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Comparative responses of two maize varieties to fertilizers on a newly cleared ferralitic soil in Southern Benin. — Economic analysis.

C. Van den Berghe*, D. Theeten and J. Totognon**

Summary

In a previous study (13), the authors compared the physical response of two maize varieties «Poza Rika 7843» and «NH2» on mineral fertilizers, especially on nitrogen. These data were used to carry out an extensive economic analysis on the responses of these varieties to fertilizers.

Based on the study of the principal profit and cost elements the optimal fertilizer dose is calculated. Furthermore, the economic potentiality of maize cultivation with chemical fertilizers is examined, the surplus profit and the gross benefit cost ratio are used as criteria of the financial profitability.

The actual structure and trend of the maize price, whose dominant features are instability and at relative low level combined to the cost structure as prevailing under the conditions of the experiment shows that mineral fertilisation for maize as a cash crop is not recommended.

Samenvatting

In een vorig artikel (13) werd de fysische reactie van twee maisvarieteiten «Poza Rika 7843» en «NH2» op minerale meststoffen, waaronder speciaal stikstof, vergeleken. Op deze gegevens werd nu een ekonomische analyse uitgevoerd.

Steunende op de winst en kost-elementen werd de optimale dosis berekend. Verder werd de ekonomische potentialiteit van de maisteelt met minerale meststoffen bestudeerd. De winst en de winst/kost verhouding werden gebruikt als criteria van de winstgevendheid.

De actuele structuur en evolutie van de maisprijs wier dominante kenmerken zijn instabiliteit en laag niveau, gecombineerd met de kostenstruktuur zoals onder de voorwaarden van dit experiment tonen de beperkte mogelijkheden aan van de minerale bemesting van mais als cash crop.

Introduction

The farmers decision to use fertilizer reflects ultimately his idea that fertilizer technology may be a useful way to achieve his major objectives, taking into account the physical and economical constraints of his environment and the limitations of his personal knowledge and production technology.

The main objectives of small land-holders in Benin and in other West African countries (3) is to produce enough to meet the family food requirements and if possible to increase the agricultural revenue.

The potential benefits that can be derived from fertilizer use on maize depends on the current price and cost situation, while the actual use of fertilizer is largely influenced by such factors as credit possibility, the functioning of the input distribution system, and the involved financial risks.

Materials and methods

The determination of the optimal fertilizer dose is carried out under the classical assumption of profit maximisation. The direct net economic benefits are measured by the increase in value of the output less the additional costs related to the fertilizer use.

The output value is calculated as the product of the physical quantity produced multiplied by the maize field price. The physical output, in function of the fertilizer used is given by the estimated response curves while the output value is given by Py.Y.

The fixed costs in the sense of costs not effected by the fertilizer rate, include costs of land clearing and preparation, seeding, weeding,... Effectively these costs do not vary with the quantity of fertilizer used. Even the cost of fertilizer application will be considered as a fixed cost with regard to the optimisation problem: the cost of application for 40 kg/ha, for example, does not differ significantly from the application cost of 30 kg/ha.

The variable costs include the cost per unit of fertilizer

(which is the sum of the market price + the additional cost of transportation and storage,...) and the interest cost on investment, taking into account the period of investment and the current interest rate.

The profit function can be expressed as ·

$$\pi = Py \cdot Y - Px \cdot X (1 + c)^t - C F$$

where:

π = total profit

Py = the maize field price per unit

Px = cost per unit of N fertilizer

Y = total yield, X = quantity of N fertilizer used

c = the interest rate on investment and t the period of investment.

CF = costs not affected by fertilizer rate.

The profit maximizing conditions are ·

$$\frac{d\pi}{dx} = P_y \qquad \frac{dy}{dx} - Px (1 + c)^t = 0$$

$$\frac{d^2\pi}{dx^2} < 0 \text{ or } \qquad \frac{d^2y}{dx^2} < 0$$

thus $\dfrac{dy}{dx} = \dfrac{Px}{Py} (1 + c)^t$ in the profit maximizing situation.

the term $\dfrac{Px}{Py} (1 + c)^t$ will be referred to as the R - value.

Two major sources of data are used:
— available data issued by the Institut National de la Statistique et de l'Analyse Economique or found in related literature (4,7)
— unedited data issued from a detailed farm survey, carried out by de Department of Rural Economics and Rural Sociology of the Faculté des Sciences Agronomiques in Benin. This survey started in 1985 in three villages, and on 96 farmers on the Adja plateau in Mono Province, a main maize producing area in Southern Benin.

Results and discussion

• Estimation of the maize field price

The field price can be a money field price when farmers sell their crops in the market or an opportunity field price when they consume the crops.

The money field price is the market price less costs that vary with yield such as harvesting, transportation, storage etc.

The opportunity field price is the amount of money the farmer either forgoes by consuming the grain rather than selling it or saves by having to purchase the grain in the market (11).

In Benin maize is largely a subsistence crop and a substantial part of the production is consumed by the producer and his family. Recent studies in the Mono province estimate that respectively less that 50% (9) or less than 33% (6) of the total

maize production is commercialised. However for this analysis the calculated field price is effectively a market field price, because the lack of sufficient data on storage costs and storage losses make it difficult to estimate an opportunity field price. The second reason for prefering a market field price is that fertilizer is rarely applied when maize is grown for proper consumption but more readily used when grown for the market (3), mainly because farmers avoid extra fund expenditure on a crop that won't generate a cash income.

Maize is sold mainly on the local markets either to merchants, detail retailers or directly to the consumers. Generally the price fluctuation of the producer price is in accordance with the price fluctuations of the consumer price (9).

Market prices vary considerably over the year on the same market (seasonal price fluctuations), the lowest average monthly price being approximately half of the highest monthly price (Table 1). Price variations between regional markets are limited and price evolution is similar (Fig. 1).
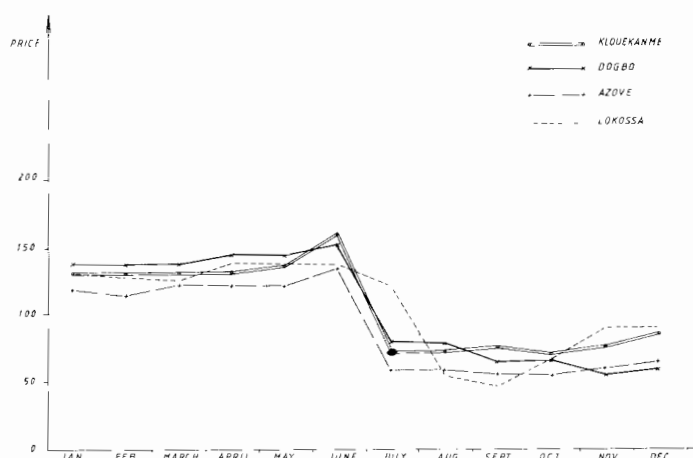

Figure 1 - Evolution of the mean monthly prices of maize on 4 markets in the Mono province in Southern Benin.

Table 1

Price in FCFA relative quantities of maize sold (Q), and number of transactions observed (N) for the period july 1985 - june 1986.

Period	Price	Q(%)	N	Period	Price	Q(%)	N
01/06-15/06	.	.	-	01/12-15/12	50.0	2.3	7
16/06-30/06	61.1	2.6	3	16/12-31/12	49.2	1.2	2
01/07-15/07	61.5	22 7	26	01/01-15/01	41.0	0.7	3
16/07-31/07	52.2	15.3	22	16/01-31/01	60.0	0.2	1
01/08-15/08	48.6	10.5	26	01/02-15/02	.	.	.
16/08-31/08	45.4	10.1	23	16/02-28/02	83.3	1.4	1
01/09-15/09	43.0	4.1	14	01/03-15/03	73.3	0.9	1
16/09-30/09	43.9	3.9	10	16/03-31/03	83.3	0.2	1
01/10-15/10	48.8	2.6	6	01/04-15/04	90.0	2.0	1
16/10-31/10	.	.		16/04-30/04	93.3	1.3	2
01/11-15/11		.	-	01/05-15/05	90.0	6.9	1
16/11-30/11	48.8	8.5	13	16/05-31/05	84.2	2.5	2

Source: survey data
based on the list of all the transactions registered for the 32 farmers in main maize producing village. The weight average price $(\Sigma \ (price \cdot Q)/ (\Sigma \ Q) = 54.9$ FCFA

The yearly fluctuations of the market prices are mainly due to climatological conditions: poor rains as during the year 1982-1983 mean poor harvests, a limited quantity offered on the market and a very high price level, abundant rains

(1984-1985) mean good harvest and low prices.

When maize is sold over an extended period an average weighted price should be calculated. As staded by K. Eicher (1), the arithmetic mean of monthly prices can differ enormously from the real price received by the farmer.

Frequently the urgent need of cash money and the technical storage difficulties push the Beninese farmer to sell his maize shortly after the harvest or even to sell the crop on the field. The survey results show that 3/4 of the maize is sold by the producers during a 3 month span and while the market prices are low. For this reason the field price will derived from the market prices during the period July-November (Table 2).

Table 2
Average maize price, over three rural markets in the Mono province, constant money (base 1985).

	July	August	Sept.	Oct.	Nov.	Mean
1982	82.5	83 4	123.3	122 0	135.3	109.3 *
1983	83.5	83 5	78.7	76.6	76.6	79.8 *
1984	72.0	55.2	56.4	56 4	62.4	60.2 *
1985	54.8	46.2	41 6	43.3	45.6	47.4 **

* Arithmetic mean. INSAE data.
** weighted mean. survey data.

The market field price will be estimated by $Py = Pm*0.9*0.7$, where Pm stands for the market consumer price (i.e. price paid by the consumer on the local market).

The calculated field prices are shown in table 3.

Table 3
Calculated market field prices, based on the market price of maize in the Mono province.

	July	August	Sept.	Oct.	Nov.	Mean
1982	52.0	52.5	77.7	76.9	85.2	68.9
1983	52.6	52.6	49.6	48.3	48.3	50.3
1984	45.4	34.8	35 5	35.5	39.3	38.1
1985	38.4	32.3	29.1	30.3	31.9	33.2*

Arithmetic mean. INSAE data and * weighted mean. survey data.

The yearly price fluctuation are very important while the monthly fluctuations, during the considered period (July - November) are less pronounced. During normal years (1982 excluded) the July price, which is the price obtained for early planted or for short-cycle maize, is substantially higher than the mean price.

To obtain the market field price, we deduced the variable harvest costs, the transportation costs and the processing costs from the producer market price (price paid to the producer on the local market).

In southern Benin the harvesting and the processing (removing the leaves and the grains from the cobs) is done by hand and transportation from the field to the village and to the market place is usually done by feet. Under these conditions the total cost for harvesting transport and processing is proportional to the volume harvested. Besides, harvesting and processing is often done by hired labour force, which is paid in kind, the payment being a fixed proportion of the quantity

harvested or processed. Processing constitues the major post-harvest cost and current payment in the Mono province amounts to 20% of the quantity processed.

As total cost for harvesting and processing we retain 30% so that 100 kg of maize harvested gives 70 kg at the market producer price. The commercial margin between producer price and consumer price on the local markets is estimated at 10%.

In the survey region the maize is traded not by kg but by volume unit (bowls) and currently the market women buy and sell the unit at the same price. The commercial margin is perceived as a slight variation of the volume of the unit. A ratio of 10 to 11, so that 10 units bought give 11 units sold, is common practice.

• The variable production costs

a. Interest cost on capital

Using fertilizer implies often an extra-expenditure of cash corresponding to the cost of fertilizer used and eventually of the additional paid labour.

At the beginning of the planting season small farmers are, in general, very short on cash, and the lack of available funds is a major constraint to the use of fertilizer (2). Hence we can safely assume that the opportunity cost of capital has a non zero value in case where farmers use their own funds, or that there exist effective interest charges when money has to be borrowed.

In Benin, only farmers who are member of a cooperative structure, have easy access to the credit provided by the «Caisse Nationale de Crédit Agricole» where interest rates of about 13,5% are charged. Individual farmers, by far the largest bulk of the maize producers, have practically no access to the official credit because they lack adequat security, hence they have to rely on private sources such as relatives or friends, money lenders, merchants etc.

Scant accurate information on interest charges of this private sources is available. Loans from friends or relatives are know to be occasionally free of charges although not always available at the appropriate time (10). Our proper investigations on the Adja plateau confirm this.

Borrowing from money lenders or merchants is generally costly: in the first case charges are high, in the second case the farmer may be obliged to sell at a lower than market price.

For some districts of an adjacent province (Zou) Sahou (10) mentions interest rates for consumption credit up to 300% on a year basis. For this study an interest rate of 14% will be retained, and as period of investment a 6 month span, which includes the maize production period and a maximum waiting period before selling of 3 months.

b. Acquisition cost of fertilizer in Benin

The only source of fertilizer is the SONAPRA (Socciété Nationale pour la Promotion Agricole) which in cooperation with the CARDER (Centre d'Action Régionale pour le Développement) distributes it to the farmers. Actually fertilizer is a subsidised input, mainly for cotton cultivation. However the

subsidy is only temporal and the present subsidy provides for a progressive subsidy reduction. The increase in real fertilizer cost is compensated for by an increase in the cotton price but is in so far totally independent of the maize price. For the 1985-1986 campaign, actual prices paid by the farmer are 90 FCFA/kg, and will be 150 F/kg in 1990.

c. Additional cost for transportation and storage

To the fertilizer price should be added the additional cost of transportation to the field. This cost varies in function with the distance and the road condition and hence is different from village to village and even from farmer to farmer.

In southern Benin this cost remains in general low because transport up to the district or community distribution point is done by the SONAPRA, and varies from 0 FCFA/kg to 10 FCFA/kg (12).

The cost of storage by the farmer is believed to be negligible. For the following cost calculations an average additional cost of 5 FCFA/kg is used.

• R value

Based on a possible field price range of 30 F CFA/kg to 60 F CFA/kg, a fertilizer cost between 95 and 155 F/kg and an interest charge of 14% corresponding R-values between 3.68 and 11,99 are found, taking into account that 1 kg of fertilizer equals 0,46 kg of N.

The experience was laid out in 1984 when rainfull was no limiting factor and the results can only be generalized in so far as comparable conditions prevail. For such years low maize prices may be suspected. The actual market structure does not seem to be able to absorb relatively large maize surplusses. For the near future unsubsidized fertilizer prices will become a reality. Thus a realistic choice of the probable R-value leads to a value of about 12, corresponding to a fertilizer price of 155 FCFA and a maize field price of 30 FCFA.

An R-value of 12 corresponds to an optimal fertilizer dose of 33 kg N/ha for the NH2 maize variety and 46 kg N/ha for the Poza-Rica variety. However, the statistical analysis showed no significant differences between the doses 40, 80 and 120 kg N/ha, hence, for the Poza-Rica 7843 variety an optimal dose of 40 kg N/ha is retained.

• Estimation of the surplus profit and the benefit cost ratio

Up till now the cost of application of fertilizer was not taken into account, because it has been considered as fixed cost. In comparing maize production without fertilizer to maize production with fertilizer it is necessary to introduce the application cost. This cost is estimated by the CARDER at 12.000 F CFA/ha when the application is done by hired labour. There is no reason to value this cost at a lower price when family labour is used because the work has to be done during a busy period. Perrin et al (8) suggest that the opportunity cost of the farmers labour during the busy period might be 125% of the hired labour.

The surplus yield is defined as the additional yield by use of the fertilizer compared to the absolute blanc. The additional costs are the fertilizer costs, interest costs and the application costs.

The surplus profit is calculated as:

$$P_Y.Y - P_Y.Y_o - (P_x.X + CA)(1 + c)^t$$

Y_o = the yield obtained without any fertilizer
$P_x.X$ = the total fertilizer cost of the basal dose plus the optimum N dose.
CA = application cost.
The surplus profit for different field price levels and different fertilizer price levels and the cost benefit ratio are given in table 4 and 5.

* Because of lack of sufficient data, the residual effect was not taken into account, so that the benefit could be slightly underestimated.

Table 4
Surplus profit (1000 FCFA/per ha) in function of the fertilizer price Px (FCFA) and the maize field price Py (FCFA) for a dose of 40 kg N/ha and an interest rate of 0.14.

	Variety: Poza-Rica 7843							
Px/Py	25	30	35	40	45	50	55	60
95	− 12.9	− 5.2	2.4	10.2	17.9	25.6	33.3	41.0
110	− 19.0	− 11.3	− 3.6	4.1	11 8	19.5	27.2	34.9
125	− 25.1	− 17.4	− 9.7	− 2.0	5.7	13.4	21.1	28.8
140	− 31.2	− 23.5	− 15.8	− 8.1	− 0.4	7.3	15.0	22.7
155	− 37.3	− 29.6	− 21.9	− 14.2	− 6.5	1.2	8.9	16.6
	Variety: NH2							
Px/Py	25	30	35	40	45	50	55	60
95	− 21.5	− 15.5	− 9.6	− 3.6	2.4	8.4	14.4	20.4
110	− 27.6	− 21.6	− 15.7	− 9.7	− 3.7	2.3	8.3	14.3
125	− 33.7	− 27.7	− 21.6	− 15.7	− 9.7	− 3.7	2.3	8.2
140	− 39.8	− 33.8	− 27.9	− 21.9	− 15.9	− 9.9	− 3.9	2.1
155	− 45.9	− 39.9	− 34.0	− 27.9	− 22.0	− 16.0	− 10.0	− 4.0

Table 5
Gross benefit/cost ratio in function of Py and Px (X = 40 kg/ha)

	Variety: Poza-Rica 7843							
Py/Px	25	30	35	40	45	50	55	60
95	0.8	1.0	1.1	1.3	1.4	1.6	1.8	1.9
110	0.7	0.9	1.0	1.1	1.3	1.4	1.6	1.7
115	0.6	0.8	0.9	1.0	1.2	1.3	1.4	1.6
140	0.6	0.7	0.8	0.9	1.1	1.2	1.3	1.4
155	0.5	0.7	0.8	0.9	1.0	1.1	1.2	1.3
	Variety: NH2							
Py/Px	25	30	35	40	45	50	55	60
95	0.6	0.7	0.9	1.0	1.1	1.2	1.4	1.5
110	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3
125	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1 2
140	0.5	0.5	0.6	0.7	0.8	0.9	1.0	1.1
155	0.4	0.5	0.6	0.7	0.8	0.8	0.9	1.0

At lower maize price levels the theoretical surplus profit is non existant or rather small, depending on the used fertilizer price.

The ratio $\dfrac{\text{incremental gross benefit}}{\text{incremental cost}}$ stays below 2 for all price/cost conditions.

• Constraints to fertilizer use

The fertilizer response function as estimated from the experimental data estimates the average response under the pre-

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3. J. Totognon. Beninese, Agronomical Engineer, Responsible for Research in Rural Milieu, Carder Atlantique. Abomey Calavi, P.R. of Benin.

Le Secrétariat de Tropicultura prie ses lecteurs de l'excuser pour l'omission qui s'est glissée dans le numéro 4 du volume 7 (1989), 148. L'article de R. Parfonry, H. Zaz et M. Saaf «Analyse de systèmes de production au sein du périmètre irrigué du Tadla (Maroc)» a été amputé de sa dernière partie, ce qui en rend la compréhension impossible.

L'article corrigé et complet paraîtra dans le numéro 2, volume 8, (1990). Le Secrétariat remercie ses abonnés pour leur compréhension.

vailing experimental conditions and therefore doesn't neces-
sarily reflect the physical and economic constraints farmers
ace. The calculated benefits should be treated as estima-
es of potential benefits rather than as estimates of actual
benefits that farmers will obtain (5).

n the survey region, the farmers are more or less familiar with
ertilizer, they use it regularly on cotton since many years. The
residual effect on maize grown after cotton is also a well
known fact and quite a lot of farmers are ready to admit that
ertilized plots give a much better yield than the unfertilized
ield. Nevertheless, even when price conditions were more
avorable than is actually the case (as in the year of the expe-
iment at fertilizer price of 60 FCFA/kg) the farmer used it but
arely on maize. When interrogated on the subject a num-
ber of reasons are advanced (12).
. Fertilizers are considered as to costly
. When needed the necessary funds are not available to
   purchase the input.
. Variable weather conditions and price fluctuations make
   maize cultivation for sale a risky speculation and the far-
   mer is not sure that he will be able to repay his debts.
. The actual fertilizer distribution system can't assure that the
   fertilizer will be available when needed.
. The proposed selected maize varieties, such as Poza-Rica
   and NH2 are for different reasons not appreciated in the
   mono region.
. Fertilizer technology is too difficult.
Some of the mentioned reasons refer to the price-cost con-
ditions but others refer to constraints inherent to the physi-
al environment or to the existing production technology and
personal knowledge.

Without further detail, because common and recurrent in
West African small land-holder agriculture, and in so far iden-
fied by Tamegnon (12) in the survey region, we can state
hat the major constraints concern the following points:
. The agricultural credit system, which doesn't provide
   adopted credit conditions for maize cultivation by the indi-
   vidual farmer.
. The actual fertilizer distribution system.
. The production system, caracterised by:
   - mixed cropping (often maize/arachide or maize/manioc)
     which means that the farmer doesn't think and doesn't
     act in terms of maize-monoculture and which complica-
     tes practically the application of fertilizer.
   - the limited storage capacity and storage technology
     which implies, in the assumption of a maize surplus
     increase, either additional investment or commercializing
     immediately after the harvest.
The risk aversion of the farmer and the consequent reluc-
tance of fund expenditure.

Conclusions

The two varieties «Poza-Rica» and NH2 have an almost iden-
tical response curve, but «Poza-Rica» being superior to NH2.
Maximum yield for the two varieties occured at the dose of
40 kg/ha and even yields up to 6.5 tons/ha have been
observed.

The study proves that only by selection of the variety, the
same rate of application of fertilizer can already provide a
significant increase in yield of grain.

Climatological suitability maps existing in Benin should be
carefully interpreted as the maize variety is an important factor
the zone being classified as less suitable for maize pro-
duction.

The fertilizer experiment was laid out on newly cleared and
fertile plots and the economic results were interpreted in the
actual economical and technological context of the Benine-
se small-land-holder in the Mono province. Existing cons-
traints on the level of fertilizer availability, credit accessibility
and farmers knowledge were not quantitatively taken into
account, nor was allowance made for yield fluctuations or risk
aversion of farmers on the other hand the residual effect of
the fertilizer was neglected.

The calculated potential net benefits are low or not existant
and the ratio gross additional benefit / additional cost stays
well below 2 for all price/cost conditions.

Assuming that in the near future the fertilizer price will tend
to the real fertilizer cost and that no substantial evolution of
the maize marketing system or of the harvesting and proces-
sing technology will occur, the described fertilizer use on mai-
ze on fertile fields cannot readily be advised and constitutes
no attractive alternative for the Beninese small-land-holder.

It should be emphasized that this doesn't mean that fertili-
zer technology on maize cannot be profitable. It is possible
that better results are obtained on less fertile plots, a situa-
tion which now more and more encountered in Benin whe-
re fallow cycles and periods become much shorter

Changes in production technology or in the marketing
system could reduce the relatively high harvesting and pro-
cessing cost or increase the producer price with a result a
higher price-cost ratio and an increase of the net benefit.

Acknowledgments

:sumé : Dans un article précédent (13) les auteurs ont comparé les réponses physiques de deux variétés de maïs : «Poza Rica 7843» et «NH2» aux
grais chimiques, spécialement les engrais azotés. Ces données ont été utilisées dans une analyse économique sur les réponses de ces variétés aux engrais
sé sur l'étude des éléments principaux de profit et de coûts, la dose optimale a été calculée. En plus, la potentialité économique de la culture du maïs
ec l'utilisation des engrais chimiques a été examinée. Le bénéfice et le rapport profit/coûts ont été utilisés comme critères de rentabilité financière.
structure actuelle et l'évolution du prix du maïs, dont les caractères déterminants sont l'instabilité et à faible niveau combiné à une structure de coûts
nme dans les conditions de cette expérience montrent que la fertilisation minérale du maïs, cultivé comme cash crop. n'est pas recommandée.