SAFGRAD PROJECT IN MALI

SEPTEMBER 1978 TO SEPTEMBER 1982

FINAL REPORT

BY THE ACCELERATED CROP PRODUCTION OFFICER
JERRY J. JOHNSON

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BRIEF TECHNICAL SUMMARY OF FARM LEVEL TESTING 1978-1981

PROJECT HISTORY IN MALI

The director of Agronomy Research, Mamadou Fatogoma Traoré, was the Malian delegate to the January 1976 meeting of research directors and donors, organized by the O.A.U. in Ouagadougou, that resulted in the creation of J.P. 31 or SAFGRAD.

In May 1977, USAID approved financing for its portion of the new SAFGRAD project and a small team of USAID officials visited Bamako and met with Malian research administrators. The Malians requested an expatriate ACPO (Accelerated Crop Production Officer) to launch the young project in Mali and the USAID officials recruited me to fill this position.

I arrived at the end of the 1977 growing season thinking M. Traoré had a definite idea of the future SAFGRAD role. He thought I would have a precise idea of this role. We sat down together and reviewed the objectives of the project and the Malian priorities for food crop research. He wanted me to become completely familiar with the Malian research literature and meet the research personnel before defining the SAFGRAD role. I visited research stations and evaluated ongoing research with the assistance of the ICRISAT/Mali agronomist, Steve Clarke. I spent several months at this task and returned to his office with a program proposal for working on maize and cowpea varietal improvement, genetic materials developed by IITA had not been tested in Mali. He was less concerned with this gap in the research program as there were negotiations underway to have an agronomist from IITA assigned to Mali for maize improvement. His priority for SAFGRAD integration into the research program was as the liaison service between the Food Crop Research Section (S.R.C.V.O.) and five extension agencies that are responsible for promoting food crop improvement in their respective zones. He requested our integration into S.R.C.V.O. as the crucial link between research and extension. Clearly, one of the objectives of the SAFGRAD project is to move research results to farmer fields; it was equally clear that Mali was in need of this liaison service. His appeal to SAFGRAD for help in farm-level testing was a pleasant surprise.

In March 1978, I presented a synopsis of the SAFGRAD project to the Food Crop Research Commission as well as a testing program for the 1978 cropping season.

The accepted methodology for the liaison activity was the design, execution, and analysis, of farm-level tests. The research topics (varieties, fertilizers, cropping systems, disease or insect control, etc...) as well as the number and location of test sites were to be decided by the extension agency and SAFGRAD. The topic for testing at the farm-level should have been tested on research stations in Mali and approved by food crop researchers in the annual research meetings.

If the welcome by research was warm, it was otherwise by the extension agencies. Shunted down to the lower officials in the extension agency, I was greeted with skepticism or hostility. There was a general low opinion of the contribution research had made to extension objectives. Researchers were characterized as intellectuals who didn't want to confuse their elegant research on stations with the realities of production found in rural Mali. One of our first priorities was to gain the respect of the extension agencies.

A recent graduate of the Malian agriculture college, Lamine Traoré, was assigned to SAFGRAD in May 1978 as my counterpart. Our program in the first season was as follows:

1978 Growing Season Program: Farm-level Tests Objectives: To compare the yield and comportment of introduced varieties of cereal (millet, maize, and sorghum) with the local variety. Each test was subdivided so that each variety was seeded in two plots: one receiving a low rate of chemical fertilizer (100 kg/ha ammonium phosphate and 50 kg/ha urea); and one receiving no chemical fertilizer.

We hoped to answer the following questions:

- Which variety will be highest yielding with and without fertilizer?

- Given the actual price of fertilizer, would yield increases due to fertilizer justify the use of this low rate of fertilizer on cereals?

Note that this fertilizer rate was the rate recommended by Agronomy Research as a result of IRAT cereal fertilizer studies.

- Finally, if these introduced varieties prove to be higher yielding than the local varieties, are they acceptable to consumers?

We visited the farmers and the agents in the field and distributed the necessary instructions, raingauges, fertilizers and seeds. The farmers executed the plowing, seeding, and weeding, under the supervision of the extension agent. We visited once every three or four weeks to make observations in the field and to verify records maintained by the agent. Each test occupied 1/4 hectare.

In 1978, we were present for the harvest of each test, put the panicles or ears in labelled sacks and then returned later for threshing with our mechanical thresher. After threshing, we recorded weights, explained the results to the farmer and the agent, and then gave all the yield to the farmer. If the introduced varieties yielded less than the local variety the farmer was compensated for the difference.

During this first season we cooperated with five different extension agencies that cover most of the arable land in Mali.

The tests included the following varieties:

- EARLY SORGHUM: E 35-1; CE 90; LOCAL VARIETY
- LATE SORGHUM : SB 66-42; LOCAL VARIETY
- EARLY MILLET : NKK; M_2D_2; LOCAL VARIETY
- LATE MILLET : M_{12}; LOCAL VARIETY
- MAIZE : TIEMANTIE DE ZAMBLARA; LOCAL VARIETY.

Results

Early Sorghum Tests

Average yields on eleven sites in kg/ha grain:

CE 90	with fertilizer	= 1,341
CE 90	without fertilizer	= 694
E 35-1	with fertilizer	= 1,500
E 35-1	without fertilizer	= 1,005
LOCAL	with fertilizer	= 1,723
LOCAL	without fertilizer	= 1,103

Late Sorghum Tests

Average yields on six sites in kg/ha grain:

SB 66-42	with fertilizer	= 1,005
SB 66-42	without fertilizer	= 689
LOCAL	with fertilizer	= 1,371
LOCAL	without fertilizer	= 1,089

Early Millet Tests

Average yields on five sites in kg/ha grain:

NKK	with fertilizer	= 526
NKK	without fertilizer	= 206
M_2D_2	with fertilizer	= 426
M_2D_2	without fertilizer	= 203
LOCAL	with fertilizer	= 632
LOCAL	without fertilizer	= 206

Late Millet Tests

Average yields on four sites in kg/ha grain:

M_{12}	with fertilizer	= 847
M_{12}	without fertilizer	= 536
LOCAL	with fertilizer	= 1,002
LOCAL	without fertilizer	= 607

Maize Tests

Average yields on five sites in kg/ha grain:

TIEMANTIE	with fertilizer	= 2,273
TIEMANTIE	without fertilizer	= 1,261
LOCAL	with fertilizer	= 1,902
LOCAL	without fertilizer	= 1,122

Discussion:

The results of this first season surprised us. In light of the remarkable results reported by the plant breeding unit we had hoped that the introduction of these new varieties (especially sorghum) would revolutionize food crop production in Mali; but, against all expectations, the local varieties out-yielded the introduced ones (except for maize).

On the other hand, given the low price of cereal paid to the producer and the relatively high cost of fertilizer, we believed that our tests would prove the economic infeasibility of fertilizer use on these cereals. However, our results showed that there was an economic benefit in the use of this low rate of fertilization on local varieties (except for late sorghum).

After deducting the cost of fertilizer there remained the following increases in yield due to fertilizer on local varieties.

EARLY SORGHUM = 250 kg/ha grain
LATE SORGHUM = -88 kg/ha grain
EARLY MILLETS = 56 kg/ha grain
LATE MILLETS = 25 kg/ha grain
MAIZE = 344 kg/ha grain

The low rate of fertilizer also had three immediately observable effects on the local varieties of cereal crops.

1) Fertilizer reduced the growing cycle by six to seven days in the early sorghum (seeding to 50% flowering).

2) Fertilizer increased the number of panicles harvested in early and late sorghum by 12%; in early millet by 55%; and in late millet by 31%.

3) Fertilizer increased the average panicle weight by 9 grams/panicle in early sorghum; by 12 grams/panicle in late sorghum; by 5 grams/head in early millet; and by 7 grams/head in late millet.

Problems Encountered

Often fields were chosen for the test with obvious heterogeneities: trees; termite hills; excessive slopes; floodable land. In this first year we suspected that the agents tended to choose the collaborating farmer as a function of the farmer's spirit of cooperation and not the availability of a suitable test site. By the time the abnormality was discovered most of the suitable fields had already been allocated to other uses.

When a dry period intervened before the precribed seeding date many farmers just scarified the test site, instead of plowing as called for in the instructions.

Our most outstanding problem during the season was the difficulty obtaining satisfactory plant populations stands in the plots of introduced varieties. 80-100% of the plots of introduced varieties had to be totally or partially reseeded. The late sorghum, SB 66-42, only attained an average of 41% of the desired plant population; CE 90 only 74%; E 35-1 only 65% while the local varieties averaged 80% of desired plant population. SRCVO sorghum breeders attributed it to poor seed quality, insect attacks, late date of seeding or excessive depth of seeding.

Urea was often spread too late in the season for optimal effect. This may have been the reason that late sorghum varieties didn't respond as well to fertilizer. The urea in these tests was spread, on the average, 72 days after planting, instead of the recommended 30 days. It was difficult to convince farmers to execute a ridging operation after the urea had been spread which led to probable losses of nitrogen.

The following diseases observed in our test plots seemed to affect yields.

1. Long Smut: CE 90 was severely attacked by this disease in several sites; E 35-1 to a lesser degree. No local varieties were attacked.

2. Covered Smut: Problem in certain local varieties but not problem in E 35-1 or CE 90.

3. Leaf Diseases: More visible on local varieties than on introduced varieties.

4. Grain Molds: SB 66-42 and CE 90 were often devasted by grain molds and several E 35-1 plots were severely attacked. Local varieties were relatively free of attack.

5. Downy Mildew: All millet sites and all varieties were attacked. Counts in farmer fields showed 25% - 60% of the millet pockets were attacked.

6. Helminthosporium : One maize site was severely attacked.

At the end of the year there were serious infestations of Striga on many of our test sites. An average of 31% of our tests sites of maize, sorghum and millet suffered from the deleterious effects of Striga.

1979 GROWING SEASON

Our report containing 1978 results was presented to the Food Crop Research Commission in March 1979 and to the National Agronomy Research Committee meetings in April 1979. The presentation of our results and the adoption of a program for 1979 solidified our role in Mali: SAFGRAD/Mali was equated specifically with farm-level trials and generally with the liaison between research and extension. At the beginning of the 1979 season, the extension agencies actively sollicited more extensive testing programs. It is important to note that the 1979 testing program was derived from the experience we gained in the first year.

VARIETAL QUESTION:

The results of the introduced varieties of early and late millet were discouraging and there were no other improved varieties that seemed more promising than those already tested. At that time there was much hope amongst the millet breeders that the "dwarf" millets would soon be ready for farm level testing. Millet varieties were eliminated from the 1979 program to be resumed later with the introduction of "dwarf" millet varieties made from local parents.

The one variety of maize in our 1978 tests, TIEMANTIE DE ZAMBLARA, was already used by the extension agencies in the appropriate zones so no further testing was necessary to confirm the good results. There were no other varieties from the research stations that consistently performed better than TIEMANTIE. The regional maize trials from IITA and CIMMYT had been conducted one year and these varieties were not yet confirmed under Malian research conditions. With no new varieties to test, maize varietal testing was abandoned in 1979.

The situation of sorghum varieties was more complex. The varieties that were chosen for testing in the first year were not the only promising varieties. In light of the problems of the first year, we felt that we could improve the choice of sites, the choice of farmers, the planting procedures, etc..... in hopes of improving plant populations to provide a better comparison between local and improved varieties. Consequently, in 1979 we had seven early sorghum tests, six late sorghum tests, and one late millet test. The same testing methodology was adopted in 1979.

SOIL FERTILITY QUESTION:

The good yield response of local varieties of maize and early sorghum to the low rate of fertilizer tested in 1978 inspired us to look for alternative means of achieving similar yield increases at lower cost to the farmer. A review of the literature indicated the agronomic validity of Malian rock phosphate originating from the Tilemsi Valley between Timbuctu and Gao, in the extreme Northeast of Mali. The phosphate deposits are sizeable (20 million tons), and though these phosphates had been tested in agronomy trials since 1933, they were only recently available on a commercial scale.

If the phosphate in the ground rock could substitute for at least part of imported fertilizer there would be obvious benefit to the country. In addition to 25-30% P_2O_5, rock phosphate contains up to 40% calcium oxide which can have a soil liming effect.

We designed a rock phosphate test for the five extension agencies. Half of the 1/4 hectare test was seeded to predominant indigenous cereal, and half of each test was planted to peanuts. It was a 2-year test seeded completely to cereal the second year. Would a peanut-cereal rotation with rock phosphate give inferior, equal, or superior, yields as a cereal-cereal rotation with the use of rock phosphate and urea? In the first year the treatments were as follows:

1. Peanut with rock phosphate
2. Peanut without rock phosphate
3. Cereal with rock phosphate with urea
4. Cereal with rock phosphate without urea
5. Cereal without rock phosphate with urea
6. Cereal without rock phosphate without urea.

The rate of 300 kg/ha rock phosphate was used. This rate of P_2O_5 is equivalent to the quantity of P_2O_5 in 200 kg/ha ammonium phosphate or the recommended low rate of ammonium phosphate for two years (100 kg/ha/year). The annual rate of urea used in the test, 90 kg/ha, is the equivalent of the amount of N in the recommended low rate of fertilizer, 100 kg/ha ammonium phosphate and 50 kg/ha urea. The rock phosphate is applied once at the beginning of the two years. In the second year the cereal plots remain the same and the peanut plots, one of which received rock phosphate in the first year, are seeded to cereal with and without urea.

The eight treatments in the second year are as follows:

1. Preceding crop peanuts, cereal with rock phosphate with urea
2. Preceding crop peanuts, cereal with rock phosphate without urea
3. Preceding crop peanuts, cereal without rock phosphate with urea
4. Preceding crop peanuts, cereal without rock phosphate without urea
5. Preceding crop cereal, cereal with rock phosphate with urea
6. Preceding crop cereal, cereal with rock phosphate without urea
7. Preceding crop cereal, cereal without rock phosphate with urea
8. Preceding crop cereal, cereal without rock phosphate without urea.

These tests were requested by all five extension agencies so we prepared and distributed 25 tests that were spread throughout the country. The local cereals used were sorghum and millet. It should be noted that the ACPO had to be evacuated just as the season preparations began. Consequently, Lamine Traoré, with the help of a new agriculture college recruit, Hassane Daou, successfully prepared these tests along with the sorghum varietal tests. The same procedure was used in the second year as that established in the first. Several farmers requested to be chosen for any new test as the periodic visits by SAFGRAD and the special attention of the extension agent served to stimulate the farmer, his family and his neighbors. Nevertheless, since the beginning there have been a certain percentage of farmers and/or agents that have been incapable of correctly executing a test. Each year we had a success rate of approximately 70%. Of the 25 tests requested and distributed for rock phosphate in the first year, 18 gave viable results.

Results

Rock phosphate results - Averages of 18 sites in kg grain/ha

Peanut with rock phosphate	- 1,369 (unshelled)
Peanut without rock phosphate	- 1,099 (unshelled)
Cereal with rock phosphate with urea	- 1,055
Cereal without rock phosphate with urea	- 739
Cereal with rock phosphate without urea	- 1,011
Cereal without rock phosphate without urea	- 770

The peanut response to rock phosphate in the first year was stronger than expected. The difference in yield of 270 kg/ha was highly significant (CV = 20%), and not only justified the cost of the rock phosphate, but gave an average return on investment of 44% in the first year!

On the cereals the urea factor was non-significant but the rock phosphate factor was highly significant. These analyses are done by considering each site as a repetition. The value of the yield increase due to rock phosphate equalled 14/15ths of the price of the rock phosphate in the first year (1979 cereal prices).

Sorghum Varietal Results in kg/ha grain

Early sorghum - Average of 7 sites

E 35-1 with fertilizer	1,239
E 35-1 without fertilizer	661
CE 99 with fertilizer	1,296
CE 99 without fertilizer	684
SB 722-1 with fertilizer	1,199
SB 722-1 without fertilizer	547
LOCAL I with fertilizer	1,045
LOCAL I without fertilizer	757
LOCAL II with fertilizer	1,336
LOCAL II without fertilizer	791

Note: In this second year two local varieties were tested at each site because of the wide diversity of characteristics found in local varieties.

Semi-late sorghums - Average of 6 sites in kg/ha grain

CE 111-6 with fertilizer	827
CE 111-6 without fertilizer	1132
VS 703 with fertilizer	828
VS 703 without fertilizer	874
LOCAL I with fertilizer	1755
LOCAL I without fertilizer	1272
LOCAL II with fertilizer	1756
LOCAL II without fertilizer	1385

Again this second year, the introduced varieties were non-competitive with the local varieties. The problems encountered were similar to those of the first year: lack of germination and poor seedling vigor led to poor stands. Grain molds attacked some fields and Striga was again an important pest. Birds took their toll wherever the introduced varieties were out of flowering syncopation with the local varieties.

An impartial observer could be discouraged by these results but they were very beneficial. First, they could save an extension agency from making a much more costly error by attempting to extend an inappropriate variety, and they also served as feedback to SRCVO sorghum breeders. Without these results the breeders could have maintained inappropriate varieties in their program and continued to report high yields for many years without knowledge of their weaknesses. The acquisition of these results coincided with the arrival of a full-time sorghum breeder, John Scheuring, on the ICRISAT/Mali team. At the time he descended from the airplane we could tell him about the need for improved sorghum seedling vigor, striga resistance, grain mold resistance and photosensitive varieties. His breeding program immediately reflected these issues. This is the best example of how the liaison between research and extension is a two-way street. Researchers benefit from farmers too.

The use of a low rate of fertilizer on local varieties was again beneficial, giving a return on investment of 16% on early sorghums and 7% on late sorghum. The FAO estimates that third world farmers are slow to make agricultural investments that yield less than 100% return on investment. Thus, it is not surprising that so few farmers use this fertilizer rate on food crops in Mali.

In the early, dry, hot months of 1980 we presented our results to the Food Crop Research Commission (March) and the National Agronomy Research Committee meetings (May). Lamine Traoré had gone to the U.S. for sorghum agronomy studies (M.S.) and N'Tji Coulibaly had been recruited from the agricultural college and assigned to our team. After the Food Crop Research Commission meetings it was obvious that we had created a larger demand for farm-level tests than we could fulfill. At the same time we recognized the necessity of a much larger testing program so that each extension agency could base extension themes on facts verified in their extension zones. Many of the extension agencies were quite new and extension themes were characterized by vague concepts. Consequently, we prepared the following paper for the National Agronomy Research Committee meetings.

PERSPECTIVE ON FARM-LEVEL TESTING IN MALI

The 18th session of the National Committee Agronomy Research recommended "the implementation of farm-level testing programs in each rural development organization".

The director of Agronomy Research had already taken action in this sense by asking the SAFGRAD project to manage the farm-level testing structure at the level of S.R.C.V.O., uniquely concerned with food crops in Mali.

SAFGRAD/Mali has just finished their second testing season in farmers' fields and what follows in this exposé pretends to bring together several outstanding issues relative to the infrastructures that are necessary to insure a strong, constant, and long-lasting bond between research and extension.

The value of farm-level tests for the extension agencies resides in the fact that tests permit the definition of new extension themes based on statistically valid results derived from farms in the extension zone. This reduces the risk of attempting to extend a theme that is inappropriate for the zone.

It is clearly in the interest of the extension agencies, hoping to increase food production, to put out a large number of tests in the shortest amount of time to prepare new extension themes with a high degree of probability of successful adoption by the farmers. For example, suppose that a new variety of maize has proven to be very productive on Malian research stations for several years and its productive potential under rural conditions is to be confirmed before proceeding with its extension. Suppose that the results of 50 tests are necessary in farmer conditions to provide the required confirmation. If the extension agency conducted five tests per year, they would need ten years to have their 50 results. On the other hand, if they conducted 50 tests in one year they would have acquired the equivalent of ten years of research in one season and farmers could begin to profit from the new variety in the second year.

Even though this extremely simple example is theoretical, it demonstrates the usefulness of a large number of tests in a given year to develop extension themes as quickly as possible with a minimum of risk.

In order to establish the necessary farm-level testing infrastructure to meet this need there are two possible approaches:

1. Enlarge the SAFGRAD team with the necessary materials, vehicles and personnel in order to respond to the need for increased numbers of tests, <u>or</u>

2. To create, at the level of each extension agency, a farm-level testing unit that would implant and control the execution of tests in their zone. This unit would consist of 1-2 technicians trained for farm-level testing and supervised by the central SAFGRAD team.

a) Given a greater chance of permanence (continued financing) of an extension agency than a foreign organization like SAFGRAD; b) Given direct benefits that accrue to the extension agency from test results; c) Given the need of extension agencies to develop test themes based on the particular extension agency priorities for their farmers (as opposed to tests designed by researchers only); it is indispensable to suggest the creation and training of a farm-level testing unit, a coordination team, at the level of each extension agency that can, with time, assume the responsibility for farm-level tests.

SAFGRAD hopes to assure the training of this unit from each extension agency at two international institutes (ICRISAT and IITA), with short-term training sessions (3-9 months), where the technicians work on research themes concerning sorghum, millet, maize and cowpeas in the labs and fields of highly-qualified institute researchers. After this training they would return to take charge of farm-level testing in their extension agency.

They probably would not be able to manage the whole program in the first year, thus they would depend heavily on SAFGRAD to elaborate test designs and distribute the tests. They can visit the test sites and farmers more regularly than is possible for the SAFGRAD team, thus the percentage of successful tests should increase. They would participate at the harvest and threshing of each test and then help with the analysis of results from their zone.

In the second year they will have acquired enough experience to play a larger role in the conception of farm-level tests and begin to influence the themes to test as a function of the specific needs of the extension agency.

The eventual role of SAFGRAD would be to coordinate the unit such that they continue to have immediate access to research station trials and results. Group visits to research stations will be organized to see new varieties or techniques that can be incorporated into farm-level tests.

In this case, if SAFGRAD diappeared after five or ten years, these units could assume the responsibility of farm-level testing and the liaison between research and extension would not be ruptured.

It would be desirable if the extension agencies were sufficiently convinced of the value of the results to assume the costs of farm-level tests in their zones.

As a beginning, two agents from two extension agencies have been trained at ICRISAT/India and have been assigned to farm-level testing in their extension agencies with our help and material support. This year, another agency is hiring an expatriate agronomist to take care of the tests in that zone. Another agency has sent an agent to ICRISAT/India this year and should be able to work on the 1981 season tests.

This, Mr. President, is the future we foresee for the reinforcement of the liaison between research and extension in Mali.

1980 GROWING SEASON

Our most ambitious testing season to date, we prepared and distributed 148 tests to the five extension agencies. 111 of these tests were new rock phosphate tests in their first year; 19 were second-year rock phosphate tests; and 18 were maize agronomy tests. The same execution process was followed as that established in the first year with the exception that an expatriate agronomist, Tom Remington, was hired to look after more than 50 tests in the Mopti zone. Two other agents executed the tests in their agencies, with variable amounts of support from SAFGRAD, after a joint preparation of the test inputs. Cowpeas and bambara nuts were added to peanuts as possible grain legumes in the rock phosphate tests and maize was added to sorghum and millet as possible cereals.

Results:

Results of first year rock phosphate tests

The effects of rock phosphate on peanuts

Average yield with rock phosphate	=	1,171 kg/ha
Average yield without rock phosphate	=	1,066 kg/ha
Difference due to rock phosphate	=	105 kg/ha.

This difference was highly significative with a C.V. of 15.46%. This yield increase of 105 kg/ha from 52 sites is less remarkable than the 270 kg/ha increase measured from 18 sites in the 1979 season.

Effect of Rock Phosphate on the cereals

Average yield with rock phosphate	=	891 kg/ha
Average yield without rock phosphate	=	837 kg/ha
Difference due to rock phosphate	=	54 kg/ha.

This difference is not statistically significant. The average on the sorghum and maize sites was 107 kg/ha as opposed to 4 kg/ha on the millet sites. In 1979, the difference on sorghum and millet sites was 278 kg/ha.

Effect of Rock Phosphate plus Urea on the Cereals

Average yield with rock phosphate plus urea	=	991 kg/ha
Average yield without rock phosphate without urea	=	832 kg/ha
Difference due to rock phosphate and urea	=	159 kg/ha.

This difference is highly significant but is unsufficient to compensate the price of the urea on the cereals.

Of the 111 first year rock phosphate tests distributed, 73 were correctly executed and yielded viable results.

Results of Second-Year Rock Phosphate Tests

Remember that the treatments in the second year are like 2 x 2 x 2 factorial design.

2 - with and without rock phosphate
2 - with and without urea
2 - 1979 peanuts or 1979 cereal as a preceding crop

$2^3 = 8$ (all seeded in local cereal)

There were 12 sites that made it through the two complete seasons, 7 in sorghum and 5 in millet. The average grain yields across the twelve sites for the second year in cereal were as follows:

1. Rock phosphate, urea, 1979 peanuts = 1,048 kg/ha
2. Rock phosphate, 1979 peanuts = 988 kg/ha
3. Urea, 1979 peanuts = 779 kg/ha
4. 1979 peanuts (no fertilizer) = 734 kg/ha
5. Rock phosphate, urea, 1979 cereal = 826 kg/ha
6. Rock phosphate, 1979 cereal = 864 kg/ha
7. Urea, 1979 cereal = 482 kg/ha
8. 1979 cereal (no fertilizer) = 513 kg/ha.

Effect of Peanuts Preceding Crop

The value of peanuts as a preceding crop varied from 125 to 296 kg/ha. There was not a positive interaction between rock phosphate and peanuts as a preceding crop. This casts doubt on the hypothesis that significantly larger amounts of nitrogen are fixed by the grain legume in the presence of phosphorus than without additional phosphorus, in naturally phosphorus-deficient soils.

Though many interesting observations can be made from the data it was clear that:

1. Urea, is either not beneficial or, if beneficial, uneconomic (given 1980 fertilizer and cereal prices);

2. Rock phosphate alone was economically beneficial on either a cereal-cereal rotation (return on investment for two years of 157%) or on an peanut-cereal rotation (return on investment for the two years of 128%).

3. It took two years for the rate of return on investment in rock phosphate to go over the 100% level considered necessary to attract the interest of third-world farmers.

MAIZE AGRONOMY TESTS

The objective of this test is designed for the higher rainfall, maize growing zones of southern and central Mali was to compare the locally improved, open-pollinated, maize variety, TIEMANTIE DE ZAMBLARA, with a complex hybrid variety, IRAT 81 from Bouaké, Ivory Coast. This test was more than a varietal comparison as yields were measured as a function of two agronomic factors; plant density, and fertilization. A 2 x 2 x 2 factorial test was designed with the assistance of Mr. Nicou and Mr. Vallée of IRAT.

Varieties	:	TIEMANTIE DE ZAMBLARA IRAT 81
Densities	:	80 cm x 15 cm = 83,333 plants/hectare 80 cm x 35 cm = 33,715 plants/hectare
Fertilization	:	100 kg/ha urea = 45-0-0 200 kg/ha cotton fertilizer - 150 kg/ha urea = 96-46-28.

The 1979 work of Dr. Mario Rodriguez, IITA/SAFGRAD maize agronomist in Upper Volta, showed the applicability of Duncan's Linear Model for the calculation of optimal plant density from only two densities. Thus, optimal plant density became accessible as a theme that could be tested in farmers' fields. Traditionally plant density trials required 4 or 5 different densities and this implied far more treatments than believed possible at the farm level.

The rationale for testing a complex hybrid, IRAT 81, in farmers' fields was that all previous varietal comparisons of maize, millet and sorghum had demonstrated the superiority of the local varieties. Therefore, we felt that all varietal alternatives should be tested despite the obvious complications of hybrid seed multiplication. Before an acrimonious debate occured on the national level concerning the feasibility of hybrid maize seed production, we proposed to assess its potential for productivity in farmer conditions. In the event that this variety, like other promising varieties from the research station, proved disappointing in farmers' fields then the hybrid-seed debate needn't occur. If, on the other hand, its high productive potential was ascertained at the farm level, then the margin of difference between it and the alternative variety could be used to calculate the feasibility of hybrid maize seed production.

These tests were the best tests yet conducted. Due to the relative complexity of the test our teams assisted with the seeding at each site. The selection of farmers was nearly perfect. Researchers, extension agents and farmers visited the tests as soon as the early vigor of IRAT 81 was evident. The director of Food Crop Research, and the director of Agronomy Research, visited several test sites. The only abnormality observable in the field during the growing season was a marked nitrogen deficiency at the time of grain-filling, even at the higher fertilizer rate.

Average Grain Yields (12-15% H_2O) for the 15 sites

Variety	Density		N-P-K		
TIEMANTIE:	83,333	density:	96-46-28	=	2,781 kg/ha
TIEMANTIE:	33,715	density:	96-46-28	=	2,452 kg/ha
TIEMANTIE:	83,333	density:	45-0-0-	=	1,927 kg/ha
TIEMANTIE:	33,715	density:	45-0-0	=	1,853 kg/ha
IRAT 81 :	33,715	density:	96-46-28	=	3,976 kg/ha
IRAT 81 :	83,333	density:	96-46-28	=	3,791 kg/ha
IRAT 81 :	33,715	density:	45-0-0	=	2,787 kg/ha
IRAT 81 :	83,333	density:	45-0-0	=	2,520 kg/ha.

The conclusions drawn from these exciting tests, that included one plot that yielded 6,313 kg/ha, were as follows:

1. Using an average of the four levels of fertilizer and density, IRAT 81, yielded 1,016 kg/ha more than TIEMANTIE.

2. IRAT 81 responded better than TIEMANTIE to an increase in rate of fertilization. IRAT 81 yielded a rate of return on investment (on the difference between 45-0-0 and 96-46-28) of 153%, while TIEMANTIE returned only 49.6% on the same difference.

3. The calculation of optimal plant density by the use of Duncan's Linear Model was very successful. The following table derived from our results illustrates the usefulness:

Variety	Fertilization	Optimal density	Yield expected at given density
TIEMANTIE	45-0-0	35,650	1,700 kg/ha
	96-46-28	44,750	2,700 kg/ha
IRAT 81	45-0-0	37,700	2,550 kg/ha
	96-46-28	49,250	3,950 kg/ha

1981 GROWING SEASON

Program

Rock Phosphate Tests in First Year

- Zone OMM	9 sites
- Zone ODIPAC	2 sites
- Zone OVSTM	2 sites
Sub-total	13 sites

Rock Phosphate Tests in Second Year

- Zone. OMM	40 sites
- Zone OHV	17 sites
- Zone ODIPAC	5 sites
- Zone CMDT	2 sites
- Zone ODIK	4 sites
Sub-total	68 sites

Rock Phosphate Tests in Third Year

Zone OMM	6 sites

Maize Variety Tests

Local Improved Variety - TIEMANTIE
Hybrid Variety - IRAT 81

- Zone CMDT	11 sites
- Zone OHV	5 sites
Sub-total	16 sites
TOTAL	103 sites

Results and Conclusions of the 1981 Growing Season: Successful Test Rate: 85%

Results: Rock Phosphate Tests in First Year

Yield average of 10 successful tests from all zones

T_1 - Peanuts with rock phosphate - 1,270 kg/ha
T_2 - Peanuts without rock phosphate - 1,048 kg/ha
T_3 - Cereal with rock phosphate - 1,019 kg/ha
T_4 - Cereal without rock phosphate - 843 kg/ha

Conclusions: The results from ODIPAC and OVSTM zones indicate hope for a beneficial effect of rock phosphate but, it isn't possible to statistically confirm this hope except with a larger number of repetitions in these highly heterogeneous zones that extend from the mountains of Guinea to the Sahel of Mauritania.

The group of six tests in the OMM zone, along the axis of Kona-Sévaré-Djenné, proved to be extremely interesting. The effect of rock phosphate in this first year, averaged over the two crops (peanuts and millet), was 217 kg/ha, or an average increase in yield of 33%. The response to rock phosphate by millet, 266 kg/ha, was more than that of peanuts, 167 kg/ha.

Results: Rock Phosphate Tests in Second Year

Zone OMM: 32 of 40 tests were successfully conducted; 29 were seeded to millet, and 3 to sorghum. The 29 sites in millet were distributed among the OMM sectors as follows: Koro 11; Bankass 8; Douentza 7; Bandiagara-Mopti-Djenné 3.

Conclusions Zone OMM: The average second year effect of rock phosphate for the total 29 sites in the zone was 111 kg/ha, or an increase in yield of 21%. This difference is highly significant. We observed that the effect of rock phosphate was about the same for both rotations; 20% increase in yield for the peanut-millet rotation, 22% for the millet-millet rotation. This indicates an absence of interaction between rock phosphate and a preceding crop of peanuts.

The effect of a preceding crop of peanuts on the following millet yield was 111 kg/ha, or an increase in yield of 21%. The beneficial effect of peanuts as a preceding crop, and the beneficial effect of rock phosphate, gave the same increase in yield; 21%.

Zone OHV: 15 of 17 sites gave exploitable results; all were seeded to local sorghum.

The average, sum effect of rock phosphate for two years, on two rotations, was 205 kg/ha; which is less than the price of the rock phosphate (equal to 212 kg/ha cereal), and statistically insignificant.

Zone ODIK, CMDT and ODIPAC (and 3 sorghum Sites Zone OMM)

This group includes all sites seeded to sorghum except those in the OHV zone. Their statistical analysis, as a group, has only little meaning due to the heterogeneity of the zones. The five sites in Kolokani (ODIPAC) zone gave an average, sum effect of rock phosphate, for two rotations and two years, of 414 kg/ha sorghum; which is about two times the cost of the rock phosphate.

Results of Six Rock Phosphate Tests in Third Year in the OMM Zone:
Seeded to millet and peanuts in third year like the first year protocol. The average third year rock phosphate effect for the two crops was significant, representing an increase in yield of 50%. These same sites gave yield increases of 73% in 1980, and 41% in 1979. The effect of rock phosphate on these sites continues to surprise us as we didn't expect such high increases in yield. Nevertheless, the progression of percent yield increases, 41% - 73% - 50%, indicate maximal effect of rock phosphate in the second year that decreases in the third year. The hypothesis will be illuminated next year when a much larger sample is considered.

The average, sum effect of rock phosphate, for the two rotations for three years, was 759 kg/ha; which is statistically highly significant and representative of a return on investment of 269%.

Maize Variety Tests: 16 of 16 tests were successfully conducted. Planting density for both varieties was 50,000 plants per hectare. Fertilizer applied was 200 kg/ha of cotton fertilizer, and 200 kg/ha of urea, or N-P-K per hectare of 118-46-28.

Maize Results: Average for 16 sites.

IRAT 81 - 4,409 kg/ha
TIEMANTIE - 3,262 kg/ha
Difference in yield = 1,147 kg/ha. (significant at 5%).
C.V. = 17%.

IRAT 81 was visibly less attacked by Helminthosporium than TIEMANTIE. Cooking tests showed that IART 81 is well adapted to the preparation of "to", "couscous", and "bouillie". The only qualms expressed by farmers concerning the superiority of IRAT 81 was the availability of hybrid seed. An economic analysis of the feasibility of production of IRAT 81 seed is presented in the annex of this report.

1982 GROWING SEASON

Program

Rock Phosphate Tests

Third year

- OMM Zone	32 sites
- OHV zone	14 sites
- ODIPAC Zone	4 sites
	50 sites

Second year

- OMM Zone	5 sites
- ODIPAC Zone	2 sites
	7 sites

First Year

- OHV Zone	54 sites
- ODIK Zone	26 sites
	80 sites

Relay Cropping Tests: Maize-Cowpeas

- OHV Zone	10 sites
- CMDT Zone	5 sites
	15 sites

Striga Tests

- OHV Zone (sorghum)	12 sites
- OMM Zone (millet)	15 sites
	27 sites

TOTAL 1982 = 179 sites

FARM LEVEL TESTING IN MALI 1978-1982

A MODEL FOR LIAISON BETWEEN RESEARCH AND EXTENSION?

This paper attempts to summarize the experiences of the SAFGRAD project in Mali which serves as the liaison agent between food crop research and the extension agencies responsible for food crop production. From these experiences I try to glean the rudiments of a model that can illuminate the process of liaison in the future. Often it is necessary to describe the history of events and experiences to provide the understanding of how we have arrived at our present model. Though I make an effort to distill our experience into a viable model for the future, it must be remembered that the project has been shaped, formed, and influenced by hundreds of individuals; all with their own ideas, energies and powers of understanding and change.

The reader must understand that the proposed model reflects my idea of the best model, but is just one of many possible models.

Introduction

There is a recognizable and real deficit of basic foodstuffs in certain regions of Mali each year. In some years the deficits are more remarkable and disastrous; in other years different regions of Mali are affected by insufficient amounts of cereals, beans, other food crops and animal products necessary to sustain human life. During the drought years of 1969 to 1975 the pendulum of rainfall probability swung the country into a food crop deficit that was so exaggerated as to attract worldwide attention. In the lee of this storm donor agencies financed new extension agencies to alleviate such a catastrophe in the future. Despite a rapid expansion in expatriate financing of agriculture development in Mali from 1960 to 1980, food crop production was the same or lower in 1980 than 1960. In the fervor of national and international concern about the shortage of basic foodstuffs in Mali many extension agencies were designed and financed on the assumption that viable extension themes were available, guarantees of increased production, just waiting to be extended. Several extension agencies have not been able to deliver the expected production increases and, in a seemingly international mood of development conservatism, these agencies are being hard pressed to account for their viability. As the pressure increases they must begin to obtain positive results from their extension efforts. In the long term, regardless of expatriate financing, Malian extension agencies can only justify their existence by increased production which will provide the necessary tax base for extension agency self-sufficiency.

Some contend that yield increases have not been achieved due to the low ceiling of yield potential in the country. Our tests have shown yields as high as seven tons per hectare of maize with relatively moderate levels of nitrogenous fertilizer. Given a chance, SAFGRAD could break ten tons of maize per hectare in farmers fields and remain above 100% return on investments for the necessary inputs. An enormous potential for food crop production exists in Mali without including the extensive irrigation projects and their large potential.

The technical reasons for the failure of most of the extension agencies in Mali are twofold: lack of viable extension themes that will unequivocally increase production if applied by the farmer in the zone; and, the inability to deliver, on a timely basis and at reasonable prices, the inputs already proven necessary for higher yields (fertilizers, herbicides and animal traction equipment). The model for liaison between research and development exposed in this section is designed to alleviate the lack of viable extension themes as its major objective. Though a rapid solution to this problem would be helpful for the solution to the food crop production problem, it is only one part of the constraints impeding Malian farmers from producing more cereal.

One might wonder what other countries have done to solve the problem of liaison between research and extension. In West Africa, it is a common problem to all countries though some countries are only now realizing the lack of liaison as a constraint to increased production. Models from other parts of the world have adoptable elements but are rarely appropriate to the administrative and technical conventions of Malian administrators and farmers. It should not be forgotten that very little of this type of liaison between research and extension is done by the public sector in the U.S. and other more developed countries. In the U.S., the private sector conducts farm-level trials throughout the country for demonstrating new varieties, fertilizers, and pesticides. In some ways the tricks in the bag of western technology are being pulled out of the bag and tried on research stations in West Africa. The tricks in the input bag are used to justify agriculture research and extension projects by the public sector in Mali, though ironically, in the countries that are financing these projects, these tricks are handled almost exclusively by the private sector. Consequently, appropriate models for achieving this goal of liaison in order to provide reliable extension themes to extension agencies are not immediately available.

OBJECTIVES OF FARM-LEVEL TRIALS

The primary objective of farm-level trials is to develop statistically viable extension themes for extension agencies based upon research station results. Viable extension themes will lead to increased production. The increased production would permit self-sufficiency for foodstuffs for the country and would provide a basis of jusfification of the extension agency itself.

The second objective, and reason that we conceive of the process as "liaison" is to provide qualitative and quantitative feedback to food crop researchers that could permit researchers and their administrators to objectively prioritize the use of available research resources. The themes used in farm-level testing have their origin in national, regional and international research programs. Farm-level testing can be used by researchers to answer two basic questions regarding a certain promising technique or variety that has been proven promising on the research station. Does the technique or variety work to increase yields in a significant manner? If so, how much does it increase yields in the zone of testing? The farm-level testing methodology used to date and recommended in this model does not answer, in a scientific manner, why a given theme increases yields or fails to increase yields. The observer in the field and the people conducting the test may have definite ideas about why a certain technique works but it would be difficult to prove the hypothesis except by conducting other trials. Nevertheless, the answers to the two questions cited above can be invaluable to the researchers. If a sorghum breeder has worked for four or five years creating and multiplying improved varieties of sorghum that fail to yield more than the local varieties when tested in farmers fields then he can save himself the time of continuing along the same lines and change his breeding program accordingly. The answer to the question of how much a given technique increases yields in the test zone is the basis for planning an extension agency. The director of an extension agency and his lieutenants can program demonstrations, training of agents and delivery of inputs on the basis of this information if the trials have been properly designed and executed. In Mali, many of the extension themes have existed since the creation of the project and are not based on statistically reliable data generated in their extension zones. Farm-level tests can submit these themes to the same rigors that it applies to new themes emanating out of research. The liaison activity has a secondary benefit to researchers by permitting themes identified in the field by agents and farmers to move through on-farm testers to researchers who have infrequent direct contact with farmers. Studies conducted by the farm-level testing team to evaluate yield loss due to a given parasite or pest can succeed in convincing researchers to change the priorities of the research program to solve the problem causing greatest loss of yield.

A tertiary objective of the on-farm testing program is training for the extension agent by introduction to a possible extension theme before its adaptation by the agency. Consequently, the need for further training of agents in the use of a new input identified by farm-level trials is reduced. The agent and his collaborating farmer have already handled the input and are familiar with its use so that it is not regarded by them as something equivalent to lunar dust when the agency adopts its use as an extension theme and tells the agent to begin its extension.

The agent and the farmer can also give preliminary feedback to the SAFGRAD coordination team and the extension agency about problems that might be encountered with its extension. An attentive extension agronomist can listen to the remarks of the agents and the farmers about a given test theme and combine these considerations with the yield results that he obtains from the tests to make a recommendation to the extension agency. This feedback, from farmers and agents, is also important in making modifications or adaptations of an input or theme so that it is more appropriate to the zone under consideration.

The agents also benefit from the manipulation of the testing methodology itself. The basis for recommendation of a new extension theme is derived from the quantification and comparison of treatments in their own farmers fields. With time the very process of quantification and comparison of treatments for the elaboration of extension themes could become the rule and not the exception. Hopefully, this process will substitute for the existing practices of choice of extension themes by the likes and dislikes of extension and donor administrators.

Though we can claim an effect of demonstration for the ag agents conducting the tests this is not wholly true for the individual farmer. In an organized extension process, farm-level demonstrations usually follow farm-level testing. The principal objective of farm-level tests being the elaboration of extension themes for a zone or ecological region considered to be the population by the statistician (extension administrator), the result of any one test means nothing by itself. No conclusions can be drawn from the results from one test without repetitions as there is no way to separate the possible beneficial effects of the input or theme from those of chance. Farmers are, however, exposed to the new theme and can be invaluable for their technical, social or economic feedback on the test theme. It is not too different from putting one's foot in the bath to see if it is too hot before jumping into a potentially scalding bath. There is general tendency among researchers to denigrate or underestimate the value of feedback that can be obtained from farmers exposed to a new technique, input or theme; they think of the farmer as bound by tradition to his present practices and unwilling to change whereas my personal observations lead me to believe that farmers are desparate to become more productive to be able to keep their offspring "down on the farm" and maintain a way of life that is threatened by obsolescence from lack of productivity. Researchers, on the other hand, as the priests of the modern religion called scientific methodology are bound to the bureaucratic rituals of research that dictate that "real" research is done in laboratories and research stations and not in farmers' fields and minds.

METHODOLOGY OF FARM LEVEL TESTING

Testing Program Definition

My first rule of thumb is "Preparation for next season begins this season or before". The acquisition of materials necessary for a testing program requires advanced planning but even more important is the advance acquisition and perfection of the ideas to be tested in a new season. This process of selection of relevant themes from researchers, extension agents, regional and international experts, farmers, previous test results and one's proper observations is the most challenging part of the testing program. Though the ideas come from many sources, once they are approved and accepted by the food crop research commission, there is little or no latitude to change them. The food crop commission tends to reduce proposed programs for farm-level testing and not increase them. I maintain a list of possible testing themes as they arise throughout the season from contact with farmers, agents, researchers in Mali, and regional or international investigators. This list is confronted with our own test results at the end of the year and with the experiment station results of food crop researchers to decide upon the components of a new program proposal. During the growing season we visit research stations and look for new varieties and themes for testing. As the farm-level testing coordination teams in the extension agencies become more experienced they propose more and more themes for farm-level testing based on problems identified by themselves and their collaborating farmers. Extension agency administrators often have express wishes for themes that they want tested in their specific zones and these are incorporated with other proposals to compose the program proposal to the food crop commission. As soon as a viable test theme is identified and thought out clearly I try to procure the necessary materials though we risk not needing the materials if the test theme proposal is not approved by the food crop commission. Seed of the hybrid maize variety, IRAT 81, for example have to be ordered a full year in advance.

SAFGRAD provides all of the inputs for the tests approved in the testing program so it is often difficult to make the budget for the peak periods correspond to the needs as the program can be reduced, or changed, well after SAFGRAD must submit the local cash budget for a given three-month period.

Finally the program proposal is composed and put into outline form for presentation to the food crop commission that meets at the end of March each year to review the results of each food crop research program for the past year and approve or change the proposed program for the coming year. Historically, the reaction of the food crop commission to SAFGRAD's proposed program has varied from 25% to 100% acceptance. The program is generally broken down into test themes and extension agencies and sometimes zones within the agency. The proposed type of test and number of each test type is generally agreed upon by the extension agency and SAFGRAD before the food crop commission.

Approval or rejection of the testing program is the major intervention by the research administration in the SAFGRAD program.

Though I might differ with some of the hasty decisions and the somewhat imperious manner with which they can be imposed upon us in the commission, I cannot disagree with the commission's right to make such decisions. Due to our ambition as a project we have often been criticized for trying to do more than believed in our realm of competence. It is true that the constant contact with farmers and agents wishing to develop and extend new themes has made us impatient with the seeming procrastination and over-caution of our colleagues at food crop research. Until recently there existed a certain amount of jealousy about the amount of financial autonomy that SAFGRAD enjoyed by comparison to other researchers that was compounded by friction caused by material benefits received by Malian SAFGRAD cadre not unilaterally available to food crop researchers. Like departmental politics in any American university, the annoying short-sighted vision of some research administrators has played a role in what SAFGRAD has been permitted to put in the ground. We have probably aggravated the friction between SAFGRAD and our research colleagues by our pride in the quality of work and data that we have acquired in farmers' fields. We have been too obvious with our criticism of what we consider to be lower quality and often less ambitious work by researchers working under much more controlled research conditions on research stations. The present atmosphere at food crop research is improving greatly and we are working closer with ICRISAT and Malian researchers with greater success.

In the month following the food crop commission meeting and before the national agriculture research committee meeting we are occupied with the last design of the tests and the writing of the protocols that are given with the necessary inputs to the agents and farmers at the beginning of the season. Materials are scrounged from wherever possible to get the necessary amounts. About nine tenths of our budget for purchase of local materials is spent within two months. It took one year to realize that the make-or-break point of our research program, once approved, is to get the materials distributed to the agents and farmers before cropping plans have been made by the farmers for the fields that we would like to have as test plots.

The national committee for agricultural research has been held every year at the end of April and a general, synthesized, version of the commission reports are presented to a larger, less specialized, audience. It is now to be held only once every two years. The periods cannot be put on the sentences describing the new program until after this committee meeting. Any changes of the program from the time of the commission to that of the committee can be considered for a last time. It was this committee that recommended a stronger, more effective, liaison between research and extension and that recommendation is the basis of the request from the Malian government to SAFGRAD to provide this liaison. One year we were lucky enough to receive a special mention for our efforts to fulfill this mandate by the committee. It is a more political body than the food crop commission.

Putting the Program in the Ground

Choice of Agent and Site for Test

In the past we would be contacting the extension agencies between the two meetings to decide on the placement of the tests in the approved program. By the time of the committee meeting we would have decided the zones of testing and the number of sites per zone with the respective agencies. After the committee meetings, with our official program in hand, we would organize trips to the zones to contact the extension head of the zone and decide with him the placement of the tests in the different sectors. Upon arrival at the sector level we would decide the placement of the tests with the sector head. The first year we chose the villages where we wanted to have the tests as a function of the wishes of the sector head. We found that many of the chosen agents felt punished and not priviledged to execute tests and this led to many incorrectly conducted tests. Consequently, we now ask the extension zone head or sector head to choose his best agents to execute tests and there has been a subsequent change in the quality of the tests as well as an increasing number of successful, exploitable, tests. The implications of the choice of the site as a function of the quality of the agent who will take care of it will be discussed later. On the national level we generally deal with the head of extension in the extension agency and then follow the administrative hierarchy of the agency down to the choice of the collaborating farmer. In the last two years this process has proven too onerous due to the increase in the number of tests to be implanted. There is too little time available between the committee meetings and the beginning of the season: approximately one month.

In 1981 when we went over 100 tests in the farm-level testing program for the first time we were in a constant state of crisis trying to get everything out to the field before the choice of new sites became impossible. The choice of new sites was hasty and the established tests were not visited soon enough to guarantee 100% successful planting.

This year we began the selection of new sites at the end of March and beginning of April. Our coordination team in Operation Haute Vallée had nearly 85 sites to select. A simple calculation was enough to know that they had to make use of the month of April to choose sites. In the past we have chosen the best agents, explained the protocol to them and then let them choose their cooperating farmer and then the two of them would choose the actual test field. Often the sites were too heterogeneous to suit our basic requirements for a test and had to be eliminated. This year we required our coordination teams to visit each agent who selected his cooperating farmer and then all three of them went and looked at possible fields before choosing the one most appropriate for the test. Though we don't yet have any results from this year we think that they are going to be better tests than ever before and that more of them will successfully finish the year and provide useful data. This process of individual pre-selection of sites down to the exact field should yield over 90% successful sites compared to 70% in previous years. The farmers know in advance that they are going to have a test and don't plan another crop for the field. The agent knows exactly where the field is located and tends not to procrastinate with plowing and seeding operations.

In other years the difficulty of preparing all the inputs for the appropriate test kits has impeded an early contact with the farmer. The inputs that we supply for tests include seeds, seed treatment, graduated seeding strings, a raingauge, fertilizer (weighed and sacked by trial treatment), plot labels with metal stakes, and experimental protocols. Despite efforts of better and longer advance planning for these needs, we either end up short of cash for this quick outlay for locally available materials, or we can't get the seeds or fertilizers necessary to compose the tests before the end of May. Thanks to the preselection of sites this year by the coordination teams in each extension agency, who went out to the field in April with only the approved program from the commission and protocols, we have had the time necessary in Bamako to prepare the inputs for distribution by the teams for their second trip to the field. The coordination team members are not hovering over us in Bamako waiting for the preparation of test inputs before going out to the field the first time. The addition of this trip before the beginning of the season will permit the total number of tests to depend upon the organization of inputs by SAFGRAD and not upon the rapidity of the coordination teams to get them out in the field. The use of the month of April to select sites and May to distribute the test inputs should permit a coordination team to locate and place at least 100 tests. If each extension agency placed 100 tests, the total testing program should be able to go over 500 tests in a given year because site selection and distribution of test inputs are the largest bottlenecks of the season. On down the road, when Mali wants to handle more than five hundred tests a year, it will be necessary to have a test program approved before the end of March to allow the necessary time for selection of new sites. By pure speculation, I would estimate a maximum of two or three thousand useful tests could be conducted and analyzed per year. The number of good tests per year could directly influence the speed of change of cereal production in Mali and is therefore constantly tempting us to put out a greater number of tests. The scientific basis for the desirability of large numbers of repetitions will be discussed in the section concerning analysis. It should be understood that neither research administrators, nor extension administrators, nor our donor administrators have put pressure upon us or even encouraged us to increase the number of test sites per year - it is our experience and the dictates of statistical methodology that have pressured us to increase the number of tests in order to respond responsibly to our mandate for better liaison between research and extension.

The choice of the test site and the farmer conducting the test has profound implications. Like any survey, the choice of the sample determines the relevancy of the data that is generated from the survey. If the sample is only representative of 5% of the population then we can only draw scientific conclusions for 5% of the farmers in a given zone. The statistical importance of the selection of our farmers and their fields to represent the desired portion of the total population escaped us for the first few years of on-farm testing. During the first two seasons we were primarily testing new varieties of sorghum, millet and maize that had given promising results on the Malian food crop research stations. In general, the new promising varieties did not yield better than the local varieties thus we had no themes to suggest to the extension agencies despite the usefulness of the testing results to the sorghum, millet, and maize breeders at food crop research. At the end of the third season of tests we obtained our first results from the effect of rock phosphate during two years and though they were arithmetically encouraging (we seemed to have finally found something that seemed to increase production) they were useless to any one extension agency for zone within an extension agency as the number of repetitions was insufficient to engage statistical significance. We had foreseen this problem by the end of the second test season so, without waiting for the third year results that confirmed our suspicions of lack of enough repetitions, we worked together with Operation Mils-Mopti to install fifty rock phosphate test sites throughout their zone. The installation of fifty sites in a given year with only one of the five extension agencies pushed us into an organizational phase of the project heretofore unkown. It was equivalent to our entire program in only one extension agency. We didn't have the vehicles and personnel necessary to devote to just one extension agency so we were forced to create a testing system that required financial participation by the extension agency.

At the end of the fourth season we had two years of yield data from this large number of tests and we could give the extension agency the statistical precision that is necessary to create an extension theme. We could tell them what yield increases to expect if the farmers in their entire agency were to adopt the use of rock phosphate on millet and peanuts. We could also separate the agency into three zones with statistically different responses to rock phosphate, that permits them to orient their extension priorities for this theme by extension zone. This was the first demonstration in Mali of the potential usefulness of on-farm testing as a tool for extension.

Our questions about the representativity of our testing sample in the sector of Douentza where rock phosphate had been statistically insignificant incited us to begin questioning the choice of our test sites in general and the degree of their representativity. The method we now use is a product of our experience of trying to obtain viable data, i.e. data reflecting (or not) the differences in treatments the tests is designed to measure. After the first two years there were no "positive" results and we didn't know if it was lack of real differences between the treatments or due to experimental error like the intervention of variables other than those of our treatments that could have a predominant effect; like date of seeding, soil preparation, lack of weed control, improper application of fertilizer or heterogenous conditions within the site. Consequently, each year up to the third year we made the conditions of testing more stringent, attempting to eliminate all other variables in order to measure more accurately the one or two treatment differences that we were testing. In our enthusiasm to reduce the effects of non-uniform variables we generally tried to get better agents and better cooperating farmers. This may have biased our sample so that the "positive" results that have been obtained may pertain to only a small portion of the farmers in the zone. Though this is a constructive and healthy criticism usually levied upon us by sociologists and economists, warranting our attention, things could be worse. We could have obtained no "positive" results. Logically, a given technique could prove "positive" for the better farmers in a zone and insignificant to the general population but this seems preferable in two alternative situations. One; when some theme is insignificant to the general population one doesn't know if it might be "positive" for a fraction of the population consisting of the better farmers. Two, if a theme is "negative" to the best farmers it is almost sure to be "negative" to the general population.

<u>Distribution of Inputs and Explication of Protocols to Agents and Farmers</u>

Up until this year the distribution of inputs for the tests occurred at the time of the first trip out to the villages when the agents were chosen, the farmers chosen and the protocol explained to farmers and agents. A more reasonable solution is to choose the sites, farmers, and agents, before the beginning of the season and use this normally "dead" time of the agricultural year to explain the protocol in detail to all concerned. We are especially concerned that the agent chosen to follow the test understands the protocol and is capable of explaining it carefully to the farmer, though, when the situation permits, we explain the protocol directly to the farmer, using the agent as an intermediary, and obtaining a union of understanding from the beginning.

<u>Role of the Extension Agent in the Execution of Tests</u>

It took us just one year to learn that the understanding and motivation of the extension agent is the single most important factor in the success of the test. To hold the agent responsible for the success of the test he must be allowed to choose the cooperating farmer that best meets the criteria for the test as outlined by SAFGRAD.

In the first few years of testing it was not immediately obvious to all of the agents chosen by the extension agency to conduct a test that the tests constitute a part of their official responsibilities. Until it was made clear by the headquarters of each extension agency that the tests constitute a part of the official responsibilities of a chosen few agents there were some recalcitrant agents and supervisors who were less than enthusiastic about conducting on-farm trials. It is time-consuming and often difficult to correctly execute a farm-level trial. Good agents have told us in the second year that they would prefer not having another test as they conceived of the tests as being too onerous for their time and abilities. Agents have often asked for some kind of recompense other than the gift of greater knowledge, reasoning that not all of the agents in an agency have to conduct tests thus they should be entitled to something for the extra work. Many complain that the amount of gasoline given to each agent by the extension agency is insufficient to cover the cost of travelling to a test that may be ten kilometers from their house every time there is a rain that must be recorded or some cropping operation that should be supervised by the agent. SAFGRAD is sympathetic to the plight of the agents, especially for gasoline for their mobylettes to follow the test correctly. We asked the extension agencies if they wanted us to intervene at the level of the agent with cash recompense or gasoline. In all cases the extension agencies have not wanted us to give any special privilege or payment to agents conducting tests as they consider the tests to be part of the official work and don't want the agents to become accustomed to some payment that cannot be continued by the agency when they eventually take over the management and financing of the tests in their extension zones. Frankly, I was surprised by this attitude in light of our readiness to support the cost of the tests to the agents to a greater degree but it is encouraging that the agencies are beginning to consider the tests as <u>their</u> tests and not just cooperation with research and SAFGRAD.

The agent is chosen at the sector or the sub-sector extension level and sought out by the SAFGRAD team or the coordination team. The experimental protocol is explained to the agent and he is asked to choose a cooperating farmer that fulfills the criteria (suitable field, oxen and plow, and some family help) and will cooperate closely with the agent. A messenger is usually sent to request the farmer to come to the agent's house and then the same explanation is given to the farmer by the agent in the local language. The farmer is asked if he wants, or accepts, to run the test under these conditions and is free to refuse. Often the farmers ask pertinent questions about the mechanics of the execution of the test that the agent answers or appeals to the coordination team member to explain. When the idea is clear to everyone, the group gets in a vehicle and goes out to the farmer's field to choose the test plot. Once in the field it is easy to avoid some of the heterogeneities that have led to cancelled tests in the past: trees in the plot, large termite hills, sterile spots; a history of Striga, excessive slope, inundations that would hold differential amounts of water in the rainy season, prior application of manure across part of the plot, or placement of the site in a zone that is abandoned by the other farmers for fallow and thus unprotected from marauding animals during the season, especially at harvest time. The presence of the agent, the coordination team member, and the farmer, together in the field at the same time also offers the possibility of obtaining supplemental information that might make a difference for the choice of the site, like the presence of Striga on a preceding cereal crop, the preceding crop, the history of the plot, the name of the soil type in the vernacular language and characteristics of the soil.

Consequently, the first job of the agent is the choice of the cooperating farmer and participation in the choice of the field, or test site. While he is waiting for the inputs to arrive and for the beginning of the rainy season he can measure stake the required plot.

When the inputs arrive he usually delivers them to the farmer who stores them at his house until rains permit plowing, spreading of fertilizers by plot and seeding.

We ask that all of the agents assist and advise the farmers for the spreading of fertilizers, the plowing, and the seeding. The seeding distances are specified in the protocol thus the agent is necessary to guarantee that the seeding distances are respected. He should attend the plowing to make sure that a minimum plowing depth is respected as well as a uniformity of plowing throughout the plot. Whenever fertilizer is to spread on the plot the agent must be present to ensure correct application because different fertilizer rates are often the objective of the test.

A raingauge is installed at the site of every test and the agent is asked to ensure correct reading of the amounts of rainfall after every rain. The site can be located far from the house of the agent so he asks a literate family member to take the daily readings that are periodically verified by the agent. Some of the farmers have undergone functional literacy training and have learned to read rain gauges at school.

During the season plant populations in the test are counted by the agent and verified by the coordination team. All dates of cropping operations are recorded by the agent in the protocol. SAFGRAD and/or the coordination team try to visit each site at least once a month and optimally once every three weeks. For these visits the agent is sought out and the progress of the test is evaluated in the field. Any particular problems to the site can be treated at this time. There is rarely a test conducted that doesn't provide some particular problem that is not general throughout all the other sites. The visit by the agent and the coordination team to the field may uncover problems that had escaped the attention of the agent. There is a certain security and importance given to the agent by regular visits by SAFGRAD or the coordination team. The agent can feel secure that the test is being correctly executed and the importance of the test is impressed upon the village by a visit from Bamako or the extension headquarters. After two or three years of cooperation with an agent, conducting tests is much easier. The agent has an idea of the relative importance of the different observations and information that he is expected to collect and feels more secure in his ability to successfully conduct a test. The growth of some of the agents in this respect is amazingly quick and provides the opportunity to conduct more than one test per year with one agent. With time, the quality of the test data increases as the agent learns how to conduct tests.

In the month of September, trips are made by SAFGRAD and the coordination teams to distribute sacks and instructions for the impending harvests of the plots. A particular emphasis is given to this operation for obvious reasons. The instructions to the agent outline exact harvest procedures.

We distribute sacks and tickets so that all plots are harvested separetely and put into labelled sacks to await the arrival of the SAFGRAD coordination team to shell the corn or thresh the sorghum or millet. The agent and the farmer are responsible for deciding the optimum harvest date. The agent must supervise the harvest and ticketing of the sacks. This has posed some problems in the past: an agent that doesn't go to see the farmer far enough in advance to make the harvest procedure clear, or a farmer that doesn't wait for the agent to begin the harvest. These sites are eliminated and the data is tragically lost. Now, that we ask all the extension agencies to give tests to only good agents and that the agents are asked to choose their own cooperating farmers, there is less of this sort of problem than before. The first year we asked agents and farmers not to harvest until we were present but we couldn't get around to all of the sites in a timely fashion and several sites were damaged by birds, or rain before we could get to them. After the first year, we have given the instructions for harvest to the agent and the agent can harvest before any damage occurs. Since we insist on the presence of SAFGRAD and/or the coordination team for threshing the harvested cereal, the harvest procedures are quite easy to verify. Poorly ticketed sacks, piles of unticketed ears or panicles of cereal, or inconsistent numbers of sacks by comparison to the observations made throughout the season, are cases that have arisen at one time or another and usually indicate a lacadaisical harvest procedure by the agent that leads to doubts about his presence at the time of harvest and eventual elimination of the site. Our basic rule is that if we have <u>any</u> reason to doubt the correctness of the harvest or the ticketing, and therefore the data, the test is eliminated.

After harvest, when the panicles are in the sacks, they must be protected from possible late rain, animals, or insects, until SAFGRAD/Coordination team arrive for threshing.

Threshing is usually done at the farmer's house. One of our inviolable rules is that the harvest should never leave the sight of the farmer. One of our objectives is to demonstrate a potentially viable technique or variety to the farmer, and in order to create and maintain the confidence of the farmer, it is essential that there is no equivocation concerning the equality of treatment for the varieties or treatments under consideration so that the harvest, threshing, and weighing, is done in front of the farmer. Several extension agencies have complained about the researchers, our predecessors in on-farm testing. It seems that Research has a tradition of paying the extension agency a modest sum for each test that is conducted in farmers' fields. At the end of the season the harvest was taken out of the field by the extension agent or researcher to thresh at some central location. Not only was all of the demonstration effect lost but sometimes the payment, destined to the farmer who had conducted the trial, was never received. Therefore we have taken extreme caution never to take the harvest out of the sight of the farmer as it constitutes, not only a demonstration of the theme but also his payment.

The farmer, his family and his friends are present for the threshing and weighing of the harvest. We count the number of panicles which gives us a check on possible mixtures at harvest or other errors. If we find that there is only half as many panicles as there were plants in the field then something else is wrong. Most of the experimental errors that we have found are obvious ones and these simple observations, and cross-checking of observations, can easily uncover them. We try to have two people read the scales when harvest weights are recorded. Tickets on the outside of the sacks are verified before the threshing occurs so illegible tickets can be checked against the ticket that is put inside of each sack at the time of harvest. We physically separate the sacks for the individual treatments so no one can accidentally drag up the wrong sack during the heat of the threshing operation and mix treatments. Moisture readings or grain samples for moisture reading are taken at the time of shelling and weighing maize. Sorghum and millet threshing is done from the last week of November until the middle to the end of January which is sufficiently long after the end of the rainy season to get uniform moisture contents though this should be verified when working in the extreme north where the low night-time temperatures reduce evapotranspiration and increase general levels of moisture until later in the year.

After the threshing and weighing we calculate treatment yields and group together the agent and the farmer to give a short talk on the implications of the results obtained from the test. We attempt to get a cropping summary of the year from the farmer with his observations about the introduced technique or variety. These meetings are frequently hasty and there isn't enough time to draw out the farmer's deeper observations as the threshing team may be trying to thresh two or three sites a day. Nevertheless the complexity and profundity of the observations of the farmers is often exciting. In sorghum variety trials where the introduced varieties did worse than the local varieties the farmers told us at the time of harvest that we shouldn't be too discouraged by the results!

They reasoned that even though the introduced variety didn't yield more in the test; they thought that the plant populations were too low for the introduced variety to show it's potential, or that the dates of seeding that we had recommended were too early as the introduced variety had flowered and come to maturity in rainy or humid conditions and had suffered from grain molds and bird attacks or that the introduced variety would do better in the growing conditions usually reserved for maize around the household compound where the organic matter content is higher and the water holding capacity is higher or that even though the grain yield was lower than the local variety, the stalks of the introduced variety were sweeter, more adapted to total stalk consumption by cattle as fodder, and their kids were even eating them. In this case of an introduced versus of the local variety there were some side effects that surprised us. Three years after SAFGRAD stopped testing introduced sorghum varieties we receive reports from some of the test zones that the introduced variety from our tests is being cultivated in particular microclimates that are chosen by the farmers. Farmers seem sorely underutilized as a source of feedback, invention, or adaption of introduced techniques.

Except where the test is pluriannual; the official duties of the agent ends with the discussion of the results with the farmer. He keeps a copy of the observations made throughout the year and the yield results. We sendhim a copy of the annual report. The more permanent test plots must be marked that wandering animals, or ill-intentioned neighbors don't destroy the plot markers.

History of the Farm-Level Test Coordination Team

No one decision concerning SAFGRAD in Mali has so affected the farm-level testing program as the decision to train several competent extension agents to supervise the test program in each extension agency. The reasons for this decision developed over the first two years. As can be seen in the Summary of Technical Achievements of the project, the first year we had about twenty-five tests that were spread throughout the country. My driver, my counterpart, and I were constantly on the road to follow these first 25 tests. We finally finished threshing in January and sat down to write our annual report and analyze our data. We had a total of twenty-five test including five different types of tests so we obtained about five repetitions for each type of test. We did a statistical analysis of the results and realized that we didn't have anywhere near enough repetitions to get statistical significance, even if the treatment differences were quite large. The five sites of a given type of test were sometimes more than 1,000 kilometers distant thus the coefficients of variation were quite important. In the end we had made twenty five rice observations by driving all around the country, nearly killing ourselves, and estranging our families, but their usefulness to the extension agency was nil. No one needed to tell us this when we presented our results, a cursory glance at the data is sufficient. We had to have more repetitions. The differences between varieties and the effect of the light dose of fertilizer were subtle enough that it was impossible to separate treatment differences (variety and fertilizer) from the lack of repetitions.

Many repetitions in a year of a given test are important for another reason as well. An important variable, if not the most important variable determining yield levels of cereal in Mali, is rainfall. If a trial is conducted in one place, for one year, with multiple repetitions, like on a research station, the results must be qualified by the fact that only one seasonal rainfall pattern was sampled. The results may not be viable, or repeatable; at the same place in another year. For wider applicability of the results, or for more precision in predicting what will happen in the future by the use of statistics, there are two choices. An investigator may repeat the trial, year after year, in the same place until he has sampled the population of probable seasonal rainfall patterns to the degree of confidance desired. For example, he may run the trial for five years in one place with multiple repetitions and determine that his results (a new fertilizer, variety or cultural technique) will increase yields by a given amount eight years out of ten. An alternative method is to replace rainfall sampling repetitions in space instead of time so that the trial conducted in five different localities (with different rainfall patterns) will be equivalent, for statistical analysis, to the same trial run in one place for five years. Though repetitions in time and space may not be 100% interchangeable, the remarkable differences of distribution of rainfall between localities that are not very far apart seem to permit us to interchange repetitions in time by more sites for our analysis. The degree of statistical precision obtained by complete interchangeability is more than enough to meet our criteria. The importance of substitution of repetitions in space for those in time is that Malians are poor and sometimes hungry. They are in a hurry to receive the benefits of agricultural science to increase food crop production and incomes. It is important that a zone of any extension agency could have thirty repetitions of the same test in one year and that the results were almost equivalent to rainfall averages for thirty years at one site. If the director of the extension agency decides, on the basis of test results, to extend a fertilizer, variety or technique, he has a high degree of statistical certitude that the fertilizer, variety, or technique, is not likely to fail due to a particular seasonal rainfall pattern. Consequently, he could begin the extension of the tested theme in the second year instead of running the test for ten years at three localities and beginning extension of the tested theme in the eleventh year.

Another beneficial effect of a large number of repetitions is that they can be grouped into sub-groups to illuminate differences between secteurs, zones, soil types, ecologies, or ethnic groups, where there is a significant difference in response to a given fertilizer, variety, or technique, from one sub-group to another. The response to rock phosphate in the OMM zone is a good example. The results after two years of testing rock phosphate showed that there was a significant extension zone effect of rock phosphate that was equivalent to more than the cost of the fertilizer. An analysis of the response by extension secteur showed that this general, significant response for the whole extension zone hid important differences between secteurs. In the secteur of Koro the response to rock phosphate was very good, there was a mediocre response in the secteur of Bankass, and the response in the secteur of Douentza was arthmetically negative but statistically insignificant. The director of OMM, with this data available, should have little question about where rock phosphate should first be extended.

The secondary objectives of on-farm testing like the training of extension agents and demonstrations for farmers are also maximized by conducting many repetitions each year.

The second year we doubled the number of tests hoping to get a number of repetitions that was within our physical and financial capacity and satisfy minimum statistical requirements. It pushed us to our organizational limits to take care of fifty tests. At the end of that year, when we analyzed our data, we had essentially the same problem of shortage of repetitions to be able to generalize over large areas with our data. Knowing that we had extended our human and financial resources to their limits, and still unsatisfied for the number of repetitions, we had to come up with an alternative system. This was especially necessary because the second year program included our first rock phosphate tests and the results in the first year were very encouraging in all locations. We had finally found a theme that we wanted to test across the country as quickly as possible. OMM asked for fifty rock phosphate tests for the third year which effectively doubled the size of our testing program. After discussion with OMM and AID, we agreed to distribute the fifty tests at the end of the second season if they would hire an expatriate agronomist (with a vehicle) who could follow the tests during the coming growing season. They hired Tom Remington, RPCV in the OMM zone, and he followed the tests after we had written the experimental protocols, provided the raingauges, peanut seed, seed treatment, seeding strings, plot labels and stakes.

Between the second and third seasons we decided that one of two courses could be followed. Either SAFGRAD increased in the budget for the vehicles and personnel necessary to put out more tests for all of the extension agencies or we had to encourage each extension agency to create a small group of extension agents to conduct the farm-level tests within their extension agency. After the enthusiastic response of OMM to increasing the size of the testing program by hiring an expatriate to follow the tests in the field we reasoned that this might be a model that could be used in the other extension agencies except that we would train experienced extension agents in research techniques and not advocate hiring five expatriate agronomists. OHV was interested by this approach and named one of their best agents to be sent to ICRISAT/India for training. Along with him went an agent from ODIK who would take care of the tests in his zone when he returned. We impressed upon the agencies the need to internalize this testing capacity as we don't know how long SAFGRAD will exist.

We were asking the agencies to provide someone who could be trained to supervise on-farm tests and a vehicle to visit the tests after training. There were our limiting factors for increasing the number of repetitions. Another advantage for the extension agency is that the coordinators would work for the extension agency and not for SAFGRAD or Research when they took over the testing program. The test themes should better reflect the needs and priorities of the extension agency and not the opinion of a researcher who may (or may not) be familiar with the zone and thinks himself qualified to decide what should or should not be included in the themes of farm-level trials.

We felt justified in going to the extension agencies with this proposal as our experience in the agencies led us to believe that there is a deficit of viable extension themes.

Our position within food crop research gives us access to the research results that can lead to viable extension themes. We felt that we had a product to sell to the extension agencies - research results, that should be in the direct interest of the extension agency to test. Therefore, they should finance at least part of the cost of the farm-level testing. Our job was to convince the agencies, by discussion and example, that the product that we were trying to sell was a worthwhile investment. Instead of considering the tests as some species of extraterrestial visit by researchers to their extension zone requesting permission to conduct tests with their farmers, we wanted them to internalize the problem of lack of viable extension themes and assert ownership over the tests. SAFGRAD would be a cooperating agency, similar to a free research consultant. The concept of having the agencies create a coordination team that would liaise with SAFGRAD for the execution of farm-level trials was the first vision of the model that is proposed in this paper.

In May 1979, SAFGRAD presented this model to the National Committee for Agricultural Research. It was approved along with our results and program for the 1979 season. I don't think that research administrators realized the amount of cooperation we were requesting from the agencies as they did not share our conviction concerning the number of repetitions necessary to make viable recommendations to the extension agencies based on farm-level test results.

Consequently we must justify, every year, the reasons for wanting a given number of repetitions of a given theme in a given zone. We don't always win this argument with research administrators and have had our testing program proposal reduced by more than one food crop research commission. /We had hoped that the approval of the model would lead to a demonstration of its usefullness and the marked lack of interested on the part of research administrators would become wild enthusiasm. The demonstration was quite clear this year after two years of rock phosphate data from OMM but the response from research administrators could not be classified as even mildly enthusiastic.

An agent from ODIPAC was trained during the third growing season but he returned to find that his extension agency was bankrupt and his services were needed in the field.

The ODIK coordinator has conducted tests for two years since his return from India and the OHV coordinator has had an increasing large program for the last three years. This year OHV decided to assign a second member, making it a coordination team, and they have 93 tests in the field.

The history of the coordination team in OMM is fraught with conflict and compromise. Tom Remington followed the tests in that physically greuling zone for one year and, though he had difficulty obtaining use of a vehicle, he was successful in obtaining good data. He was replaced by Tony Johnson last year and there were no problems with the agency until their AID financing was cut off. We received very good field observations which permitted us to define two new themes based on problems observed and quantified in the field (Striga and Chibra). The identification of farm-level testing themes based upon real problems from the field is superior to the generation of themes from the reports of food crop researchers that may or may not have been treating the most important problems faced by farmers. Tony Johnson was replaced by Jim Baird and it is hoped that he will be replaced by the OMM counterpart, Macono Tangara, who has worked with Tom Remington and Tony Johnson. The coordination team in OMM could conduct three or four hundred tests per year if food crop researchers would approve themes that justify this number of tests, and if the Malian replacements of the expatriate agronomists get the same support from the agency as the expatriates agency with the least potential for increasing yields has thus far been the most enthusiastic cooperator in the farm-level testing program.

Role of the Coordination Team

Some of the exact tasks of the coordination team have come to light in relief with the responsibilities of the extension agents. The long-term objective of the coordination team is to become fully capable of designing, executing and analyzing farm-level tests in their zone. The long-term presence of SAFGRAD or another suitable structure on the national research level, capable of fulfilling this function, is less likely than the continuation of the extension agency. For rhetorical purposes, one could say that since the primary objective of the farm-level testing program is to develop viable extension themes for the agency, if there is no agency then there is no need for extension themes. The process of developing this capacity in four or five extension agencies spread throughout the country with four different sources of donor financing is not as easily done as said.

ICRISAT/India, the coordination team member, had a succinct introduction to the techniques and theory of agricultural research in a serious research environment. This training, with particular emphasis on millet and sorghum, should be broadened by training at IITA on maize and cowpeas when the opportunity arises. We have had some difficulty obtaining places in these three-month courses at IITA.

The most important part of the training of the coordination team is out in the field while they are conducting farm-level trials under our supervision. What they are capable of doing in the first year is less than what they can do in the second. During the first year we try to accompany them on all pre-season visits to the field to choose test plots and explanations to farmers concerning the objectives of the tests and the respective responsibilities of SAFGRAD, the coordinator, the agent, and the farmer. If the coordination team member has evolved in the extension agency then he is usually a better interlocutor with farmers than we are. Later in the season, when the sites, farmers, and agents, have been selected and the crop is in the ground they visit sites without an accompanying member of the SAFGRAD family. At the time of harvest SAFGRAD sends a team and a thresher to the field with the coordinators.

During the analysis of the data we would like the coordinator to come to Sotuba to analyze his data with the help of the other SAFGRAD members. The yield tables and other tables (rainfall, plant populations, names of farmers, agents, geographic coordinates, and dates of seeding, weeding, etc.) are elaborated and then the yield data is analyzed. Each Malian who has cooperated with us, whether his origin be research or extension, has requested to do his own statistical analysis with the help of the more experienced members of the team. When analysis are complete, I meet with the coordinators and SAFGRAD members responsible for each group of tests and we discuss the possible conclusions and implications of the tests. I would like each extension agency coordination team to produce its own report independent of the SAFGRAD report, based on <u>their</u> observations during the year, <u>their</u> data and <u>their</u> conclusions drawn from the analysis. Only OMM has systematically written an independent report.

The SAFGRAD/Coordination team experience of a complete testing year then is focused on the proposal for the program for the coming year. Coordinators have more definite ideas after this first year about what should be tested in their zone in another season. By discussing the program possibilities with the coordinator, instead of meeting with the agency administrators for each proposal and change to the proposal, much time can be saved if the coordinator discusses the program with his agency administrators and they agree on program components. If the agency wants to make changes, they can be carried back to SAFGRAD by the coordinator, and incorporated into the SAFGRAD program proposal presented to the food crop commission.

Experienced coordinators intervene in the methodology of conducting tests. Researchers, (SAFGRAD ACPO's included), dream up tests and treatments that are unreasonable in light of the farmer's world that they are designed to improve. The coordinator tells us that he understands the objectives of the test but is in disagreement with one or more of the treatments, and for what reasons. We might design a farm-level test that requires twenty-five theoretic tons of manure per hectare. When the plot sizes are calculated and the amount of necessary manure known, the coordinator might point out that not only is that an unreasonably high rate of organic fertilization given the mean amounts of manure in the zone, but that he doesn't think that he could find an entire village in his zone with enough manure for one test.

In the second year the coordinator chooses his own agents, cooperating farmers, and new sites, without assistance from SAFGRAD other than the criteria for choice of these elements outlined in the protocol. While SAFGRAD members are preoccupied with the elaboration and presentation of the annual report to the food crop commission and the national committee, the coordinators can be out in the field choosing their sites for a new testing season. This jump on the normal unrolling of affairs permits them to have sufficient time to individually visit each new sites, farmer, and agent, before the rush of the new rainy season. Many more tests can be conducted by spreading the work load of a constraining time, (beginning of the season), to a more relaxed part of the year, (end of the dry season).

In this manner the coordinator takes over more and more of the responsibilities of the tests and the total number of tests can be expanded without sacrificing testing quality standards.

In the second season, SAFGRAD would visit all of the test sites, at least once, with the coordinator. They would be within easy reach should anything special arise that is beyond his competence and would visit those tests involving a new test subject three or four times during the season. In the third year there may not be enough time to visit every test in all of the extension agencies so SAFGRAD may visit sample sites. Some day the extension agencies should be harvesting all of their own tests and coming to SAFGRAD with data for analysis.

It should be noted that the role of SAFGRAD changes inversely to the change in the capacity of the coordinators. The objective of maintaining a small, highly trained, core of SAFGRAD personnel that coordinate the transfer of results from research to extension should be possible.

The Threshing Season and Data Collection

Maize harvest begins at the end of September and the shelling and weighing tour for the maize sites is usually finished before the end of November when the millet and sorghum threshing season begins. The testing program can be divided to spread out the threshing season to permit a larger number of sites if the threshing period becomes a major constraint. The threshing is almost always done in the presence of someone from the SAFGRAD team along with the coordinator from the extension agency.

It is the most opportune time to insure correct data. Correct data is our major responsibility to the Malian scientific community. We take pride in the correctness quality of our data. The time, effort, and care, necessary to execute, record, and analyze, a full research program without error is very difficult, even with multiple checks and controls. Not all researchers have been exposed to a rigorous scientific community outside of Mali and do not place enough importance on absolutely errorless data reporting and analysis. One frustrating part of my task to train my counterparts occurs when an error is discovered and shown to the person responsible for having made the faulty calculation. A common response is a shrug of shoulders. I don't fear the mistakes that are found but those that might not be found. As the program grows, a temptation will arise to deal less seriouslessly with the increased amount of data. Without absolutely correct data we are wasting funds provided by the donor, the time of the agents and farmers who conducted the tests and, our own time and effort.

The threshing season finishes about the middle of January and everyone is fatigued from the effort necessary to harvest sites spread throughout the country. After two months out in the field, in a perpetually hurried state of movement from one site to another, it takes a week or ten days to settle into the report season.

Report Season

After threshing, a different pressure begins to build that characterizes the report season. The annual report must be presented to the food crop commission in the third week in March and it takes about three weeks to produce the report; that is, type it on stencils, correct the stencils, make arrangements for running off the stencils, collate the report, and have a cover printed. Working backwards from the third week in March and subtracting three weeks for the reproduction of the report, that leaves essentially one month to collate the data, analyze the results, write the text of the report, verify all of the calculations, and then type and correct the final copy.

As we collect and analyze our results, we refine and change the proposal for the testing program for the coming year. When we are satisfied that we have all of the elements of the proposal for a given extension agency, we begin meeting with extension agency administrators so that the testing program proposal that we present to the food crop research commission reflects a consensusof opinion about what should be done in the coming year in each extension agency.

Finally the big day arrives, the reports are distributed, and the SAFGRAD report of yearly activities is presentedto the food crop commission. The food crop commission is designed to give particular emphasis to the examination of food crop research results by other food crop researchers and the extension agencies responsible for increasing food crop production. Formerly there was just one annual research meeting that united researchers from all of the disciplines in agricultural research for a three or four day encounter with extension people and other interested government services. This formula was found lacking as individual research could not be examined in detail and desired level of control of research could not be applied. A mistaken approach could go on for years without being subject to correction, comment or critical examination. Researchers felt that their results were not being applied by the extension agencies due to lack of understanding by extension administrators who didn't have enough time at this single annual meeting to help orient research programs towards the solution of the most crucial production constraints. The entire agricultural research program was growing larger and larger as trained Malians returned from overseas training to manage research projects. Consequently, another level of annual meeting was designed to alleviate the above problems. The food crop commission unites food crop researchers and extension agency representatives for three days of intensive meetings where all of the results for the past year are presented and reviewed by the commission and then the programs for the coming year are examined, changed, modified or approved.

The twenty minute presentation of the report to the food crop commission represents the end of the research year. The beginning of the research year starts immediately afterwards with a ten or twenty minute presentation of the program proposal for the coming year.

RESULTS

This section outlines my personal evaluation of the major achievements of SAFGRAD during the past five years. This paper has outlined the governmental structures, and relationships among structures, involved in the establishment of an infrastructure of liaison between food crop research and extension. I have described the beginnings and the modifications that have been made as it evolved. The structures that SAFGRAD reinforced and enlarged within food crop research, and the ones that were created within the extension agencies for on-farm testing, are our greatest contribution to increasing food production. These structures, tied together by SAFGRAD, have the capacity to expand and grow in a quantitative sense (more tests per year). Though our experience is limited to five agricultural seasons, we have laid the foundation that can be expanded and exploited more successfully each year by researchers and extension agencies.

The working cooperation of researchers and extension agents through appropriate government structures is unified by the definition, execution, and demonstration of a methodology that addresses problems common to both research and extension. Farm-level testing is a physical encounter of research and extension before we take pride, (perhaps too much), in the successful completion of more and more farm-level tests each year. The methodology of farm-level testing necessitates a distribution of tasks among researchers, SAFGRAD, coordination teams, extension agency administrators, extension agents in the field, farmers and donors. This paper outlines how those tasks have been divided in Mali. We have come to many forks in the road and chosen one direction or another without knowing what would have happened had the decision been reversed. It is impossible to satisfy all of the people all of the time but our repartition of tasks seems to satisfy most of the people most of the time. I have insisted (with obvious vanity) upon the creation of a methodology for liaison as the best method to guarantee that the success that we have enjoyed can continue to grow without me.

The validity of the methodology has not yet been demonstrated despite the execution each year of hundreds of tests. The major objective of on-farm testing is to establish viable extension themes for the extension agencies. The first two years there were not any promising results from the stations that we tested in farmers' fields. Since then we have shown that rock phosphate should be an extension theme in several extension agencies but the agencies haven't wholeheartedly adopted it and tried to extend its use. Actual extension of one of the themes systematically elaborated by SAFGRAD is the only way to know if the methodology fulfills its major objective. If the farmers within the extension agency use rock phosphate and get the same results as those predicted by our tests then the methodology is successful. If farmers react negatively to the use of rock phosphate and the yields are not affected as we would predict then it is a failure. If the results of extension of a given variety, technique, or fertilizer do not accord with the prediction made by our testing methodology one could suspect that our sampling technique is not representative and should be revised.

An important component of the infrastructure of liaison is training. The SAFGRAD team has learned to make the methodology work with diminishing involvement by me. Many tasks are now 100% executed by Malian agronomists, accountants, and drivers after a general decision has been made. As I relinguished chores to the Malian SAFGRAD staff, I could spend more time planning, and as they executed the tasks that I had formerly done alone, they became more involved in the decision-making process as our collective experience guided our new directions.

An example of this process is the design of a new experimental theme. In the beginning I would have had the idea and discussed it with my counterpart agronomists and then made the proposal to extension administrators to see if they were intersted in the theme, explaining the points of interest. If one is paying attention to research that is being done in the region, one can pick out probable successful research themes even before they come to Malian research stations, follow it as it is being tested in Mali, and then propose it for the farm-level testing program. Anyway we assume that such a theme was defined and it seemed to meet some constraint that we have observed in the field then we try to get it into our testing program. After the idea I would have decided on the most relevant treatments for different zones and the zones in which it would most likelty succeed. If research and extension administrators were agreed, we would put it out in the field after we had written the protocol. My team members would help me prepare the inputs, weigh the seeds, distribute and explain the inputs and protocol, follow the tests in the field, make observations until harvest, and then we would analyze the data and write up the results. My counterparts have learned to execute protocols without difficulty and have become important sources of information as they have been out in the fields even more than I by now. It has become more and more important to consult with them for the mechanics of the execution of a protocol, the best choice of zones, and the relevant importance of several alternative ideas for farm-level test themes. My trips to the field have become limited to control by spot checking testing programs that are too large to visit entirely. By sharing ideas with team members in the field, we solve problems together and then use the same solutions in fields that I can't visit.

The coordination teams in the agencies are chosen by the extension agency and trained by us to conduct and analyze farm-level tests. The training for three or six months at the international institutes is to expose them to a serious research environment and to give them the confidence necessary to design and conduct agronomy trials. By sharing common training experiences, we can share assumptions necessary to decide what most needs to be done in the testing program. Upon return to their extension agencies they handle the simple tests that we conduct with relative ease and with a good understanding of the reasons underlying the choice of treatments within a test. Then, because they are selected for having been good extension agents, they teach their fellow extension agents how to conduct tests and make the necessary observations. Having worked in the agent's environment, they understand the agent's problems better than from outside their bureaucratic structure. As within the SAFGRAD team, individuals excel differentially as coordination agents and there are many different styles of coordination as there are coordination agents.

One of the most surprising, and pleasant, developments during the five years has been the continually improving skills of the extension agents out in the field to understand and conduct farm-level tests. One can notice an increased understanding by the agents in the second and third year of cooperation with us. After the first year they know what has to be done and they get better at accomplishing it with more precision. Ultimately, this permits us to put our trials with increasing sophistication or trials with more detailed observations, making a higher return on our research investment. Some of the most satisfying contacts that I have made in Mali have been with individual agents out in the bush that work in almost impossible physical and bureaucratic conditions to make Malian agriculture more productive. Despite the increased workload that a test represents for an individual agent and despite the increased bureaucratic risk of making a serious mistake that could threaten job security, most of the agents welcome the tests and our frequent (and frequently bothersome) visits. Many individual sacrifices that have been made by agents for the sake of a successful test is a source of inspiration for us.

Almost all of the farmers that have conducted tests would conduct another one in the next year. Several have not wanted to be bothered by an insistent agent for plowing, seeding, and weeding, such a small field when their own bigger fields seem more important. Several have had a shortage of help to keep a test properly weeded and resign after the first year. Tests are often given to the farmer who conducts it by village consensus, or by the authority of the chief and his counsellors, in the hope that all of the village will benefit from the experience of one farmer executing the test. This gives a certain prestige to the chosen farmer in front of his peers.

Our second objective is to provide feedback to food crop researchers from farmers fields that could permit them to set priorities among the multiple alternatives of their research programs. What feedback SAFGRAD has given to food crop researchers?

The first and second year of testing featured varietal tests comparing introduced and local varities with, and without, the recommended low dose of fertilizer. I thought that we were going to revolutionize sorghum and millet production in Mali with the introduction of improved varieties that had yields reported from Malian research stations of ten times the average yields in farmers fields. With this kind of margin in our favor, we enthusiastically attacked the Malian sorghum, millet, and maize, growing regions with improved varieties released from food crop research and apparently ready for extension.

Simultaneaously, development administrators, both Malian and expatriate, were wondering why more farmers were not using fertilizers on sorghum and millet to increase total production following the drought. A few studies from the field indicated that the fertilizer was uneconomical for use on sorghum and millet. Extension agency administrators and agriculture ministry officials apparently refused to recognize this fact and wouldn't increase the official price of cereal nor reduce the price of imported fertilizers. In fact, the fertilizer subsidies that had been established earlier were being lifted and a national objective was to remove all fertilizer subsidies. Consequently, we put our varietal tests out in the with, and without, the recommended low rate of fertilizer for sorghum and millet thinking that we would generate sufficiently convincing data to demonstrate the lack of economic response of sorghum and millet to fertilizer to convince the ministry officials to take action and create a more favorable economic environment for the frequently expressed desire to increase food production in the country.

After chasing around the country for eight months conducting our first tests, we were the first ones to be surprised that the introduced varieties of sorghum and millet did worse, and not better, than the local varieties. On the other hand, the arithmetic means showed that the use of fertilizer was economically justified on local varieties of sorghum and millet, even if the return on investment wasn't very much and considered too low, on the average, to interest the subsistance farmer.

The improved varieties, in general, were not bred to withstand the varied pressures put on them in the many different conditions found in farmers fields. Our first problem was the difficulty of establishing acceptable seedling stands though germination tests prior to the season gave satisfactory results. Germinating seeds shrivelled and died before making it to the surface while the seeds of the local varieties were vigorous enough to overcome soil and climatic conditions unfavorable to emergence. The introduced varities seemed more susceptible to the deleterious effects of Striga. At the end of the season, the introduced varieties generally matured earlier than the local varieties and the late rains provoked considerable grain mold damage on them by comparison to the local varieties. What the late rains didn't ruin with grain mold, the birds took care of, as the earlier maturing introduced sorghum found itself as the first sorghum available to the bird populations.

Thinking that perhaps we had not chosen the best varieties available at food crop research and wanting to confirm the results of the first year we chose new varieties and new sites and conducted the same tests again in the second season.

At the end of the first season, we realized that fertilizers could have a larger impact on food production than varieties. Instead of carrying the bad news to Malian officials that fertilizer was uneconomical, we tried to conceive of a fertilizer scheme for sorghum and millet that would increase the return on investment by lowering the cost of the fertilizer. This led us to an interest in the direct use of Malian rock phosphates for food crops. They had been studied in Mali since the 1930's and the Germans had recently financed a project to mine and grind them for direct use in agriculture. Agronomy research in Mali had finished all of their research on rock phosphate and recommended their use by the extension agencies. Only one of our cooperating agencies had used them to date. We began a series of tests in the second year concerning the direct use of rock phosphate by comparison to its benefits in soils that are almost all poor in phosphorous would yield a greater return on investment than imported phosphate fertilizers. The advantages for the country of using a natural resource, found and exploited in the country, by comparison to importation of synthetic fertilizers, would be obvious if we could obtain the desired crop response to make it economically attractive to the individual farmer. This example illustrates how the choice of new themes can be a result of our testing program.

The value of the first year of testing of sorghum and millet varieties in farmers' fields (confirmed in the second year) was, ironically, from negative results. It was a perfect demonstration of the oft-stated "no correct results in research are negative". They were negative in the sense that they failed to identify new varieties that could be immediately multiplied and then extended to farmers through the extension agencies. On the other hand they may have been the most important results that we have generated in the five years of testing. Had we not systematically tested the improved varieties one could have assumed that there was an available genetic resource, ready for extension, that was not being exploited. The real value, or lack of value, of the sorghum and millet varieties that we tested may never have been quantified in farmers fields. Extension agencies could have taken them directly to farmers who would not grow the new varieties and researchers could be blamed for giving them varieties that did not outperform local varieties. Researchers would have pointed to the results derived from station trials and claimed that they had provided improved varieties but that extension agents were not correctly popularizing their use. Our results coincided with the arrival, in Mali, of the new ICRISAT sorghum breeder who could begin his breeding program without prejudice to previous results. We were able to tell him that seedling vigor, Striga resistance, grain mold resistance, photosensitivity, and consumer acceptability were the most important factors in the failure of the improved varieties that we had tested. He could bring modern breeding techniques to bear on these problems and more. This year, or next, we will be testing some of the sorghum varieties that he has developed in the last four years. This was an example of on-farm trial feedback to food crop research.

Our job is to increase food crop production in Mali by the application of research results to farmer conditions. The results of our first and second years convinced us that soil fertility was the factor limiting production that seemed most manageable by researchers, extension agents, and farmers alike, to increase sorghum and millet yields. This realization pushed us into testing the use of rock phosphate. We new that rock phosphate contains only one of the three macronutrients so we looked for methods of complementing the phosphorus in rock phosphate with a suitable source of nitrogen. Malian soils are relatively rich in potassium so we were less concerned with providing potassium from an outside source than nitrogen.

It seemed that there were two possible sources of nitrogen that could be tested to complement the phosphate rock. One of them was from imported nitrogenous fertilizers; urea, amonium nitrate, etc. The other source was nitrogen fixed by grain legumes; especially peanuts, but also cowpeas and bambara groundnuts. The amounts of available nitrogen in manure were not enough, unless applied at unrealistically high rates; to provide appreciable amounts of this element.

Our rock phosphate protocol included treatments that compared the efficiency of providing nitrogen from urea and from grain legumes. We couldn't measure the effect of the nitrogen fixed by peanuts until the end of the second season. In the meantime we compared the effectiveness of urea against its cost.

The effect of urea at the end of the first year surprised us. It was statistically insignificant and, though the urea treatments usually had mean yields higher than those treatments without urea, the difference in yields never justified the cost of the urea. Unsure if this lack of economic response to a single low rate of urea was due to a real lack of response, or some fault in application, we ran the same treatments a second year in all of the rock phosphate test sites (which were much more numerous the second year than the first year), and we obtained the same results. Urea, at the rate of 90 kg/ha was not economical to use on sorghum and millet, in combination with rock phosphate or not.

By the time that this was confirmed, we had our first results on the effect of peanuts on cereal yields that followed it and were encouraged by the results. On a small number of sites peanuts increased sorghum and millet yields by about 200 kg/ha, and this was statistically significant. These same results confirmed a year later on a much larger number of sites. These results confirmed results that had been obtained on research stations by IRAT researchers for almost twenty years so it was not a new discovery, but a confirmation of the utility of peanuts as a preceding crop in farmers' fields.

In the grain legumes literature there are examples of a strong interaction between the application of phosphorus to phosphorus-poor soils of West Africa and the benefit of a grain legumes as a preceding crop. The theory is that grain legumes will fix significantly more nitrogen in the presence of phosphorus than will be fixed without phosphorus. Our treatments permitted us to test this hypothesis as the director of OMM wanted to quantify the interaction for another reason. OMM had been created to stimulate the production of millet in the fifth region to provide millet for the national cereal marketing board that in turn supplied millet to the population centers, especially to civil servants.

The director of OMM was not anxious to do anything to endanger the amount of millet marketing annually by the agency. Millet is difficult to make into a cash crop as it is the major food crop for the zone. Some cash crop seemed to be needed to serve as a motor for the inputs necessary for increased crop production in general; animal traction equipment, fertilizers, pesticides, etc. At that time the most likely candidate for a cash crop was peanuts. Though it would have been relatively easy for the agency to begin marketing peanuts, and providing the necessary inputs, the director of OMM was hesitant to begin such a program as he feared that farmers would abandon millet cropping to gain cash from peanuts. We thought that the use of rock phosphate along with the beneficial effects of peanuts might sufficiently raise millet yields so that any potential loss in millet land to peanut cropping would be compensated: Total millet production, thus the agnecy millet marketing quota, would not be endangered and farmers would have the necessary cash to invest in agricultural inputs. The validity of this reasoning depended partially on the assumption of a positive, and statistically significant, interaction between rock phosphate and peanuts, so that the effect of the two practices used together would be more than the sum of the two individual practices.

Across the forty sites in the OMM region we did not show any interaction effect though rock phosphate was significantly vialbe (200 kg/ha cereal in two years) and peanuts as a preceding crop was significantly viable (about 200 kg/ha cereal due to peanut as the preceding crop).

Our sites planted to sorghum in the OHV zone (higher rainfall) showed some interaction but it was also not statistically significant.

To resume, we have been able to demonstrate the beneficial effect of peanuts as a preceding crop that we assume to be due to the nitrogen fixed by peanuts and left for the use of the following cereal crop. This is not a satisfatory solution to the problem of supply of nitrogen for food crops as the amount of land cultivated in peanuts in any given year, in any zone, does not equal the amount of land planted to sorghum and millet. I would guess that five to ten times the area planted to peanuts (or a sum of grain legumes in pure stands) is planted to food cereals.

A question for the future would be to compare the rotation, peanuts-cereal, with the rotation, cereal intercropped with cowpeas-cereal intercopped with cowpeas: in the presence and absence of rock phosphate to compare the effects of peanuts as a preceding crop to the more prevalent practice of continual cereal intercropped with cowpeas. The cereal-cereal rotation would be maintained as a check.

A warning about the generalization that we have made concerning the uneconomic response of millet and sorghum to urea would be that this does not seem to be the case for maize. We have not conducted specific tests to measure the response of maize to urea, but indications from our maize varietal tests where three different doses of nitrogen have shown almost a linear response to nitrogen up to 120 kg/ha. Soil scientists at Sotuba have shown a linear response of the hybrid maize, IRAT 81, to 250 kg N/ha. We may be getting more than 20 kg of maize per kg of nitrogen in farmers' fields.

The results of our work on rock phosphate are the best known and we have run so many rock phosphate tests that "SAFGRAD" has almost become synonomous with "rock phosphate".

Work that had been done on Malian research stations indicated the viability of rock phosphate long before we began testing it. Our job has been to quantify the beneficial effect of rock phosphate so that an extension agency can decide whether it is economical for their farmers to use it on food crops in any given ecological zone.

In general, rock phosphate becomes soluable, thus useful to crops, as a function of the pH of the soil. In general, the pHs of the soils are a function of annual rainfall, so that the more rain a region receives, the more the soil is leached, the lower the pH, and the more it would be expected to react to rock phosphate in a given amount of time. One would expect to get the best results with rock phosphate in southern Mali and less results in northern Mali. It becomes important then, on a national level, to find out where rock phosphate is economically viable, and where it is not. This implies tests over several years, as the reported effect of rock phosphate can last up to five years.

It was far from certain that rock phosphate would significantly increase yields in the dry fifth region where we placed a large number of tests. Even if it increased yields, it was even less certain that the yield increase would economically justify its use. USAID and OMM administrators asked us to run trials on farmers' fields to answer this question in the shortest amount of time as possible. Food crop researchers working for fifty years on the research station that is found in the OMM zone could not have answered that question with the same degree of precision as we could in three years of farm-level trials. The advantage of farm-level testing over research station testing of this question is purely statistical. The physical variables affecting the usefulness of rock phosphate are rainfall and soil characteristics. Given a long enough time at any one place the mean rainfall would probably have reflected the mean for the zone in which rock phosphate use was to be used, but, no matter how long one worked at one point in the zone, one could not arrive at a mean soil response that would predict the mean of the zone. The best, if not the only, method of arriving at the mean soil reaction to rock phosphate for the zone is to test throughout the zone, sampling the different soils for which rock phosphate is going to be recommended or discouraged. Though we are often accused of not being "real" researchers, due to the fact that we are working in farmers' fields and not on research stations, and because we use large plots with a secondary objective of demonstration, and because we don't have repetitions within a given farmer's field, and because our farmers' fields also often have trees, termite hills, and other variables not found on research stations, the testing of rock phosphate in the OMM zone is an example of how farm-level tests are useful research tools as well as tools for extension.

In fact, what we found was that not all of the zones of the OMM region react in a similar manner to rock phosphate and the difference was so great that, though rock phosphate should be extended for farmer use as soon as possible in one of the zones, it should not be used in another zone unless further testing shows that our samples were unrepresentative of the zone. Besides being invaluable to the extension agency that learned where it should begin extension of rock phosphate, and where it should hold off, the tests were a triumph for farm-level testing as a research methodology. Some questions related to the practical use of a given variety, technique, or fertilizer, for a given zone are best answered by farm-level testing and not by continually more elaborate research station trials, even if the research station is in the zone of the extension agency.

The last of our concrete results during the four agricultural seasons has been farm-level proof that the maize hybrid (actually double hybrid), IRAT 81, is superior to the most popular, open-pollinated, mass-selected, improved local variety, Tiemantie de Zamblara. The difference between the two varieties of about one ton per hectare is confirmed by 31 farm-level tests conducted during two agricultural seasons. The difference is statistically significant to highly significant and the coefficients of variation were 17% and 34%.

Despite these extremely good results, no IRAT 81 seed was sold to farmers and probably will not be sold. Some effort of multiplication is being made by the seed production section of the Mali Sud project. This is not disconcerting to us as it might seem as the original objective of the comparison was to take what seemed to be the variety with the greatest amount of potential, compare it to the best local variety, and see if a potential for varietal improvement could be demonstrated or not. If so, did the hybrid variety require higher levels of fertilizer to maintain its superiority, or did it do better than the local variety even in lower fertility conditions? It turns out that it significantly outyielded the improved local variety at all three levels of fertilizer application, the lowest being 46-0-0 per hectare and the highest was 118-46-28 kg per hectare.

After testing improved varieties of sorghum and millet against the local varieties and finding out that the improved varieties didn't significantly yield more than the local varieties, we asked ourselves if any of the so-called "improved" varieties for any of the cereal species yielded better than the local varieties. We went to the top of the scale for improved maize varieties and selected IRAT 81 for comparison with the improved local variety Tiemantie, that had been demonstrated superior to the unimproved local varieties of maize in our first season. Between Tiemantie and IRAT 81, there exist hundreds of open-pollinated varieties of maize that are potentially better than Tiemantie and probably less productive than IRAT 81. None of these varieties had been throughly tested on Malian research stations and were not available to us for farm-level testing. Therefore we tested what we considered to be the variety having the highest potential for increasing yields over the local varieties, reasoning that if the results were negative we would not waste our on-farm testing effort on varieties that were less productive than IRAT 81 on research stations. If the results were positive, as they were, then two things could happen. From the differences between the two varieties we could calculate the feasibility of producing IRAT 81 seed in Mali (see annex) and/or test those open-pollinated varieties that fall between IRAT 81 and Tiemantie in yield trials on Malian reserach stations.

Several political and practical considerations should be underlined here. There were two prevalent criticisms of the use of hybrid maize in our tests. One was that hybrid varieties require high levels of inputs to be equal to or superior to local varieties. Though this one was banished by our field data in the first year, the second one is persisting until now and has a certain amount of merit. IRAT 81 is a hybrid maize which means that farmers would have to buy new seed each year or suffer yield loss due to degeneration of hybrid vigor in the following generation. Farmers in Mali produce almost all of their own seed due to the young seed production industry run by the government and the failure, heretofore, to identify improved varieties of sorghum, millet and maize (with one exception) that will consistently out-yield local varieties and merit multiplication. It was felt, by research and extension administrators, that Mali doesn't have the capacity to produce and deliver hybrid maize seed, even less, seed of a variety that is a double hybrid. This may be the case but a superior variety has been identified and proven superior in farmers fields' to all other varieties. Researchers, and extension administrators, should question their assumption that hybrid seed cannot be produced in Mali in light of the facts, or real differences of yield, that exist between IRAT 81 and the best of the local improved varieties.

We are proud of these results but we are not recommending the use of hybrid maize. We are trying to use our data, and the data generated by other researchers, to incite Malian decision-makers to reason on the basis of the experimental facts.

The World Bank has financed a large development project in the Mali-Sud zone which is the major maize-growing zone in Mali and most concerned by IRAT 81. An expatriate agronomist was hired to begin a maize seed multiplication farm north of Sikasso. Many of the promising open-pollinated varieties from CIMMYT, IITA, and IRAT, have not been properly tested in Malian conditions.

Being outside the official research structure, he was impotent to speed up the official testing of these varieties. Consequently, he has circumvented the official structures and proceeded to test many varieties in the Mali-Sud zone. He felt that there were many alternative varieties to IRAT 81 that would yield from 90%-100% as well as IRAT 81, and because of their open-pollinated character, would be easier to introduce and maintain in farmer conditions. He claims that one of the open-pollinated parents of IRAT 81 is just as productive as IRAT 81. The major potential user of IRAT 81, Mali-Sud, is not convinced of its usefulness and remains unprepared to produce hybrid maize seed.

One of our most frustrating experiences has been the attempt to get more results out of agronomy research and into the farmers' fields. The problem with testing open-pollinated varieties of maize from IITA, CIMMYT, and IRAT, in farmers' fields is indicative of a peculiar attitude prevalent among food crop researchers. It frustrates me and frustrates the extension agencies trying to get access to research results for use in their extension zone. Researchers seem determined to hold onto genetic material and improved techniques until there is a unanimous and popular bureaucratic decision to try them in farmers' fields. Maize breeders want to test varieties (not bred in Mali and already tested in surrounding countries for three to five years) for three to four years in Mali. As we showed with sorghum varieties recommended by food crop research, positive results, to the satisfaction of researchers and research administrators, are no guarantee that the varieties are appropriate to farmer conditions. One has the impression that varieties will not be released by better varieties. In which case, research administrators so no point in releasing them. Agricultural research decisions are highly centralized in Mali. One man is judge and jury, deciding, almost by himself, what will, and what will not, be given to extension; despite the existence of progressive research commissions designed to fill this function. Lip servie is given to ideal that food crop research exists to the needs of the extension agencies, but the delegate from the largest extension agency has no more power over the outcome of the commission decisions than the greenest of ag college recruits. No amount of reasoning based on scientific data can prevail if the obvious outcome is distasteful to the hierarchy of agricultural research. We have tried, unsuccessfully, to get research administrators to evaluate the risk of permitting a theme to be tested in farmers' fields before refusal. Never has a farmer complained to any government official that we had precociously tested a theme in his field.

Therefore, an unfavorable environment for research on hybrid maize exists, and the maize breeder for food crop research refuses to release open-pollinated varieties that could be alternatives to the hybrid variety. We find ourselves in a difficult position, though we are not trying to push the introduction of hybrid maize, we do have data proving its superiority and can't get access to open-pollinated varieties that could challenge that superiority.

PROBLEMS IDENTIFIED FROM FARM-LEVEL TRIALS FOR FOOD CROP RESEARCHERS

Some of these problems have been discussed in the previous section and will be but brushed upon in the resume. One of our objectives consists of quantifying problems encountered in farmers' fields that could be solved by food crop researchers. They could use this data to prioritize their research programs. In reality, this is some ways on down the road but some progress has been made that merits attention.

Our work on the use of the low rate of fertilizer recommended for sorghum and millet showed that there was a 7%-12% return on investment. Our farmers are most likely unrepresentatively good farmers, thus most likely to have higher returns on investment than could be expected if the low rate of fertilizer were adopted by all farmers. This probably explains better than anything why so little fertilizer is sold to farmers for use on sorghum and millet, and should have been a challenge to food crop researchers, as it was to us, to derive alternative schemes for fertilizing food crops. Food crop production is probably more affected by soil fertility than by any other manageable factor; to deprive farmers of rational and economically viable schemes for improving soil fertility is to deprive him access to rapid increases in yields. To continue to passively recommend an economically unviable rate of fertilizer in light of our data is to unestimate the problem, or to believe that there are no alternatives. Rock phosphate is a viable form of phosphorous that can be made available to Malian farmers should extension agencies be convinced to do so. Manure is becoming more available in those zones where animal traction techniques are progressing toward a better integration of cropping and livestock management. Potassium will probably not become an economic problem for quite some time even in the highest yielding zones. The research problem for fertilization of food crops is to find an economical form of nitrogen to provide for the doubling of yields that are otherwise possible, even under sub-optimal rainfall conditions.

Every year the problem of Striga arises as a major problem encountered in farmers' fields and not encountered, to any great degree, by researchers working on research stations. Last year, our coordinators in OMM and OHV, underlined Striga as a major factor decreasing yields of sorghum and millet in our rock phosphate tests. We are running separate tests to deal with the factors influencing the effect of Striga on millet and sorghum; fifteen sites in the OHV zone concerning the effect of Striga on sorghum and fifteen sites in the OMM zone for its effect on millet. The S.R.C.V.O. weed science specialist has welcomed our cooperation on these tests as a starting point to understanding the parameters of the problem of Striga on food crops in Mali.

Millet has some wild forms of its species that will outcross with it and give a plant called "false millet". It is very obvious in the field any time after flowering. Some zones are heavily infested with this semi-domesticated species that yields only very small grains, is almost impossible to separate from its chaff, and actively competes for the same water and nutrients as cultivated millet. We are cooperating with food crop researchers to attempt to measure the amount of yield lost to this competitor.

One of the problems of the higher rainfall, and higher yielding, zone of Koutiala in the CMDT, is the source of forage for animals that are kept at the compound instead of being permitted to roam. Crop residues and cotton seed sufficed for the most part of the last twenty years as the farming systems were changing rapidly and only recently developing the fruitful potential of a symbiotic marriage of livestock fattening and crop production. Cotton seed has become less available as oil is now being extracted from the seed instead of making it available to the farmers for livestock feed. Despite many years of research throughout Africa to find productive forage crops that can be grown by small farmers, the best forage crop has been local varieties of cowpeas. We are trying to encourage the screening of the collection of cowpea varieties available at food crop research for improved forage varieties.

In summary of this section concerning the identification of problems in the field that can be transmitted to food crop researchers for solution via this extension-research system, it should be said that this aspect of our objectives could be greatly improved. Hopefully, that more and more researchers will take advantage of the farm-level testing program to identify and quantify problems, and then implement research programs for solutions.

Perhaps the most exciting potential for feedback to researchers is the existence, on the village level, of an accumulation of thousands of years of empirical experience dealing with the production of food in this environment.

One of the obvious uses of the SAFGRAD cooperating farmers has been the collection of some of the local varieties of food crops for use in research breeding programs. We helped with the collection of Malian varieties of sorghum that have an indigenous name equivalent to "Striga resistant".

Another continuing effort has been to constitute a Malian collection of bambara groundnuts from the different zones of Mali. I hope to leave about two hundred entries in that collection that need to be screened on the research station, described by characteristic descriptors, and catalogued for use by breeders.

There is, however, an even greater potential contribution to food crop research that can be made through the farm-level testing program. I have recently become convinced that farmers are sorely underutilized as a source of knowledge about the environment, and more specifically food crop production. Some of the problems that are identified in the field by us, or other observers, and then transmitted to researchers for their solution, could be refined by a systematic questioning of farmers by researchers before an actual research project is launched. Farmers are an important source of feedback and make good consultants by their acceptance, rejection or modification, of themes proposed by research and extension. Bambara farmers are naturalists, observing carefully the plant and animal kingdoms that constitute their worlds. This empirical knowledge is generally passed from one generation to another while cultivating, hunting, and talking together; day after day, week after week. Educated Malians rarely realize that they sacrificed a traditional education, one explanation of the macrocosm, to acquire a modern education. The complicated bambara botanical vocabulary is indicative of its sophistication.

Upon return to Bamako we went back to the Land Use Inventory Project (which is across the street from our offices in Sotuba) and asked for their correlations between bambara soil-vegetation classification units and the American ones that they had been imposing on Malian land for the last four years. We found that no attempt had been made to even find out what system the bambara might process for classifying the land in their zones. There is a general disregard for potentially important and useful information that is known on the local level and not tapped by the expatriate and Malian experts working on the problem. In the future, SAFGRAD can do more to bring researchers in contact with knowledgeable farmers, or bring information from knowledgeable farmers to the researchers. This aspect of the work is fascinating in as much as the methodology that is going to win the confidence of the farmer is going to be the one than can best manipulate the environment for the good of the farmer. They have been at it for thousands of years. The tool that we have at our disposition, scientific methodology, can be used to measure the best manipulation of the environment in this contest between local traditional practices and the western bag of tricks developed in different environment.

THE PITFALLS OF PRE-EXTENSION TESTING AND RECOMMENDATIONS FOR THE FUTURE

General Comments

The basis of the farm-level testing program is to provide extension agencies viable extension themes. The lack of these themes has already led to the failure of several extension agencies. To change the principal objective of farm-level testing would be to change the entire system that has been created to date.

One of the secondary objectives of the testing program has been to provide a demonstration of improved varieties and techniques to extension agents and farmers. This can be done better than we have done it. More attention must be given to the agent-farmer complex instead of only to the agent for the correct execution of the tests. There should be more "farmer day" demonstrations of good tests to enhance their effect on the extension of promising themes and to expose more farmers to the experience. These would not be difficult or expensive to accomplish at the time of harvest, when a slow, clear calculation of the economic benefits of the improved technique could be elaborated by the coordinator or SAFGRAD team member. Farmers could give detailed feedback to the test. Effort needs to be made to get the extension agent to take the annual SAFGRAD report back to the farmer so that the farmer can understand how his results corresponded to those of other farmers conducting the same tests. Little of this have been done.

There are many types of problems that do not lend themselves to farm-level testing and that may have as big or bigger effect on production than the themes that we are testing. An example is the role of farm machinery in the production scheme. We could test the effect of plowing on yields, but the major effect of animal traction will be the amount of land that a farmer will cultivate in a given year. Many production decisions are based on factors out of the control of the individual farmer; like official prices for farm products. We could demonstrate the beneficial effects of peanuts on the following cereal crops and not change the amount of land dedicated to this crop unless the price of peanuts changed as well. We can prove the beneficial effect of ten tons per hectare of manure to millet farmers in the Seno, but if there are only miniscule amounts of manure available, it will serve little purpose. Themes for farm-level tests must be selected, not only on their agronomic merit, but also on the realistic possibility of the farmer to implement the technique should it prove beneficial.

In the month of March before the first growing season we could not find of the seeds of improved varieties that had been approved by the food crop commission for our testing program. The director of food crop research shook his (pretty) head and said; "Oh well. I guess you will have to wait until next year to begin testing in farmers' fields". We found the seeds and put out the tests, but the situation was indicative of the height of unpreparedness for the testing season that has gotten better each year.

It is still far from what it will need to be in order to execute several thousand of tests in one year. This year, for the first time, we chose many of the new test sites well in advance of the rainy season. The next most limiting factor for the expansion of the testing program is the limit imposed by approval of the annual program at the time of the food crop research commission at the end of March. If SAFGRAD is going to test improved varieties of maize, millet, sorghum, or cowpeas, and the decision on the varieties to be tested cannot be made until the end of March, it is impossible to produce seed between the decision and the beginning of a new season. More than once, we have multiplied seed of promising varieties that the food crop commission did not authorize to test in farmers' fields. Other varieties could have been authorized but the seed necessary for the area of our tests was not available from the plant breeders and we could not conduct the tests. Hybrid maize seed must be ordered in May of the year before the season that you want to use it. Some test themes require a soil treatment in the fall and this impedes us from proposing them as tests because we wouldn't know until March if they had been authorized. Some plot preparation might be desirable in the growing season before the one in which the tests are to be conducted. It would be optimal to establish the entire testing season program just one year in advance. Once the crop is in the ground, meetings could be held with the extension agencies to outline the themes to be tested the coming year. Though the theoretical role of the food crop commission cannot be disputed for the annual organization of agriculture research in Mali; in reality, the major decisions are made by one or two people. The decisions are not always directly related to the available scientific data. One must ask if these decisions could not be made before late March. This year, for the first time, I am trying to work out a new program with one of the extension agencies. They want to conduct three hundred tests next year. We have met and agreed upon seven themes for farm-level tests and they are going to address a letter to the headquarters of agricultural research for a preliminary acceptance, so that the necessary preparations can be made, by them as well as us, to allow such a large program to be executed.

Observations on the Statistical Validity of Farm-level Testing

Statistical analysis of the results of on-farm tests is potentially the most valuable service that we have to provide to the extension agencies. Extension agencies are not requesting greater significance of our tests. For the most part, they do not understand the usefulness of statistical significance in a farm-level testing program. This is indicative of the fact that they do not recognize a need for extension themes that are guaranteed to be viable. The prevalent attitude amongst extension administrators is that farm-level testing should be done, that they are intrinsically good, but the relationship between farm-level testing and new extension themes is not clear. Last year we began to attach more importance to the statistical significance of our tests though we had been doing statistical analysis of our data since the first year. If it is agreed that farmers will eventually adopt the system of agriculture that best manipulates the environment to their advantage, then we have to have a tool for predicting the ability of a given technique to manipulate the farmer's environment. Statistics is that tool. If our farm-level test results indicate that a given technique or variety will increase yields by 20%, if implemented in the same conditions as our tests, then it should average that yield increase, in 95 out of 100 cases, or there has been a mistake. We have not had definitive feedback necessary to know if our predictions for yield increase based on our test results are true or not as no extension agency has not yet attempted a systematic extension of a test theme and then measured the effect of the theme on yields. Until this happens, we will never know if our predictions are correct, or not. We expect them to be correct, but if they are drastically different from the real effect, (for better or for worse), then we would suspect that our sample (test sites used to derive the predictions for the general population) was unrepresentative. We have tried to eliminate all other sources of error, but the last step in the development of our model is to verify the representativity of our sample for any group of tests. We have worked hard to provide research and extension with reliable data and this has meant that our choice of farmers, though most likely to give us good data, is probably biased in favor of the richest, and most productive, part of the farmer population. For example, we are conducting rock phosphate tests and would like to make sure that the rock phosphate is incorporated for agronomic reasons. Incorporation necessitates choosing a farmer who has animal traction equipment, and only about 40% of Malian farmers have this equipment. One would suspect that they are the most progressive farmers in the population. Does this mean that the results acquired from our rock phosphate tests are applicable only to farmers with animal traction? The yield increase predicted from the test data would probably not be the same for farmers without animal traction. It could have a better, or worse, effect on these farms. This is an example of how one must choose the target population within all the farmers in a given zone and then sample within the target population in a random fashion and restrain the recommendations derived from the sample study to the target population. In this case, it would not be impossible to have the basic number of repetitions with farmers owning animal equipment <u>and</u> with farmers not having access to animal drawn equipment. A comparison of the results to see if they constitute significantly different target populations with regard to the response to rock phosphate must be made. Some might think that a good agronomist, extension administrator, could solve this without testing by just going out and looking at the response in the field. However, the results of tests could imply a planning decision that would take four or five years to verify.

If IRAT 81 proves to produce a ton per hectare more than any of the alternative varieties, it would take an extension agency three to five years to establish a seed production scheme to supply the farmers in their zone with the necessary amounts of seed. In such a case, the agency would want to be very certain that the sample was representative of the eventual users the hybrid maize seed.

Farm-level test data can remain viable for a long time. Unless there is a change in the baseline population of farming practices, or in the weather patterns (already averaged over many sites or years) then the relevancy of the data should not change. Our greatest critics have been economists and sociologists that claim that our samples are not representative. This aspect of our sampling has received too little attention and if someone would show us how it would be adviseable to change our sampling technique, we would be the first ones to want to do so. We have mastered the difficulties of obtaining good data from farmers' fields and can afford to sample farmers and farm fields that might require more attention and patience. We didn't do it in the first years for several reasons:

- we had no "positive" results thus nothing to be able to distinguish trial error from lack of response;
- we didn't understand the statistical importance of representative sampling and how it applied to our testing program;
- we figured that it was a higher priority to attempt to get some (any) promising results from the better farmers, that might be applicable to lesser farmers, than to enlarge the sample and risk finding nothing. If it worked with the better farmers, it might work with the remainder. If it didn't work with the best farmers, it is almost sure not to work with all farmers.

The challenge for SAFGRAD is to sell the usefulness of statistical validity to researchers and extension agencies. Research administrators must be convinced to obtain the authority to run the number of repetitions necessary for statistical significance. We must encourage extension agencies to use the results as a basis of extension themes.

1982

SAFGRAD PROJECT IN MALI SEPTEMBER 1978 TO SEPTEMBER 1982, FINAL REPORT

JERRY j., Johnson

AU-SAFGRAD