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Research article

CHEMICAL COMPOSITION OF THE NEST AND MODELS OF THE METAMOPHIC POLYMORPHISM OF THE MUD DAUBER WASP

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ABSTRACT

The work involves the determination of the chemical composition of the nest and modeling of metamorphors polyphenism of the Mud Dauber wasp. The samples were analyzed at Fugro consultants (Nig.) Ltd; a high standard laboratory with sophisticated equipments, which aided in producing an acceptable result considering the state of the place of analysis.Research showed that wasp generally excretes saliva to the mixture of water and their various building materials which include paper and clay soil. The composition of their saliva was found to contain Phosphorus, Magnesium, Sulphur, Chlorine, Potassium, and Calcium. The result showed that Phenol and Iron were found to have been present in the saliva, while nest showed a decrease in the quantity of potassium in ordinary clay soil. More, so, the models developed with the data obtained from the study of the specie, *Brachymenes dyscherus*, actually represented the biological and biochemical systems. The methods of analysis used are those stipulated by

institutions such as America Public Health Association (APHA), America Society for Testing and Material (ASTM), and Chemical Analysis of Ecological Materials (CAEM).

Keywords: Chemical Composition, Nest, Biomodeling, Metamorphors, Polyphenism, Mud dauber wasp, Cell, Layer, Curve fit.

1.0 INTRODUCTION

A wasp is any insect of the order Hymenoptera and suborder Apocrita that is neither a bee nor an ant [1]. Wasp is any member of the aculeate family Vespidae, which includes the yellowjacket (Vespula and Dolichovespula) and hornest (Vespa). They are usually found around our homes, buildings, bridges and trees with mud, paper, leaves, treebacks and other materials.. This makes the mixture adhesively strong and lighter than clay, which is their source of building material [2]. In their construction of nest, a mud dauber wasp makes use of clay. Clay soils are hydrous aluminum phyllosilicates, sometimes with variable amounts of iron, magnesium, alkali metals, alkaline earths and other cations [3,4].They gather mud, moisten it and add their saliva which serves as the cement to the mixture.The saliva derived spittle overlies and unites the building mud laminally and vertically. On the outside of the spherical button-like structures that are rich in phosphorus. From the research carried out by physiology and pharmacology department, Tel Aviv University Israel, it was deduced that the saliva of the mud dauber wasp is composed of phosphorus, Magnesium, Sulphur, Chlorine, potassium, Calcium and other unidentified elements.

Bioengineering applies engineering principles to the full spectrum of living systems. This is achieved by utilizing existing methodologies in such fields are molecular biology, biochemistry, microbiology, pharmacology and neuroscience, and applies them to the design of medical devices, diagnostic equipment. Bioengineering is not limited to the medical field alone, it relates to biotechnology also [5]. Biomathematics or computational biomedical is an interdisciplinary field of academic study which aims at modeling natural and biological processes using applied mathematical techniques and tools[6,7,8]. This work aim to determine the chemical composition of the mud used by the mud dauber wasp in the construction of its nest, with a view to knowing the chemical components responsible for adhesion, strength and durability of the nest, also to provide insight on the possibility of producing a locally made and cost effective cement and finally to develop models to represent the biological systems with the data obtained from the study of the species, *Brachymenes dyscherus* ,for better understanding and bioengineering application. The research work is centered on the analysis of the composition of mud dauber nest and modeling of the system with the data obtained from the study of the metamorphous polyphenism of the wasp species *Brachymenes dyscherus*.

2.0EXPERIMENTAL

2.1 ANALYSIS OF THE MUD DAUBER WASP NEST

The composition of the wasp dauber nest was analyzed using ASTM 1999 for determination of pH and density, ASTM 1999/APHA 1998 for determination of heavy metals, chloride and exchangeable cations, and APHA 1998/CAEM for determination of phosphate and sulphate.

2.2 MODEL DEVELOPMENT

From the study carried out in Brazil on the specie *Brachymenes Dyscherus*, statistical data were obtained. These data are biomodeled to develop mathematical equations that represent the bioengineering system. The plots to be biomodeled are made from data tablesas extracted from the study in Cajuru, Brazil, 1996 [9, 10, 11].

3.0 RESULTS AND DISCUSSION

3.1 Results of the Analysis of the Mud Dauber Wasp Nest

Table 12: Results of the Chemical Analysis of the Mud Dauber Wasp Nest

	Analysis	Result		
S/N	Parameters	Wasp Nest(W)	Clay Soil (C)	W-C (Wasp added)
1	pH (H_2O) at 25^0C	6.33	6.93	-0.6
2	Density (g/ml)	1.01	1.46	-0.35
3	Phenol (mg/kg	7.24	6.95	0.29
4	Calcium (mg/kg)	955	109	846
5	Magnesium (mg/kg)	407	12.2	394.8
6	Potassium (mg/kg	623	1023	-500
7	Aluminum (mg/kg	6587	7968	-1381
8	Total Iron	14650	7701	6949
9	Extractable Chloride (mg/kg)	271	14	257
10	Extractable Sulphate (mg/kg)	100	50	50
11	Phosphate (mg/kg)	38.5	0.85	37.65

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3.2 Model Results

The following tables contain the values of the models constants (co-efficient) and statistical data for the curve-fitting of data tables (1a-11a, not shown) obtained from Cajuru, Brazil, 1996.

Table 1: Plots of Table 1a for Model $y = a_o + a_1 Cos(wx) + b_1 Sin(wx)$

S/N	Co-efficient(95% confidence bound)	Goodness of fit
1	a_o = 17.46	SSE = 0.0002113
2	a_1 = 18.45	R-squared = 1
3	b_1 = 1.359	Adjusted R^2 =NaN
4	w =2.633	RMSE = NaN

***Table* 2: *Plots of Table* 2*a for Model* $y = a_0 + a_1 Cos(wx) + b_1 Sin(wx)$(*see Fig.* 2)**

S/N	**Co-efficient(95% confidence bound)**	**Goodness of fit**
1	a_o = 100.40	SSE = $2.443e^{-6}$
2	a_1 = -85.49	R-squared = 1
3	b_1 = 24.6	Adjusted R^2 =NaN
4	w = 1.547	RMSE = NaN

***Table* 3: *Plots of Table* 3*a for Model* $y = p_1x^3 + p_2x^2 + p_3x + p_4$(*see Fig.* 3)**

S/N	Co-efficient(95% confidence bound)	Goodness of fit
1	ao = 17.46	SSE = 0.0002113
2	a1 = 18.45	R-squared = 1
3	B1 = 1.359	Adjusted R^2 =NaN
4	w =2.633	RMSE = NaN

***Table* 4: *Plots of Table* 4*a for Model* $y = aexp(-bx) + c$(*see Fig.* 4)**

S/N	Co-efficient(95% confidence bound)	Goodness of fit
1	a = 6.334(297.8, 969)	SSE = 43.98
2	b = 0.6082(-0.4097,1.626)	R-squared =0.9991
3	c = -49.04(-315.4, 217.3)	Adj. R^2 = 0.9973
		RMSE = 6.631

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$\boldsymbol{Table\ 5: Plots\ of\ Table\ 5a\ for\ Model\ y = p_1x^3 + p_2x^2 + p_3x + p_4(see\ Fig.5)}$

S/N	Co-efficient(95% confidence bound)	Goodness of fit
1	P_1 = -6.333	SSE = 2.636e^{-28}
2	P_2= 53	R-squared = 1
3	P_3 = -142.7	Adjusted R2 =NaN
4	P_4 =128	RMSE = NaN

$\boldsymbol{Table\ 6: Plots\ of\ Table\ 6a\ for\ Model\ y = p_1x^3 + p_2x^2 + p_3x + p_4(see\ Fig.6)}$

S/N	Co-efficient(95% confidence bound)	Goodness of fit
1	P_1 = 0.5	SSE = 1.016e^{-28}
2	P_2 = -3.5	R-squared = 1
3	P_3 =5	Adjusted R^2 =NaN
4	P_4 = 4	RMSE = NaN

Table 7: Plots of Table 7a for Model $y = a_1exp[-\{(x-b_1/c_1\}^2] + a_2exp[-\{(x-b_2/c_2\}^2]$(See Fig. 7)

S/N	Co-efficient (95% confidence bound)	Goodness of fit
1	a_1 = 39.17 (-3197, 3275)	SSE = 2.511
2	b_1 = -158.7(5892, 5574)	R-squared =0.9855
3	c_1 = 112.3(-1628, 1852)	Adjusted R^2 = 0.9673
4	a_2 = 9.338 (4.686, 13.99)	RMSE = 0.7923
5	b_2 = 19.38 (17.87, 21.99)	
6	c_2 = 9.412 (4.353, 14.47)	

Table 8: Plots of Table 8a for Model $y = p_1x^5 + p_2x^4 + p_3x^3 + p_4x^2 + p_5x + p_6$(See Fig. 8)

S/N	Co-efficient (95% confidence bound)	Goodness of fit
1	p_1 = 6.24e^{-5}(1.344e^{-6}, 0.0001236)	SSE = 5.356
2	p_2 = -0.006066(-0.01122,0.0009146)	R-squared =0.9918
3	p_3 = 0.2241(0.6019, 0.388)	Adjusted R^2 = 0.985
4	p_4= -3.828(-6.262, -1.395)	RMSE = 0.9448
5	p_5 = 28.15(11.53, 4477)	
6	p_6 = -52.76(-93.89, -11.62)	

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Table 9: Plots of Table 9a for Model $y = a_1exp[-\{(x-b_1/c_1\}^2] + a_2exp[-\{(x-b_2/c_2\}^2]$(See Fig. 7)

S/N	Co-efficient (95% confidence bound)	Goodness of fit
1	a_0 = 58.84 (53.7,63.97)	SSE = 63.36
2	a_1 = -25.737(-41.72, -9.746)	R-squared =0.9959
3	b_1 = -45.93(54, -37.86)	Adjusted R^2 = 0.9907
4	a_2 = 1.381 (-5.95,8.711)	RMSE = 3.98
5	b_2 = -7.112 (-12.67, -1.555)	
6	w = 0.6899 (-0.6375,0.7418)	

Table 10: Plots of Table 10a for Model $y = p_1x^5 + p_2x^4 + p_3x^3 + p_4x^2 + p_5x + p_6x^2 + p_7 + p_8$(See Fig. 10)

S/N	Co-efficient (95% confidence bound)	Goodness of fit
1	p_1 = 0.002902	SSE = 3.489
2	p_2 = -0.106	R-squared =0.9995
3	p_3 = 1.543	Adjusted R^2 = 0.9976
4	p_4 = -11.3	RMSE = 1.321
5	p_5 = 42.47	
6	p_6 = -72.97	
7	p_7= 51.18	
8	p_8 =-6.853	

Table 11: Plots of Table 11a for Model $y = p_1x^5 + p_2x^4 + p_3x^3 + p_4x^2 + p_5x + p_6x^2 + p_7 + p_8$(See Fig. 11)

S/N	Co-efficient (95% confidence bound)	Goodness of fit
1	p_1 = 0.03407	SSE = $2.968e^{-20}$
2	p_2 = 1.053	R-squared = 1
3	p_3 = -13.26	Adjusted R^2 = NaN
4	p_4 = 87.61	RMSE = NaN
5	p_5 = -324.80	
6	p_6 = -72.97	
7	p_7= 666.2	
8	p_8=256.5	

3.3 Discussion

3.3.1 Analysis of the Mud Dauber Wasp Nest

From the comparative analysis between the wasp dauber nest sample and the ordinary clay soil, it was observed(see Table 12) that the density of the wasp nests was lower than that of ordinary clay sample. This means that the wasp nest is lighter and less dense than the clay sample. Also from table 12, pH, K and Al are lower compared to the clay sample. But phenol, calcium, magnesium, total iron, phosphate, extractable chloride and sulphate are higher in the wasp nest than in ordinary clay soil.

Therefore, from the analysis of the chemical composition of the cement used by the Mud wasp dauber, which is the saliva of the insect, it can be deduced that the composition of the chemical compound of the cement for nest construction that makes it lighter and stronger than ordinary clay contains high quality of phenol, calcium, magnesium, iron, chloride, sulphur and phosphorus and low potassium and aluminum contents than normal ordinary clay soil in Nigeria. This could vary from one country clay soil to another.

3.3.2 Mathematical Modeling of the Study of Brachymenes Dyscherus

From the models developed with the statistical data extracted from the study carried out on *Brachymenes dyscherus* , Cajuru, Brazil, relation between the number of layers per nest was accurately represented by the 1st Fourier equation(R^2 = 1; Fig. 1). Also the number of male and female adults that emerged, the number of lost samples and accidental damages of samples, and the number of empty cells found in each layer of the nest are represented by their models(R^2 = 1;Figs. 2, 3, 4, 5 and 6). The number of parasitoids and dead immature found in each cell has an accuracy very slightly less than one, (R^2 = 0.9991; Fig. 4). This can also be used to represent the system because the accuracy is almost one.

The models developed from number of cells constructed by the insect per month, number of cells per wasp nest, number of preys per cell of the wasp nest, and the number of males emerged per month yielded accuracies (R^2 of 98.55, 99.18, 99.59 and 99.95 respectively after computer smoothening(Figs. 7,8,9 and 10). Because of the smoothening, these figures fairly represented the biochemical or biotechnological systems.

After computer-smoothening the data obtained for the number of female adult that emerged monthly, the curve-fitting gave a model equation that gave an accuracy of 100% (Fig. 11). Again, because of computer-smoothening Fig. 11 gave fair representation of the system.

4.0 CONCLUSION

From the analysis and the observation, it can be concluded that the composition of the chemical compound that is responsible for the adhesive characteristics, strength and lightness of the Mud Dauber waspnest is made up of phenol, calcium, magnesium, iron, chlorine, sulphur, phosphorus, potassium and aluminum in varying quatities.

Also the model equations developed actually described and represented fairly their respective biochemical and bioengineering systems.

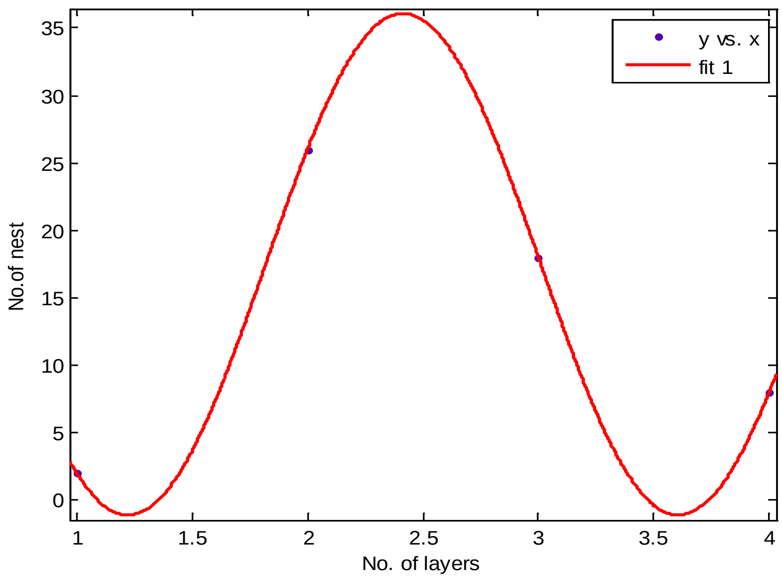

Fig. 1: No. of nests vs. no of layers

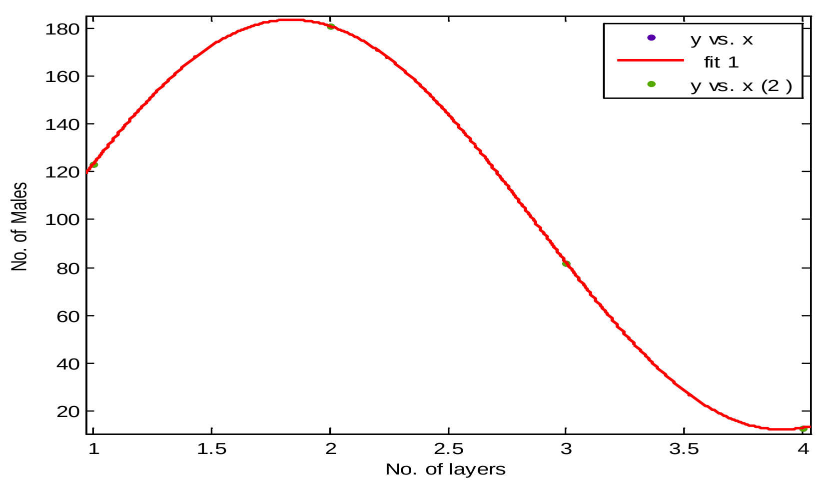

Fig. 2: No. of males vs. no of layers

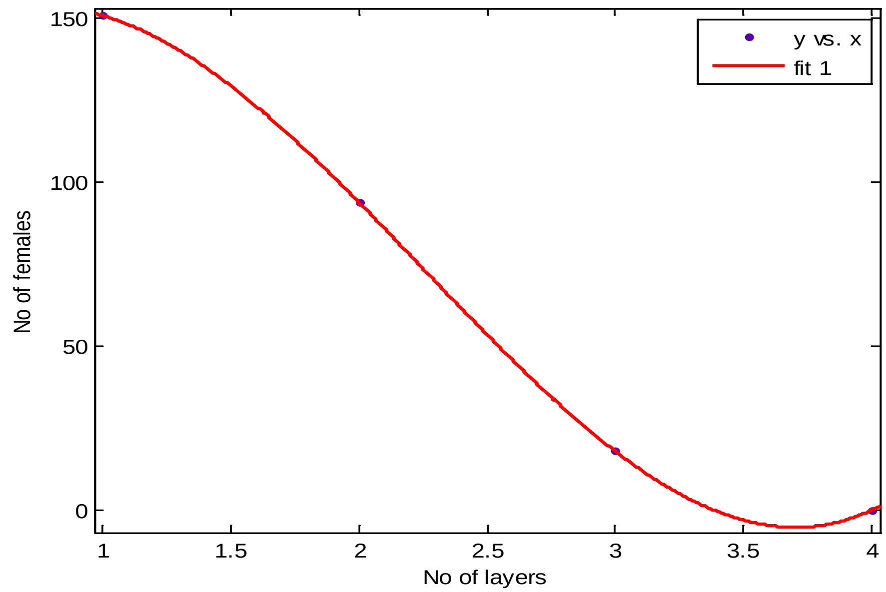

Fig. 3: No of females vs. no of layers

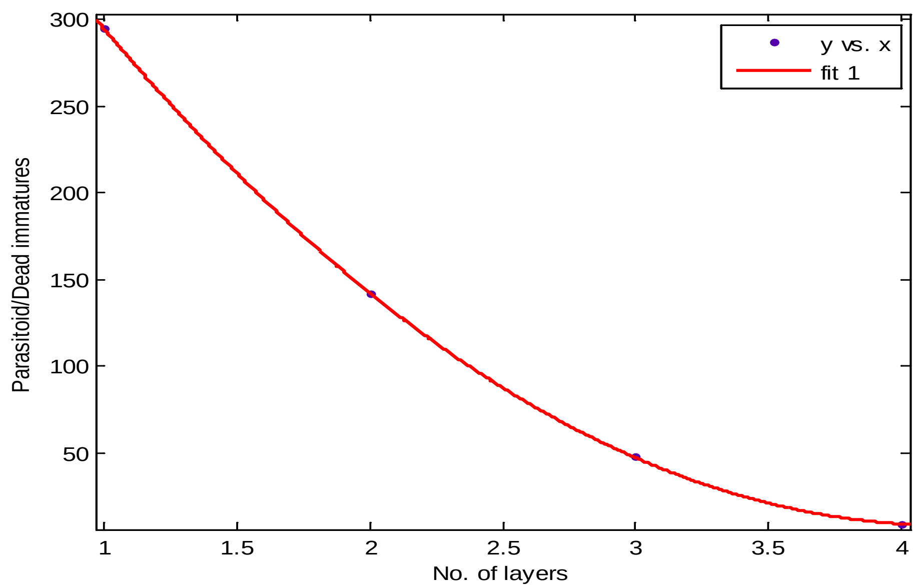

Fig. 4: No of parasitoids vs. no of layers

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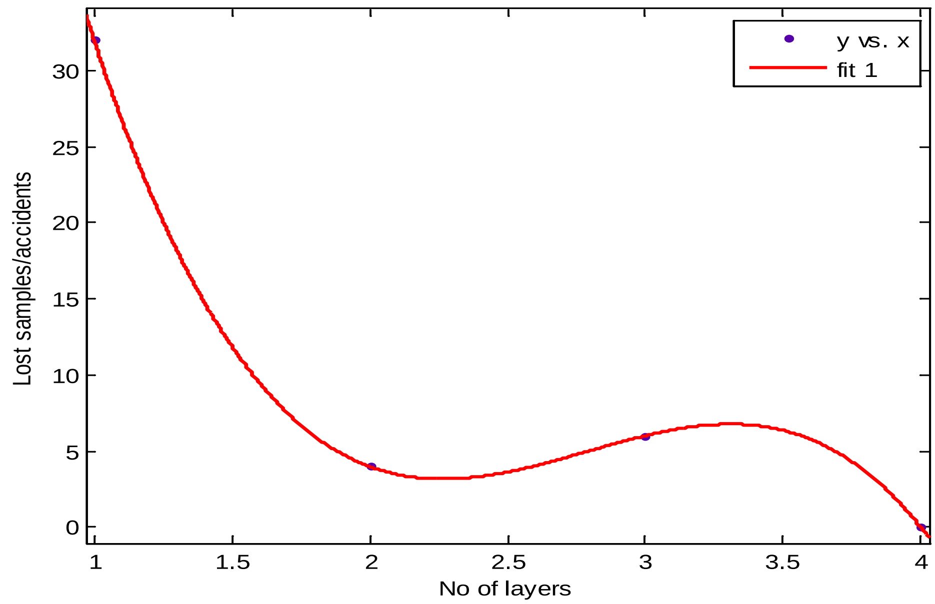

Fig.5: lost samples/accidents vs. no of layers

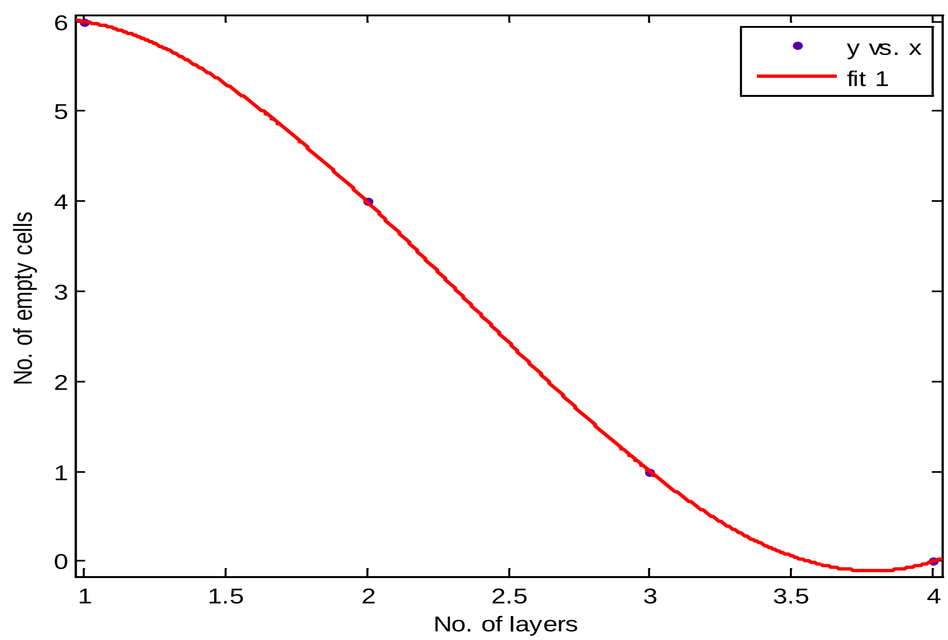

Fig. 6: Empty cells vs. no. of layers

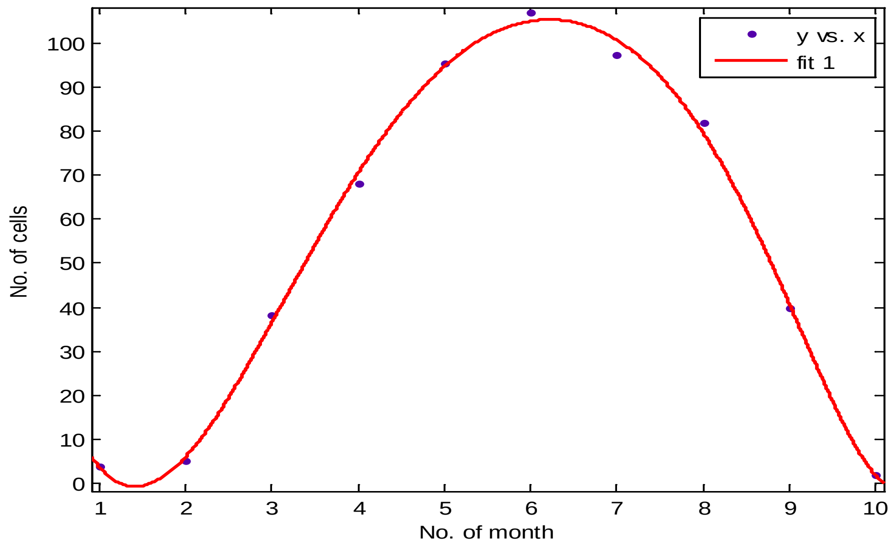

Fig. 7: No. of cells vs. no. of month

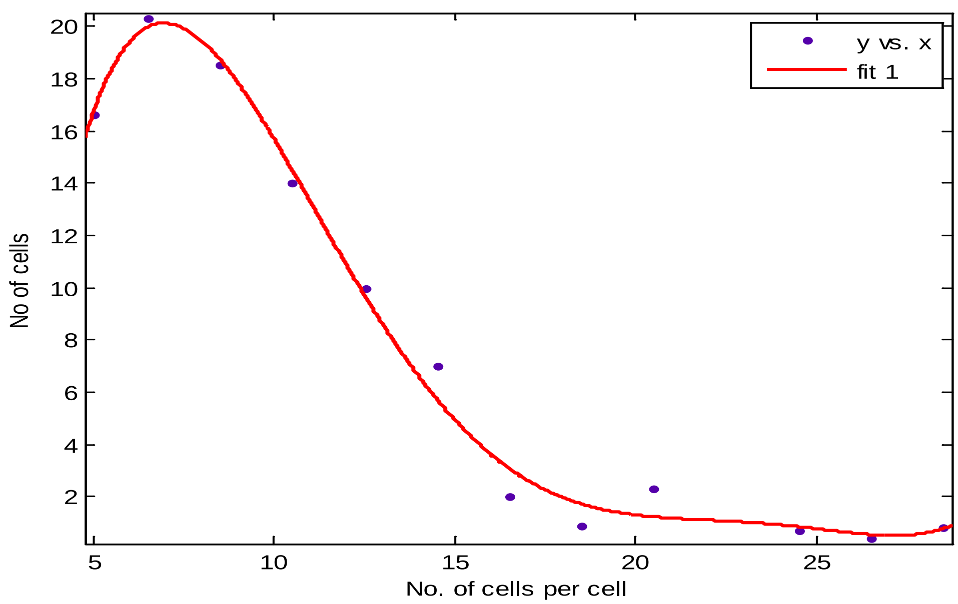

Fig.8: No. of cells vs no. of cell per nest

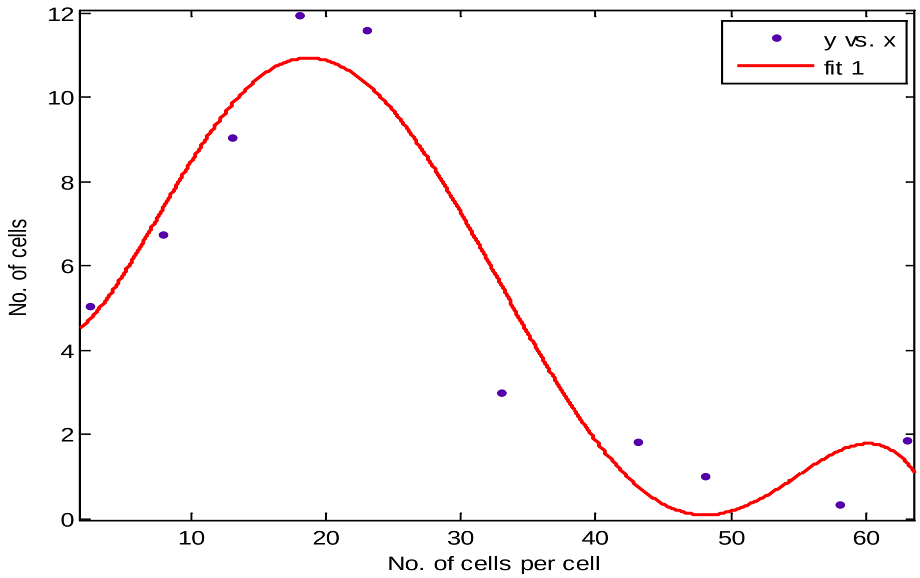

Fig. 9: No. of cells vs no. of cell per nest

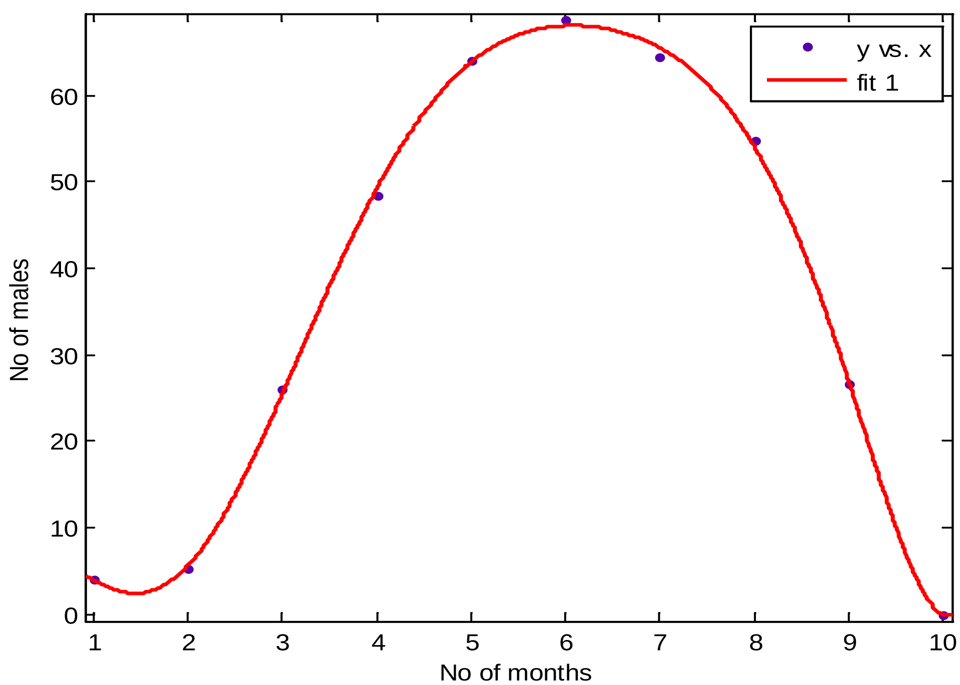

Fig. 10: No. of males vs. no. of month

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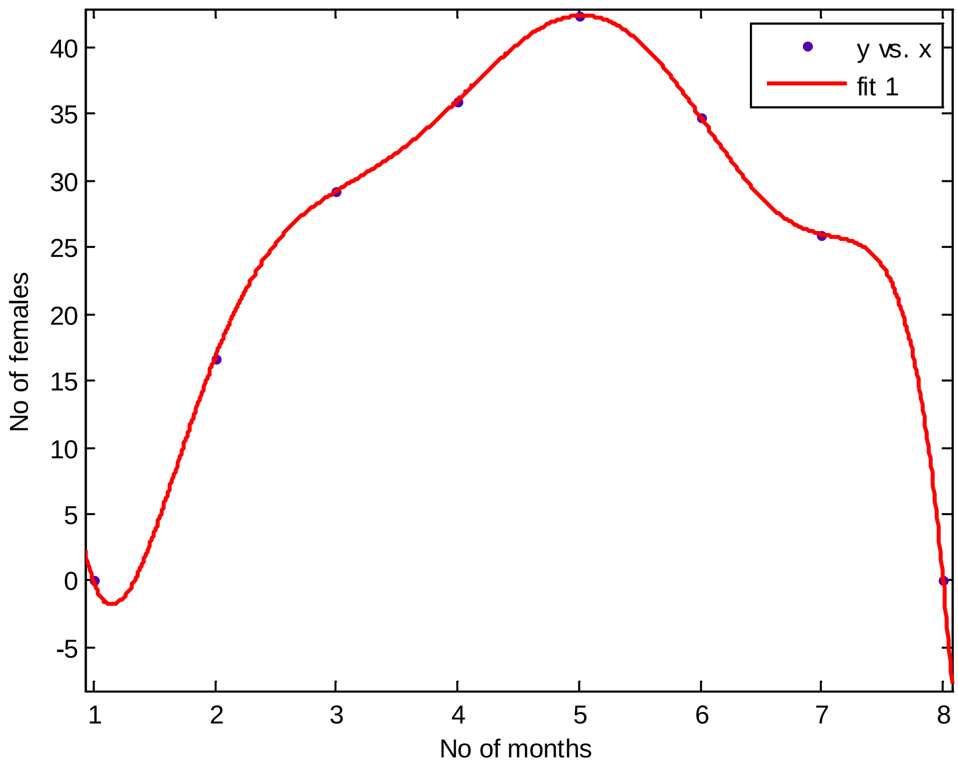

Fig. 11: No of females vs. no of months

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