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Maximum Likelihood Estimates in Clinical Efficacy of Moringa Oleifera on Malaria Treatment

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Abstract

Moringa oleifera is among the many plants that is used to treat malaria in Africa, and Ghana in particular. The herbal plant contains oleifera alkaloids when administered orally which shows efficacy in reducing Plasmodium falciparum parasites more in humans more than chloroquin related drugs. Moringa leaves were converted to tea bag of 2.5 grams and was given to 50 malaria patients(27 females and 23 males) in 5 separate stages. In this case, every stage was made up of 10 new patients. The healing process of uncomplicated malaria was assessed by using exponential model according to World Health Organizationmandatory time for remission. Looking at the probability figuresobtainedfrom overall survival probabilities in the work, it is reasonable to conclude that a patient whoundergone treatment in the first stage will have a survival probabilityof 0.3, alsothe second stage and the thirdstage have 0.6 and 0.7 survival probabilities. The fourth and fifth stages had their survival probabilities to be beyond 0.8 and hence a malaria patient probability of being cleared from malaria fever in that stage is 0.8 which is obviously high probability of success. For this reason, it is clear that Moringa Oleifera has very propensity of curing uncomplicated malaria and therefore those affected with uncomplicated malaria are admonished to use herbal plant for treatment.

Keywords: *Moringa oleifera, uncomplicated malaria, least square estimates, maximum likelihood.*

1. INTRODUCTION

Using herbal plants is predominantly one of the most usefulcomponents in Ghana healthcare system. This is very common in our local areas where modern healthcare facility systems are woefully inadequate. Access to quality health care is widely acknowledged as a fundamental human right. However, the realization of this right remains constrained by numerous challenges within the modern health care system in rural communities in Ghana, rendering it accessible to only a segment of the population. Health facilities in these areas are limited in number and often inadequately equipped, while the shortage of trained health professionals further weakens service delivery. Consequently, traditional medicine and herbal practitioners continue to play a prominent role within Ghana's health care landscape. Additionally, the preference of many rural residents to simultaneously utilize both indigenous and modern medical systems complicates health service utilization, thereby constituting a significant public health concern. Government has initiated many healthcare projects to bridge the gap existing between urban centers and the rural communities. The current Agenda 111 intervention initiated by Ghanaian government to build health facilities at strategic centers for easy accessible to all.

Despite efforts by the government and its development partners to ensure that modern health care services are accessible, available, affordable, and acceptable to all Ghanaians, significant challenges persist, particularly in rural areas where health facilities are scarce, poorly equipped, and often located far from the communities they serve, with inadequate road networks further limiting access, especially during the rainy season. These barriers, coupled with the rising cost of modern medical care, which is increasingly unaffordable for many people in Ghana and other African countries, have contributed to a growing reliance on traditional medicine among rural populations. While many indigenous remedies remain inadequately

regulated and raise concerns regarding safety and quality, the appropriate use of certain traditional medicines has shown potential benefits in disease management, including malaria. Malaria remains a major public health problem and a leading cause of morbidity in Ghana, transmitted through the bite of an infected female *Anopheles* mosquito and characterized by high fever and chills, and in this context, traditional remedies such as *Moringa oleifera* continue to be used in the treatment of uncomplicated malaria, underscoring the enduring role of indigenous health practices within the national health care system.

2. MORINGA OLEIFERA

Moringa oleifera is widely utilized for diverse purposes in India and is also extensively available across Africa, where it is cultivated in large quantities. The plant is a fast-growing edible species that has become naturalized in tropical regions and is commonly found in backyard gardens, where it is often grown as a vegetable or used as a border plant. Botanically, *Moringa oleifera* is a deciduous perennial tree regarded as one of the most valuable multipurpose plants globally, as nearly all its parts have nutritional and medicinal applications. Phytochemical studies have identified the presence of bioactive compounds in *Moringa*, including alkaloids and triterpenoids (Don Pedro, 1990; Isman, 1993). In addition, pterygospermin, a compound with documented bactericidal and fungicidal properties, has been isolated from the plant, further supporting its medicinal relevance.

3.0 MATERIAL AND METHODS

3.1 Maximum likelihood

Maximum likelihood is increasingly applied in survival distribution and clinical trial estimates since conceptually, it is a simple procedure. Although clinical researchers encounter computational problems since patients data are mostly paucity and contain censored values. The asymptotic properties of maximum likelihood estimators under fairly general conditions make it use desirable in all phases of clinical trials. In patients remission assessments, maximum likelihood afford a general method of estimation of parameters even when observations are censored.

Supposed that x_1 malaria patients of the n_i on clinical trial study at stage i survive, where we represent $i = 1,2,\ k$. Thus assuming the k stages to be statistically independent, the likelihood function for all k stages is given by

$$L(\alpha_1, \alpha_2) = \prod_{i=1}^{k} \binom{n_i}{x_i} [p_i(\alpha_1, \alpha_2)]^{x_i} [1 - p_i(\alpha_1, \alpha_2)]^{n_i - x_i}$$

Mostly, the parameter to consider (α_1, α_2) can be obtained with respect to the observations by the usual maximum likelihood procedures. To use the maximum likelihood method, it be noted that $0 \le p_i \le 1$. Where $i = 1,2,3,\ldots k$ gives restricted constraint on the maximum likelihood estimators as well as the least squares estimators. In the first place the parameter (α_1, α_2) can be maximized with respect to the observation by maximum likelihood procedure. The maximum likelihood estimators $\hat{\alpha}_1$ and $\hat{\alpha}_2$ are the values of the parameters α_1 and α_2 respectively that simultaneously maximize $L(\alpha_1, \alpha_2)$ *or* $log_e L(\alpha_1, \alpha_2)$. The vector $L(\hat{\alpha}_1, \hat{\alpha}_2)$ is the solution of

$$\sum_{i=1}^{k} \frac{x_i}{P_{i(\hat{\alpha}_1, \hat{\alpha}_2)}} \frac{\partial P_i(\hat{\alpha}_1, \hat{\alpha}_2)}{\partial \hat{\alpha}_1} - \sum_{i=1}^{k} \frac{n_i - x_i}{1 - P_i(\hat{\alpha}_1, \hat{\alpha}_2)} \frac{\partial P_i(\hat{\alpha}_1, \hat{\alpha}_2)}{\partial \hat{\alpha}_1} = 0 \quad (1)$$

And

$$\sum_{i=1}^{k} \frac{x_i}{P_{i(\hat{\alpha}_1, \hat{\alpha}_2)}} \frac{\partial P_i(\hat{\alpha}_1, \hat{\alpha}_2)}{\partial \hat{\alpha}_2} - \sum_{i=1}^{k} \frac{n_i - x_i}{1 - P_i(\hat{\alpha}_1, \hat{\alpha}_2)} \frac{\partial P_i(\hat{\alpha}_1, \hat{\alpha}_2)}{\partial \hat{\alpha}_2} = 0 \quad (2)$$

That maximizes $L(\alpha_1, \alpha_2)$. Since in clinical trial, remission of patients from disease parasite follows decreasing function, $P_i = P_\infty - \alpha G(i)$. Suppose $P_i(\alpha_1, \alpha_2)$ where $i = 1, 2, \ldots k$. Let $\alpha_1 \equiv P_\infty$ and $\alpha_2 \equiv \alpha$. Let also assume that the success ratio for the k stages are respectively

$x_1/n_1, x_2/n_2, x_3/n_3, \ldots x_k/n_k$. The least squares equations is

$$\gamma(P_\infty, \alpha) = \sum_{i=1}^{k} [\frac{x_i}{n_i} - P_\infty + \alpha G(i)]^2 \quad (3)$$

Differentiating $\gamma(P_\infty, \alpha)$ with respect to P_∞ and α, the solution of these equations is the vector (P_∞^*, α^*) which is obtained by solving

$$\sum_{i=1}^{k} [\frac{x_i}{n_i} - P_\infty^* + \alpha^* G(i)] = 0 \quad (4)$$

And

$$\sum_{i=1}^{k} [\left(\frac{x_i}{n_i}\right) G(i) - P_\infty^* G(i) + \alpha^* G^2(i)] = 0 \quad (5)$$

The least square estimators P_∞^* and α^* are obtained by solving equations (4) and (5) hence

$$P_\infty^* = \frac{(\sum_{i=1}^{k} G^2(i))(\sum_{i=1}^{k} \frac{x_i}{n_i}) - (\sum_{i=1}^{k} G(i))(\sum_{i=1}^{k} G(i)\frac{x_i}{n_i})}{(\sum_{i=1}^{k} G^2(i)) - (\sum_{i=1}^{k} G(i))^2} \quad (6)$$

And

$$\alpha^* = \frac{(\sum_{i=1}^{k} G(i))(\sum_{i=1}^{k} \frac{x_i}{n_i}) - k(\sum_{i=1}^{k} G(i)\frac{x_i}{n_i})}{k(\sum_{i=1}^{k} G^2(i)) - (\sum_{i=1}^{k} G(i))^2} \quad (7)$$

The natural likelihood function is

$$\log_e L = C + \sum_{i=1}^{k} x_i \log_e(P_\infty - \alpha G(i)) + \sum_{i=1}^{k} (n_i - x_i) \log_e(1 - P_\infty + \alpha G(i))$$

Where C represents constant. From this deduction, solution to the maximum likelihood estimators is

$$\frac{dL}{d\alpha} = \sum_{i=1}^{k} \frac{x_i}{(\hat{P}_\infty - \hat{\alpha} G(i))} - \sum_{i=1}^{k} \frac{n_i - x_i}{(1 - \hat{P}_\infty - \hat{\alpha} G(i))} = 0 \quad (8)$$

$$\frac{dL}{dP_\infty} = \sum_{i=1}^{k} \frac{x_i G(i)}{(\hat{P}_\infty - \hat{\alpha} G(i))} + \sum_{i=1}^{k} \frac{(n_i - x_i) G(i)}{(1 - \hat{P}_\infty - \hat{\alpha} G(i))} = 0 \quad (9)$$

The estimators $\hat{P}_\infty$ and $\hat{\alpha}$ are uniquely establish by examining the second partial derivative matrix

$$Q = \begin{bmatrix} f_{11} & f_{12} \\ f_{12} & f_{22} \end{bmatrix} \quad (10)$$

From (10), we define

$f_{11} = \frac{d^2 \log_e L}{dP_\infty^2}, f_{12} = \frac{d^2 \log_e L}{dP_\infty \alpha}$, $f_{11} = \frac{d^2 \log_e L}{d\alpha^2}$. It is not difficult to see that $f_{11} < 0, f_{22} < 0$ but $f_{11} f_{22} - f_{12}^2 > 0$. $(\hat{P}_\infty, \hat{\alpha})$ of the vector parameter gives the maximum estimators (Taylor,1955). Unfortunately $\hat{P}_\infty$ and $\hat{\alpha}$ cannot be obtained in closed form like the least squares estimators. For this reason P_∞^* and α^* are preferred if they provide a good fit to the data. In clinical trial, patients data are mostly paucity and contains censored values. Least squares estimators are not good fit. It is observed that $\hat{P}_\infty$ and $\hat{\alpha}$ have desirable large sample properties and by using Newton – Raphson two dimensional algorithm, the series converges rapidly. This is done by using the least squares estimators as initial estimates. To achieve this, let us define

$$\hat{g}_{1,n-1} = \sum_{i=1}^{k} \frac{x_i}{\hat{P}_{\infty,n-1} - \hat{\alpha}_{n-1} G(i)} - \sum_{i=1}^{k} \frac{n_i - x_i}{(1 - \hat{P}_{\infty,n-1} + \hat{\alpha}_{n-1} G(i))} \quad (11)$$

$$\hat{g}_{2,n-1} = \sum_{i=1}^{k} \frac{x_i G(i)}{\hat{P}_{\infty,n-1} - \hat{\alpha}_{n-1} G(i)} + \sum_{i=1}^{k} \frac{(n_i - x_i) G(i)}{(1 - \hat{P}_{\infty,n-1} + \hat{\alpha}_{n-1} G(i))} \quad (12)$$

$$\hat{f}_{11,n-1} = [\sum_{i=1}^{k} \frac{x_i}{(\hat{P}_{\infty,n-1} - \hat{\alpha}_{n-1} G(i))^2} + \sum_{i=1}^{k} \frac{n_i - x_i}{(1 - \hat{P}_{\infty,n-1} + \hat{\alpha}_{n-1} G(i))^2}] \quad (13)$$

$$\hat{f}_{12,n-1} = [\sum_{i=1}^{k} \frac{x_i G(i)}{(\hat{P}_{\infty,n-1} - \hat{\alpha}_{n-1} G(i))^2} + \sum_{i=1}^{k} \frac{(n_i - x_i) G(i)}{(1 - \hat{P}_{\infty,n-1} + \hat{\alpha}_{n-1} G(i))^2}] \quad (14)$$

$$\hat{f}_{22,n-1} = [\sum_{i=1}^{k} \frac{x_i G(i)^2}{(\hat{P}_{\infty,n-1} - \hat{\alpha}_{n-1} G(i))^2} + \sum_{i=1}^{k} \frac{(n_i - x_i) G(i)^2}{(1 - \hat{P}_{\infty,n-1} + \hat{\alpha}_{n-1} G(i))^2}] \quad (15)$$

Where $\hat{P}_{\infty,n-1}$ and $\hat{\alpha}_{n-1}$ are the values of $\hat{P}_\infty$ and $\hat{\alpha}$ after $n-1$ iterations. It follows that $\hat{P}_{\infty,n}$ and $\hat{\alpha}_n$ are estimated by solving the vector equation

$$\begin{pmatrix} \hat{P}_{\infty,n} \\ \hat{\alpha}_n \end{pmatrix} = \begin{pmatrix} \hat{P}_{\infty,n-1} \\ \hat{\alpha}_{n-1} \end{pmatrix} - \begin{bmatrix} \hat{f}_{11,n-1} & \hat{f}_{12,n-1} \\ \hat{f}_{12,n-1} & \hat{f}_{22,n-1} \end{bmatrix}^{-1} \begin{bmatrix} \hat{g}_{1,n-1} \\ \hat{g}_{2,n-1} \end{bmatrix} \quad (16)$$

From (16), it is not difficult to see that, the individual values $\hat{P}_{\infty,n}$ and $\hat{\alpha}_n$ can be obtained as

$$\hat{P}_{\infty,n} = \hat{P}_{\infty,n-1} - \frac{\hat{g}_{1,n-1}\hat{f}_{11,n-1} - \hat{g}_{2,n-1}\hat{f}_{12,n-1}}{\hat{f}_{11,n-1}\hat{f}_{22,n-1} - \hat{f}_{12,n-1}^2} \quad (17)$$

And

$$\hat{\alpha}_n = \hat{\alpha}_{n-1} - \frac{\hat{g}_{2,n-1}\hat{f}_{11,n-1} - \hat{g}_{1,n-1}\hat{f}_{12,n-1}}{\hat{f}_{11,n-1}\hat{f}_{22,n-1} - \hat{f}_{12,n-1}^2} \quad (18)$$

3.2 Confidence regions and intervals for the exponential growth model

To obtain ajoint elliptical confidence region for P_∞ and α, we must find σ^{11}, σ^{12} and σ^{22}

An approximate (1-α)100 percent elliptical confidence region for the parameter vector $\binom{P_\infty}{\alpha}$ is

$$\sigma^{11}(\hat{P}_{\infty,} - P_\infty)^2 + \sigma^{22}(\hat{\alpha} - \alpha)^2 + 2\sigma^{12}(\hat{P}_{\infty,} - P_\infty)(\hat{\alpha} - \alpha) = \chi^2(1 - \gamma; 2)$$

Where $\chi^2(1-\gamma; 2)$ is the (1-γ)100 percentage point of the chi-square distribution with 2 degree of freedom. Here we observe that

$$\frac{\partial^2 log_e L}{\partial P_\infty^2} = [\sum_{i=1}^{k} \frac{x_i}{(P_\infty - \alpha G(i))^2} + \sum_{i=1}^{k} \frac{n_i - x_i}{(1 - p_\infty + \alpha G(i))^2} \quad (19)$$

We see that the ith stage x_i is a binomial variable whose mean is $n_i(p_\infty - \alpha G(i)$. It follows that

$$\sigma^{11} \equiv -E\left(\frac{\partial^2 log_e L}{\partial P_\infty^2}\right) = \sum_{i=1}^{k} \frac{n_i}{[(P_\infty - \alpha G(i)][1 - p_\infty + \alpha G(i)]}$$

$$\sigma^{12} = \sum_{i=1}^{k} \frac{n_i G(i)}{[(P_\infty - \alpha G(i)][1 - p_\infty + \alpha G(i)]}$$

$$\sigma^{22} = \sum_{i=1}^{k} \frac{n_i G^2(i)}{[(P_\infty - \alpha G(i)][1 - p_\infty + \alpha G(i)]}$$

4. APPLICATIONS

Moringa leaves were converted herbal tea bag prepared from 2.5grams dried leaves ofMoringa oleiferawas studied on 50 malaria patients (27 females and 23 males) in 5 independent stages in a clinical trial. Accordingly, each phase of the study comprised a new cohort of patients, with ten individuals diagnosed with uncomplicated malaria enrolled at each stage. Participants who had used chloroquine or chloroquine-related medications within the preceding two to four weeks were excluded from the study. Eligible patients received the herbal tea three times daily for five consecutive days, in line with the World Health Organization's extended seven-day test protocol, and were subsequently monitored for a period of 28 days following treatment. The proportion of patients who achieved

complete clearance of *Plasmodium falciparum* parasitaemia within 72 hours at each stage is presented below. $^{3}/_{10}, {}^{6}/_{10}, {}^{7}/_{10}, {}^{7}/_{10}$, and $^{8}/_{10}$. For stages 1 to 5. We proposed that the probability of a patient remission at the various ith stage is $p_i = p_\infty - {}^{\alpha}/_{i}$ where $i = 1, 2, 3, 4, 5$.Malaria parasite clearance exhibits decreasing function and for this reason, we use function $G(i) = {}^{1}/_{i}$. Our aim is to obtain the maximum likelihood estimates $\hat{p}_\infty$ and $\hat{\alpha}$. First we obtain the least squares estimates p_∞^* and α^* from (6) and (7)

$$p_\infty^* = \frac{(\sum_{i=1}^{k} G^2(i))(\sum_{i=1}^{k} {}^{x_i}/_{n_i}) - (\sum_{i=1}^{k} G(i))(\sum_{i=1}^{k} G(i)\,{}^{x_i}/_{n_i})}{k\sum_{i=1}^{k} G^2(i) - (\sum_{i=1}^{k} G(i))^2}$$

$$\alpha^* = \frac{(\sum_{i=1}^{k} G^2(i))(\sum_{i=1}^{k} {}^{x_i}/_{n_i}) - k(\sum_{i=1}^{k} G(i)\,{}^{x_i}/_{n_i})}{k\sum_{i=1}^{k} G^2(i) - (\sum_{i=1}^{k} G(i))^2}$$

Table 1 The results of least square computation

Stage i	${}^{1}/_{i}$	${}^{1}/_{i^2}$	${}^{x_i}/_{n_i}$	$({}^{x_i}/_{n_i})({}^{1}/_{i})$
1	1	1	$^{3}/_{10}$	$^{3}/_{10}$
2	$^{1}/_{2}$	$^{1}/_{4}$	$^{6}/_{10}$	$^{3}/_{10}$
3	$^{1}/_{3}$	$^{1}/_{9}$	$^{7}/_{10}$	$^{7}/_{30}$
4	$^{1}/_{4}$	$^{1}/_{16}$	$^{7}/_{10}$	$^{7}/_{40}$
5	$^{1}/_{5}$	$^{1}/_{25}$	$^{8}/_{10}$	$^{8}/_{50}$
Total	2.2833	1.4636	3.1000	1.1683

From table 1 and (6) and (7) with $G(i) = {}^{1}/_{i}$, we have

$$p_\infty^* = \frac{(1.4636)(3.1000) - (2.2833)(1.1683)}{5(1.4636) - (2.2833)^2} = 0.888$$

And

$$\alpha^* = \frac{(2.2833)(3.1000) - 5(1.1683)}{5(1.4636) - (2.2833)^2} = 0.588$$

We compute Newton Raphson iteration, we take p_∞^* and α^* as $\widehat{p_\infty^*}_0$ and $\widehat{\alpha^*}_0$ and Table 2 is given.

Here

$\hat{g}_{10i}, \hat{g}_{20i}$,-$\hat{f}_{110i}, \hat{f}_{120i}$ and -$\hat{f}_{220i}$are respectively,

$\left[{}^{x_i}/_{\hat{p}_{i0}} - \frac{n_i - x_i}{(1-\hat{p}_{i0})}\right], -\left[\frac{x_i}{i\hat{p}_{i0}} - \frac{n_i - x_i}{i(1-\hat{p}_{i0})}\right], \left[\frac{x_i}{p_{i0}^2} + \frac{n_i - x_i}{(1-\hat{p}_{i0})^2}\right], \left[\frac{x_i}{i\hat{p}_{i0}^2} + \frac{n_i - x_i}{i(1-\hat{p}_{i0})^2}\right]$, and$[\frac{x_i}{i^2\hat{p}_{i0}^2} + (n_i - x_i)/i^2(1-\hat{p}_{i0})^2$ where $\hat{p}_{i0} = \hat{p}_{\infty.0} - \frac{\hat{\alpha}_0}{i}$.

Table 2 Maximum likelihood computation for first iteration

Stage i	$\hat{g}_{10i}$	$\hat{g}_{20i}$	-$\hat{f}_{110i}$	$\hat{f}_{120i}$	-$\hat{f}_{220i}$
1	0.0000	0.0000	47.6190	47.6190	47.6190
2	0.2488	-0.1244	41.2716	20.6358	10.3179
3	0.3753	-0.1251	46.2421	15.4140	5.1380
4	-2.1363	0.5341	57.4706	14.3677	3.5919
5	1.6734	-0.3347	51.4180	10.2836	2.0567
Total	0.1612	-0.0501	244.0215	108.3202	68.7236

$$\hat{p}_{\infty.1} = 0.8880 + \frac{(0.1612)(68.7236) - (0.0501)(108.3202)}{(244.0215)(68.7236) - (108.3202)^2} = 0.8891$$

$$\hat{\alpha}_1 = 0.5880 - \frac{(0.0501)(244.0215) - (0.1612)(108.3202)}{(244.0215)(68.7236) - (108.3202)^2} = 0.5891$$

Examining these results indicates that iteration is necessary.

Table 3 Maximum likelihood computation layout (second iteration)

Stage	$\hat{g}_{11i}$	$\hat{g}_{21i}$	$-\hat{f}_{111i}$	$\hat{f}_{121i}$	$-\hat{f}_{221i}$
1	-0.0039	0.0039	47.6041	47.6041	47.6041
2	0.2239	-0.1120	41.3093	20.6547	10.3273
3	0.3394	-0.1131	46.3693	15.4564	5.1521
4	-2.1860	0.5465	57.7402	14.4351	3.6088
5	1.6263	-0.3253	51.6900	10.3380	2.0676
Total	-0.0002	0.0001	244.7129	108.3380	68.7599

Again from table 3

$$\hat{p}_{\infty.2} = 0.8891 + \frac{(0.0002)(68.7599) - (0.0001)(108.4882)}{(244.7129)(68.7599) - (108.4882)^2} = 0.8891$$

$$\hat{\alpha}_2 = 0.5891 - \frac{(0.0001)(244.7129) - (0.0002)(108.4882)}{(244.7129)(68.7599) - (108.4882)^2} = 0.5892$$

This second iteration gives the requisite maximum likelihood estimates since further iterations do not change the results. Since we have obtained both the least squares and maximum likelihood estimates for p_∞ and α, it is useful to compare the observed and expected remission probabilities in each stage. This is presented in the Table 4 below where MLE = maximum likelihood estimate and LSE = least squares estimates.

Table 4. Expected and observed remission probabilities for malaria patients at each stage of the clinical trial.

Stage i	Observed Probability	Expected MLE Probability	Expected LSE Probability
1	0.3000	0.2999	0.3000
2	0.6000	0.5945	0.5940
3	0.7000	0.6927	0.6920
4	0.7000	0.7418	0.7410
5	0.8000	0.7713	0.7704

Table 4 demonstrates a consistent increase in survivability across the successive stages of the study. The results further indicate that the least squares estimates tend to overestimate the observed probabilities of recovery at each stage, whereas the maximum likelihood estimates underestimate these probabilities. Consequently, the least squares estimates appear overly optimistic, while the maximum likelihood estimates provide a more conservative assessment of survivability.

The maximum likelihood estimates for the parameters p_∞ and α from the malaria remission data are $\hat{p}_\infty = 0.8891$ and $\hat{\alpha} = 0.5892$. using these values for $p_\infty$and α, the estimated values $\hat{\sigma}^{11}$,$\hat{\sigma}^{12}$, $\hat{\sigma}^{22}$ are found to be $\hat{\sigma}^{11} = 244.9822$, $\hat{\sigma}^{12} = -108.4053$, and $\hat{\sigma}^{22} = 68.7327$

The values $\hat{\sigma}^2_{p\infty}$, $\hat{\sigma}^2_{\alpha}$ and $\hat{\sigma}_{p_\infty \alpha}$ are obtained by writing the matrix of $\hat{\sigma}^{11}$,$\hat{\sigma}^{12}$, $\hat{\sigma}^{22}$

$$\begin{bmatrix} \hat{\sigma}^2_{p\infty} & \hat{\sigma}_{p_\infty \alpha} \\ \hat{\sigma}_{p_\infty \alpha} & \hat{\sigma}^2_{\alpha} \end{bmatrix} = \begin{bmatrix} 244.9822 & -108.4053 \\ -108.4053 & 68.7327 \end{bmatrix}^{-1} = \begin{bmatrix} 0.0135 & 0.0213 \\ 0.0213 & 0.0482 \end{bmatrix} \backslash$$

From $G(i) = {}^{1}/_{i}$, we have

$$Varp_i(\hat{p}_\infty, \hat{\alpha}) = 0.0135 + \frac{0.0482}{i^2} - \frac{0.0426}{i}$$

At each stage *I* of the clinical trial, the percent lower limit for probability of remission is

$$P_{Li}(\hat{p}_\infty, \hat{\alpha}) = \left(0.8891 - \frac{0.5892}{i}\right) - Z(1-\gamma)\sqrt{0.0135 + \frac{0.0482}{i^2} - \frac{0.0426}{i}}$$

Table 5 gives the values of $P_{Li}(\hat{p}_\infty, \hat{\alpha})$ at each of the five stages of the clinical trial and the predicted value $P_{Li}(\hat{p}_\infty, \hat{\alpha})$ with 95% confidence.

Stage *i*	$P_{Li}(\hat{p}_\infty, \hat{\alpha})$
1	0.0727
2	0.3800
3	0.5815
4	0.6158
5	0.6346
6	0.6462

CONCLUSION

Summary

Malaria fever remains one of the ten most common outpatient diseases in Ghana and continues to be a leading cause of mortality, as reported by the Ghana Health Service. Data obtained from herbal clinics in the Ashanti Region—the second largest region in Ghana—indicate a steady increase in reported malaria cases between 2011 and 2013. Specifically, records from Amen Scientific Clinic show a rise in cases from 322 in 2011 to 772 in 2012 and 1,000 in 2013, reflecting a consistent year-on-year increase. This upward trend has been largely attributed to poor hygienic practices, particularly in rural communities, which facilitate the spread of the disease. In addition, many affected individuals face significant barriers to accessing orthodox health care facilities due to poverty. Although awareness exists regarding the potential effectiveness of certain traditional medicines, negative perceptions associated with their use often limit their acceptance. Against this background, the present study sought to evaluate the survivability outcomes and reliability of the therapeutic efficacy of *Moringa oleifera* as an alternative antimalarial treatment to chloroquine.

The primary objective of this study was to determine the survival probability, growth pattern, and reliability of patients treated with *Moringa oleifera* as a herbal remedy, as well as to evaluate the overall probability of survival at each stage of the clinical trial. Survivability growth was assessed using both least squares and maximum likelihood estimation techniques applied to data obtained from a herbal clinic. The analytical model was carefully selected following the application of a smoothing curve to the clinical data, which revealed a gradual increase in survivability during the initial stages of the trial that stabilized in the later stages.

Both least squares and maximum likelihood estimation methods were employed to derive the expected probabilities of relief, which were subsequently compared with the observed probabilities at each stage of the trial. In addition, confidence regions for the probability of relief were estimated for each stage. The overall probability of success at each stage was computed primarily through the estimation of inverse variances and smoothing constants, which together facilitated a comprehensive assessment of treatment effectiveness across the different phases of the clinical trial.

The least squares estimates served as the initial values for the maximum likelihood estimation process, with initial estimates of $p^*_\infty = 0.888$and $\alpha^* = 0.588$. These values were subsequently used in the Newton–Raphson iterative procedure to obtain the maximum likelihood estimates. Convergence was achieved after the second iteration, yielding estimates of $\hat{p}_{\infty,2} = 0.8891$and $\hat{\alpha}_2 = 0.5892$, which were adopted as the final maximum likelihood

estimates. A comparative analysis of the observed and expected relief probabilities at each stage, based on both estimation methods, was then conducted to evaluate the consistency and reliability of the results.

A 95 percent lower confidence limit for $P_{Li}(\hat{p}_{\infty}, \hat{\alpha})$, $i = 1,2,\ldots,6$, noting that 1.645 is the upper 95th percentage point of the standard normal distribution was constructed. Each stage with its lower limit was found to be 1=0.0727, 2=0.3800, 3=0.5815, 4=0.6158, 5=0.6346. A predicted value $P_{L6}(\hat{p}_{\infty}, \hat{\alpha})$ with confidence 0.6462 was also calculated for.

Based on the analysis conducted and the estimates obtained through the Newton–Raphson procedure, it is concluded that, since α^>0, the drug demonstrates reliability and is highly effective in the treatment and recovery process of malaria.

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