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Viewing the Blood Glucose Levels of the Drug-Induced Diabetic Experimental Rats Treated With the Cissampelos Pareira L. (Menispermaceae) Root Extract - II

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Abstract - We propose a quadratic polynomial model for understanding the pattern of the average values of the blood glucose levels of the first group of experimental rats which are classified by the name Group 1 Normal Control (G1NC) in a recent study conducted by Ankit Kumar et al. (see, Ankit Kumar, Ravindra Semwal, Ashutosh Chauhan, Ruchi Badoni Semwal, Subhash Chandra, Debabrata Sircar, Partha Roy and Deepak Kumar Semwal, Evaluation of antidiabetic effect of Cissampelos pareira L. (Menispermaceae) root extract in streptozotocin-nicotinamide-induced diabetic rats via targeting SGLT2 inhibition, Phytomedicine Plus 2 (2022) 100374, 11pp., https://doi.org/10.1016/j.phyplu.2022.100374) which was aimed at finding how the plant Cissampelos pareira L. (Menispermaceae) could be the source of one of the effective drugs for the treatment of diabetes. In our earlier study on this subject, we discussed a dose response Hill model for the pattern of averages of blood glucose levels of the rats of the group G1NC of this study of Ankit Kumar et al. We also show here that the quadratic model discussed here is a better model than the Hill model earlier discussed by us. Some characteristic features of the covariance matrix of the proposed quadratic polynomial model are also discussed by us which include its inverse, Gram Schmidt orthogonalization, eigenvalues, eigenvectors and the positive definiteness.

Keywords: Diabetes, Cissampelos pareira, blood glucose, regression, quadratic polynomial, DR-Hill, covariance matrix.

2020 Mathematics Subject Classification: 62J02, 62J05, 62J10, 62J99, 62P05, 62P20, 91B62, 91B74, 91B99, 91G70, 91G99.

1. INTRODUCTION

Throughout the history of mankind, there has been a continuous search in the lap of nature by man to look for therapeutic remedies available from the plant kingdom to alleviate the sufferings of man. Millenniums have passed and very slowly the knowledge of man about a number of drugs available or extractable from the various plants have slowly increased and this treasure of knowledge for the posterity has been handed down for centuries by our ancestors to us across the different races and tribes inhabiting the globe by our great forefathers. One such important flowering medicinal plant is Cissampelos pareira Linn belonging to the family Menispermaceae [1]. Also known by its common name Velvetleaf [1-3], the plant is a dioecious climber distributed globally in the regions of Madagascar, America, Mauritius, East Africa, West Indies, Australia, Asia, Seychelles, Comoros, India, etc. [4,5]. In Asia the leaves of this plant are used for edible purposes [3]. The

authors of [6] have found that in India Cissampelos pareira has a both medicinal and economic use by focusing on the results of their survey and studies conducted in the states of Uttarakhand, Odisha, Himachal Pradesh, Jharkhand, Punjab and West Bengal during the period 2018-2022. The study [6] records that in India the juice, decoction or paste of the roots of Cissampelos pareira is used for alleviating the sufferings of the menstrual disorders, stomach ache and wounds. The decoction of the leaves, flowers and the whole plant of Cissampelos pareira is also found useful for the treatment of fever, wounds, stomach pain and irregularity of periods and menstrual cramps [6] and the paste of the whole plant is used for the treatment of jaundice [6]. On the economic side, the study [6] records that the roots of Cissampelos pareira are sold for medicinal purposes and pills made of the root powder of Cissampelos pareira and rice powder are sold by the name 'Ranu' in the local markets of Mayurbhanj and Sundargarh in Odisha for making a country liquor called 'Mahua'. It is well known that Cissampelos pareira has been long used in various parts of the world as a medicinal plant. Scientifically its medicinal values have been proved by a number of experimental studies [3]. In [3] we find a brief and beautiful informative description of many of the medicinal uses of this plant including a very short mention of the active chemical compounds of this plant. This source [3] also underlines the therapeutic properties of Cissampelos pareira by mentioning that a 'water-ethanol extract of the rhizomes' has been found effective in checking the propagation and proliferation of stomach tumors and the 'ethanolic rhizome extracts' of Cissampelos pareira 'have shown antihistaminic, hypotensive, antispasmodic and anticonvulsant properties [3]'. The plant Cissampelos pareira is also found effective in the treatment of diabetes, and researchers have also investigated its antidiabetic properties, some pertinent references in this direction are [5, 7] and [8]. We also notice that one of the main focus area of the researchers working in unraveling the antidiabetic properties of the active compounds found in Cissampelos pareira is the technique of utilizing an aqueous-ethanolic extract of the roots of this plant [3,7,8] in experimental rats. This technique is also followed by the learned authors of [9], which basic study forms the source of the secondary data of our explorations in this and the related forthcoming series of papers [20] in continuation of our previous studies [21,22].

We find it only informative to remark here that the technique of regression, as a versatile tool of research, is widely used in almost all branches of study. Some representative literary references about the tool of regression analysis are [10-19], which we find interesting for our purpose and having a bearing on our work in this paper. We propose a quadratic polynomial model in this study for the experimental data concerning the average blood glucose levels of the rats belonging to the group named G1NC (group one normal control) of the paper [9]. In section 2 we reproduce the relevant data for our analysis in this paper, whose original source is Table 3 on page 6 of 11 of [9]. The description of our proposed quadratic model is the matter of section 3. In section 4 we compare the dose response Hill model fitted by us to this dataset in our previous study [20] to the present quadratic polynomial model and show that the latter model is a better model over the previous model. In section 5 we discuss some characteristic features of the covariance matrix of the proposed quadratic polynomial model which include its inverse, eigenvalues, eigenvectors, positive definiteness, Gram Schmidt orthogonalization and the like. The conclusion of the study is finally summed up in section 6.

1.1 Abbreviations Used in the Paper

We use the following abbreviations at different places in this paper for our convenience. Some of these abbreviations are the same as those are normally used in the medical terminology often used in the medical research literature and in the medical profession by the practitioners of medicine, which we have retained, and the abbreviations used by the authors of [4] are also retained by us for our use in this study.

G1NC: group 1 normal control
Day: Day of Experiment
1.2345E+03 = 1.2345×10^{3}
CPRE: Cissampelos Pareira root extract

S.D.: Standard Deviation
G1NCm: Mean of G1NC
1.2345E-03 = 1.2345×10^{-3}

2. DATA FOR THE STUDY

We present in Table 1 below the secondary data, which is taken by us from Table 3 on p. 6 of 11 of the work of A. Kumar et al. [9]. Most sincerely and gratefully we acknowledge that source [9] and all the learned authors and the publishers of the Journal [9]. In Table 1(a) below we arrange a very small portion of the original data of Table 1 in a form suitable for our study in this paper.

Table -1: The effect of CPRE on blood glucose levels of experimental animals.

Day	Blood glucose (mg/dL)			
	G1NC	G2DC	G3S	G4T
Basal (0) Day	74.53 ±02.77	305.73 ±23.83	313.40±23.01	303.9 ± 19.40
7th Day	79.60 ±08.57	321.76 ±22.01	188.37±13.89	288.54±16.32
14th Day	96.17 ±11.70	381.06 ±13.66	276.94±16.19	250.24±13.26
21st Day	95.09 ±14.61	470.26 ±25.72	180.12 ±18.83*	225.35±14.18
28th Day	96.89 ±07.09	514.56 ±17.86	188.92 ±12.44*	198.56 ±13.20*

Values are given as mean±SD. Abbrev: G1NC = Group 1 normal control, G2DC = Group 2 diabetic control, G3S = Group 3 standard, G4T = Group 4 test, * = statistical significant ($p<0.05$).

Source: A. Kumar et al. [9]

Table -1: (a). Measurements of the blood glucose levels in mg/dL of the experimental rats of the group G1NC showing the effect of the CPRE on it.

S. No.	Day	G1NCm
1.	0	74.53
2.	7	79.60
3.	14	96.17
4.	21	95.09
5.	28	96.89

Source: A. Kumar et al. [9]

3. QUADRATIC POLYNOMIAL MODEL FOR THE MEAN BLOOD GLUCOSE LEVELS OF THE RATS OF THE GROUP G1NC

Now we discuss a quadratic polynomial model to the dataset of Table 1(a), which has appeared to us as a good competing model to perceive the observed average values of the blood glucose levels as a function of the number of days. The proposed quadratic polynomial model for the data of Table 1(a) is given below in (3.1):

$$y = a + bx + cx^2 \quad (3.1)$$

where, in (3.1) y denotes the response (the mean blood glucose level of the group G1NC) and x represents the predictor (i.e., the number of days as shown in the second column of Table1) and a, b, c are the three regression parameters. Table 2(a) presents the elementary details of the model of (3.1). The degrees of freedom is 2 and the value of Akaike Information Criterion (corrected) AICc is 20.722522, which being less than the corresponding AICc value of 24.431168 for the DR Hill model proposed by us in our earlier study [20], indicates that the present Quadratic Polynomial 2 is a better fit to explain the variation in the trends of the data of Table 1(a). From Fig. 1 it is self evident that out of the five sample points only the fifth sample point of 96 mg/dL (corresponding to measurement of the average blood glucose level of the 28th day) lies on the curve of (3.1), which in contrast to the fact that two of the data values (viz., 74.53 mg/dL and 79.60 mg/dL) of Table 1(a) lay exactly on the DR Hill Model curve plot of our earlier probe [20] and the third value of 96.17 mg/dL lay very near that curve in [20]. But these visual observations do not help us decide too much when the actual comparison of two possible fitting models to a dataset is made, which process is based on rigorous mathematical criterion. We can also see that all the five values of the dataset of Table 1(a) here lie well within the 95% confidence band (the narrower dark red colored region around the plot line of (3.1)) and not even a single observation of the dataset lies in the 95% prediction band (the wider light red colored region around the curve of (3.1)), a feature which is similar to the plot of the DR Hill model given by us in our previous study [20].

Table -2: (a): Details of the Quadratic Polynomial Model of (3.1)

Name:Polynomial Regression (degree=2)		
Kind:Regression		
Family:Linear Regressions		
No. of Independent Variables:1		
Parameters:		
a =7.29582857142856E+01		
b =1.84748979591839E+00		
c =-3.52623906705540E-02		
Value	Std Err	Range (95% confidence)

a	72.958286	4.348005	54.250329 to 91.666242
b	1.847490	0.735793	-1.318373 to 5.013353
c	-0.035262	0.025199	-0.143685 to 0.073160
Standard Error:		4.62001329620845E+00	
Coefficient of Determination (r^2):		9.04500983972169E-01	
Correlation Coefficient (r):		9.51052566355913E-01	
	DOF:	2	
	AICc:	20.722522	
Parameter Standard Deviations:			
a_stddev =4.34800515366835E+00			
b_stddev =7.35793237010340E-01			
c_stddev =2.51989896162568E-02			
Parameter Uncertainties, 95%:			
a_unc =1.87079562440994E+01			
b_unc =3.16586277987279E+00			
c_unc =1.08422501463393E-01			

Table -2: (b): Covariance matrix of the Quadratic Polynomial Model of (3.1)

	a	b	c
a	8.8571428571428534E-01	-1.1020408163265290E-01	2.9154518950437261E-03
b	-1.1020408163265290E-01	2.5364431486880428E-02	-8.3298625572677902E-04
c	2.9154518950437261E-03	-8.3298625572677913E-04	2.9749509133099252E-05

The Residual Plot of the model of (3.2) is drawn in Fig. 2, which shows a random pattern of residuals about the Zero Line, a desired characteristic of a good fit. The light red colored Residual Regression Line in Fig. 2 coincides with the black colored Zero Line, therefore, it is not separately visible here in contrast to the distinct Regression Line of the dose response Hill Model of the authors' earlier study (Fig. 2, p. 10 , [20]). Since the P-Value of a Wald-Wolfowitz runs test performed on the residuals is 0.5434, which being higher than the

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threshold of 0.05, shows that the pattern is not unlikely. Table 3(a) shows the forecasted values of the average blood glucose values of the rats which belonged to the group G1NC of the study [9] on a daily basis for a period of one month (thirty days).

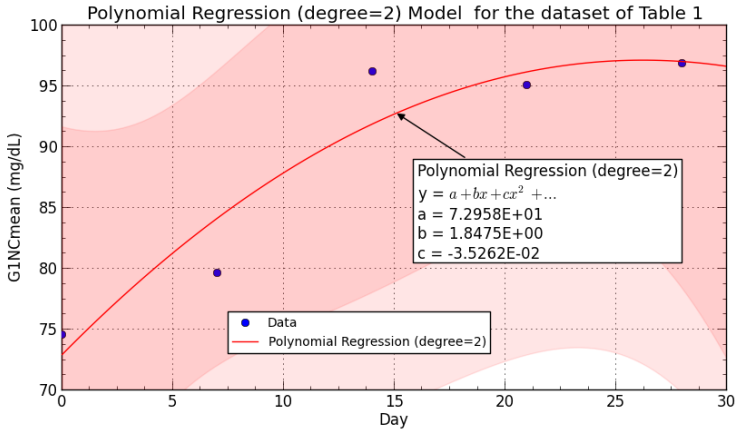

Fig -1:The Plot of the Quadratic Polynomial Model of (3.1) for the mean of the blood glucose level of the group G1NC.

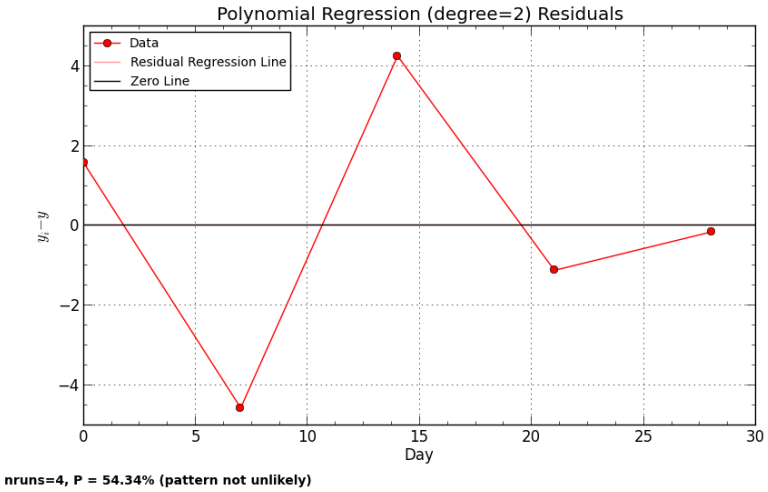

Fig -2: The Residual Plot of the Quadratic Polynomial Model of (3.1).

Table -3: (a): A representative prediction table for the Quadratic Polynomial Model of (3.1) for the mean blood glucose levels of the group G1NC on a daily basis.

$x =$ No. of Day	$y =$ Mean blood glucose level of the group G1NC (mg/dL)

0.00000000000000000E+00	7.2958285714285552E+01
1.00000000000000000E+00	7.4770513119533391E+01
2.00000000000000000E+00	7.6512215743440109E+01
3.00000000000000000E+00	7.8183393586005721E+01
4.00000000000000000E+00	7.9784046647230241E+01
5.00000000000000000E+00	8.1314174927113640E+01
6.00000000000000000E+00	8.2773778425655934E+01
7.00000000000000000E+00	8.4162857142857106E+01
8.00000000000000000E+00	8.5481411078717187E+01
9.00000000000000000E+00	8.6729440233236147E+01
1.00000000000000000E+01	8.7906944606414015E+01
1.10000000000000000E+01	8.9013924198250763E+01
1.20000000000000000E+01	9.0050379008746404E+01
1.30000000000000000E+01	9.1016309037900953E+01
1.40000000000000000E+01	9.1911714285714368E+01
1.50000000000000000E+01	9.2736594752186690E+01
1.60000000000000000E+01	9.3490950437317906E+01
1.70000000000000000E+01	9.4174781341108002E+01
1.80000000000000000E+01	9.4788087463557005E+01
1.90000000000000000E+01	9.5330868804664888E+01
2.00000000000000000E+01	9.5803125364431679E+01
2.10000000000000000E+01	9.6204857142857350E+01
2.20000000000000000E+01	9.6536064139941914E+01
2.30000000000000000E+01	9.6796746355685357E+01
2.40000000000000000E+01	9.6986903790087709E+01
2.50000000000000000E+01	9.7106536443148940E+01
2.60000000000000000E+01	9.7155644314869079E+01
2.70000000000000000E+01	9.7134227405248097E+01
2.80000000000000000E+01	9.7042285714286010E+01
2.90000000000000000E+01	9.6879819241982830E+01

3.0000000000000000E+01	9.6646827988338515E+01

The percentage error in the fitted values of the response (y) for their observed values as per the model of (3.1) are calculated in Table 3(b) from where we can see that our model of (3.1) after deviating slightly in the middle range of the dataset (i.e., the seventh and fourteenth days) of Table 1(a) approximates the sample observations very well towards the end (i.e., the twenty first and the twenty eighth day) of the dataset. In Table 3(c) we recover some values of the predictor x (no. of days) from the given values of the response y (average blood glucose level) using the model of (3.1) with an initial value of the predictor as $x0=14$ days. It can be noted from Table 3(c) that for the last three values of the response, the values of the predictor cannot be recovered because as we can see from Fig. 1 that from the values of the response which are slightly above 96.25 mg/dL, the curve of (3.1) becomes almost flat, i.e., from here onwards the change in the values of the predictor does not result in an appreciable change in the values of the response, which is the main reason why we are unable to recover the values of the predictor from the model of (3.1) for values beyond 96.25 mg/dL approximately with an initialization value of $x0=14$ days. We can of course recover the values of the predictor in such cases by using a symbolic computation tool like, Mathematica, etc., which we have done and shown our results in Fig. 3. We also note from Fig. 3 that for some values of y (G1NCmean), the value of x (Day) is returned as a complex number. This is because a quadratic equation on solving can also yield a pair of conjugate complex roots. In such cases we find it reasonable to interpret x (Day) as the modulus of the complex root obtained by solving the corresponding quadratic equation. For example, in Fig. 3 the solution of the Input number 4 (In[4]) yields as solution one of the complex root as $26.1963+5.82814i$, whose modulus is 26.83679097, which we take as the corresponding value of the Day. The reader will also notice from Fig. 3(c) that due to the symmetry of the parabola about its axis, we get two values of x in all the outcomes.

Table -3: (b): Percentage error for the forecasted values of the average blood glucose levels by the Model of (3.1)

S. No.	Day (x)	G1NCm (y) mg/dL	Fitted by (3.1) $(\hat{y})$ mg/dL	Residual $(y-\hat{y})$ mg/dL	Percentage Error $\left(100\frac{\lvert y-\hat{y}\rvert}{y}\right)$
1.	0	74.53	72.9583	1.5717	2.1088
2.	7	79.60	84.1629	-4.5629	6.1223
3.	14	96.17	91.9117	4.2583	4.4279
4.	21	95.09	96.2049	-1.1149	1.1725
5.	28	96.89	97.0423	-0.1523	0.15719

Table -3: (c): Recovering the values of the predictor (x) from the response (y) from the Model of (3.1)

S. No.	G1NCm (y)	Day (x) with $x0=14$

	mg/dL	days
1.	7.4417783790084840E+01	0.802274814293
2.	7.7132909620989921E+01	2.36651193372
3.	8.1467442142856640E+01	5.10277825356
4.	8.6087622857142364E+01	8.47868449234
5.	8.9369323615159487E+01	11.33531627
6.	9.4378649329444215E+01	17.3198992546
7.	9.6950796268219008E+01	23.7780999689
8.	9.8354770043728706E+01	Not available
9.	9.8087439999996931E+01	Not available
10.	9.4519405714283778E+01	Not available

```
In[1]:= Solve[7.29582857142856 * 10^1 + 1.84748979591839 * x - 3.52623906705540 * 10^-2 * x^2 ==
          9.4519405714283778 * 10^1, x]

Out[1]= {{x → 17.5477}, {x → 34.845}}

In[2]:= Solve[7.29582857142856 * 10^1 + 1.84748979591839 * x - 3.52623906705540 * 10^-2 * x^2 ==
          9.6827434999997294 * 10^1, x]

Out[2]= {{x → 23.1392}, {x → 29.2535}}

In[3]:= Solve[7.29582857142856 * 10^1 + 1.84748979591839 * x - 3.52623906705540 * 10^-2 * x^2 ==
          9.6280028381921667 * 10^1, x]

Out[3]= {{x → 21.2093}, {x → 31.1833}}

In[4]:= Solve[7.29582857142856 * 10^1 + 1.84748979591839 * x - 3.52623906705540 * 10^-2 * x^2 ==
          9.8354770043728706 * 10^1, x]

Out[4]= {{x → 26.1963 - 5.82814 i}, {x → 26.1963 + 5.82814 i}}

In[5]:= Solve[7.29582857142856 * 10^1 + 1.84748979591839 * x - 3.52623906705540 * 10^-2 * x^2 ==
          9.8087439999996931 * 10^1, x]

Out[5]= {{x → 26.1963 - 5.13674 i}, {x → 26.1963 + 5.13674 i}}

In[6]:= Solve[7.29582857142856 * 10^1 + 1.84748979591839 * x - 3.52623906705540 * 10^-2 * x^2 ==
          9.7488981224486878 * 10^1, x]

Out[6]= {{x → 26.1963 - 3.06831 i}, {x → 26.1963 + 3.06831 i}}
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Fig -3: Recovering the values of the predictor (x) from the response (y) from the Model of (3.1) using Mathematica.

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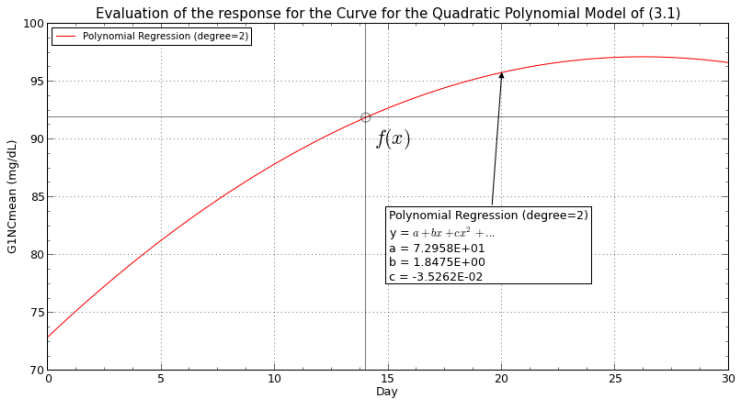

Fig -4: Evaluation of a value of the response for a given value of the predictor by the Quadratic Polynomial Model of (3.1).

Fig. 4 shows an evaluation process for the Model of (3.1), where we find the response y (G1NCmean) for a given value of predictor x (Day), which gives $y = 91.9117142857$ mg/dL for $x = 14$ Day, which corresponds to a percentage error of 4.4279% as mentioned in Table 3(b). A sample calculation of the slope of the curve of (3.1) at $x = 14$ Day is exhibited in Fig. 5 giving us that $f'(x)\big|_{x=14} = \frac{dy}{dx}\big|_{x=14} = 0.860142890247$ mg/(dLday).

The total area under the curve of (3.1) is shown in Fig. 6, which yields that $\int_0^{28} f(x)\,dx = 2509.02133333$ (mg/dL)(day). The entire arclength of the curve of (3.1) is found in Fig. 6, giving us $\int_0^{28} \sqrt{1+\left(f'(x)\right)^2}\,dx = 39.0608134645$ mg/dL.

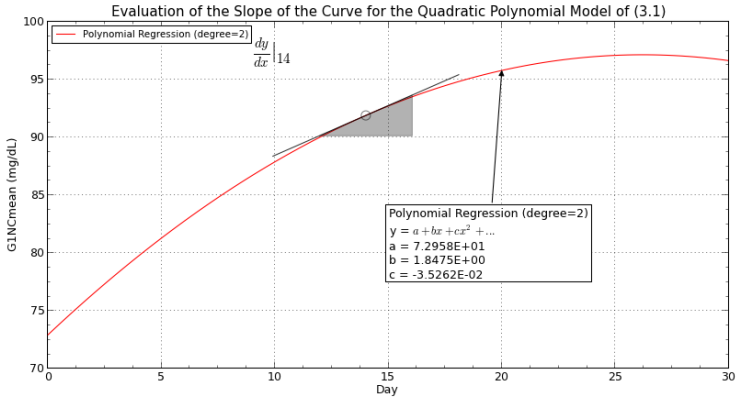

Fig -5: Evaluation of the slope of the curve for a given value of the predictor by the Quadratic Polynomial Model of (3.1).

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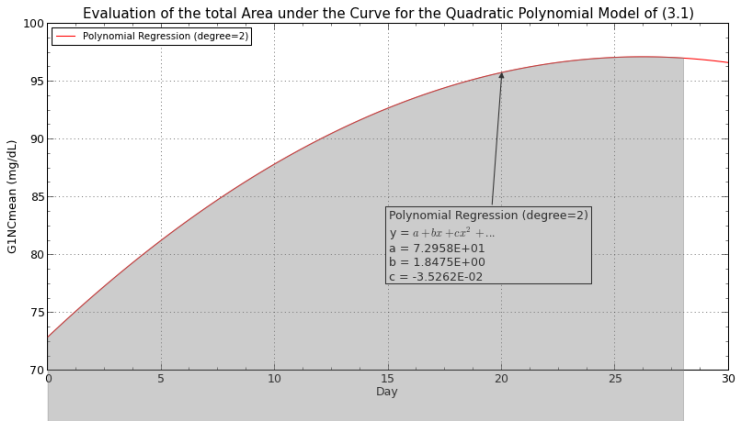

Fig -6: Evaluation of the total area under the curve for the Quadratic Polynomial Model of (3.1).

Table -4: A representative Analysis table for the Quadratic Polynomial Model of (3.1) for the average values of blood glucose levels of the rats of the group G1NC for some of the representative values of the predictor (day).

S. No.	Day a	Slope of the curve of at this point , i.e., $f'(x)\|_{x=a}$ in mg/(dLday)	Area under the curve from $x=a$ up to this point, i.e., $\int_a^x f(x)dx$ in (mg/dL)(day)	Total Arclength under the curve up to this point, i.e., $\int_a^x \sqrt{1+(f'(x))^2}dx$ in mg/dL
1.	5.9999999999999998E-01	1.80517503168	0	0
2.	2.3999999999999999E+00	1.67823053232	136.153186531	3.61520546175
3.	5.7000000000000002E+00	1.44549865411	399.592936968	9.73644734955
4.	8.0999999999999996E+00	1.27623920321	601.217409621	13.790104745
5.	1.1699999999999999E+01	1.02234949395	917.132833469	19.2772383936
6.	1.5600000000000000E+01	0.747303019466	1274.22326676	24.4899241088
7.	1.7699999999999999E+01	0.599201399609	1471.47732472	27.0226034269
8.	2.0399999999999999E+01	0.408784117667	1728.8811084	30.0490364802
9.	2.3399999999999999E+01	0.197210070496	2018.32011918	33.1886244052
10.	2.6099999999999998E+01	0.00679314382523	2280.38702799	35.9066448853
11.	2.9099999999999998E+01	-0.204781258617	2571.5702637	38.926814301

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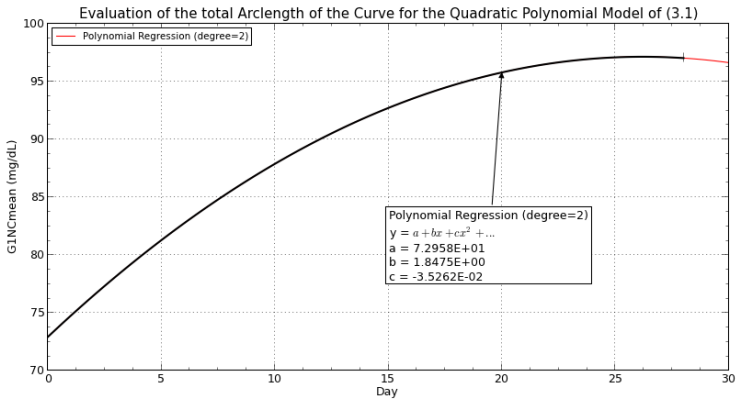

Fig -7: Evaluation of the total arclength of the curve for the Quadratic Polynomial Model of (3.1).

Table -4: above presents a representative analysis table for the model given by (3.1) for some give values of the predictor. In this table, the second entry under the Area column gives $\int_{5.9999999999999998E-01}^{2.3999999999999999E+00} f(x)dx = 136.153186531$ (mg/dL)(day), while the second entry under the Arclength column gives $\int_{5.9999999999999998E-01}^{2.3999999999999999E+00} \sqrt{1+\left(f'(x)\right)^2}\,dx = 3.61520546175$ mg/dL. Similar explanations hold for the remaining entries of this table for these last two columns.

4. COMPARISON OF THE DR-HILL AND THE QUADRATIC POLYNOMILA MODELS

Having discussed the DR (dose response) Hill Model for the dataset of Table 1(a) in our earlier paper [see, (3.1), p. 8, 20] and the Quadratic Polynomial Model in this work, it is natural for us to outline a comparison of these two models, which according to our experiments, so far, have emerged as two vying models for the sample described in Table 1(a). From the comparison table shown in Table 5 below it is at once obvious that the Quadratic Polynomial Model of (3.1) is a better fit to the sample of Table 1(a) based on the results of both the AICc (Akaike Information Criterion corrected) and the F test. The prerequisite for the validity of the F test demands that the simpler model (Quadratic Polynomial) is obtained from the more complex model (here, DR-Hill) by setting some parameters as constants in its equation, but this is obviously not possible in our case here, as the DR- Hill model of [20] is given by:

$$y = \alpha + \frac{\theta x^{\eta}}{\kappa^{\eta} + x^{\eta}} \quad (4.1)$$

where,

$$\alpha = 7.45300000185508E+01, \theta = 2.15200001418859E+01,$$
$$\eta = 2.69780497324766E+01, \kappa = 7.31214981870510E+00. \quad (4.2)$$

Thus, instead of the results of the F test, we rely on the outcome of the AICc test which is valid in all cases to infer that the Quadratic Polynomial of (3.1) is a better fit to the dataset of Table 1(a) vis-à-vis the DR-Hill model of (4.1). The comparison plots of these two models of (3.1) and (4.1) are shown in Fig. 8 underneath.

Table -5: Comparison of the DR-Hill Model of (4.1) and the Quadratic Polynomial Model of (3.1)

Overview

Model	Sum of Squares	DOF	AICc
Polynomial Regression (degree=2)	42.689	2	20.7225
DR-Hill	1.6416	1	24.4312

Comparison

The best regression is (chosen via the AICc test): Polynomial Regression (degree=2)

The best regression is (chosen via the F-Test): Polynomial Regression (degree=2)

Justification

Akaike's Information Criterion

Model	AICc
Polynomial Regression (degree=2)	20.7225
DR-Hill	24.4312

Delta = 3.70865

Probability = 0.135366

The likelihood that Polynomial Regression (degree=2) is the better model is 86.4634%.

F-Test

The more complicated model (DR-Hill has a better sum of squares than the simpler model (Polynomial Regression (degree=2)). Performing an F test. Because the result of an F test is strictly not valid unless the simpler model is a subset of the more complex model; i.e., the simpler model can be obtained by setting some parameters in the more complex model to certain constants. As the software cannot currently decide this issue, therefore, it presents F-Test results regardless of this fact.

F = 25.0045

P = 0.125655

If the simpler model were correct, the sum of squares would increase by approximately the gain in degrees of freedom when moving from the complex model to the simple one (i.e., F = 1). There is a 12.5655% probability that the simpler regression (Polynomial Regression (degree=2)) is the better fit to the data.

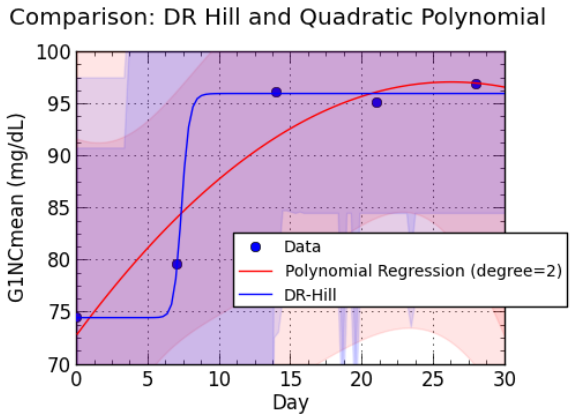

Fig -8: Comparison Plots of the Quadratic Polynomial Model of (3.1) and the DR-Hill Model of (4.1).

5. SOME CHARACTERISTIC FEATURES OF THE COVARIANCE MATRIX OF THE QAUDRATIC POLYNOMIAL MODEL OF (3.1)

We focus now our attention on the covariance matrix of the model of (3.1) shown in Table 2(b). For the various concepts of Matrix Theory and Linear Algebra used by us in this section for our exposition, we refer the reader to the standard textbooks on these subjects, some of which are [23-27]. Since the covariance matrix is essentially a symmetric matrix, we find on observing the matrix in Table 2(b), that it is by and large a symmetric matrix, except that to convert it into a symmetric matrix we round of both the entries -8.3298625572677902E-04 and -8.3298625572677913E-04 to -8.32986255726779E-04, then the covariance matrix of the Quadratic Polynomial Model of (3.1) is now given by

$$A := \begin{bmatrix} 0.8857142857 & -0.1102040816 & 0.002915451895 \\ -0.1102040816 & 0.02536443149 & -0.0008329862557 \\ 0.002915451895 & -0.0008329862557 & 0.00002974950913 \end{bmatrix} \quad (5.1)$$

The row space and column space of the matrix A defined by (5.1) are respectively spanned by the vectors

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$$\text{RowSpace}(A) = \left[\left[1.\quad 0.\quad 0.\right],\left[0.\quad 1.\quad 0.\right],\left[0.\quad 0.\quad 1.\right]\right]$$

$$\text{ColumnSpace(A)} = \left[\begin{bmatrix}1.\\0.\\0.\end{bmatrix},\begin{bmatrix}0.\\1.\\0.\end{bmatrix},\begin{bmatrix}0.\\0.\\1.\end{bmatrix}\right] \tag{5.2}$$

An orthogonal basis for the three linearly independent column vectors of A defined by (5.1) according to the procedure of the Gram-Schmidt orthogonalization process is given by

$$ord := \left[\begin{bmatrix}0.8857142857\\-0.1102040816\\0.002915451895\end{bmatrix},\begin{bmatrix}0.00142924379999999\\0.0114745707200000\\-0.000465529621600000\end{bmatrix},\begin{bmatrix}2.0312934429118910^{-9}\\4.7432774753189610^{-8}\\0.00000117461658788537\end{bmatrix}\right] \tag{5.3}$$

while the corresponding orthonormal basis generated by the Gram-Schmidt orthogonalization process is

$$\text{orthnor} = \left\{\begin{bmatrix}0.123502320699650\\0.991528606212784\\-0.0402268588620292\end{bmatrix},\begin{bmatrix}0.9923427776\\-0.1234712211\\0.003266434423\end{bmatrix},\begin{bmatrix}0.00172791383746118\\0.0403485513780447\\0.999184171543943\end{bmatrix}\right\} \tag{5.4}$$

Since the rank of A is three, therefore, it is a real symmetric positive definite matrix with a nonzero value of its determinant and having an empty null space as shown below

$$\text{Rank}(A) = 3;\quad \text{NullSpace}(A) = kern := \{\ \}$$
$$\text{IsDefinite(A, query = 'positive\_definite')} = true;$$
$$\text{Determinant(A, method = float)} = 1.21426568881044\times 10^{-8} \tag{5.5}$$

The characteristic polynomial of A in terms of a variable λ is given by

$$\text{CharacteristicPolynomial}(A,\ \lambda) =$$
$$-1.21426568810^{-8} + 0.01033861014\lambda - 0.9111084667\lambda^2 + \lambda^3 \tag{5.6}$$

which when solved for λ gives the following eigenvalues and the corresponding eigenvectors of A

$$v,\ e := \text{Eigenvectors}(A) \Rightarrow$$
$$v := \begin{bmatrix}0.899616236771939 + 0.I\\0.0114910553095382 + 0.I\\0.00000117461765231437 + 0.I\end{bmatrix},$$
$$e := \begin{bmatrix}0.992142577947710 + 0.I & -0.125100427425779 + 0.I & 0.00172860671043725 + 0.I\\-0.125068013382417 + 0.I & -0.991328290491769 + 0.I & 0.0403263251393240 + 0.I\\0.00333122377625001 + 0.I & 0.0402256575900803 + 0.I & 0.999185067652433 + 0.I\end{bmatrix}. \tag{5.7}$$

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In (5.7) corresponding to the first eigenvalue $\lambda_1 = 0.899616236771939 + 0.I$ of the matrix A in the vector v, the corresponding eigenvector is given by the first column vector of the matrix e, which is precisely the vector

$$e_1 = \begin{bmatrix} 0.992142577947710 + 0.I \\ -0.125068013382417 + 0.I \\ 0.00333122377625001 + 0.I \end{bmatrix}; I = \sqrt{-1},$$

with similar interpretations for the remaining two eigenvalues of A and their corresponding eigenvectors. The inverse of matrix A is given as below

$$\text{MatrixInverse}(A) = A^{-1} = \begin{bmatrix} 4.99999996404302 & 69.9999993301005 & 1469.99998486408 \\ 69.9999993301005 & 1469.99998776471 & 34299.9997254150 \\ 1469.99998486408 & 34299.9997254150 & 8.4995399385477310^5 \end{bmatrix}. \quad (5.8)$$

Finally, we draw a three dimensional matrix plot of the covariance matrix A of the Quadratic Polynomial Model of (3.1) defined by (5.1) in Fig. 9 below:

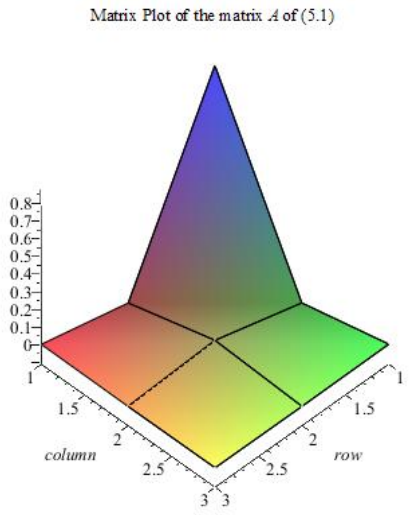

Fig -9: Matrix Plot of the covariance matrix A of the Quadratic Polynomial Model of (3.1).

6. CONCLUSIONS

In this paper we put forward a Quadratic Polynomial Model to explain the dataset of Table 1(a) concerning the average values of the blood glucose levels of the experimental rats of the group G1NC of the study [9]. A comparison of this model with our previously proposed Dose Response Hill Model of [20] showed that the present model is better than the earlier model on the basis of the Akaike Information Criterion (corrected). We also outlined some salient features of the covariance matrix of the Quadratic Polynomial Model dealt by us. In our next communication of this series we shall discuss another nonlinear model for the sample of Table 1(a) and show that that new model excels both these two models.

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REFERENCES

[1] Cissampelos pareira – Wikipedia. https://en.wikipedia.org/wiki/Cissampelos_pareira
[2] Velvetleaf - Encyclopedia of Life. http://eol.org/pages/594912/details
[3] Tropical Plants Database, Ken Fern. tropical.theferns.info. https://tropical.theferns.info/viewtropical.php?id=Cissampelos+pareira
[4] M. V. Sudhakaran (2012). "Histo-morphological, fluorescent and powder microscopic characterization of Cissampelos pareira Linn", Pharmacogn. J., 4 (34), 57–68.
[5] Surekha Kumari, Anmol, Vinod Bhatt, Shivprasad Suresh Patil, and Upendra Sharma (2021). " Cissampelos pareira L.: A review of its traditional uses, phytochemistry, and pharmacology", Journal of Ethnopharmacology, Volume 274, 28 June 2021, 113850.- https://doi.org/10.1016/j.jep.2021.113850 https://pubmed.ncbi.nlm.nih.gov/33485976/#:~:text=pareira%20have%20shown%20various%20pharmacological,antimalarial%2C%20and%20immunomodulatory%2C%20etc. https://www.sciencedirect.com/science/article/abs/pii/S0378874121000763?via%3Dihub
[6] Bhagwati Prashad Sharma, Manish Kumar, Goutam Basak, Amardeep Kaur, Sugimani Marndi, and Sanjeet Kumar (2022). "Medicinal and economic values of Cissampelos pareira (Menispermaceae)", in Medico-Biowealth of India, Volume- VI, 16-20. ISBN:978-81-952750-9-0 , https://www.researchgate.net/publication/362092874 , DOI: 10.5281/zenodo.6860204
[7] K. A. Kumar, T. Satyanarayana, A. Mathews, Y. S. Rao, and K. R. Kiran (2011). "Antihyperglycemic activity of methanolic extract of Cissampelos pareira Linn. roots on blood glucose levels of streptozotocin-induced diabetic rats", J. Pharm. Res., 4, 3399–3401.
[8] N. M. Piero, N. N. M. Eliud, K. N. Susan, O. O. George, and N. J. M. M. David (2015). "In vivo antidiabetic activity and safety in rats of Cissampelos pareira traditionally used in the management of diabetes mellitus in Embu County, Kenya", Drug Metab. Toxicol., 6, 3.
[9] Ankit Kumar, Ravindra Semwal, Ashutosh Chauhan, Ruchi Badoni Semwal, Subhash Chandra, Debabrata Sircar, Partha Roy, and Deepak Kumar Semwal (2022). "Evaluation of antidiabetic effect of Cissampelos pareira L. (Menispermaceae) root extract in streptozotocin-nicotinamide-induced diabetic rats via targeting SGLT2 inhibition", Phytomedicine Plus 2 (2022) 100374, 11pp. https://doi.org/10.1016/j.phyplu.2022.100374
[10] D. A. Ratkowsky,(1983). Nonlinear Regression Modeling: A Unified Practical Approach, Marcel Dekker, New York.
[11] N. Lynch, T. Hoang, T. E. O'Brien (2016). "Acute toxicity of binary-metal mixtures of copper, zinc, and nickel to Pimephales Promelas: evidence of more-than-additive effect", Environ. Toxicol. Chem., 35(2), 446–457. https://doi.org/10.1002/etc.3204
[12] Z. Govindarajulu (2001) Statistical techniques in bioassay, 2nd edn. Karger, Basel.
[13] D. M. Bates, and D. G. Watts (2007). Nonlinear Regression Analysis and its Applications, Wiley, New York.
[14] D. Faraggi, P. Izikson, and B. Reiser (2003). "Confidence intervals for the 50 per cent response dose", Stat. Med., 22(12), 1977–1988. https://doi.org/10.1002/sim.1368
[15] Prajneshu (1998). "A nonlinear statistical model for aphid population growth", Jour. Ind. Soc. Ag. Statistics, 51, 73–80.
[16] Paul H. Morgan, L. Preston Mercer, and Nestor W. Flodin (1975). "General model for nutritional responses of higher organisms (bioassay/saturation kinetics/growth responses)", Proc. Nat. Acad. Sci. USA, Vol. 72, No. 11, pp. 4327-4331, November 1975, Biochemistry.
[17] Hafeez Muhammad Yakasai, and Mohd. Yunus Abd Shukor,(2020). "Predictive mathematical modelling of the total number of COVID-19 cases for the United States", Bioremediation Science and Technology Research (BSTR), Vol 8, No. 1, 11-16.

[18] Hossein Riazoshams, Habshah Midi, and Gebrenegus Ghilagaber (2018). Robust Nonlinear Regression with Applications using R, Wiley, New York. ISBN: 9781118738061

[19] Michael H. Kutner, Christopher J. Nachtsheim, John Neter, and Li, William (2005). Applied Linear Statistical Models, Fifth Edition, McGraw-Hill Irwin, New York, USA. ISBN 0-07-238688-6

[20] L. M. Upadhyaya, and S. Aggarwal (2024). "Viewing the blood glucose levels of the drug induced diabetic experimental rats treated with the Cissampelos pareira L. (Menispermaceae) root extract", Journal of Advanced Research in Applied Mathematics and Statistics, 9(1&2), 5-15.

[21] A. Sathyavathi, and L. M. Upadhyaya (2023). "Possible regression models for the municipal finances of the municipal corporations of various Indian states", Bull. Pure Appl. Sci. Sect. E Math. Stat. 42E(1), 72 – 93.

[22] A. Sathyavathi, L. M. Upadhyaya, and S. Aggarwal. "Possible regression models for the municipal finances of the municipal corporations of various Indian states –II", Bull. Pure Appl. Sci. Sect. E Math. Stat. 42E(2), 143 – 179.

[23] Carl D. Meyer (2000). Matrix Analysis and Applied Linear Algebra, SIAM, Philadelphia. ISBN 0- 89871-454-0

[24] Kenneth Hoffman, and Ray Kunze (1971). Linear Algebra, Second Edition, Prentice Hall, Inc. Englewood Cliffs, New Jersey.

[25] Curtis, Morton L. (1990). Abstract Linear Algebra with Revisions by Paul Place, Springer-Verlag, New York, Berlin, Heidelberg, London, Paris, Tokyo, Hong Kong.

[26] John W. Dettman (1986). Introduction to Linear Algebra and Differential Equations, Dover Publications, Inc. New York.

[27] A. R. G. Heesterman (1990). Matrices and Their Roots – A Textbook of Matrix Algebra, World Scientific Publishing Co. Pte. Ltd., Singapore, New Jersey, London, Hong Kong. ISBN: 981-02-0395-0.