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THE EFFECT OF ENERGY OF THE HYPHAL DEATH ON YHWX BRANCHING

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Abstract. In this study, we looked at the YHWX fungus's growth conditions and found that it uses up all available energy. We do this by using mathematical models in the form of partial differential equations (PDEs), which are difficult to solve and depict the biological events unique to each species.The fact about fungal development is that solving problems of this type takes time. For this reason, we shall rely on the numerical solution to acquire an approximation of the solution. For this reason, we must do certain actions in order to solve it utilizing the Traveling Wave Solution, the Numerical Solution, Code Phase Plane 9, and PDEPE in Matlap.

Key words: Tip-hypha Anastomosis, Hyphal death, Lateral Branching, Tip Death Due to Overcrowding, Dichotomous Branching.

Introduction

The design of mathematical models in modeling and simulation depends on several foundations, the most important of which are: Define the objective The main objective of the mathematical model must be defined and what researchers want to study or analyze through the mode, Define the variables The main variables that will affect and control the model must be defined, such as physical,economic, or social variables, Define the relationships The relationships between the different variables in the model must be defined, so that they can be represented mathematically or formally, Define the criteria: The criteria that will be used to evaluate the performance of the model and compare it to reality must be defined, such as the accuracy of prediction or the ability to predict future behavior, Verification and improvement The validity of the model and its ability to predict future behavior must be verified, and this can be done by comparing the results of the model with actual data and improving and modifying the model if necessary, Documentation and Communication: All steps and processes used in designing the model should be documented, so that others can understand, and communicate about it. Flexibility and Modification: The model should be modifiable and scalable so that changes can be made to variables, relationships, or criteria without having to completely rebuild the model.[7-11]

A new model for mycorrhizal development will be constructed. PDEs that simulate the biomass's interaction with the underlying substrate work well at this size.

The complex mathematical structure of these models is made up of hyperbolic and equivalent components.[2] This group of any number of species can be expressed through the stages of growth of a specific fungal species, with the abbreviated seed symbols for each species, which describe to us some biological species. As a result, its analytical and numerical results are not trivial and aid in the discussion of the results. By doing a mathematical analysis of each kind and providing an explanation and description of its variables, we shall combine particular kinds of fungi in this section. [4]

The Mathematical Models

Mathematical modeling is simply a technique for using mathematics to represent or describe global phenomena. This technique uses symbols, numbers, and formulas to represent the world and predict future events. Mathematical modeling is used in many scientific and engineering applications, from predicting the effect of changes in the environment on the distribution of species, to designing bridges and buildings, to forecasting economic events. Models can be simple or complex as needed to explain the phenomenon to be represented. Mathematical modeling can be used to understand practical problems and phenomena, by transforming them into mathematical problems that can be solved. This is usually done by transforming the rules and laws that govern the phenomenon into mathematical equations. Once these equations are solved, they can provide solutions to the original practical problem. The majority of the area of operations research uses the mathematical model that we utilized to address the fungal branching with fungal death problem. where mathematical models are used to the fields of philosophy, linguistics, and music (e.g., the careful study of analytical philosophy) [1][12][13][14]. A model could be used to examine the effects of various components, provide philosophical interpretations of the system, and make predictions regarding the growth of fungi. We examine a novel form of branching (YHWX) that indicates [5][6]

$$Y = \propto_1 n\,, \qquad H = -\beta_2 np\,, \qquad F = \alpha_2 p\,, \qquad x = -\beta_3 p^2$$

Where

$\boldsymbol{Y}$:	The dichotomous branching
$\propto_1$:	The rate constant of autolysis in hyphal
n :	shows the density of the tip
H:	The tip-hypha anastomosis
β_2:	the likelihood of fusion for each tip encounter, while the negative reference denotes the tip removal methods built into σ but with negative contributions
p:	demonstrates the hyphal length
F:	The lateral branching
α_2:	is the quantity of branches generated in hyphae with a given length and time
x:	The tip death due to overcrowding
$\beta_{3:}$	is the rate at which nearby hyphae work t0gether to eliminate tips

Hyphal growth can be explained by the following system (1):

$$\begin{aligned} \frac{\partial \boldsymbol{p}}{\partial \boldsymbol{t}} &= \boldsymbol{J_a} - \boldsymbol{D} \\ \frac{\partial \boldsymbol{n}}{\partial \boldsymbol{t}} &= -\frac{\partial \boldsymbol{J_a}}{\partial \boldsymbol{x}} + \text{"}\mathbf{exp}\big(\boldsymbol{\sigma}(\boldsymbol{p},\boldsymbol{n})\big) \\ &\quad - \boldsymbol{\varphi}(\boldsymbol{x})\text{"} \end{aligned} \tag{1}$$

Where$J_a = nv$ pointed to the flow and $D = \gamma p$ is haphea death , by a compensation about ($\sigma(p,n) = \alpha_1 n - \beta_2 np + \alpha_2 p - \beta_3 p^2$) in the system(1), for getting the new system[2]

$$\begin{aligned} \frac{\partial p}{\partial t} &= nv - p \\ \frac{\partial n}{\partial t} &= -\frac{\partial (nv)}{\partial x} + exp(\alpha_1 n - \beta_2 np + \alpha_2 p - \beta_3 p^2) \\ &\quad - \varphi(x) \end{aligned} \tag{2}$$

That indicates that all of the energy has been used up. and in this system let ψ(x) = 1, we get the system :

$$\begin{aligned} \frac{\partial p}{\partial t} &= nv - p \\ \frac{\partial n}{\partial t} &= -\frac{\partial (nv)}{\partial x} + exp(\alpha_1 n - \beta_2 np + \alpha_2 p - \beta_3 p^2) \\ &\quad - 1 \end{aligned} \tag{3}$$

Now *we need to* the Stability, and Non-dimensionlision uniform a solution:

We will demonstrate how to set these parameters to obtain dimension reduction in this section, presuming:

$$p^* = \frac{p}{\bar{p}},\ n^* = \frac{n}{\bar{n}}\ ,\ t^* = \frac{1}{\tau}\ ,\quad and\ \ x^* = \frac{x}{\bar{x}}$$

And compensation in (3), we get

$$\begin{aligned} \frac{\partial p^*}{\partial t^*} &= n^* - p^* \\ \frac{\partial n^*}{\partial t^*} &= -\frac{\partial n^*}{\partial x^*} + exp\left(\frac{\alpha_1}{\gamma} n^* - \frac{\beta_2\, \bar{p}}{\gamma} n^* p^* + \frac{\alpha_2}{\bar{n}\gamma} \bar{p} p^* \right. \\ &\quad \left. - \frac{\beta_3 \bar{p}^2}{\bar{n}\,\gamma} p^{*^2}\right) - 1 \end{aligned} \tag{4}$$

Where ,$\bar{x} = \tau v$,$\bar{x} = \frac{\bar{p}}{\bar{n}}$, and to lift the stars, then the system (6) becomes:

$$\frac{\partial p}{\partial t} = n - p$$
$$\frac{\partial n}{\partial t} = -\frac{\partial (n)}{\partial x} + exp(\alpha n(1 - p\ ) + \beta p(1 - p)) - 1 \quad (5)$$

Where $\bar{p} = \frac{\alpha_1}{\beta_3}$, $\beta = \frac{\alpha_2^2}{\gamma \bar{n}}$ and $\bar{p} = \frac{\alpha_1}{\beta_2}$, $\alpha = \frac{\alpha_1}{\gamma}$

The rate of hyphal branching per unit hyphal per unit length hypha per unit time is described by these parameters,we get a new system:

$$\frac{\partial p}{\partial t} = n - p$$
$$\frac{\partial n}{\partial t} = -\frac{\partial (n)}{\partial x} + exp((1 - p\ )\ (\alpha n + \beta p)) - 1 \quad (6)$$

Now, we found the steady state by using a system (6) , we get the next:

$$n - p = 0 \quad \rightarrow \quad f(p,n)$$
$$1 = 0 \quad \rightarrow \quad exp((1 - p\ )(\alpha n + \beta p)) - g(p,n) \quad (7)$$

Take the logarithm of both sides, we get:

$$n - p = 0 \quad \rightarrow \quad f(p,n)$$
$$0 \quad \rightarrow \quad (1 - p)(\alpha n + \beta p) = g(p,n) \quad (8)$$

By a system (8), we get the solution of these , the values for (p,n), is a steady states are $(1,1),(0,0)$ .Now, we can taken Jacobain to the systems(8)

$$J_{(p,n)} = \begin{bmatrix} -1 & 1 \\ -\alpha n + \beta - 2\beta p & \alpha - \alpha p \end{bmatrix} \quad (9)$$

We get two eigenvalues of λ:

When (0, 0) → $\lambda_{(1,2)}$

$$= \frac{-\alpha p + \alpha - 1 \mp \sqrt{\alpha^2 p^2 - 2\alpha^2 p + \alpha^2 - 4\alpha n - 2\alpha p - 8\beta p + 2\alpha + 4\beta + 1}}{2}$$

When (1, 1) → $\lambda_1 = \frac{1}{2}(-1 + \sqrt{1 - 4\alpha - 4\beta}),\ \lambda_2 = \frac{1}{2}(-1 - \sqrt{-4\beta + 1 - 4\alpha})$

we note the probabilities of the α, β by solution of these equation to found the value for (p, n) The. saddle point in (0, 0), and the unstable spiral in (1,1), the figure below illustrates the (p,n)-plane

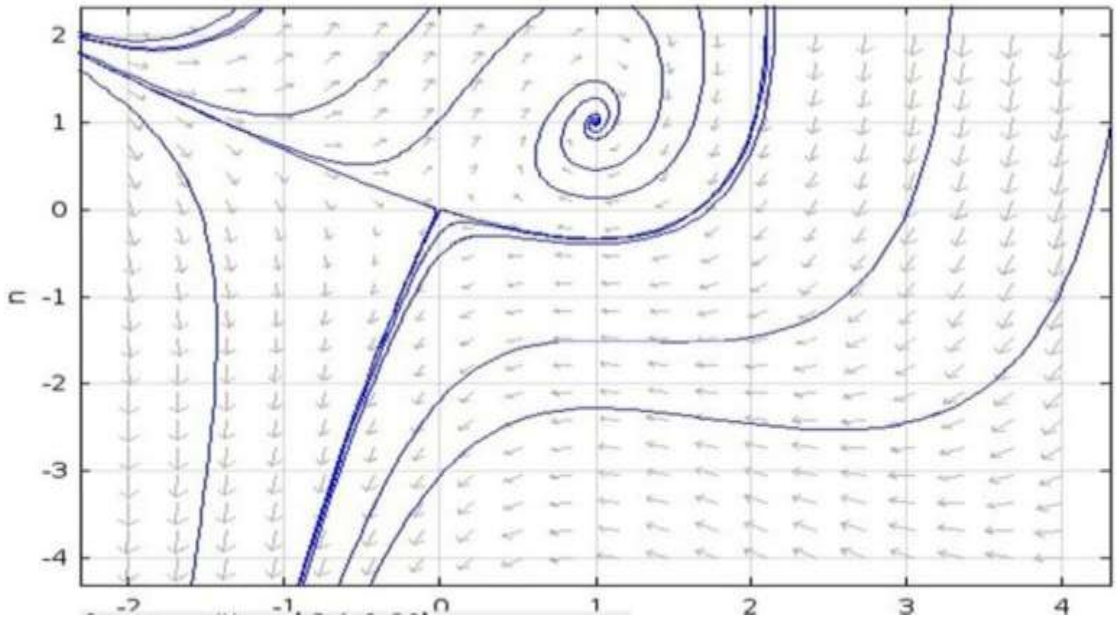


Figure 1. The figure indicated to a point(p, n)-plane not that the path links a saddle point (0,0) to the unstable spiral point (1,1), where the value of $\alpha = 2, \beta = 2$

The traveling Wave Solution and the steady states

Assuming $q = x - ct$ in this section, we impose

$P(x,t) = P(q)$

$N(x,t) = N(q)$ (10)

Where c rate of colony propagation, and $\mathrm{P(q), N(q)}$ show the density profile and that (q) is a positive function. The function $P(x,t), N(x,t)$ *is moving, and a traveling wave at constant speed (c) when* $c > 0$ *and* $\alpha = 1$ *is not negative in the x-direction* [3][16]. The traveling wave solution for the system in x and t is presented as follows: (6)

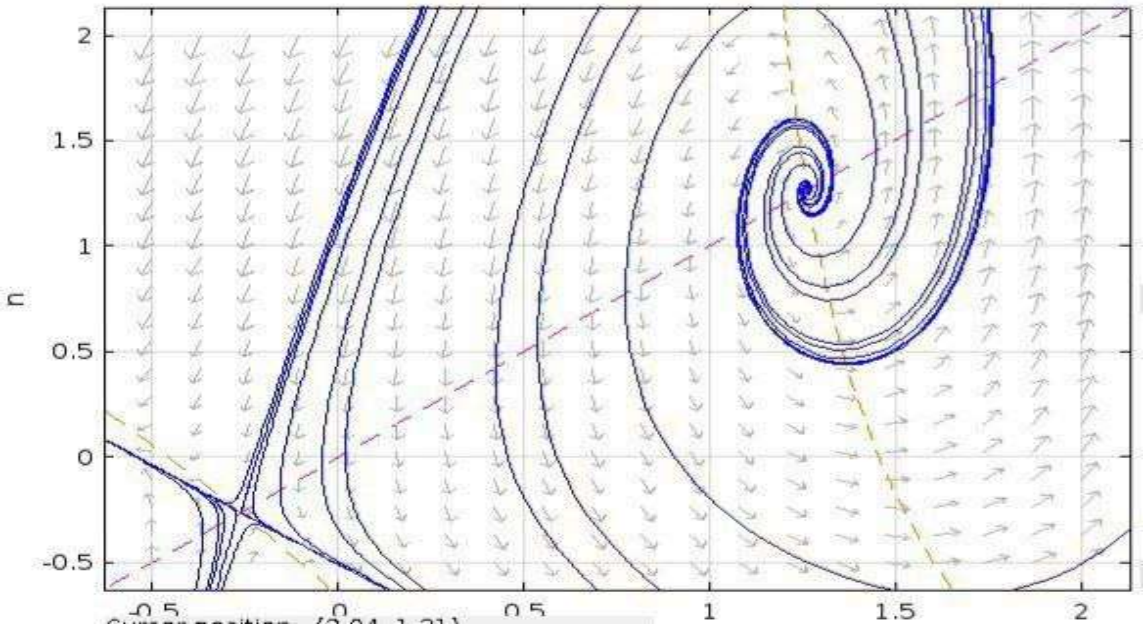
$$\frac{\partial \mathrm{p}}{\partial \mathrm{t}} = -c\frac{dp}{dt}, \qquad \frac{\partial n}{\partial t} = -c\frac{dN}{dt}, \qquad \frac{\partial n}{\partial t} = \frac{dN}{dq}$$

the system (6) turns into:

$$\frac{dp}{dt} = \frac{-1}{c}\ [N - D]$$

$$\frac{dN}{dt} = \frac{1}{1-c}\ [exp\ (\ ((1-P)\ (\alpha N + \beta P)) - 1], \qquad c \neq 1, \quad -\infty < q < \infty \tag{11}$$

The system is in a stable state (11). are (P, N)-(0,0), and (1, 1), where the point (0,0) is saddle point , and the point (1, 1) is unstable spiral for all C not negative, see the fig(2) illustrates the (P,N)-plane



The figure 2. The figure represents the (P,N)-plane, with saddle point (0,0) and unstable spiral point (1, 1) for all C positive values $of\ \alpha = 1.5$ and $\beta = 1.5$.

The Numerical Solution

To see how the pdepe code in MATLAB solves system (6), check Fig. (3), which shows the beginning conditions of the branch (p) and tip (n)

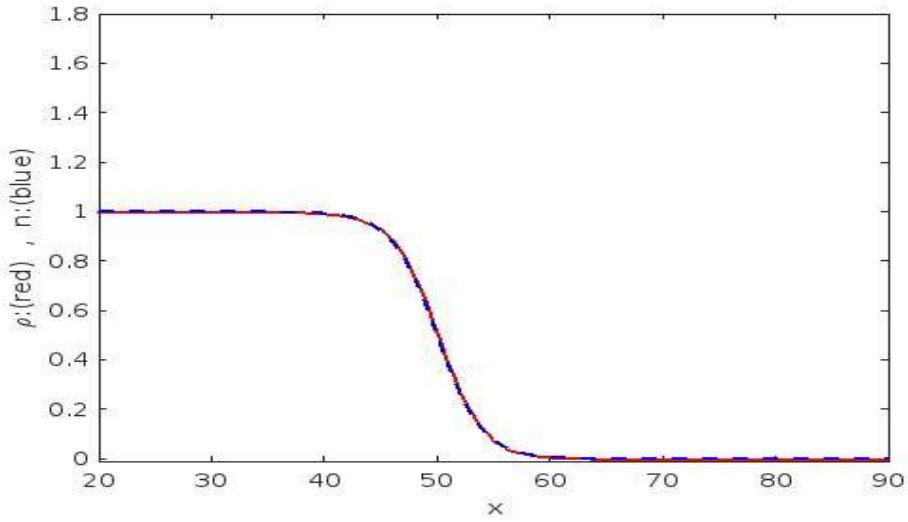
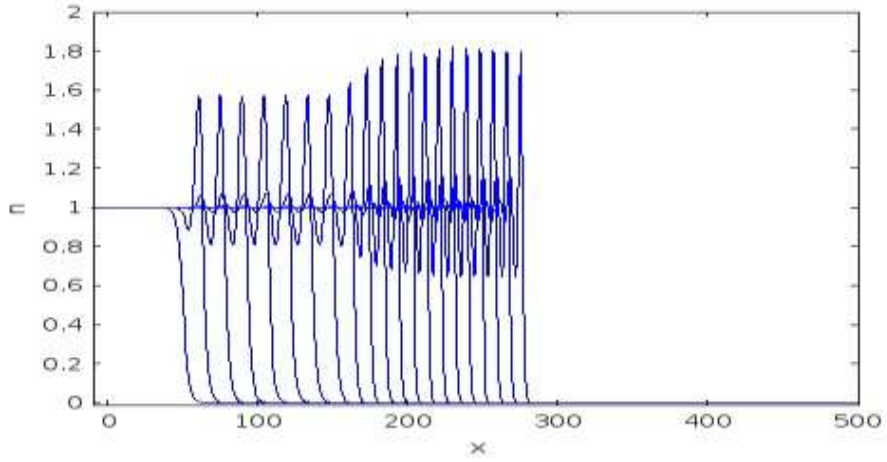
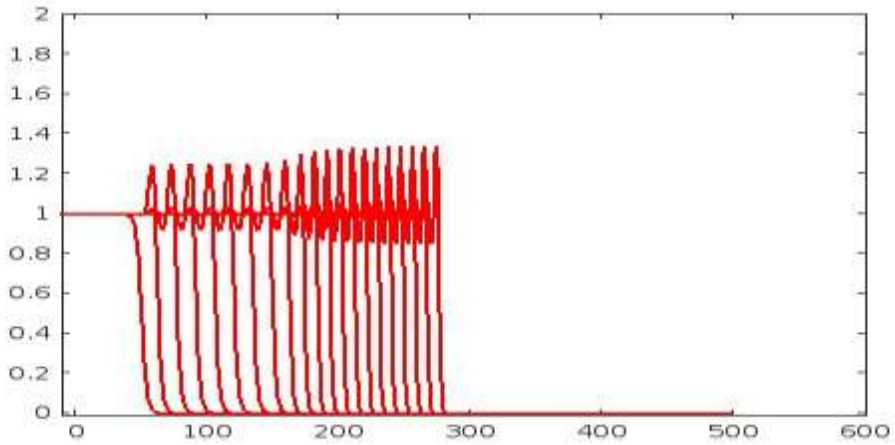


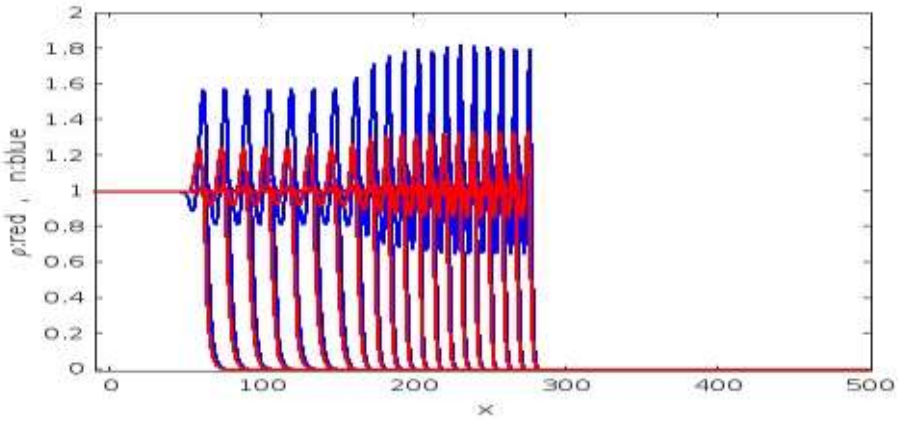
Figure 3. The system (6) $p, n{:}(1 \to 0)$ with parameter α, β has an initial condition of 1.5, which is the solution to the system (3)



(i)



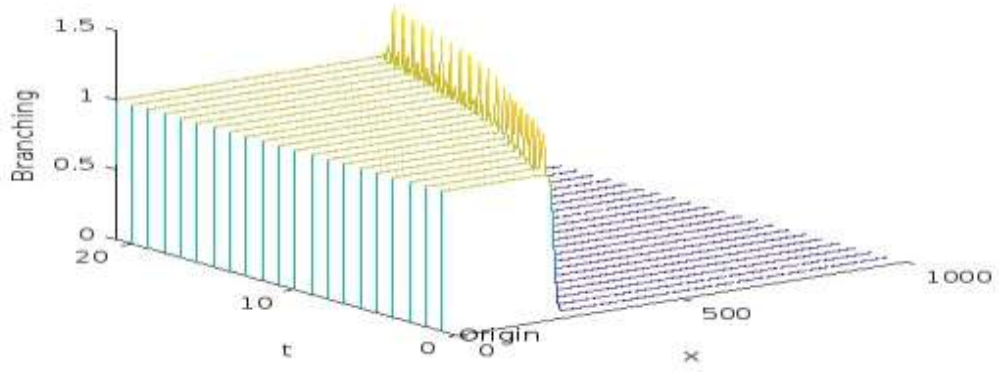
(ii)



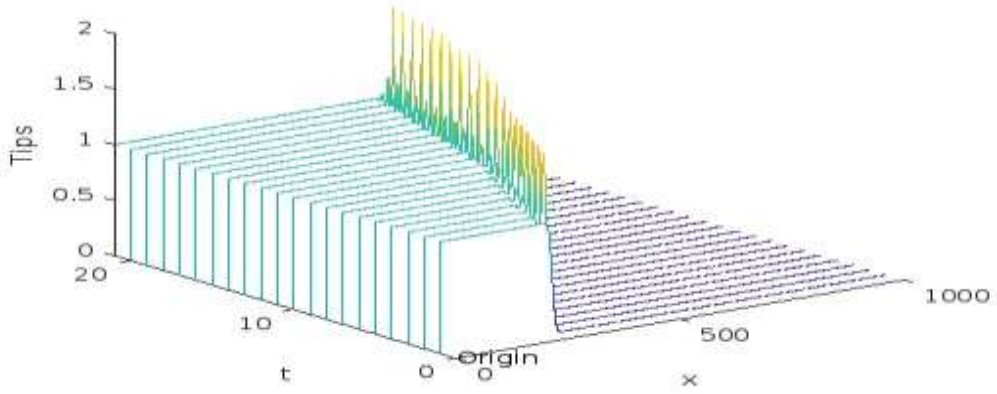
(iii)

Figure 4. solution of system (6) with parameter $\alpha = 0.5, \beta = 1$, where the red line represents the branches (p), the blue line denotes the tips (n), and the wave speed $c = 2.8912$ with the red line representing the branches (p)

It is evident from figure (4) that the solutions to p and n are numerically given values of $\alpha = 0.5$ and$\beta = 1$. This indicates a traveling wave solution that moves from left to right while maintaining the same wave



(a)



(b)

Figure 5. system (6) solution, where the wave travels $c = 2.8912$ for time t and the parameter $\alpha = 1$. where branches (p) were represented by the red line in (a) and tips (n) by the blue line in (b). The solution generated with **Matlab PDEPE**

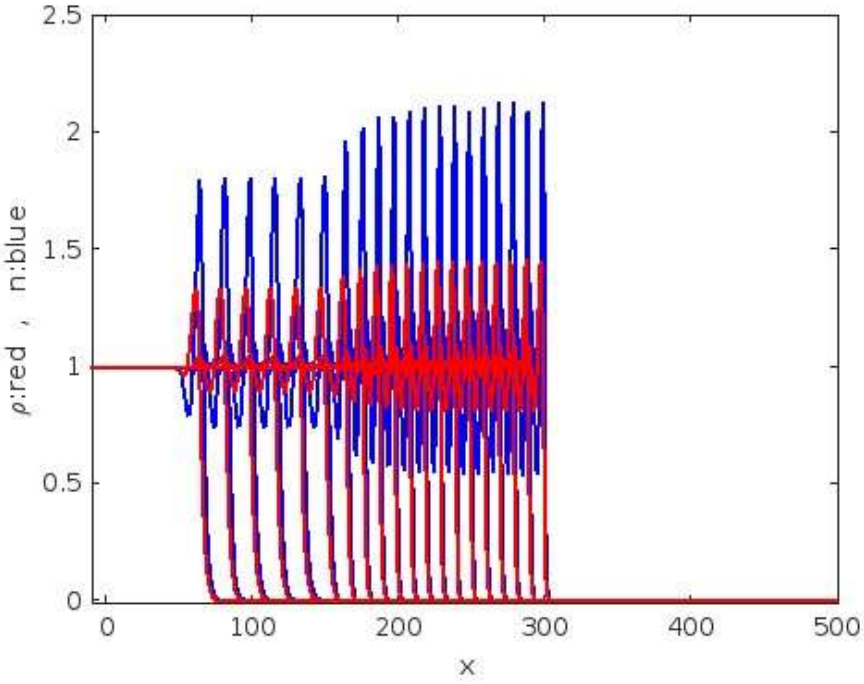


Figure 6. This figure indicated to the solution of the system (6) with the parameters $\alpha = 0.8, \beta = 1$,and traveling wave $c = 3.4227$ for all time Red line indicated branch p and blue line represented tips n

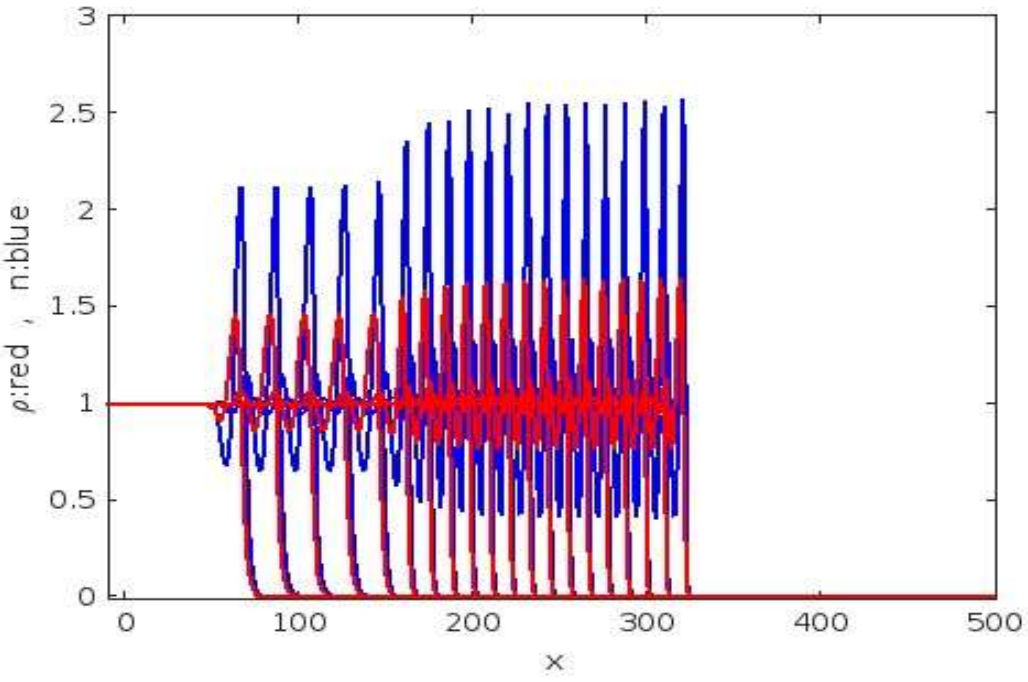


Figure 7. This figure indicated to a solution of the system (6) with the parameters $\alpha = 1.1, \beta = 1$,and traveling wave $c = 3.9647$ for all time , where noted a blue line indicated to the tips (n) and red line represented branches (p).

Figures (6) and (7) provide the numerical answers for n and p using take values (0.8, 1) and the wave speed c $(3.4227, 3.9647)$ respectively, so the traveling wave solution starts on the left and continues as a single wave.

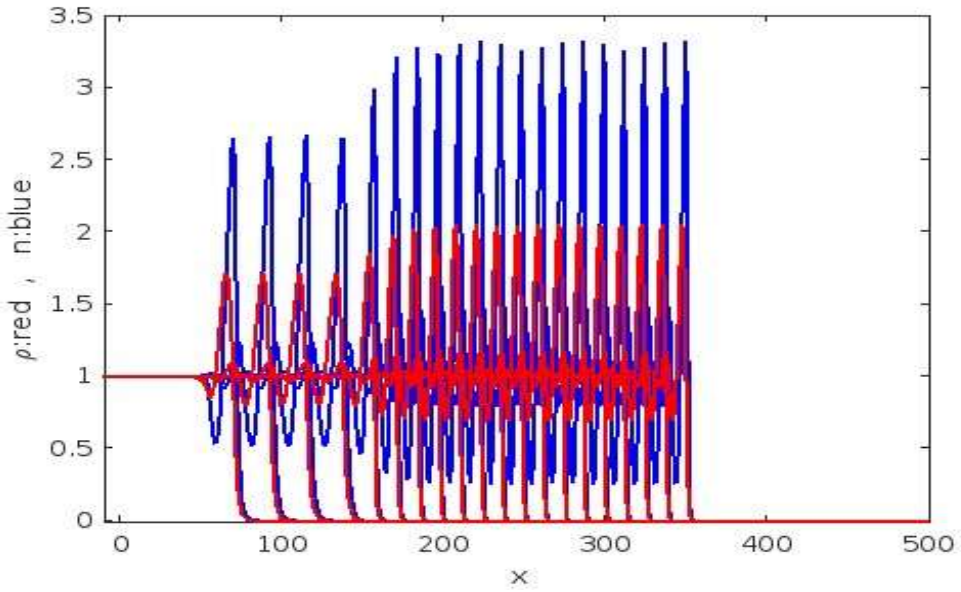


Figure 8. figure indicated to the solution to a system (6), and a parameters $\alpha = 1.4, \beta = 1$,and traveling wave $c = 4.4996$ for all time , where the blue line indicated to the tips n, the red line represented branch p

By the operation we get a relationship betwee parameters α , and β and (c) where α , β increasing, that is a traveling wave solution (c) is increasing, (see Figs. 9 and 11)

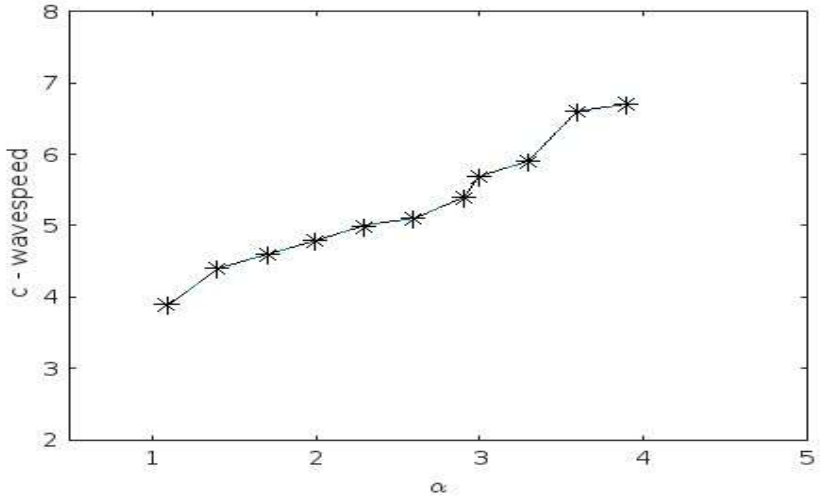


Figure 9. This figure indicated to the relation between β and where waves speed c (1) is taken

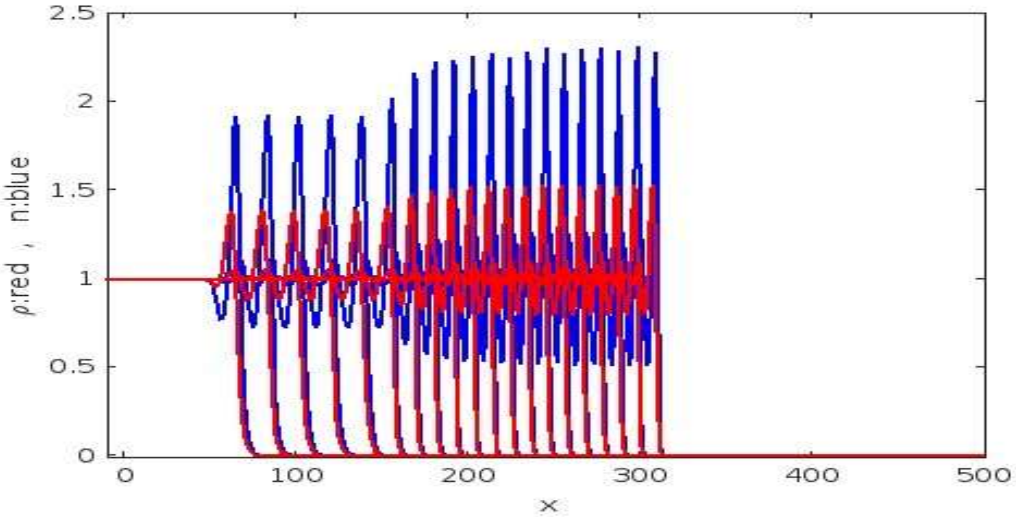


Figure 10. This figure indicated to the resolution of a system (6) with the parameter" $\alpha = 1, \beta = 0.8$,and traveling wave $c = 3.9647$ for all time , where a blue line represented tips$n$, but a red line represented branche

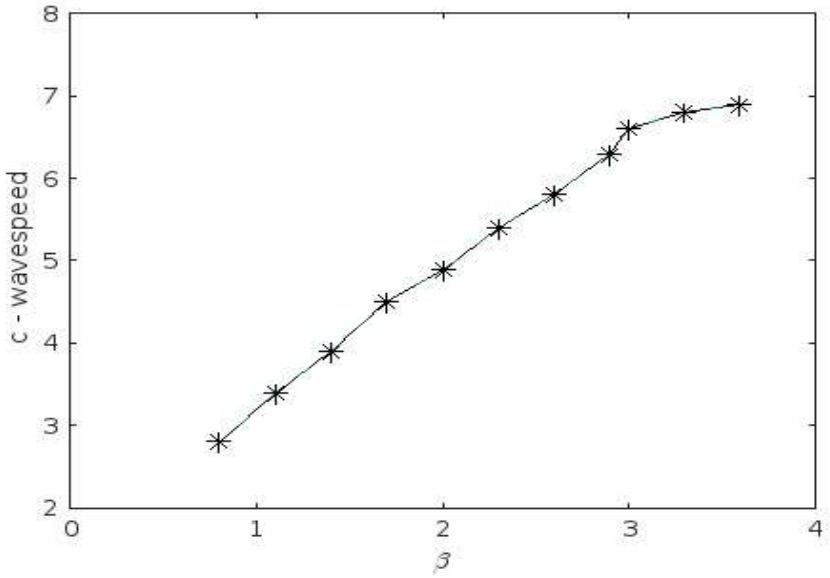


Figure 11. This figure indicated to the relation between β and where waves speed c (1) is taken

Conclution

from through above, notice the direct relationship between the traveling wave c, α, and β where the values of α,β are increase whenever the traveling wave c , is an increase ,for time . So, we noted a value of $\alpha = \frac{\alpha_1}{\gamma}$, $\beta = \frac{\alpha_2^2}{\gamma \bar{n}}$, also we notice that$\alpha$ directly proportionaly with α_1 where pointing to the value of the tip pduced per unit of time, "and inversely proportionall γ the rate constant for a hyphal autolytic . In the fig(10) , indecated to the relationship between c, and β , where the traveller's wave increase whenever you the value of β bigger at same time, where the α is still constant. As well the value of $\beta = \frac{\alpha_2^2}{\gamma \bar{n}}$, and we see that β directly proportionall with α_2

From a biological perspective, this means that as growth grows, α and β also increase.

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