

Profitability of Fungicide Use Decisions Among Cocoa Farmers in Southwestern Nigeria

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ABSTRACT This study examined the compatibility of the Cocoa Research Institute of Nigeria (CRIN) recommended fungicide use rate with profit maximization objective of Nigerian cocoa farmers. To achieve this research objective, a cross-sectional survey of cocoa farmers in four Local Government areas (LGAs) each in Osun and Ondo states was carried out. A three stage sampling procedure was adopted in selecting the respondents. A decision theoretic approach and the OLS regression method were used to analyze the data collected. The results indicated that (i) expected crop loss should be taken into account when deciding on the amount of fungicides to apply in the study area and (ii) the use rate recommended by CRIN could not be used in all situations – it is better used when the probability of large expected crop loss is extremely high (80%)

INTRODUCTION

Nigeria cocoa farmers have been shown to react positively to price incentives (Helleiner, 1966; Oni, 1972; CBN/NISER, 1992). It is evident from past studies that Nigeria's smallholder cocoa farmers have historically undertaken long-term measures to increase cocoa cultivation in response to remunerative producer prices (World Bank Report, 1973). This implies that the present price structure which has arisen as a result of the exchange rate policy and new marketing arrangement can in a like manner be relied upon to create an impact which will have favourable long-term ramifications for cocoa cultivation and production.

It is, however, suggested (Helleiner, 1966 and World Bank Report, 1973) that for the present price structure to have long term expansionary impact on cocoa cultivation and production, the farmers, assisted by government policy, should adopt a number of improved cultural practices among which is an effective pest and disease control program. Baquet et al. (1976) also recognised that the decisions made relative to pest and disease control (although just a phase of an orchard management process) have a direct and significant economic effect on orchard production since if the crop is lost to disease(s), the decisions pertinent to orchard operation for the rest of the season may have limited or no effect on current year production.

Many diseases affect cocoa on the field. Some of them are *Phytophthora* Black pod disease, *Phytophthora* Canker, *Phytophthora* seedling

blight, *Thielaviopsis* pod rot, Cocoa Swollen Shoot Virus (CSSV) disease, Cherelle wilt, Charcoal pod rot and Collar crack disease (Adegbola, 1979). But those of economic importance in Nigeria are three: Black pod disease, swollen shoot virus and Cherelle wilt (Opeke, 1987).

In economic terms, black pod is the most serious disease of cocoa in Nigeria. It is caused by a soil-borne fungus, *Phytophthora palmivora* and is prevalent only during the wet season. The disease is therefore worse in areas of heavy rainfall. Major damage from the disease is the rotting of both small and large pods. Chupons, seedlings (in the nursery) and leaves of trees are attacked and killed under specially severe disease conditions following long periods of cool, rainy weather (Opeke op cit.).

Losses due to black pod vary from place to place and from variety to variety. Adegbola (1979) put the average at about 40 percent over several parts of West Africa and up to about 90 percent in certain places in Nigeria.

Deduction from analysis of data from the Cocoa research Institute of Nigeria (CRIN) indicates that pod loss due to blackpod infection varies with variety of cocoa. The average percent pod loss over the years 1962 – 1993 is 7.56 for Amazon I, 6.56 for Amazon II, 7.01 for Amazon III and 13.03 for Amelonado varieties respectively.

Babcock et al. (1992) noted that those yield losses can be reduced through the use of chemical and non-chemical damage control agents. However, chemical control agents (Synthetic pesticides) have been favoured

because of their effectiveness (although in many cases this diminishes over time), their relative long shelf life (when properly stored), and the ease with which they can be transported, stored and applied. They were available at inexpensive (subsidised) prices especially before the inception of Structural Adjustment Programme in Nigeria. For example, Eguagie (1974) and Idachaba and Olayide (1976) have indicated a possible loss in yields of between 50 and 70% in cocoa production if no chemical control measures were applied.

The non-popularity of biopesticides in addition to the absence of truly resistant cultivars make the use of synthetic pesticides in controlling black pod disease inevitable, hence fungicides are still being used to control it.

The fact that both black pod and cocoa thrive under the same climatic conditions (fairly high rainfall and fairly high humidity) suggests greater efforts at abating pod damage due to black pod through (increased) pesticide application.

On the basis of this, it can be asserted, as did Aina (1992), that Nigerian farmers will continue to rely heavily on pesticides at least throughout our generation and pesticides will remain our first line of defense against pests and diseases when damage levels reach economic threshold.

Various suggestions have been made in respect of the application of fungicides against black pod. Opeke (1987) suggests that spraying should be started very early in the season and application repeated every three weeks until rains ceased. Cocoa Research Institute of Nigeria (CRIN) also recommends fixed quantities of spraying materials per season¹. In these two cases, spraying is expected to prevent the development of the disease¹. However, Thorold (1959) suggests that spraying should be practiced when the potential yield is twelve or more pods per tree.

The foregoing pre-supposes that chemical control of black pod is feasible, acceptable and desirable, that is, technically possible, practically feasible, environmentally acceptable, economically desirable and politically advantageous (Norton, 1993). However, economic desirability appears questionable in the face of escalating costs of agricultural inputs since the inception of SAP. This is particularly relevant to chemicals that are largely imported, into Nigeria. Over 95 percent of agrochemicals used in Nigeria are

usually imported, mainly as finished prepacked products (Ikemefuna, 1998).

The relevant question at this juncture is that: If the CRIN recommendations were followed, would cocoa farmers be maximizing (expected) profit (utility) under SAP? Given the aforementioned situation, the objective of this study is to determine the compatibility of recommended fungicide use rate with profit maximization objective of Nigerian cocoa farmers.

AREA OF STUDY

The study was conducted in Osun and Ondo States of Nigeria. The choice of these states is premised on two factors (i) the two states jointly constitute the largest cocoa producing states in Nigeria; In 1971/72, for example these states produce 74.1% of cocoa gradings in western cocoa zone (Agboola, 1979) and (ii) the incidence of black pod disease is most prevalent in these states.

DATA AND THEIR SOURCES

Primary and secondary data were used for this study. The primary were sourced from cross-sectional survey of cocoa farmers in four Local Government Areas (LGAs) each in Osun and Ondo States in the last quarter of 1997. Information was collected on the socio-economic characteristics of the farmers, the diseases afflicting cocoa on the farm, disease control practices, output of cocoa beans per hectare, varieties of cocoa grown; fungicide and application cost and other inputs costs.

A three-stage sampling procedure was adopted in collecting the primary data. At the first stage the LGAs were selected, then five villages were selected from each of the LGAs, that is, a total of 20 villages were selected per state. At the final stage, eight farmers were selected from each chosen village, thus totaling 160 respondents per state.

Information was obtained from each farmer with the aid of a pre-tested structured questionnaire administered by the author with the assistance of trained enumerators². Secondary data were obtained through personal interview and official records from the Cocoa Research Institute of Nigeria (CRIN) and Ministry of Agriculture in Osun and Ondo States.

FUNGICIDE USE DECISION MODEL

This model introduces *a priori* information into a decision framework in which fungicide treatment levels are choice variables. Specifically, black pod disease is modeled under the following assumptions: (a) The management objective is the maximization of expected profit, (b) Decision variables consist of discrete actions representing alternative fungicide treatments, (c) The level of black pod infection is characterized by uncertain outcomes measured by a probability density function and (d) prices are independent of disease control decisions.

This decision theory approach (Rae, 1981) involves enumerating all possible payoffs and selecting the action that provides the highest payoff.

Under this 'no data' strategy the decision maker (farmer) could only use information from a priori probability distribution ($P(\theta)$) and monetary payoff (λ_{ij}) (if the utility function is assumed to be linear over the relevant range) associated with each action-state of nature combination to make the desired decision. The optimal strategy (Rae, *op cit*), which is generally defined as one that maximizes expected utility under the 'no data' situation, can be represented by

$$\begin{aligned} E(V) &= \max (\lambda_{ij}(P(\theta)) \dots \dots \dots (1) \\ E(V) &= \text{expected profit} \\ \lambda_{ij} &= \text{Payoff (profit) derived from each action-state of nature pair, and} \\ P(\theta) &= \text{the decision maker's subjective (prior) probability distribution for the random variable (i.e., yield (pod) loss due to black pod disease).} \end{aligned}$$

In other words, under this strategy, the decision maker estimates all possible payoffs from action-state of nature pairs and uses his prior (subjective) probabilities as weights in deriving expected payoffs, after which he chooses the strategy with the highest payoff.

The subjective or judgemental probability of an event is the degree of belief that an individual has in the occurrence of that event (Karmel and Polasek, (1977). It is argued that when people take decisions they act as though they base their choice upon their own ideas of probability (Savage, 1964). These subjective probabilities may be gained from the so-called objective evidence (historical data), plus less formal sources such as their advisers, their experience, the media and gossip. The major criticism of subjective

probabilities is that they are vague and imprecise. However, special procedures for evoking and measuring decision makers subjective probabilities can help overcome the vagueness problem.

Edward (1961) has suggested two basic methods of measuring subjective probabilities: (a) direct interrogation of subjects and (b) inference from the choices of subjects. The method involves verbal articulation of perceived relative frequencies in density or cumulative form. For example, one might ask "How many years in twenty would you expect a loss of 0-5 percent, 5-10 percent, etc. The inference procedure, on the other hand, places the subject in a simple decision situation and he makes choices based on the subjective probabilities used to make simple choices which are the same as those used in more complex decisions. However, a set of probabilities must satisfy the following consistency conditions (Anderson et al., 1977): (i) the probability of any individual event must be between zero and 1.0, inclusive; (ii) the probability of two or more mutually exclusive events occurring is the sum of the probabilities of each individual event and (iii) the sum of the probabilities of all possible events must equal 1.0.

The direct elicitation of probabilities from a decision maker may not satisfy these three conditions. Hence Robinson et al. (1984) have recommended two simple procedures to translate a decision maker's beliefs about future events into probability statements: (i) strength-of-conviction method and (ii) triangular-distribution technique. The strength-of-conviction method requires the following four steps to generate a set of probabilities:

- (a) Divide the range of possible events into a small number of logical groups.
- (b) Specify the decision maker's strength of conviction about the relative occurrence of each event on a numeric scale (i.e., a scale of 0 to 10, with 0 implying that the event cannot occur and 10 implying certainty).
- (c) Sum the degrees of conviction for all events.
- (d) Find the subjective probability of each event by dividing the degree of conviction for each event by the sum calculated in (c).

The triangular - distribution method requires less information to estimate the probability distribution. Thus, it is simpler to use, but less

accurate. The use of the triangular – distribution requires three items from the decision maker:

- (i) the most likely value to occur (M),
- (ii) the lowest possible value (L),
- (iii) the highest possible value (H).

Based on these values and requiring that all probabilities sum to 1.0, the following formulas can be used to calculate a cumulative distribution that is useful for decision making. To calculate the probability (P) of a value of X being less than X_i , one of two formulas is used,

- (i) For a value $X_i \leq M$, $P_i = (X_i - L)^2 / (H - L)$ (M-L)
- (ii) For a value $X_i > M$, $P_i = 1.0 - (X_i - H)^2 / (H - L)$ (H-M)

This method would be used to estimate the subjective probability distribution ($P(\theta)$) of yield loss due to black pod infection because of its ease of use both in elicitation and in computing parameters (Pingali and Carlson, 1985).

RESULTS AND DISCUSSION

Fungicides Use Decision: Four fungicide actions that a farmer might select to control black pod disease are: spray 26.88kg/ha/season of fungicide (the recommended rate), spray 13.35kg/ha/season (overall use rate), spray 7.68kg/ha/season (Osun use rate), and spray 18.9kg/ha/season (Ondo use rate). Average number of applications per season is seven times. Six states of nature are defined in terms of non-overlapping percent crop losses as follows: 15, 30, 45, 60, 75, and 90. Fungicide material and application costs are ₦7010, ₦4505 and ₦5242 per hectare for recommended, overall, Osun and Ondo use rates, respectively. The other production costs per hectare is on the average ₦16,766. Crop value is set at ₦90,000 per tonne.

Yields are estimates obtained from the following equation:

$$Y = 0.0042X_1^{.401} X_2^{-0.45} X_3^{.08} X_4^{.544} X_5^{-.226} X_6^{.277} X_7^{.162} \dots\dots\dots(2)$$

Where

- Y = tonnes of cocoa beans per hectare
- X_1 = fungicide use rate (kilograms per hectare)
- X_2 = farm size (hectares)
- X_3 = depreciation charges (Naira)
- X_4 = labour (mandays)
- X_5 = number of farm locations
- X_6 = formal education (years)
- X_7 = Age of cocoa farm (years)

These yields are 0.32, 0.24, 0.19, and 0.28 for recommended R, overall (O), Osun (OS), and Ondo (ON), use rates respectively.

With above specification of fungicide effectiveness, costs, prices, and yields, net returns for each of the actions and states of nature was computed by

$$\lambda_{ij} = \text{management income per hectare for each action, and state, } S_j, \dots\dots\dots(3)$$

P = cocoa price per tonne (in Naira)
 Y = estimated yield per hectare
 L = crop loss percent
 F = other production costs, and
 S = fungicide material and application cost.

The estimated subjective probability (obtained using triangular distribution method) is [0.204, 0.035, 0.004, 0.109, 0.303, and 0.0345] for each state of nature, θ_1 to θ_6 .

Table 1 shows optimal fungicide applications and the associated expected net returns when various states of nature occurred. The optimal strategy that maximizes expected net return to management is [OS,O, ON, R, R, R] for each state of nature, θ_1 to θ_6 .

Table 2 shows that the optimal strategy for the estimated prior probability distribution is RUR. This implies that the fungicide application of cocoa farmers in the study areas is not optimal given their subjective probabilities of cocoa pod (bean) losses associated with non-application of fungicides. It shows that if the chances that at least, 60% of cocoa beans would be lost due to black pod infection if no chemical control is undertaken, is about 80%, then it would be optimal to apply recommended dosage of fungicides per hectare. The solution however changes with changes in subjective probability distribution-for example it is shown that if on the other hand the chance that at most 45% of the crop could be lost to blackpod if no chemical control is undertaken is about 80%, it would not be optimal to apply recommended rate as overall average use rate would be optimal.

The solution does not change with a

Table 1: Optimal strategies and associated expected net returns for various states of nature.

States of nature	Expected returns ₦	Optimal strategy
1	-1170	Osun use rate (OSUR)
2	1013	Overall use rate (OUR)
3	3986	Ondo use rate (ONUR)
4	7490	Recommended use rate (RUR)
5	11115	Recommended use rate (RUR)
6	14749	Recommended use rate (RUR)

reduction in product price by ₦10,000. (Table 3) but a minor change is recorded with a 10% reduction in yield. Table 4 indicates a change in the optimal solution for θ_2 from OUR to OSUR. This means that the quantity of fungicide applied per hectare is dependent on the level of yield.

This analysis has shown that it may not be economically wise to apply fungicides at the recommended rates in the study area if the crop loss is not higher than 45%. As a corollary, using fungicide at the recommended rate in the study areas regardless of the level of blackpod infection would only amount to economic waste if the objective of the farmers is to maximize net return to management. This finding is not consistent with the submission of the agronomists who believe that fungicides should be applied at recommended rate regardless of the degree of black pod infection. The agronomic reason in support of recommended usage level is that

disease infestation levels are generally unobservable before significant damage occurs, so that growers treat preventively according to a predetermined schedule. The situation depicts the natural scientist's preoccupation with technical efficiency in contrast to the farmers' concern with economic efficiency.

SUMMARY

This study has examined the compatibility of the recommended fungicide use rate with profit maximization objective of farmers in cacao cultivation in southwestern Nigeria.

The analytical technique used is decision theoretic model. The primary data on cocoa agriculture were derived from a sample survey of 320 cocoa farmers in Osun and Ondo States in southwestern Nigeria.

The study shows that if profit maximization

Table 2: Expected net returns from fungicide actions.

Possible Actions	State of nature: Crop loss percent						Expected returns
	θ_1 (15%)	θ_2 (30%)	θ_3 (45%)	θ_4 (60%)	θ_5 (75%)	θ_6 (90%)	
Recommended	-3385	240	3865	7490	11,115	14,740	8603
Overall	-1624	1013	3649	6286	8,922	11,558	7095
Osun	-1170	917	3004	5091	7,179	9,266	5732
Ondo	-2166	910	3986	7062	10,138	13,213	8006
Subjective Probability $P(\theta_j)$	0.204	0.035	0.004	0.109	0.303	0.345	

Table 3: Expected net returns resulting from a change in probability distribution.

Possible Actions	State of nature: Crop loss percent						Expected returns
	1	2	3	4	5	6	
Recommended	-3880	-750	2380	5510	8640	11,770	6523
Overall	-1984	293	2569	4846	7122	9,398	5544
Osun	-1455	347	2149	3951	5754	7,556	4505
Ondo	-2586	70	2726	5382	8038	10,693	6197
Subjective Probability $P(\theta_j)$	0.345	0.303	0.204	0.109	0.035	0.004	

Table 4: Expected net returns resulting from 10% reduction in yields.

Possible Actions	State of nature: Crop loss percent						Expected returns
	1	2	3	4	5	6	
Recommended	-3748	-485	2778	6040	9303	12,565	7041
Overall	-1887	486	2859	5231	7604	9,977	5959
Osun	-1379	500	2378	4257	6135	8,014	4888
Ondo	-1379	295	3063	5831	8599	11,368	6680
Subjective Probability $P(\theta_j)$	0.204	0.035	0.004	0.109	0.303	0.345	

is the principal objective of an average farmer in the study area, he should (a) not follow the recommended fungicide use rate if expected crop loss is not at least greater than 45%, (b) if it is greater than or equal to 60%, fungicide recommended use rate should be applied; (c) if less than or equal to 15%, 7.68kg/ha of fungicide (that is, Osun average use rate) should be applied; (d) if the range is 15% to 30%, the farmer should not spray more than 13.35kg/ha of fungicides, and finally (e) if the range is 30% to 45%, then not more than 18.9kg/ha (Ondo average use rate) of fungicides should be applied per season.

The study also shows that if the probability that at least 60% of cocoa beans would be lost if no chemical control of black pod is undertaken is 80%, recommended use rate (26.88kg/ha) should be applied. If on the other hand the probability that at most 45% of the crop would be lost to black pod disease if no chemical control is undertaken is 80%, the recommended use rate should not be applied. This implies that expected crop loss should be taken into account when deciding on the amount of fungicides to apply in the study area. This is however not consistent with agronomic recommendations. The study suggests that the rate recommended by CRIN could not be used in all situations – it is better used when the probability of large expected crop loss is extremely high (80%).

CONCLUSION

The foregoing results suggest the establishment of crop yield forecasting service (as done in developed countries) not only for cocoa but for all major crops in Nigerian agriculture in order to maximize farmers income through elimination of excessive application of crop protection chemicals including fungicides.

NOTES

¹ CRIN recommends 26.88kg of fungicides per hectare, 10.82 litres of lindane insecticides per hectare, 8.12 litres of Unden per hectare and 3.25kg of elecron per hectare.

² Pod losses associated with black pod disease vary from one season to another hence farmers could well apply heavy doses of fungicides as an insurance against disease development even though in some years they will have applied an excess of materials given the potential

loss from disease that existed in those years. In such cases, we think the farmer will be spending more on fungicides than would have been necessary if the potential disease occurrence in any year has been predictable. However, this contention could not be tested because of the difficulty of obtaining inoculum load necessary to predict black pod infection.

³ The limitations of this method have been dealt with in the literature on research methodology, Adesim (1988).

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