0/m

0079

Semi-Arid Food Grain Research
and Development Program

Farming Systems Unit
F. S. U.

OUA/CSTR - Joint Project 31
Contract AFR-C-1472 between
USAID and Purdue University

Document n° 6

S A F G R A D

ROCK PHOSPHATE FERTILIZER IN UPPER VOLTA

PART.: A REPORT ON POLICY IMPLICATIONS OF CEREAL YIELD RESPONSE CHARACTERISTICS

Dr. Paul Christensen, Agronomist
and Chief of Party
SAFGRAD/FSU
B.P. 1783
Ouagadougou, Upper Volta

September 1981

1.0. INTRODUCTION

1.1. The Objective of the Report

The objective of this report is to describe and delineate the different effects which occur as a consequence of choosing to apply mixtures of fertilizers including rock phosphorous rather than to apply soluble conventional fertilizers in Upper Volta. And, furthermore, to argue that the nature of these effects may vary with changes in rainfall and/or soil characteristics. The report is based upon an investigation and synthesis of information using a subjective analysis to categorize the elements of these differences. The information was collected through literature surveys of experimental station bulletins and project reports of fertilize studies, as well as, professional discussions with other researchers together with a review of the physical properties of fertilizers and soils. The report is prepared and presented because the author has observed that in the formulation of policy positions for rural development in Upper Volta, there is a need to recognize the differences between the attributes of rock phosphate based fertilizers and those of soluble conventional fertilizers, and therefore, to understand the impact of these differences upon the farming and economic systems.

1.2. The Economic Environment of Central Upper Volta

The major argument for the use of rock phosphate fertilizer rather than soluble conventional fertilizer is that a larger proportion of the market value would be retained in the Upper Volta economy and that low production and delivery costs could be maintained.

Implementation of a program of increased cereal production based on imported fertilizer usage is problematic within the economic environment of Upper Volta. Economic conditions do not currently encourage the export of cereals. It would be difficult to earn the foreign exchange necessary to pay for importing fertilizer. Creating a system of increased

.../...

cereal production based on locally produced fertilizer would require less foreign exchange and is currently more economically attractive. The local production and distribution of fertilizer would not only make cereal yield increases physically possible for the rural sector, but also increase the urban or industrial sector's ability to pay for the locally produced cereals which they would like to purchase. However, the local production of fertilizers will require considerable quantities of imported equipment and materials, especially petroleum products. To offset this cost it is necessary that the program of sales for locally produced fertilizer be accompanied by increases in cash crop production in areas of Upper Volta where cash crop production is currently low.

The existence of rock phosphate deposits in Upper Volta and the possibility of their use as fertilizer represents a significant opportunity for the increased integration of Upper Volta into regional agricultural markets, as well as for the integration of the rural and urban sectors. It is a base upon which Upper Volta can develop a relative advantage in the production of certain agricultural commodities for which such a relative advantage has not previously existed.

1.3. The cereal Production Environment

In the central portion of Upper Volta, soil characteristics vary with the location of the soil in the toposequence. The lowland (bas-fond) soils are heavy clays which are relatively rich in phosphorous and have good exchange capacities. The physical characteristics of these soils result in drainage problems which make them difficult and expensive to cultivate. Nevertheless, the saturated lowland soils are used for rice production and the heavy soils located next to the saturated soils are used to produce late, photoperiod-sensitive sorghum. On the slopes, the soils are more gravelly and may have good moisture holding characteristics, if the lateritic layer has broken down, or poor moisture holding

.../...

I'm surprised. I would have thought N was always limiting also. Maybe not for grain production because P is so limiting.

capacity if they are over laterite rock. In either case, phosphorous is likely to be the limiting nutrient for plant growth. Nitrogen may limit plant growth or not, depending on the level of organic matter in the soil, and therefore on its history. Higher up on the toposequence there are shallow sandy-clay soils of poor structure. They are usually deficient in phosphorous, and may or may not be deficient in nitrogen, depending on their histories.

The gravelly and sandy-clay soils are more prevalent than the heavy soils, and are therefore more important in crop production. The concentration of plant nutrients (nitrogen and phosphorous) in these soils are low and their moisture retension capacities are poor but they can be improved. This is evident from the yields of garden plots around the houses where household wastes and animal manure are commonly applied, and from the superior plant growth on termite hills.

Cereal production in central Upper Volta can be divided into 3 categories:

1. Lowland areas where production is limited by soil management problems and nitrogen deficiency;
2. Improved upland soils where production is limited by availability of animal manure, and
3. Unimproved upland soils where production is limited by low moisture retension capacity, low phosphate content; and finally, low nitrogen content.

The farmer's traditional strategy for cereal production on these latter fields is to accept low yields per unit area and to try to cultivate larger areas. The factors limiting the total area which a man can cultivate are the capability to weed the area and the capability to plant the land before weeding must be started. Thus, the factors limit the areas which can be cultivated, and therefore limit the production from these unimproved upland fields.

.../...

In this report, physical responses are specified for two classes of environments. This classification will simplify the discussion of the profitability of fertilizer mixtures based on rock phosphate. The first class is characterized by higher rainfall and better soil moisture retension capacities. The second class is characterized by lower rainfall and poorer soil moisture retension capacities.

While the division of central Upper Volta into two environements may not be inadequate for making recommendations for farmers, it will be shown that this simple division has important implications for the method of distribution rock phosphate to the farmers. The nature of the distribution systems is the policy question. The simple division is both pertinent and useful in obtaining the necessary answers.

1.4. Phosphate Fertilization in the Unimproved Uplands

What then is the justification for utilizing phosphate fertilizer in the extensive cereal production systems, given that it is feasible to upgrade the physical characteristics of many of these soils to the point where they can be cropped intensively?

If one is to build on the traditional system in a step-wise fashion, phosphorous fertilization must be accompanied by good weeding and timely planting. Good weeding and timely planting would allow farmers to actually achieve yield increases without improved soil nutrient status. The constraint of weeding precludes a general change to the practice of preplanting plowing for fields using an extensive production strategy and limits the possibility for incorporation of the fertilizer into the soil. This is turn limits the response which one can expect from the use of any fertilizer under extensive production conditions. However,

.../...

the return from the overall package of soil improvement techniques which is necessary for upgrading a soil to the point where it can be cropped intensively may be lower than the return from either the traditional system without fertilizer or the use of fertilizer in an intensive system, but return from the phosphate fertilizer alone may be higher. The returns from any of the components of the intensive system may be quite high in the presence of the other components, while the returns from the whole package may be relatively poor. Thus, one can expect farmers to expand the area where they cultivate intensively if and when they acquire the resources to expand; nevertheless, they will continue to cultivate on an extensive basis until the resources necessary for the transition from extensive to intensive production are available at a cost to justify their utilization.

Using intensive production techniques the response to the phosphorous application would be better. However, one can not recommend a general transformation to intensive cereal production because, although the returns to the phosphorous may be higher in the intensive systems, the returns to all of the inputs used will generally be lower than either the returns to the inputs used in the traditional systems or the inputs used in the improved extensive system. The returns to any of the individual components of the intensive system can be quite high while the returns to the whole package taken together may be unacceptably low. Although one can expect a gradual increase in the portion of upland soils which are cultivated intensively if the relative prices for the materials and equipment tend to decline, as they have over the past decade, extensive production on unimproved uplands will continue to be important.

In general, a fertilization program for the upland soils would allow one to maintain soil fertility at a level where one can benefit from investment in improved weeding techniques and from investment in some basic soil erosion control measures. This level may be in the 600-800 kg/ha range. Adoption of improved weeding techniques and improved water usage practices should not be allowed to result in long-term degredation of the chemical fertility status of the soils of the area.

.../...

2.0 BENEFITS OF THE USE OF ROCK PHOSPHATE AS A FERTILIZER IN THE SHORT AND LONG TERMS.

2.1. The Physical Characteristics of Rock Phosphate and Other Phosphate Fertilizers which Determine the Nature of Their Yield Responses Over Time

2.1.1. The soils of West Africa and Central Upper Volta and Their Phosphate Response Characteristics

The land surfaces from which West African soils were formed have undergone, in the past, heavy rainfall and leaching of nutrients from the soil. This is particularly true of the upland soils. This leaching resulted in removal of phosphorous, calcium, and other important plant nutrients, and thus, formed soil types which are not conducive to the retention of soil nutrients. In the semi-arid tropics this process has stopped with the passing of the heavy rainfall levels.

The depletion of phosphorous and calcium when the soil is acid is due to solubilization of the soils' phosphorous and calcium. The acidity of soils through geologic time depends on the nature of the rock from which it was formed. In central Upper Volta, most soils are formed from granite, which is an acid rock. Thus, the soils of central Upper Volta have a particular tendency to be both acid and low in phosphorous and calcium.

When the bush land is cleared, burned, and cultivated for a number of years, the reserves of plant nutrients from organic matter and ashs of the original cover are depleted. Phosphorous is the first plant nutrient to become a limiting factor in plant growth and therefore the first limiting factor in production. Presently, the farmers use efficiently phosphorous containing manures which are available, and plant crops which produce most efficiently with low levels of soil phosphorous. Phosphorous efficiency tends to determine the cropping pattern of the farm. Millet

.../...

is one of the principal elements of this pattern because it is able to produce where the available phosphorous concentration is relatively low.

Although phosphorous deficiencies are widespread in central Upper Volta they are neither homogeneous or universal. There are general statements which can be made about phosphorous deficiencies for the different kinds of soils which are used in agricultural production. One such generality has already been mentioned. The location of the field in the toposequence is an important determinant of plant response to phosphorous fertilization. In the lowlands (bas-fonds), soils are less acid because of impeded drainage and slower water movement. Clays accumulate, and, the higher cation exchange capacities of these clays discourages soil acidification. The basic cations lost by the soils higher in the toposequence tend to accumulate, as do the phosphates which have been leached away from the surrounding acid soils.

Another generality which can be made about phosphorous deficiencies is that newly cleared fields will be less deficient in phosphorous than fields which have been under cultivation for long periods of time. Frequently however, the fertility of land which has just been cleared and the importance of bush fallows are over emphasized. Even the growth of the bush vegetation and the animal feeding is limited by low soil phosphorous. Good yield responses to the application of phosphorous fertilizers can be obtained on land newly cleared from bush fallow. Although phosphorous levels in the soil decline with cultivation the initial levels are low by comparison to the quantities needed for good plant growth.

The soils of the fields which are normally manured each year are another important class of exceptions to the general rule of serious phosphorous deficiency. In contrast to the newly cleared bush fields on manured fields, (particularly the fields around the family compound) there is a possibility of building up large reserves of phosphorous in

.../...

the soil by applying more phosphorous each year than one crop can extract. The existence of such fields does not diminish the importance of phosphorous fertilization. The phosphorous content of the animal manure used on these fields is relatively low, and on a parcel of land which had not been as heavily fertilized in the past, the other plant nutrients in the animal manure could be more effective if used with a phosphorous fertilizer.

One phenomenon which does not occur to a great extent in Upper Volta is phosphorous fixation. In some soils found in the humid tropics, extreme acidity combines with high concentrations of iron to create conditions where soluble phosphorous is transformed into insoluble compounds in which the phosphorous becomes unavailable to plants. The soils of central Upper Volta do not have a chemical composition such that soluble phosphorous in the soil could be transformed into insoluble components, which would then not be available to plants. The residue of both soluble and rock phosphate fertilizers tends to remain available for uptake by plants in subsequent years. There is variability in the availability of the phosphorous in the soil but only very small amounts need to be in soluble form for plant use at any one time. The transformation of soluble phosphorous into less soluble forms insures that it will be possible to obtain growth responses with additions of soluble phosphate fertilizers, even in soils where residual levels of phosphorous are relatively high.

The phosphorous from all phosphorous fertilizer is relatively immobile in the soil. In order for the plant to obtain its phosphorous needs, its roots must come in contact with the particles to which the phosphate ions are attached, and the plant must actively transfer the phosphate ions into the interior of these roots. The greater the concentration of the phosphate ions in the soil, the larger the amount of phosphate the plant can effectively contact and take up. In contrast, nitrogen compounds in the soil are quite mobile. Nitrogen compounds move toward the plant along with the water which it takes up.

.../...

The upland soils of central Upper Volta are not only low in phosphate, but poor in structure, and therefore plant rooting is usually shallow. The problem of low phosphate concentration is aggravated by poor plant root penetration. The poorer the root growth, the more susceptible the plant is to suffer from phosphorous deficiency, and the more responsive it will be to the phosphate fertilizer in the soil mass that it does contact. Some of the ill effects of poor soil structure under low rainfall can be compensated by application of phosphorous fertilizer. not if water is limiting also

2.1.2 The Characteristics of Rock Phosphate and Soluble Phosphate Fertilizers in Use

In natural phosphates such as rock phosphate, the phosphorous is chemically bound into calcium compounds. In order for the phosphorous to be transformed into usable soluble forms, these calcium phosphate compounds must react with the soil solution and decompose chemically. The rates of these chemical decomposition reactions are determined by:

1) the size of the particles of rock phosphate,
2) the pH of the soil,
3) the concentration of phosphorous in the soil solution, and
4) the concentration of calcium in the soil solution.

The smaller the particle size, the lower the pH, the lower the phosphorous concentration is the soil, and the lower the calcium concentration, the greater will be the rate of decomposition of rock phosphate. In addition, the reaction only proceeds when the soil is moist, so that the reaction proceeds faster in the areas where the rainy seasons are longer.

Because the chemical decomposition of the rock phosphate depends on the concentration of phosphorous and calcium in solution, an equilibrium-level of phosphate concentration tends to be established in the soil as the rock decomposes. Soluble fertilizers move into the soil solution almost as quickly as they come into contact with it. The concentration of phosphates in the soil depends more directly on the quantities

.../...

of fertilizer applied. In the short term, the equilibrium concentration will be lower for rock phosphate fertilization than the levels attained through the use of soluble phosphate fertilizer. With time, the phosphorous applied in soluble fertilizer is transformed into less soluble compounds in the soil, which may be no more available than the rock phosphate. In the long run, phosphate levels in the soil solution may be similar for both types, assuming that applications of phosphate fertilizers do not continue.

The amount of calcium in the two kinds of fertilizer is another substantial difference between them. Rock phosphate has a much higher calcium concentration than the soluble cotton fertilizer commonly used in Upper Volta. The low level of calcium in the soils of central Upper Volta tends to increase the rate of decomposition of the rock phosphate fertilizer. In fact, yield response to the calcium released may exist quite independently of the yield response to the phosphorous. In addition, the release of calcium from the decomposing rock phosphate will have a tendency to inhibit soil acidification at least where the pH values are below 5. Soil acidification is largely a bi-product of calcium loss under these conditions.

Because the rapid solubilization of rock phosphate is promoted by low pH levels and promoted by low concentrations of phosphorous and calcium in the soil solution, concentrations which are well below optimum for plant growth, it can not serve as the only phosphorous source for very high yield system. The additional time for solubilization, and the additional quantities of phosphorous fertilizers which would have to be applied to achieve really high yields, would seriously reduce the solubility of the rock, and render it less productive, where its productivity is measured by the increase in yield per hectare for each additional unit of rock applied.

.../...

The role for the rock phosphate is in making limited yield improvement on the shallow upland soils of Upper Volta. Under these conditions, the principle constraint limiting the practical utility of rock phosphate as a fertilizer is soil moisture and the amount applied and brought into contact with moist soil. Cultivation practices used to incorporate the rock phosphate into the soil can be modified to reduce this constraint.

2.1.3. The Accomodation to Phosphate Deficiency of Traditional Production Systems in Central Upper Volta.

Factorial fertilizer yield trials consistantly indicate that phosphorous is the most important of the major nutrient elements for producing the first increments of yield increase. Within the traditional subsistence system of crop production little phosphorous is lost. This is in marked contrast to nitrogen, which is volitilized and lost when nitrogen-containing organic matter is left to dry on the surface of the soil. The relative importance of phosphorous, calcium and potassium vis-a-vis nitrogen, is demonstrated by the practice of field burning. The nitrogen wasted by this practice is apparently of less potential benefit to the farmer than the phosphorous, calcium and potassium released by burning.

Man not only alters the phosphorous cycle by burning the vegetative matter from fallows and crop residues, but also by transporting phosphorous from his bush towards his compounds. This phosphorous is in the grain which he harvests and takes home, in the stalks and hay for his animals, and in animal wastes which are moved toward the compound as the animals walk home in the evenings with full stomachs. Much of this movement in unintentional, but considerable choice is exerciced by the farmer in deciding where large animals will spend the night, and where the accumulated manure of both large and small animals will be used in the spring, as well as in deciding where the household wastes will be used.

2.1.4 Timing Fertilizer Applications for High Return

Sorghum yield responses for rock phosphate based fertilizers and for soluble fertilizers, for three different patterns of application in time and for three different levels of nitrogen application, are presented in Tables 1 and 2. These data form the basis for an economic comparison of the relative benefits from different patterns of application in time, as well as the comparison of benefits from different nitrogen levels and forms of phosphate. Certain of the data is taken from the results of replicated trials on farmers' fields in Upper Volta. The values of the responses to soluble fertilizers on good soils in the first year are from the results of trials of three years with about 100 replications per year, observed by the National Fertilizer Service (FAO cooperative program of the Voltaic Direction des Services Agricoles, DSA. The first year data for rock phosphate responses on good soils are derived from the soluble fertilizer responses by assuming that urea - rock phosphate mixtures will give 60% of the soluble fertilizer yield response where the nitrogen and phosphorous concentrations are the same, as was observed in trials conducted during 1977 and 1978 by Phosphate Project of the Voltaic DSA.

The data for succeeding years are less substantiated and frequently based on expectations rather than observations. They are subject to discussion, therefore, the validity of the results presented here rests on the assumption that the relative magnitudes are generally correct.

For annual applications, sorghum yield responses are assumed to increase each year. The mangitudes of the first and second year responses are based on observations made by the Phosphate Project. The responses for succeeding years are based on the assumption that the percentage increase will be smaller, and the assumption that the maximum yield increase attainable under current management practices is 450 kg/ha. The base yield is assumed to be 450 kg.

.../...

TABLEAU 1.

ACCROISSEMENT DE LA PRODUCTIVITE DU SORGHO EN KG/HA SUR DE BONS SOLS
POUR 2 FORMES DE PHOSPHATE, 3 NIVEAUX D'AZOTE ET 3 MODES D'APPLICATION

Engrais utilisé	1re année			2e année			3e année			4e année		
	Composition chimique (N-P)			Composition chimique (N-P)			Composition chimique (N-P)			Composition chimique (N-P)		
	0-25	15-25	35-25	0-25	16-25	35-25	0-25	15-25	35-25	0-25	15-25	35-25
<u>Application annuelle</u>												
- soluble	88	250	450	109	310	450	130	372	450	143	409	450
- PB + urée	58	165	297	81	231	415	105	300	450	130	372	450
<u>Application bi-annuelle</u>												
- soluble	88	250	450	52	52	126	120	343	450	70	70	150
- PB + urée	58	165	297	45	45	113	100	280	450	65	65	143
<u>Application unique</u>												
- soluble	88	250	450	52	52	126	30	30	30	18	18	18
- PB + urée	58	165	297	45	45	113	45	45	45	30	30	30

The data is even less reliable for soils with poorer moisture retention capacities. A 4 year yield trial done by IRAT at Saria provides the most concrete data. The yield response to the annual application of rock phosphate mixtures were shown to increase annually by a uniform increment. The first and second year responses to application of rock phosphate without nitrogen are substantiated by observations in FSU trial data. This information has been incorporated into Table 2.

The residual effects are substantiated by IRAT data from the 60's. The magnitude of the residual effects have been scaled back to correspond to the 450 kg base yield. Recent results from the Phosphate Project also support the magnitude of the residual effects, as do the general patterns of declining responses observed in long term experiments in temperate countries.

The benefit to cost ratios calculated for the four year streams of income and expenses are presented in table 3 through 6. The only costs and prices included were those of the fertilizer and grain in Ouagadougou (all soluble fertilizers at 90 CFA/kg; rock phosphate at 30 CFA/Kg; and sorghum at 50 CFA/kg). Given that other costs are not included, all benefit to cost ratios gives relative benefits in the eyes of the small farmer, whereas the 10% rate is appropriated for national planning.

Tables 3 through 6 indicate that one can achieve reasonably high benefit to cost ratios with soluble fertilizers, either by using high rates of nitrogen (urea), or by distributing these fertilizers over time to allow maximization of the benefits from the residual effects. The adoption of the high urea alternative therefore is a high risk. Using annual applications one cannot attain a benefit to cost ratio of 2.0 using soluble fertilizers at any rate of nitrogen (urea) application. This would not be true if the 450 kg/ha maximum response restriction did not exist, and substantiates the assertion that the profitability of soluble fertilizer

.../...

TABLEAU 2.

ACCROISSEMENT DE LA PRODUCTIVITE DU SORGHO EN KG/HA SUR DES SOLS MEDIOCRES
POUR 2 FORMES DE PHOSPHATE, 3 NIVEAUX D'AZOTE ET 3 MODES D'APPLICATION

Engrais utilisé	1re année			2e année			3e année			4e année		
	Composition chimique (N-P)			Composition chimique (N-P)			Composition chimique (N-P)			Composition cchimi- (N-P)		
	0-25	15-25	35-25	0-25	15-25	35-25	0-25	15-25	35-25	0-25	15-25	35-25
<u>Application annuelle</u>												
- soluble	65	185	344	81	229	350	97	275	350	107	302	350
- PB + urée	25	49	80	50	97	160	75	145	240	100	193	320
<u>Application bi-annuelle</u>												
- soluble	65	185	344	38	61	93	88	253	350	51	76	110
- PB + urée	25	49	80	40	66	100	65	130	200	51	76	110
<u>Application unique</u>												
- soluble	65	185	344	38	61	93	25	25	25	20	20	20
- PB + urée	25	49	80	40	66	100	30	30	30	25	25	25

use depends on improved crop management and maintenance of very high yields (1500 kg/ha). The figures indicate that the current farmers' practice of distributing available fertilizer over several fields in alternating years is indeed more profitable given the existence of a yield plateau at 900 kg/ha.

For poorer soils, all mixtures of rock phosphate plus urea have better benefit to cost ratios than soluble fertilizers, whereas soluble fertilizers are not acceptable under any of the applications patterns. Only single applications of rock phosphate (once every four years) proved to have a benefit to cost ratio of more than 2.0, and this was subject to the condition that future benefits are not depreciated to nearly zero with high interest rates; This has important implications for extensive cereal production as will be indicated in the following section.

By increasing levels of nitrogen application on poorer soils, (see Table 2) one will decrease the profitability of using rock phosphate mixtures, while increasing rates of nitrogen application will increase the profitability of using soluble fertilizer (see Table 1). This difference has discouraged agronomists from recommending rock phosphate fertilizer in Upper Volta, because the agronomists have focused on high yields possible with high nitrogen application rates. The poor response to nitrogen can be overcome by using massive doses of rock phosphate (500 kg/ha) in the first year. Such applications increase dramatically the yield response to nitrogen, but only at the cost of decreasing the benefit per unit weight of the phosphate. Initially, such applications are not justified for domestic cereal production. However, they might become more economic in the future if market conditions were developed to balance crop exports with nitrogen fertilizer imports.

.../...

TABLEAU 3.

RAPPORT BENEFICE.COUT POUR LA PRODUCTION DU SORGHO SUR DE BONS SOLS A 10 % D'INTERET CORRESPONDANT A 2 FORMES D'ENGRAIS, 3 MELANGES D'ENGRAIS, ET 3 MODES D'APPLICATION

Engrais utilisé	Composition chimique (N-P)		
	0-25	15-25	35-25
Application annuelle			
- soluble	1.15	1.66	1.63
- PB + urée	1.81	2.37	2.12
Application bi-annuelle			
- soluble	1.58	1.75	2.07
- PB + urée	2.52	2.44	2.57
Application unique			
- soluble	1.72	1.68	2.17
- PB + urée	3.14	2.43	2.45

TABLEAU 4.

RAPPORT BENEFICE/COUT POUR LA PRODUCTION DU SORGHO SUR DES SOLS MEDIOCRES A 10 % D'INTERET CORRESPONDANT A 2 FORMES D'ENGRAIS, 3 MELANGES D'ENGRAIS, ET 3 MODES D'APPLICATION

Engrais utilisé	Composition chimique (N-P)		
	0-25	15-25	35-25
Application annuelle			
- soluble	0.85	1.22	1.26
- PB + urée	1.19	1.05	1.01
Application bi-annuelle			
- soluble	1.24	1.39	1.56
- PB + urée	1.67	1.37	1.22
Application unique			
- soluble	1.34	1.38	1.67
- PB + urée	2.08	1.39	1.14

TABLEAU 5.

RAPPORT BENEFICE/COUT POUR LA PRODUCTION DU SORGHO SUR DE BONS SOLS A 30 % D'INTERET CORRESPONDANT A 2 FORMES D'ENGRAIS, 3 MELANGES D'ENGRAIS, ET 3 MODES D'APPLICATION

Engrais utilisé	Composition chimique (N-P)		
	0-25	15-25	35-25
Application annuelle			
- soluble	1.09	1.57	1.62
- PB + urée	1.67	2.18	2.03
Application bi-annuelle			
- soluble	1.39	1.62	1.97
- PB + urée	2.16	2.20	2.32
Application unique			
- soluble	1.53	1.55	2.19
- PB + urée	2.44	2.10	2.18

TABLEAU 6.

RAPPORT BENEFICE/COUT POUR LA PRODUCTION DU SORGHO SUR DES SOLS MEDIOCRES A 30 % D'INTERET CORRESPONDANT A 2 FORMES D'ENGRAIS, 3 MELANGES D'ENGRAIS, ET 3 MODES D'APPLICATION

Engrais utilisé	Composition chimique (N-P)		
	0-25	15-25	35-25
Application annuelle			
- soluble	0.81	1.16	1.25
- PB + urée	1.04	0.92	0.88
Application bi-annuelle			
- soluble	1.02	1.28	1.50
- PB + urée	1.38	1.14	1.02
Application unique			
- soluble	1.10	1.25	1.55
- PB + urée	1.53	1.09	0.92

3.0 USE OF ROCK PHOSPHATE FERTILIZER IN EXTENSIVE AND INTENSIVE PRODUCTION

3.1. Improving the Productivity of Extensive Production Sub-systems and the General Characteristics of the Extensive Production sub-systems

3.1.1. The extensive production systems of the region have evolved in an environment where very low yields per unit area are expected. The farmers' strategy is to plant large areas and this extensive strategy is reflected in their choice of agronomic techniques. The principle constraint to extensive production within the traditional system is weed control. The amount of time available for hand hoeing determines the area on which the farmer can produce crops effectively. Farmers are anxious to plant early because early weeding of major bush fields and the planting operations for some activities of intensive crop production occur at the same time of the year and therefore compete for the manower available.

Within this context, the farmers' perceived need is to be able to do more weeding so that they can cultivate more land. Currently, the most cost effective means of increasing area in the central zone is to purchase a donkey drawn cultivator or hoe. The donkey drawn hoe, "hcue Manga", is the most popular animal drawn implement in the zone.

To use the donkey drawn hoe to weed, it is necessary to plant in lines. The usual means of doing this operation is to remove all but the two outside teeth from the hoe, spread the teeth to a spacing of about 60 cm and mark or furrow twice where 2 teeth are used. The farmers derive an additional direct agronomic benefit from planting in this little furrow. The seedlings come up better because their roots are deeper, in soil which remains moist longer, and because the furrow funnels additional water onto the young plants.

.../...

To speed up the marking process, one improvement to this system is to use a larger animal to pull the hoe and to mount a bar across the top of the hoe with 4 teeth on it. The farmer can then mark in both directions, leaving a criss-cross pattern in the field. Planting in this square grid, and cultivation in both directions with the animal drawn hoe would allow him to eliminate almost all the hand weeding. A greater amount of hand cleanup has to be done when one uses the donkey drawn hoe to hoe up and down the rows but not across them.

Currently, the extensive cereal crop production system does not use any plowing. Even when animal drawn plows are available, the farmers' perceived need to plant early discourages the farmers from using the plow. The increase in yield levels are frequently so low that the absolute magnitude of the increases in response to plowing are not justified in the farmers' opinion. In addition, they are discouraged butthe delay in their planting schedule if they were to plow. Soil fertility and soil moisture retension capacity limit yield to such an extent as to reduce the economic return to plowing. (Investment in the removal of these constraints to production is treated with the discussion of intensive production strategies).

When the phosphate is applied to the surface of the soil and incorporated either by hand or with an animal drawn hoe, it will be mixed only with the top 3-5 cm of soil.

The rate of decomposition of rock phosphate in the soil, even in its fine ground form is very much determined by the moisture content of the soil. The rate of decomposition of rock phosphate will be lower where it is hoed into the soil than the rate of decomposition where it is plowed into soil. In addition, there are less plant roots present at the surface because the upper part of the soil mass is frequently dry even in the rainy season. When the rock phosphate does break down, the phosphate which is released will not be taken up as quickly as if it had been lower

.../...

in the soil profile. The soil has a very high affinity for phosphates and very little movement in the soil can be expected. The crop plants themselves are fortunately able to solve the problem, at least in the long run. Phosphate is taken up actively by the plant. If the phosphate is unevenly distributed in the soil, the plant will selectively absorb phosphate from where the concentration is highest. The plants will therefore transport some phosphorous down the roots at the end of the season in rather easily available forms. Insect activity in the soil is another potential source of downward phosphate transfer.

Most of the FSU on-farm experimental trials have used relatively shallow incorporation, (frequently less by intention than because of the difficult of plowing in the fertilizer on small plots). The results of these trials are encouraging. There is no indication that the shallow placement of the phosphate is a barrier to its economic effectiveness.

In order to be used in the extensive system, the phosphate would have to be applied as a side dressing at the time of the first weeding. This is usually the first cultivation of the field. Application of rock phosphate fertilizer as a side dressing provides even less favorable conditions for decomposition than the shallow preplanting applications which are normally tested. The delay in application may not be as important as it would seem because the surface would be dry for much of the time between May 20, the time of planting, and June 20, the date of the first weeding. The first weeding takes place when the rainfall normally becomes regular and thus the phosphate rock could be effectively broken down in the surface soil.

3.1.2. Fertilization in Extensive Production Sub-Systems

Less frequent applications of fertilizer are generally more profitable because of the benefit derived from residual effects of the fertilizer. When discussing yield responses to fertilizer application over time and the optimal time of applications for maximum benefit to the farmer (in the case of soils with poor moisture retension capacities), less

.../...

frequent applications were the critical factor in deciding profitability. A large portion of the soils used for agricultural production in Upper Volta are of poor quality, and might not support the profitable transformation to high yielding production sub-systems. The average yield increase over the four year period for a single application of 100 kg of rock phosphate without urea is 30 kg per year (Table 2). The acceptance of infrequent fertilizer applications indicates that yield increases will be small in absolute terms, even through they might be large in percentage terms.

On good soils there can be a real choice between intensive and extensive production techniques. High fertilizer application rates seem profitable and high yield levels appear to be economically attainable (Table 5). For soluble fertilizers, the profitability is contingent on very high nitrogen applications, but are associated with both high risk to the farmer and problems with foreign exchange. The high benefit to cost ratios associated with infrequent rock phosphate applications in extensive production sub-systems are therefore a particularly attractive alternative even on good soils. The mean annual increase in production over a four year period on good soil is not much greater than that on poor soils, even though the first year response is much better (44.5 kg/ha per year). One is maintaining an environment in which phosphorous is very much the limiting factor of production, assuring high yield responses on a per kg basis to phosphate application.

Good soils have an advantage over poor soils in that bi-annuel applications of rock phosphate seem highly profitable. Although the average annual yield increase under a strategy of bi-annual rock phosphate application is low, 67 kg/ha., the strategy has the major advantage of flexibility in that nitrogen responsiveness would be better than for less frequent applications. Because the phosphate levels in the soil would be relatively high, the farmers could profitably add urea fertilization at any time when the higher risk seemed warranted.

.../...

Those who might doubt the importance of national fertilization strategy which would increase yields by 30 kg per year should consider the following figures. Upper Volta has approximately 2.2 million hectares of land under cereal cultivation. For purposes of simplicity let us assume that 2.0 million hectares (90% of the total) are used in the extensive production of sorghum and millet and that an application of 100 kg of rock phosphate would produce an average of 30 kg of extra millet per year as we have assumed for sorghum (at high yield levels the response of millet is markedly less than that of sorghum, but at low yield levels this is not true). The surplus cereals produced would be 60,000 tons per year for a national application of 50,000 tons of phosphate. The average cereal deficit for Upper Volta over the past few years has been of this order of magnitude. A program of rock phosphate application in extensive production has the potential of making a substantial contribution to a solution to Upper Volta's cereal production problem.

On poorer soils, rock phosphate suffers from the disadvantage that the major yield response is in the second year. The benefit to cost ratio at higher interest rates is reduced substantially (2.08 for single applications at 10% verses 1.53 for single applications at 30%.) This provides a major justification for some national subsidy either on the cost of the fertilizer or on the cost of financing. Possibly the easiest and most effective from of subsidy would simply be to subsidize the delivery of the fertilizer to the villages. This would be particularly effective during the introduction period before the role of the rock phosphate in farmers' production strategy becomes clear to them. Nevertheless, the introduction of a major program of rock phosphate usage need not wait for the developme of a source of funds for subsidy. The returns are sufficiently good on soils of good moisture capacity to encourage farmers to use rock phosphate even where they discount the future benefits at 30%.

.../...

This is an appropriate point to interject a word of caution about pricing policy for rock phosphate fertilizer. 30 CFA per kg has been used as the price in all the calculations in this report. This is roughly 2.5 times the world market price for phosphate rock, and reflects the cost of fine grinding and the high cost of local transport. However, if volume production cannot be achieved, one will probably not be able to keep costs below this level. Success of the system depends on high volume usage which would permit lower costs of distribution and commercialization, as well as lower costs of marketing of the potential surplus. Thus, the major argument for subsidy is not to solve problem at the farmer's level, but to enable one to achieve the economies of scale necessary for national success.

Another word of caution concerning the sources of the nitrogen and potassium for crop production is also appropriate. The assumption supporting the establishment of the yield increments is that these elements would assure that this remains the general case. The traditional practice of intercropping cowpeas with cereals must be encouraged, as should the traditional practice of rotating peanuts with cereals. Crop residues should not be burned, as the nitrogen contained in then is lost in burning. The residues could be fed to animals and the manure recycled. The farmers' returns from such practices would increase as the level of phosphorous in the soil increases.

Presently, infrequent fertilization with rock phosphate fertilizer seems to be the fertilization strategy most worth considering for poor soils. On better soils there is a real choice as to whether one should use an intensive or extensive system. Even on good soil the extensive system has the advantage of minimum cost, low risk, high return, and less change in current cereal production technology.

The poor returns for intensive cereal production stem from the rather arbitrary calculation of maximum yield at 900 kg/ha (equivalent to a yield increment of 450 kg/ha in Table 1 and 2). This figure is intended to show the limitations of Voltaic farmers' current management techniques.

The arguments presented here are intended to indicate that Voltaic farmers should practice intensive cereal production on areas similar in size to those land areas they currently use for intensive production. It is important to realize that soil fertility improvement and weeding for extensive production should rank before varietal improvement and plowing on a scale of importance ranking the technologies necessary for the transition to intensive cereal improvement.

3.2. The Characteristics of the Traditional Intensive Cereal Production sub-systems in Central Upper Volta and Possibilities for Improving their Fertility

Nearly all families in the central portion of Upper Volta practice some intensive cereal production. Most of this intensive production is associated with the village fields and garden plots. The maize is produced on an intensive basis, with large applications of animal manure, ashes from the family cooking fires, and household refuse. Sorghum and millet also are grown on an intensive basis on village fields receiving applications of animal manures. Red sorghum frequently is found in the fields of those villages located high in the toposequence where the soils are sandy or gravelly. The relatively early maturity of the red sorghum is an advantage because the moisture holding capacities of the soils are limited.

Another aspect of the families intensive cereal production is based on utilization of numerous termite hills in their fields. The termites bring up the subsoil, which is chemically rich and collect organic matter from the surrounding area. When the old hills are knocked down they provide a fertile medium for plant growth, but they have poor physical soil structure. In order to make the soils of the termite hills permeable, the farmers pile stalks on the hills. This improves the chemical state of the soil as well as aiding in water penetration and in keeping the soil moist.

.../...

Few investigations of yield responses from the traditional intensive cereal production have been made. However, one can expect that yield responses should be similar to those obtained from projects at experiment stations. The results of one experiment done in a field using the traditional intensive method is presented in table 7.

Currently, when farmers have access to fertilizer they apply it on this kind of intensive production. Frequently corn and sorghum are intercropped with cotton on the very best fields. This combination allows the farmer a cereal crop for his own use and a cash crop with which to finance the fertilizer. However, the total area of this intensive production is small, including only 3% of the farmer's fields under intensive production. On a national basis this amounts to 66,000 hectares. If production levels could be increased by 300 kg per ha from their existing high level, the total surplus produced would be 19,800 tons. The annual cereal deficit for Upper Volta has been above this figure for several years, thus a policy of fertilizing existing intensively cultivated fields would not be sufficient to alleviate the national problem.

3.2. <u>Changing from Extensive to Intensive Production on Good Soils</u>

On good soils the transition from extensive to intensive production appears to be feasible and profitable as well. Annual applications of rock phosphate(urea mixtures show benefit to cost ratios of more than 2, even when the income and expenditure streams are discounted at 30% (Table 5). Conversely, returns from the application of soluble fertilizers annually are not profitable, and therefore would not achieve the 900 kg/ha average level which has been designated as the lower limit of yields corresponding to intensive production. Economic returns of soluble fertilizers are contingent on improvements in crop and soil management permitting higher yields.

.../...

TABLE 7.

YIELD INCREMENTS (KG/HA) OF SORGHUM FOR TWO MANAGEMENT LEVELS

Management Practices	Village Fields		Bush Fields	
	Local Variety	E-35-1	Local Variety	E-35-1
Traditional	1247 + 0	1247 + 210	315 + 0	315 - 177
Preplanting cultivation; 100 kg/ha rock phosphate 40 kg/ha urea	1247 + 366	1247 + 521	315 + 581	315 + 440

There are two limitations to achieving intensive production using rock phosphate fertilizer. The first limitation is a physical problem, and the second is related to the economics of the national cereal market. The first indicates that the expectations for increased yield on intensively cultivated fields could be unreasonably high in the long term. One might not be physically able to achieve the highest yield levels on a year after year basis because other mineral deficiencies may develop such as a deficiency in potassium.

In establishing the tables of yield responses (Tables 1 and 2) potassium was not mentioned. However, within the four year time span described, and given the relatively low yields, potasssium is not likely to limit growth, because other management factors are more important in determining yield. After 5 years in intensive production, potassium deficiencies may start to limit responses to phosphorous and nitrogen. This would not happen with the soluble cotton fertilizer now on the market which is formulated for long term soil fertility maintenance and contains adequate potassium.

Mixtures of rock phosphate and urea do not provide any potassium. The soluble complete fertilizers, such as the current cotton fertilizer, would perform better in the long run and continue to maintain relatively high yield levels. Unfortunately, low profitabilities in the initial years would preclude their usage on cereals where potassium would rarely add to productivity. One might speculate that farmers could produce intensively for a few years using the rock phosphate and then allow the fields to return to extensive production, retaining those areas which the farmers' own supplies of potassium might support, or they could continue intensive production using the cotton fertilizer with potassium.

Soil acidification and the depletion of soil organic matter is another physical constraint which could limit the development of intensive production based on the use of rock phosphate/urea mixtures. As a limitation to intensification however, this would be less important than acidification in systems using soluble fertilizers.

.../...

The economic argument against the viability of intensive cereal production is more conclusive, but it is important to realize that the arguments which are presented here do not apply to exportable cash crops, and would not even apply to cereals if they were to be exported.

The total area of good soils in Upper Volta is difficult to determine, but it is safe to assume that the area is sufficiently large to make it physically possible to produce a quantity of grain several times the magnitude of the present national deficit. If a large portion of the local farmers adapted an intensive production strategy and the surplus were not exported, the price of grain would fall to the point where fertilizer applications would cease to be economic. As the price of grain falls not only would intensive production using large amounts of fertilizer cease to be economic, but fertilization of extensive production on poor soils would cease to be economic as well. Only for relatively extensive production on good soils could the fertilizer continue to be used. Intensive production of exportable cash crops on the better soils should have a high priority in development of national policy. Annual fertilizer applications and high nitrogen application rates then could be reserved for production of cash crops for export.

The cropping pattern which is emerging in the southwestern area of Upper Volta shows tendencies to utilize this strategy even though rock phosphate is not a part of the system. Large amounts of fertilizer are applied to the cotton which is rotated with corn or sorghum to take maximum advantage of the residual effects of the fertilizer. Growing cereals without nitrogen application on residual mineral nutrients left after fertilized cotton is comparable to growing cereals using rock phosphate alone. Upper Volta's relative advantage in agricultural production exists in using a local resource, rock phosphate, and a production system within which that resource can be profitable employed without extensive changes in the system.

.../...

4.0. THE USE OF PHOSPHATE FERTILIZER IN INCREASING RETURNS TO OTHER AGRICULTURAL PRODUCTION TECHNIQUES

The traditional farming systems of Upper Volta reflect the phosphate deficiency of its soils. Phosphorous is neither volitalized nor leached, and thus is only lost from the system when it is physically removed. Plant recovery rates of phosphorous are low, and if applications of small amounts continue over time phosphorous levels will build up. The removal of phosphorous as a constraint to plant and animal growth could allow the production system to change to accomodate a new resource base.

To derive the maximum advantages from this transition, the farmer should be aware in advance of the nature of the changes which can occur. He can expect higher returns with additional manures which can be generated on the farm or in the household. The incentive for keeping more animals should increase because of the increased demand for their manure. The incentive for improved manure conservation will increase because the nitrogen which can be conserved becomes much more important (of the major nutrients, only the nitrogen is lost when animal manure is left to dry in the sun). For relatively high yielding fields which have been in production a long time, the farmer may be able to get profitable responses from ashes and thus have more incentive to spread them further than the family corn field. Finally, the returns to application of imported urea increase dramatically after a certain quantity of rock phosphate has been applied, and some time has passed.

All forms of phosphate are essentially immobile in the soil except when actively transported by plants, therefore returns from improved cultivation should be markedly increased because it will move the phosphate further down the soil profile. Together with the increased yield response to application of animal manure, the incentives for the adoption of animal traction would be greater than they are currently. The opportunities for plowing are limited within the traditional extensive production system and

Problem in logic here. No need to move down in profile. Probably fixation if it does the need to plant early is very great where the areas to be weeded are relatively large; nevertheless, it would seem to be profitable for families to plow about 1 hectare of land. Peanuts, corn, and some red sorghums can be planted after plowing when plowing time is available. The opportunity provided by plowing in rock phosphate for peanuts is greater than what might be indicated by the response of the peanuts themselves. Peanuts are always grown in rotation with millet or sorghum and the residual effects of the phosphate is improved by deeper plowing. The late planted red sorghum, and other photoperiod-insensitive sorghum planted on village fields receiving limited amounts of animal manure, would be responsive to plowing and rock phosphate applications in combination.

In terms of improved varieties, the interaction with the rock phosphate may not be so important. The yield levels attained in extensive production are too low for the improved varieties to perform well. In the second phase, where rock phosphate has its impact on the levels of other components in the crop management equation, the contribution of varietal improvement should be much greater.

.../...

5.0. SUMMARY AND CONCLUSIONS

The principle benefits of the use of rock phosphate fertilizer as compared to the use of soluble fertilizers are economic. The foreign exchange component of cost of rock phosphate fertilizer would be lower than the foreign exchange component of the cost of soluble fertilizers. Production and distribution of rock phosphate fertilizer would allow increased integration of the industrial and agricultural sectors of the economy of Upper Volta. The use of rock phosphate fertilizer can lower the cost of production of some agricultural commodities. In the case of leguminous crops, the use of rock phosphate fertilizer should increase Upper Volta's ability to export and in turn should increase the country's ability to invest in agriculture.

The yield responses over time to mixtures of rock phosphate and urea are different than those of soluble fertilizers having the same nitrogen and phosphorous levels. The relative advantage of rock phosphate compared to soluble phosphate fertilizers occurs where it is applied with little or no nitrogen, where the applications are infrequent, and where phosphorous application rates are low. In the absence of nitrogen fertilizer usage, where application rates are low and applications are infrequent, the returns to a unit of rock phosphate fertilizer are highest. When nitrogen is not applied with the rock phosphate these modes of application would allow Upper Volta to achieve the maximum benefit from the rock phosphate that the country produces.

The situations where nitrogen fertilizers can be profitable applied with rock phosphate fertilizer will be limited. Generally higher cost fertilizers will only be profitable where growing conditions are good. On good soils the profitabilities of fertilizer mixtures increase with increasing nitrogen concentration, whereas on poor soils the profitabilities of fertilizer mixtures decrease with increasing nitrogen concentration. Parallel statements will hold true for good and poor crop management. Economic conditions will severely limit the use of imported nitrogenous fertilizer on cereal crops for domestic consumption.

.../...

These findings, together with some of the other physical properties of rock phosphate fertilizer, indicate that its most important role may be as a fertilizer for extensive cereal production. Extensive cereal production is particularly important in Upper Volta because of the nature of the country's soils, rainfall, and other resources. A transformation to intensive cereal production would require imported tools and materials for which the country will not be able to pay in the near future. Relatively small per hectare yield increases, on the order of 25 kg/ha, if achieved over the entire area of sorghum and millet now cultivated, would be able to eliminate current national cereal deficits. The use of rock phosphate in cereal production for the domestic market is therefore particularly attractive.

Although use of rock phosphate would be most attractive in extensive production in the immediate future, its use would be an important step toward the intensification of agricultural production. In the long term, rock phosphate fertilizer can improve the overall productivity of the soils of the region. Specifically, it improves the returns to nitrogen fertilizer, to other fertilizer nutrients, and to improvements in soil structure; It also incrases the secondary benefits of leguminous crops in the cropping patterns of the region. These effects will in turn increase the profitability of animal traction and the frequency of cases in which animal traction can be profitably incorporated into the farming systems of the area.

Currently the three principle blocks to the expansion of rock phosphate usage in the central region of Upper Volta are :

1. Lack of knowledge of the special characteristics of rock phosphate fertilizer on the part of farmers.
2. Lack of an efficient distribution system for rock phosphate.
3. Weakness of cash crop markets and the consequent constraint on the availability of cash with which to purchase fertilizers.

.../...

Modification of policies, and investment in institutions which could remove these constraints would lead to an improvement in the level of incomes to farm families in Upper Volta, increase the ability of the agricultural sector to produce food for the urban sector, lead to better integration of the agricultural and industrial sectors of Upper Volta, and improve Upper Volta's ability to export agricultural commodities.

1981-09

ROCK PHOSPHATE FERTILIZER IN UPPER VOLTA

Christensen, Paul

AU-SAFGRAD