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The decomposition of woody fibers by multiple fungi and their interaction

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Abstract: In this paper, we study the fungal community in which woody fibers are decomposed through fungal activity. Firstly, by analyzing the data of fungal traits, we establish Model I: a model for the decomposition of woody fibers by multiple fungi and their interaction. Secondly, under the existing microbiology research, we establish Model II: The Fungal Population Competition Model, to predict the relative advantages of species combinations in different environments and the importance and role of biodiversity. For this question, we extract the data of different fungi's hyphal extension rate, moisture tolerance and decomposition rate. Then by modeling the Binary Nonlinear Regression model based on the least square method, we describe the breakdown of ground litter and woody fibers through two traits of fungi. Finally, we analyze the accuracy and sensitivity of the model, and prove that our model is accurate and stable for different parameters. Also, we discuss the latest developments in the role of fungi in ecosystems.

1. Problem Statement

Fungi, the main decomposer in the ecosystem, play an important role in the global carbon cycle. In a research article, the author pointed out that hyphal extension rate -the growth rate of fungi is an important traits of fungi, and the slow growing strains of fungi tend to be better able to survive and grow in the presence of environmental changes with respect to moisture and temperature, while the faster growing strains tend to be less robust to the same changes. Exploring these two interesting characteristics of fungi, namely the relationship between growth rate and moisture resistance and decomposition rate, and understanding the role of fungi in ecosystems is of great significance to biodiversity.

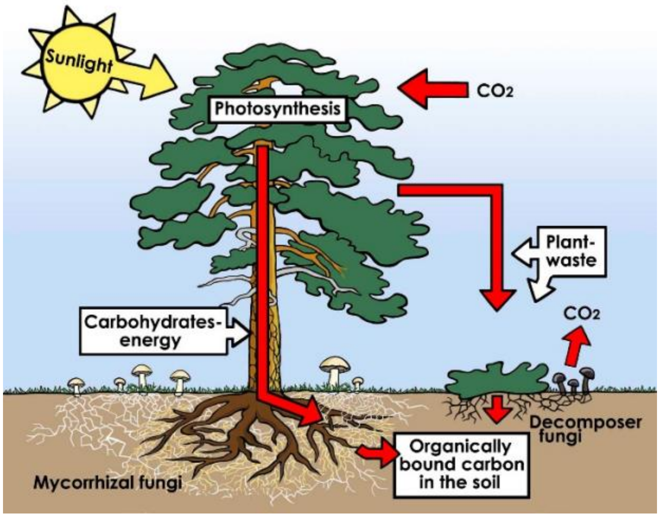

Figure 1: The Carbon Cycle (by Lisa Larsson)

2. Model I: A model for the decomposition of woody fibers by multiple fungi and their interaction

2.1 Model I-1: Binary Nonlinear Regression Model

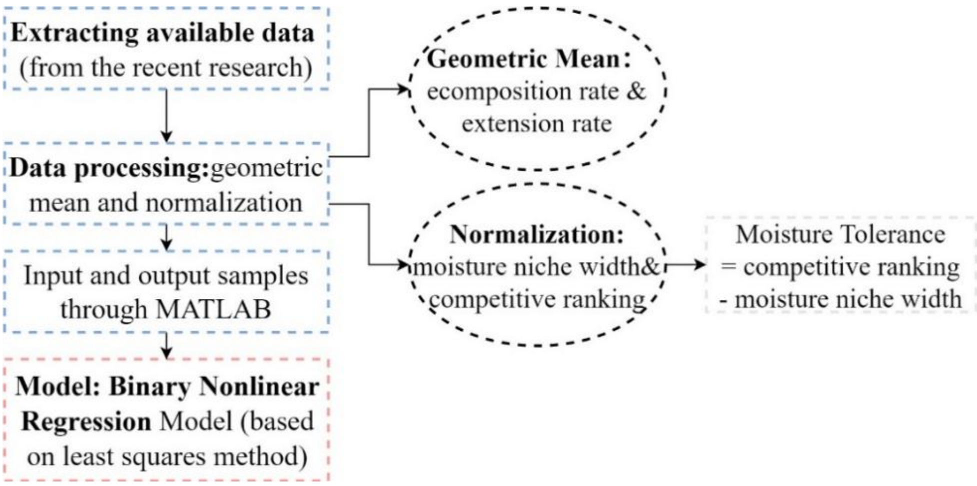

Figure 2: Flow chart

2.1.1 Data processing

We extract the data of hyphal extension rate and decomposition rate of 34 wood-rot fungi at 10°C, 16°C and 22°C, then calculate their geometric mean, the competition ranking and moisture niche width of these fungi are obtained through related articles. After normalizing the data, we calculate the moisture tolerance (competition ranking-moisture niche width).

2.1.2 Model building

According to results, it is obvious that neither the growth rate nor the moisture resistance has a standard linear relationship with the decomposition rate, so we consider using curve fitting to perform multiple regression analysis on these three variables.

In a recent article, the author obtained a set of data on the traits of 34 fungi, to find the functional relationship between growth rate, moisture resistance and decomposition rate. Generally, the form of the function can be determined by experience, prior knowledge, or intuitive observation of the data. We already known that: the slow growing strains of fungi tend to be better able to survive and grow in the presence of environmental changes with respect to moisture and temperature, while the faster growing strains tend to be less robust to the same changes.

In summary, we establish the following two kinds of multiple nonlinear regression models to compare and obtain the functional relationship that fits the data best. The two function forms are

$$D = a_0 + a_1 v + a_2 m + a_3 v^2 + a_4 vm + a_5 m^2 \tag{1}$$

$$D = a_0 + a_1 v + a_2 e^m + a_3 v^2 + a_4 v e^m + a_5 e^{2m} \tag{2}$$

In Eq(1),(2), D denotes decomposition rate(%), v denotes growth rate(mm/day), m denotes moisture tolerance. $a_0, a_1, a_2, a_3, a_4, a_5$ are regression parameters

We use the least square method to calculate the value of regression parameters $a_0, a_1, a_2, a_3, a_4, a_5$ and the coefficient of determination R^2 from the known data. indicates to what extent the equation can explain the variation of the dependent variable D.

At the end of the optimization iteration, we get the parameter estimates $(a_0, a_1, a_2, a_3, a_4, a_5)$ of the two equations and R^2

${R_2}^2$=0.819>${R_1}^2$=0.706, So we choose the equation(2):

$$D = -4.271 - 2.449v + 27.363e^m - 0.465v^2 + 6.9x_1 e^m - 20.619e^{2m} \tag{3}$$

According to the data samples, based on the binary nonlinear regression model, we can get the three-dimensional graph of the relationship between fungi growth rate, humidity tolerance and decomposition rate. The upper and lower limits of the predicted values are drawn in the 95% confidence interval.

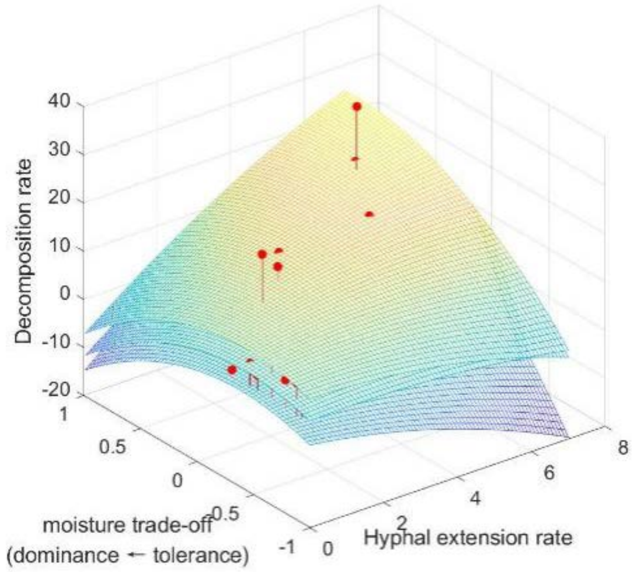

Figure 3

Figure 3: fitting surface of growth rate v, humidity tolerance m and decomposition rate of fungi. That is, the decomposition rate distribution of wood fiber under certain growth rate and moisture resistance.

It can be seen from the figure that the decomposition rate increases with the growth rate when the humidity tolerance is constant, which is consistent with the conclusion in the original question. However, when the growth rate is constant, the decomposition rate first increases and then decreases with the increase of humidity tolerance, which is not in line with the reality.

2.1.3 Model optimization

By analyzing the preliminary fitting results, we get that there are large errors in the predicted values of some test sample points. This shows that the application of multiple regression analysis method in this section is easily affected by environmental noise. The data points with very large deviation from the model may be caused by measurement errors, so we delete these points and then further optimize the iteration.

The regression equation is

$$D = 3.37 + 3.109v - 7.003e^{m} - 0.13v^{2} + 2.739x_{1}e^{m} - 8.144e^{2m} \qquad (4)$$

(R^2=0.902)>($R_2{}^2$=0.819), The fitting accuracy is improved obviously, Therefore, a better fitting curve can be obtained (Fig. 4).

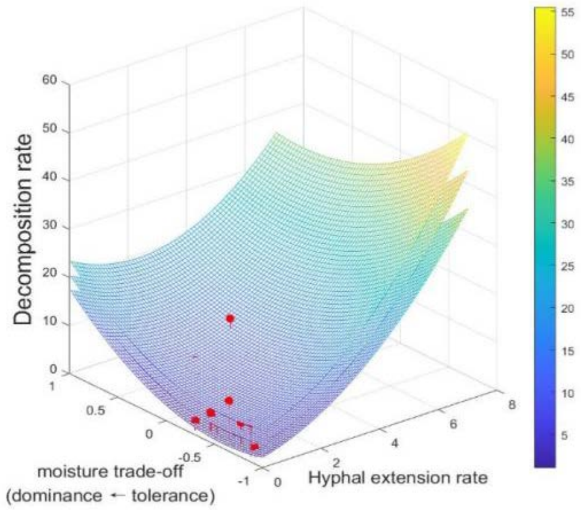

Figure 4

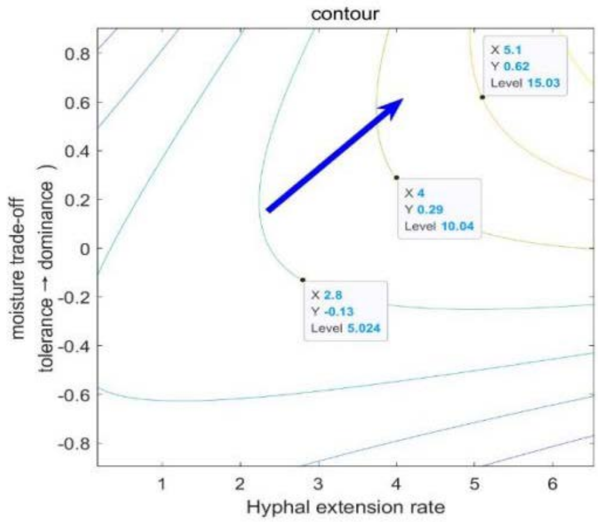

Figure 5

Figure 4: The fitting surface of fungi growth rate, humidity tolerance and decomposition rate was obtained by using the samples after noise reduction.

Figure 5: Contour map. The horizontal axis represents the growth rate (mm/day), the vertical axis indicates humidity resistance, the decomposition rate is the same on the same contour. The dots (2.8,-0.13, 5.024) in the figure indicate that the growth rate is 3.6 mm / day, the humidity resistance is -0.13, the decomposition rate is 5.024%, the decomposition rate on this curve is 5.024%.

In order to better describe the relationship between growth rate, humidity tolerance and decomposition rate, we transformed the three-dimensional curve into a plane top contour

References

[1] Nicky Lustenhouwer, Daniel S. Maynard, Mark A. Bradford, Daniel L. Lindner, Brad Oberle, Amy E. Zanne, and Thomas W. Crowther," A trait-based understanding of wood decomposition by fungi," Proceedings of the National Academy of Sciences of the United States, May 13, 2020.

[2] Otso Ovaskainen, Jenni Hottola and Juha Siitonen, "Modeling species co-occurrence by multivariate logistic regression generates new hypotheses on fungal interactions,"Published by Wiley on behalf of the Ecological Society of America, September 2010, Vol. 91, No. 9 (September 2010), pp. 2514-2521

[3] M. Jabed A. Choudhury, Philip M. J. Trevelyan & Graeme P. Boswell" A mathematical model of nutrient inflfluence on fungal competition," Article in Journal of Theoretical Biology, November 2017
[4] Diogenis A. Kiziridis ,Mike S. Fowler and Chenggui Yuan,"Modelling fungal competition for space - Towards prediction of community dynamics,"Published by DISCRETE AND CONTINUOUS DYNAMICAL SYSTEMS SERIES B , Volume 25, Number 11, November 2020, pp. 4411–4426