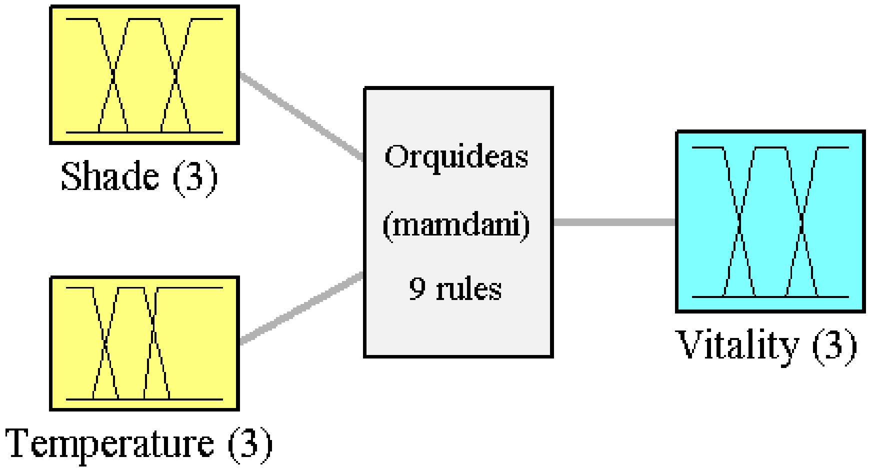
Current assay develops a fuzzy rules-based system for the management of *Catasetum fimbriatum* aiming at an adequate cultivation environment due to the difficulty in cultivating the species and its high added value.

4 MATERIALS AND METHODS

Current paper was based on a review of the literature for better cultivation conditions of *Catasetum fimbriatum.* Experimental data for modeling have been described by Watanabe (2002).

A system based on fuzzy rules was established to find the best temperature and shade conditions as the main characteristics for adequate management. An input processor (fuzzifier), a set of linguistic rules, a fuzzy inference method and an output processor (de-fuzzifier) for the generation of a real number as output, were defined. Figure 1 illustrates the proposed system based on fuzzy rules.

Figure 1. System based on fuzzy rules for the cultivation of *Catasetum Fimbiratum*.

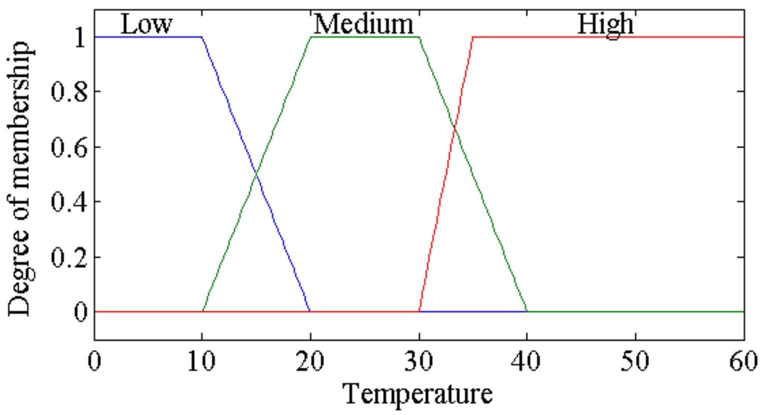


Temperature and Shade, the best conditions for the cultivation of *Catasetum Fimbiratum*, were the input variables of the fuzzy rules-system. Degree of membership Low (L). Medium (M) and High (H) were defined for each variable. Degree of membership for the variable Temperature is given in Table 1 and Figure 2.

Table 1. Definition of degree of membership for the variable Temperature.

Fuzzy set	Type	Limitator
Low (L)	Trapezoid	[-1 0 10 20]
Medium (M)	Trapezoid	[10 20 30 40]
High (H)	Trapezoid	[30 35 60 61]

Figure 2. Degree of Membership for fuzzy sets of the input variable Temperature.

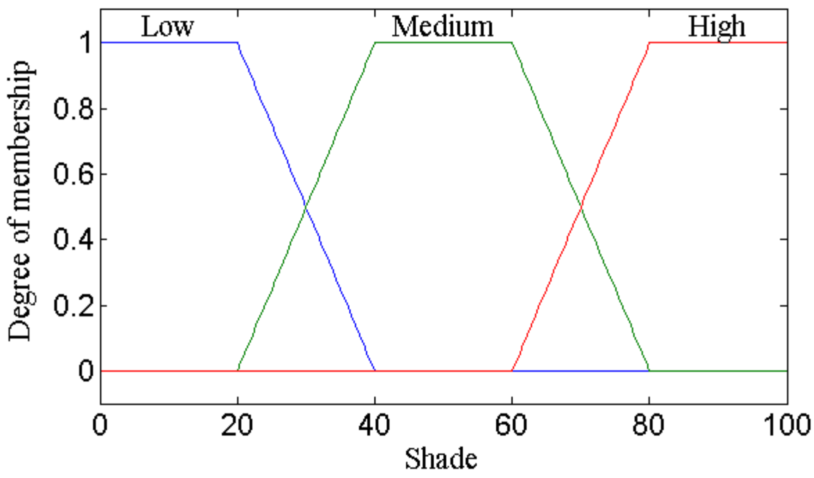


The variable Shade, or rather, the amount of sunshine that may be removed to protect the plant against sun rays, is given in percentage (%), with degree of membership according to Table 1 and Figure 3.

Table 2. Degree of Membership for variable Shade.

Fuzzy set	Type	Limitator
Low (L)	Trapezoid	[-1 0 20 40]
Medium (M)	Trapezoid	[20 40 60 80]
High (H)	Trapezoid	[60 80 100 101]

Figure 3. Degree of membership for fuzzy sets of the input variable Shade.

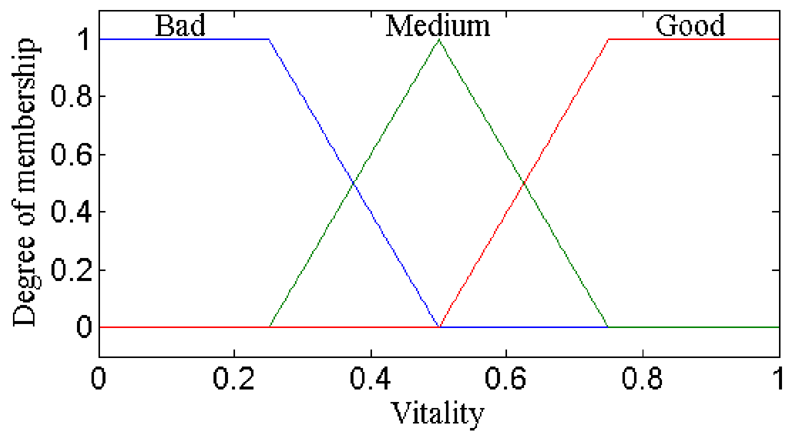


The system´s output variable was called fuzzy vitality and a real number was generated for the interval [0,1]. Degrees of membership of the variable were called Bad (B), Medium (M) and Good (G), following Table 3 and Figure 4.

Table 3. Definition of degrees of membership of input variables.

Fuzzy set	Type	Limitators
Bad (B)	Trapezoid	[-1 0 0.20 0.40]
Medium (M)	Trapezoid	[0.20 0.40 0.60 0.80]
Good (G)	Trapezoid	[0.60 0.80 1 2]

Figure 4. Degrees of membership for fuzzy sets of the output variable Vitality.



Nine (3 × 3) combinations are taken into consideration between the fuzzy sets of the two input variables to obtain the fuzzy system´s rule base. Rules for the fuzzy system were prepared according to Watanabe et al. (2002), as in Table 4.

Table 4. Temperature and Shade rates for the construction of fuzzy systems´s rule base.

Temperature /Shade	**<15°**	**15°-35°**	**>35°**
0%-40%	Bad	Medium	Bad
40%-60%	Bad	Good	Bad
60%-100%	Bad	Good	Good

So that the fuzzy system could be prepared, rates were transformed into language and thus Low (L), Medium (M) and High (H) were adopted for both input variables, following Table 5.

Table 5. Combinations of the input variables with scales for degrees of membership 1 associated to the fuzzy sets for the generation of rule base.

Humidity/Temperature	**Low**	**Medium**	**High**
Low	Bad	Medium	Bad
Medium	Bad	Good	Bad
High	Bad	Good	Bad

Inference method used for the calculation of the numerical value of the output variable according to the Rule Base is Mandani´s method.

The Gravity Center method or Centroid, the most usually employed de-fuzzification technique, was employed for de-fuzzification, given as a weighed average in which $\mu_A(x)$ is the weight of x.

If x is discrete, the de-fuzzification of the fuzzy set A is given by:

$$\bar{z} = \frac{\sum_x \mu_A(x)x}{\sum_x \mu_A(x)}$$

(1)

Similarly, if x is continuous, then

$$\bar{z} = \frac{\int \mu_A(x)xdx}{\int \mu_A(x)dx} \quad (2)$$

A system based on computer fuzzy rules was established by Fuzzy Logic Toolbox of MATLAB® 7.0 (MathWorks Inc. Copyright 1984-2004), coupled to surface and representation contour map of the system.

5 RESULTS AND DISCUSSION

Figure 5 shows surface as a solution of the fuzzy system by Mamdani´s Inference Method, with contour map illustrated in Figure 6.

Figure 5. Fuzzy Vitality for *Catasetum fimbiratum* in 3-D.

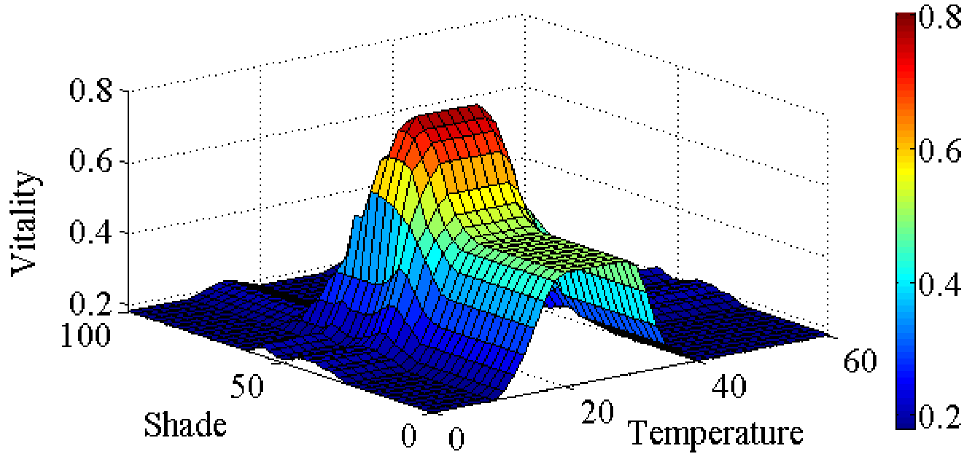


Figure 6. Contour map of fuzzy surface Vitality.

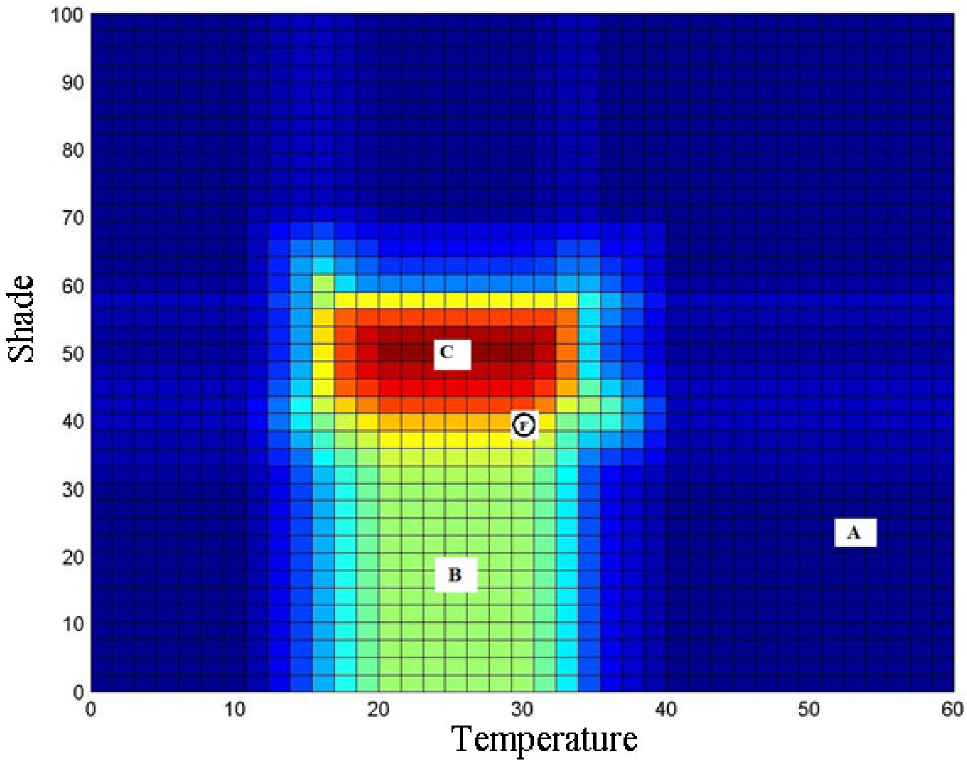


Figure 6 identifies the region on the plane *Temperature* × *Shade* that establishes the highest and lowest rates for Fuzzy Vitality, featuring an excellent tool for the orchid expert to a more adequate management and thus more favorable environmental conditions. In fact, the management of orchids is highly complex.

Region *C* represents favorable conditions for cultivation since it provides temperature and shade, the best conditions for cultivation. It is thus classified as the best condition (High). Whereas region B provides less favorable conditions for cultivation than region A, albeit with low shade, it is not the best for management. Likewise, region A with a low temperature has not the best management conditions.

Figure 6 also shows possible modifications with regard to the shade system of the orchid greenhouse. Studies on agronomic experimentation may be developed to investigate (i) the relationship between shade increase in the orchid greenhouse and temperature decline, and (ii) the relationship between shade decrease and temperature increase. These activities which would be indicated in such events as (i) Low Shade and High Temperature, and (ii) High Shade and Low Temperature would establish conditions so that the new condition may be found in Region C, related to a higher degree of vitality.

Figure 6 also reveals that if the temperature in the greenhouse is Low (< 15ºC) or High (> 25ºC), the orchids´ vitality degree will be low. If Shade is High (> 60%), degree will be low. The above conditions represent an unfavorable environment for orchid development. However, shade decrease (if it is high) should be executed with care. As explained above, the activity may cause temperature increase. If the orchid greenhouse has an average temperature (between 15ºC and 25ºC) and High Shade (> 60ºC), shade decrease may cause a temperature rise (which has to be verified experimentally in future assays). In this case, an additional refrigeration system (and costs) may be recommended, besides shade decrease.

Figure 7 simulates the system based on fuzzy rules for rates Temperature and Shade, indicated by F in Figure 6. The point lies within an intermediate condition, which is also taken into account to determine Vitality, given as 0.760. When degrees of membership of the output variable is analyzed, it may be seen that the point has a higher degree of membership within the fuzzy set Good (G), as Figure 8 shows.

Figure 7. Mandani´s inference method for *Temperature* = 30°C and *Shade* = 45 %, with a fuzzy Vitality rate = 0.760.

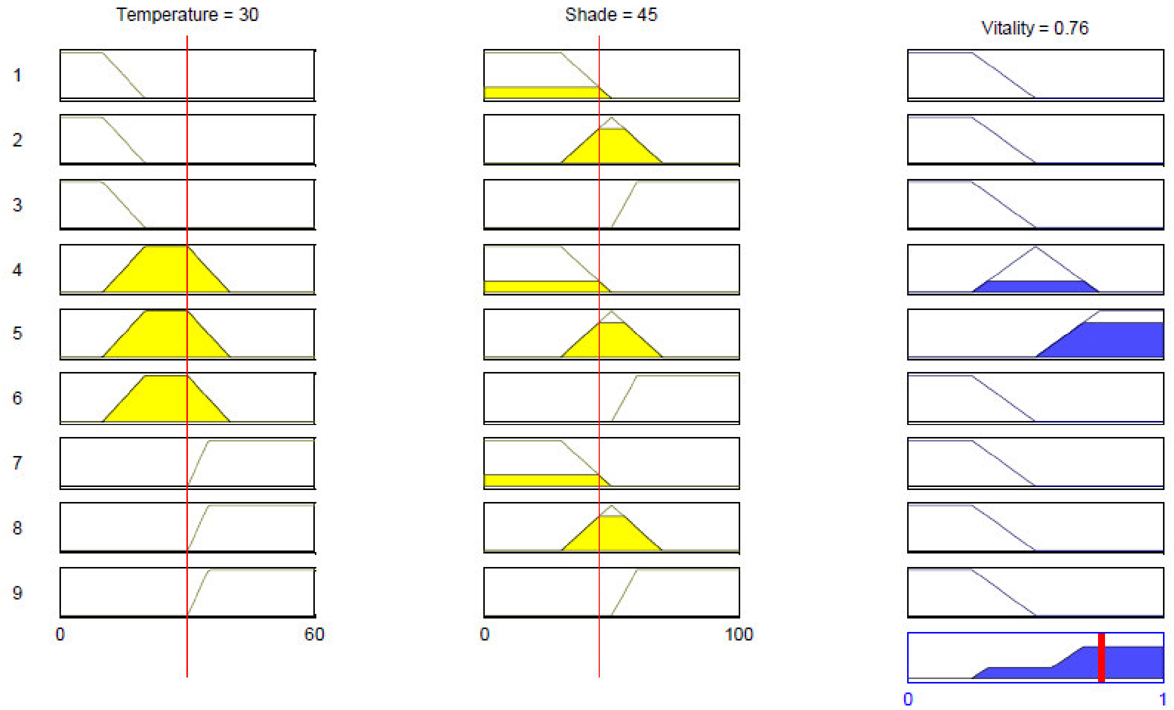
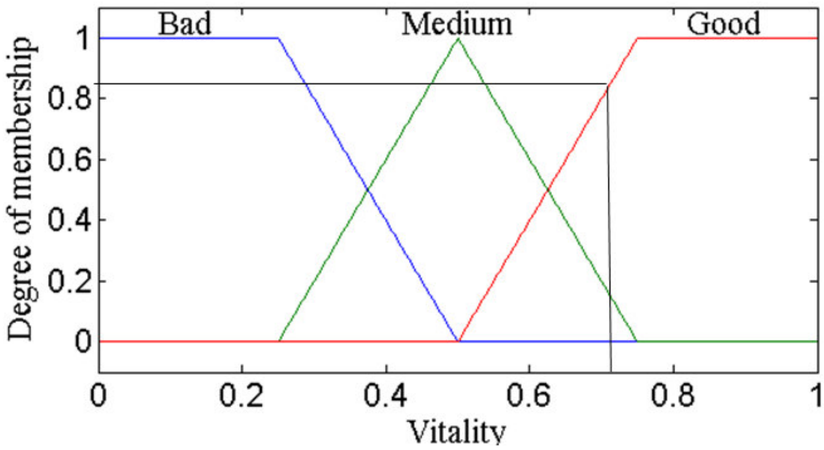


Figure 8. Indication of greater degree of membership for the fuzzy set Good of point Vitality = 0.760.



6 CONCLUSIONS

Current assay establishes a computer method to interpret conditions adequate for species management. The method, based on fuzzy logic, partially imitates human reasoning.

The above interpretation on the use of Fuzzy logic for the adequate management of cultivation conditions is highly relevant for the management of the species by orchid experts and amateurs. Different temperatures and shades directly affect flowering. A significant innovation within the systems based on fuzzy rules is that the rule bases were not established from interviews with experts but by a review of the literature as a theoretic foregrounding. The system based on fuzzy rules developed in current research is an easy system and may be a great help to orchid experts and amateurs in the management of *Catasetum fimbriatum.*

7 REFERENCES

AL-FARAJ, A.; MEYER, E. G.; HORST, G. L. A crop water stress index for all fescue (Festuca arundinacea Schreb.) irrigation decision-making - a fuzzy logic method. **Computers and Eletronics in Agriculture**, Amsterdam, v. 32, n. 69-84, 2001.

AMENDOLA, M.; SOUZA, A. L.; BARROS, L. C. **Manual do uso da teoria dos conjuntos Fuzzy no MATLAB 6.5.** Campinas: CPG, 2004.

CREMASCO, C. P.; GABRIEL FILHO, L. R. A.; CATANEO, A. Metodologia de determinação de funções de pertinência de controladores fuzzy para avaliação energética de empresas de avicultura de postura. **Energia na Agricultura**, Botucatu, v. 25, n. 1, p. 21-39, 2010.

GABRIEL FILHO, L. R. A.; CREMACO, C.C.; PUTTI, F. F.; CHACUR, M. M. Application of fuzzy logic for the evaluation of livestock slaughtering. **Engenharia Agrícola**, Jaboticabal, v. 31, n. 4, p. 813-825 , 2011.

HAHN, F. Fuzzy controller decreases tomato cracking in greenhouses. **Computers and Electronics in Agriculture**, Amsterdam, v. 77, p. 21-27, 2011.

HOEHNE, F. C. As plantas ornamentais da flora brasílica. **Boletim de Agricultura**, São Paulo, v. 1, p. 247-273, 1938.

MACHADO, E. F. *Catasetum*, uma orquídea diferente. **O Mundo das Orquídeas**, [S.l.], v. 4, p. 5-6, 1998.

MONTAZAR, A.; GHEIDARI, O. N.; SNYDER, R. L. A fuzzy analytical hierarchy methodology for the performance assessment of irrigation projects. **Agricultural Water Management**, Cidade, v. 121, p. 113-123, 2013.

OLIVEIRA, V. C.; SAJO, M. G. Morfo-anatomia caulinar de nove espécies de Orchidaceae. **Acta Botânica Brasilica**. v. 15, n. 2, p. 177-188, 2001.

PANDORFI, H. et al. Uso da lógica fuzzy na caracterização do ambiente produtivo para matrizes gestantes. **Engenharia agrícola**, Jaboticabal, v. 27, n. 1, p. 83-92, 2007.

PEREIRA, D. F. et al. Sistema fuzzy para estimativa do bem-estar de matrizes pesadas. **Engenharia Agrícola**, Jaboticabal, v. 28, p. 624-634, 2008.

PEREIRA, O. L., BARRETO, R. W. First report of Sphenospora kevorkianii (Raveneliaceae) on the orchid Catasetum fimbratum in Brazil. **Plant Pathology**, Sutton Bonington, 53, p. 256, 2004.

SARUWATARI, N.; YOMOTA, A. Forecasting system of irrigation water on paddy field by fuzzy theory. **Agricultural Water Management**, Amsterdam, v. 28, p. 163-178, 1995.

SILVA, A. O. et al. Zoneamento agroclimático da pitangueira para três cenários distintos de precipitação pluvial em Pernambuco. **Revista Caatinga**, Mossoró, v. 24, n. 1, p.104-115, 2011.

SURESH, K. R.; MUJUMBAR, P. P. A fuzzy risk approach for performance evaluation of an irrigation reservoir system. **Agricultural Water Management**, Amsterdam, v. 69, p. 159-177, 2004.

MATLAB for Windows User's Guide, The Math Works Inc., 1991.

WATANABE, D. **Orquídeas**: manual de cultivo. 2. ed. São Paulo: AOSP, 2002. 296 p.

ZADEH, L. A**.** Fuzzy sets. **Informat Control**, Amsterdam, v.8 , n. 338-353, p. 338-353, 1965.