*Artículo de Investigación. Revista Ciencia e Ingeniería. Vol. 37, No. 1 pp. 45-50, diciembre - marzo, 2016.*
*ISSN 1316-7081. ISSN Elect. 2244-8780 Universidad de los Andes (ULA)*

# Comportamiento Catastrófico en el Control de Mosca Doméstica Usando Beauveria Bassiana

# Catastrophic Behavior in Control of Domestic Fly by Using Beauveria Bassiana

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**Abstract**

*In this paper we show catastrophic behavior in the process of controlling domestic flies by means of the application of the fungus Beauveria bassiana. Spores of a stock of Beauveria bassiana isolated in Venezuela, dosages running from $1{\times}10^3$to $1{\times}10^7$ spores/ml, were piled at a rate of 0.5 microliters/fly in a population of 100 domestic flies per each concentration. We counted the flies death rate for 22 days and analyzed the dynamic of mortality equation by using a computer, we became aware that the behavior is a catastrophic one, indeed the cusp catastrophe model.*

***Key words*:** Biological control, beauveria bassiana, musca domestica, cathastrophe.

**Resumen**

*En este trabajo se muestra el comportamiento catastrófico en el proceso de control de la mosca doméstica por medio de la aplicación de los hongos Beauveria bassiana. Las esporas de un depósito de Beauveria bassiana aisladas en Venezuela, la dosis es desde los tiempos $1{\times}10^3$hasta $1{\times}\ 10^7$ esporas/ml, son apilados a un ritmo de 0.5 microlitros/mosca en una población de 100 mosca doméstica por cada concentración. Contamos la data de las moscas muertas en 22 días y analizado la ecuación dinámica de la mortalidad usando computador, nos dimos cuenta de que la conducta es una catastrófica, de hecho, el modelo de catástrofe en cúspide.*

***Palabras claves:*** Control biológico, beauveria bassiana, mosca doméstica, catástrofe.

## 1 Introducción

There is plentiful information about the role played by the domestic fly in the transport of pathogen agents, among them, virus, bacteria and protozoa, which are of capital importance from sanitation point of view (Greenberg 1973). More recently it has been shown that that transport is not only mechanic, by contamination, but internal by means of excretion, this is the case of Escherichia coli (Sasaki and col., 2000). Beside these facts, it has been confirmed (by experience) the increasing of resistance, in the domestic fly, to all known class of insecticides.

Chicken manure, amply used as fertilizer by farmers, is an excellent environment for the growing of domestic fly larvae (Moon and col., 2001). This makes domestic fly an abundant and prevailing specie in bird farms (Avencini and col., 2000).

It was reported (Waddington 1972) that the natural infection of domestic fly by Beauveria bassiana an imperfect (that is, asexual reproduction only) fungus whose spores remain alive and infecting along two years of storing at environment temperature.

Beauveria bassiana is a fungus that grows naturally in soils throughout the world and acts as a parasite on various arthropod species, causing white muscardine disease; it thus belongs to the entomopathogenic fungi. It is being used as a biological insecticide to control a number of pests such as termites, trips, whiteflies, aphids and different beetles. Its use in the control of bedbugs (Barbarin and col., 2012) and malaria-transmitting mosquitos is under investigation.

In this paper we evaluate the entomopathogenic of a native stock of Beauveria bassiana in order to test biological control of domestic flies in chicken farms, checking the

time of deaths at different concentrations
of the fungus.

Here we report results, in laboratory conditions, via individual contamination by contact with conidia of this fungus in anaesthetize flies. This data was introduced in a computer and the result, after plotting, was the cusp catastrophe model shown in the graph of the corresponding surfaces.

A Catastrophe is a discontinuous transition that happens in a system with more than one stable equilibria or where it may follow more than one changing trajectory (Thom 1977).

According to Waddington the Catastrophe can be represented as an imaginary landscape where an object rolls from one valley to another. Also as the flowing of water in a river.

In every system, controlled by a potential function, in which the behavior is determined by no more than four controls (variables), only eight types of qualitative different discontinuities are possible. These are divided in two groups; the so called Cuspid catastrophes consisting of the Fold, the Cusp, the Swallowtail, the Butterfly, and the Wigwam; and the Umbilici catastrophes given by the Elliptic Umbilici, the Hyperbolic Umbilici, and the Parabolic Umbilici (Arnold 1972).

When the system is behavior depends on two controls it can be represented as Cusp model (see figure 2) which is wave surface like (R3) in a fold each point of this surface is an equilibrium point. All the points under the fold are unstable, those along the line of the fold are inflexion point, stable and unstable points, the rest of them are stable ones (Zeeman 1976).

## 2 Methods and Instrument

Now we describe the methods and instruments used in this research.

- Stock of Beauveria bassiana. Conidia of this fungus, isolated LF 08, obtained by natural infection of Hypothenemus hampei in coffee beans in a farm located at San Cristóbal de las Casas, Mérida State, Venezuela in 2003. It has been propagated in potatoes crops and then in sterilized and semiraw rice beans.
- Obtaining of F1 flies from wild ones. We caught them in a bird farm by using nets, these flies were grown at the laboratory at a temperature of 25 until a new gene-ration (Cova and col., 2006, Scorza and col., 2006) appeared.
- Evaluation of the stock of LF 8 (Beauveria bassiana) for adults domestic flies. From a suspension of 1×108conidias/ml, marked dilutions were performed in tween 80 in water at 0.01% in order to prepare suspensions containing between 1×103 and1×107conidias/ml in volumes of 10 mls and kept at 5 untilthey were used no more that 12 hours later.
- Anaesthetized flies with ether, in groups of 25 individuals, were contaminated with 0.5 ul of the suspension of conidia by putting small drops from the snout to the coaxial. With each suspension, 100 flies were contaminated for each concentration of conidia, and they were confined in four 4.8 liter jars, another100 flies were used as control Daily counting of the dead flies were performed for 22 days long with special attention, to the fallen ones, to risen of whitish or pale pink pop corn looking forty after eight hours on humid filter paper.

## 3 Elements of Catastrophe Theory

The model we have already studied, after plotting the data, shows a cuspid catastrophic behavior. The standard unfolding (Poston and col., 1978) is the form

V (b; a; x) = x2 +bx+c (1)

for a constant c. Since we are interested only in critical points of V(b,a,x) we may take c=0 (or translate the origin of the function values) without loss, and we then have

V (b; a; x) = x2 +bx (2)

this formula defines what we shall call cuspid catastrophic. The next step, at which we actually get usefully information, is the analysis of the critical points of V(b,a,x). Before we perform this analysis (which is now routine) it is worth remarking in what respects the above work differs from a “classical applied mathematical” treatment.

We shall analysis the critical point structure of the functions V(b,a,x). For fixed (a,b) the critical points of (2) are given by

V (b; a; x) =0.

The fractions in the coefficients are chosen to obtain this simple form. This is a cubic in x, and so must have least one and at most three real roots. The nature of the roots depends on the values of a and b: specifically on the discriminant

D=4a3+27b2

of the cubic equation. It is well known (Salmon, 1985) that say if D<0 there are three distinct real roots, and if D>0 there is one real root and a conjugate pair of complex roots. If D=0 there are in a sense three real roots, but some of them coincide: in fact if D=0 but a≠ 0 or b≠0 two of the real roots are equal, if D=0 and a=b=0, then all three roots are equal.

Geometrically, this means that the nature of the roots, and hence of the equilibria of the catastrophic function, depends on the position (a,b) in the plane (a,b)--plane, relative to the curve with equation 4a3+27b2=0.

The corresponding potential functions (2) take the forms shown in the fig. 1. We see that V(b,a,x) has one min-imum for (a,b). Dynamically, minima of V(b,a,x) cor-re-spond to stable equilibria, whereas maxima or inflexions correspond to unstable equilibria. So for control parameters in fig. 1 there is a single stable equilibrium.

This somewhat complex behavior of the potential can be capture geometrically, in a very revealing way, if we draw the associated catastrophic manifold or equilibrium surface in (b,a,x)-space. This is the set M (equal Induced dead zone of the figure 2) of points (b,a,x) satisfying equa-tion (2), which we rewrite here:

$$x3+ax+b=0.$$

It has the appearance of a folded surface, and is illus-trated in figure 2. As it happens, we drew this surface in slightly different coordinates.

Notice that around most points the surface can locally be thought of as graph of a function of (a,b), as required by our discussion of how a critical point varies with (a,b). Much of the physical literature attempts to extend this point of view to the places where visibly it will not work, by us-ing “branched functions”. There is not coherent way of do-ing this around the point c in the fig. 2, which in many physical applications is the focus of interest. Conceptual chaos is the usual result. A far clearer picture comes from analysis of the well defined catastrophic map

X: M-----> C

which projects points on M to the (a,b)--plane C (con-centration vs days) according to

$$(b,a,x) \mapsto (a,x) \quad (b \in M)$$

in the neighborhood of the origin.

The catastrophe manifold M is a smooth submanifold of R3. It is sometimes thought that M is not smooth at the origin, but this is an illusion. The smoothness is immediate-ly visible in a three dimensional model of the surface.

We must point out that the vector field (2) is the most general perturbation of the function x3 with lower order terms because any term involving x2 can always be elimi-nated by an appropriate change of variables of the variable.

On the other hand, this stuff can be seen as a bifurca-tion problem of the differential equation

$$= b + ax + x3 \; V (b; a; x) \qquad (3)$$

where the bifurcation points must satisfy

$$V (b; a; x) = 0 \quad \text{and} \quad V (b; a; x) = 0$$

or equivalently

$$x3 + ax+ b = 0 \text{ and } 3x2 + a = 0.$$

We can consider these equations as defining b and a parametrically in terms of x. Solving the second equation for a and substituting the result into the first equation yields

$$a = -3x2 \text{ and } b = -2x2. \qquad (4)$$

Now, if we eliminate x from these two equations, we obtain the following equation for a cusp ( see Hale and col., 1991 for more details)

(5) $4a3 = 27b2$.

This situation is depicted in Figure 1.

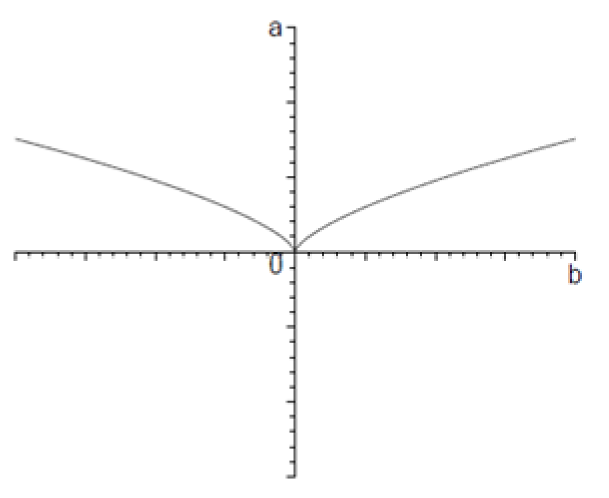


Fig. Potential Function

The bifurcation diagram of equation (2) in the three–dimensional (b; a; x)–space can be then drawn, which is al-so the catastrophe manifold, as we said before, from the equation $b+ax+x3 = 0$; see Figure 2. The cusp below is the set of points in the (b; a)–plane for which the folding sur-face above has vertical tangency; over a point inside the cusp.

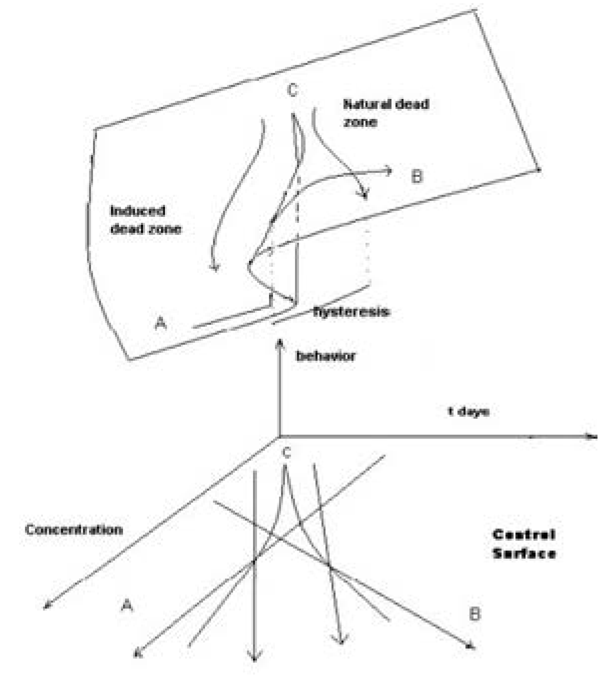


Fig. 2 Catastrophic Manifold

Two functions $f$: $Rn \to R$ and $g$: $Rn \to R$ are equivalent around 0 if there is a local diffeomorphism $h$: $Rn \to Rn$ and a constant “shear term” $\lambda$ such that

$$g(x)=f(h(x))+\lambda$$

in a neighborhood of 0. For families of functions f,g: $Rn\ xRl \to R$ we require an appropriately souped-up notion of equivalence. The diffeomorphism h becomes a family of diffeomorphisms hs: $Rn \to Rn$, $s\ \varepsilon Rl$, which vary smoothly with s; the constant $\lambda$ becomes a “family of constant” varying smoothly with s, or what is the same, a smooth function $Rl \to R$. Finally, we allow a diffeomorphism $Rl \to Rl$ as well: this has no non-trivial counterpart in the case of a single function (the only diffeomorphism on the single point R0 is the identity!!) but is needed for families.

The family

$$Wa(x)= + \ x2$$

is not structurally stable. It is easy to verify that it is not transverse, in the above sense: that is, the graph of $\partial x$ W is not transverse to the zero plane. For we have

$$Wa(x)=x3+ax,$$

and this intersects the zero-plane. There are various coincidences which occur for catastrophes whose potential involves one variable, which do not extend to two or more variables. This intersection is clearly not transverse at 0. If we perturb W by adding a term bx, then the surface shifts up or down by b, and the intersection becomes transverse.

This makes it at least plausible that for the enlarged family

$$V(x,a,b)= + \ x2+bx$$

the intersection has become transverse.

## 4 Plotting of the Data

In (Scorza and col., 2006) a quantitative analysis of death data is performed by means of formula given in (Abbot 1925), these are rectified with respect to the control.

Then they compute TL50 and TL95 (lethal time of mortality of50% and 95% respectively) by using the Probit method of statistic package Minita®Statistical Software, Release 14. Minitab. Inc; obtaining results, for TL50 and TL95 with different concentrations of conidiophore of Beauveria bassiana, showing the fungus effectiveness in the Musca domestica control.

In the qualitative analysis the data is plotted without being rectified, this is done searching for perturbations, the plotting is done by taking as axes mortality, concentration and time.

For the control trial we took 10oconidiophores/ml and got a total death (100%) in 22 days, the highest concentration taken was of 107conidiophores/ml observing 100% of deaths seven days later. We plotted the data and looked at the resulting curves, putting every thing together the resulting surface looks like the epigenetic landscape shown in (Waddington 1972), there the phenomenon appears in two different valleys (see figure 4), one in each side, these valleys are given as a function of concentration, conidiophore and time in our case. This behavior is analyzed in this paper by using the cuspid model.

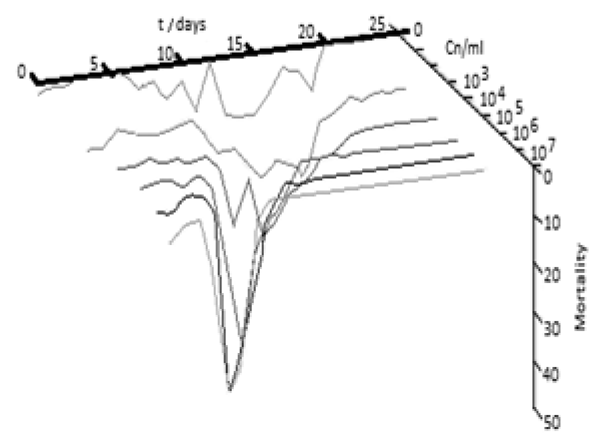


Fig. 3 Data Graph

## 5 Discussion

The experimental curves “Flies Mortality vs. Concentration of Beauveria bassiana” show quantitative perturbations in comparison with the ones genera-ted by the potential of the cusp model (Arnold 1972), this is due to the imperfections of the manipulation on one hand and to uncontrollable factors on the other.

For the qualitative analysis by using the corresponding classification (Zeeman 1976) we ruled out the imperfections and show the spread of the

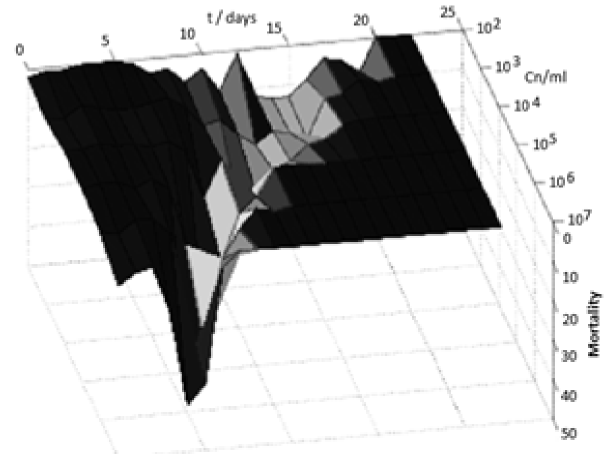


Fig. 4 . Mantle Over Data

Phenomenon, which becomes determined by two colliding factors, concentration of the pathogenic (Beauveria basiana) and time /in days, these are represented in the control surface while the flies behavior(natural and induced death) in the vertical axis.

At extreme concentration of the fungus, that is, at 10oand 107, we get a unique form of behavior; natural and induced death respectively. However in the catastrophic zone (control surface) these two forms of death are present; this phenomenon is known as hysteresis, which can be clearified 8 hrs. after be put the whole fly population on humid filter paper. In fig 3, 4 we can see that natural total death occurs 22days.

## 6. Conclusions

We have shown, experimentally, that it is possible to use catastrophe theory in order to explain mortality of Musca domestica under different concentrations of Beauveria basiana applied in time. We know about the equilibrium that must show nature, that is why we have to be very careful in using this fungus, which attacks insects in an indiscriminate way. Under this perspective we recommend its use in chicken farms in our state since these places are the most generating source of Musca domestic due to the abundant chicken manure produced at there.

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***Recibido:*** *01 de octubre de 2014*

***Aceptado:*** *07 de Julio de 2015*

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