PN-AAA 032

ISN = 53974

Report #4

Report of GARD Consultancy

Soil Science

E. E. Schulte

International Agricultural Programs
University of Wisconsin-Madison

March, 1986

Evaluation of Soil Fertility Programs
and the
Soil Testing Lab, Yundum

E. E. Schulte

Department of Soil Science

University of Wisconsin-Madison

Short-Term Trainer/Advisor

2 - 26 March, 1986

ACKNOWLEDGMENTS

Information on soil fertility research in The Gambia was derived mainly from reports obtained from Messrs. Y. Christiansen (F.A.O. Fertilizer Program) and S. Taal (Soils Laboratory, Yundum). Mr. Taal also provided information on equipment and supplies in the soils laboratory and supplies needed to make make the lab fully operative. This cooperation in freely providing this data is greatly appreciated.

Gratitude is expressed to Prof. Glen Fulcher of the Mixed Farming Project for permitting us to "tag along" with the evaluation team on a trip to villages up-country to observe activities of the Mixed Farming Group. This trip gave us a rapid initiation into Gambian agriculture that would not otherwise have been possible.

Madison and Schulte wish to thank Messrs. Harvey Metz and John Fye of the SWMU for allowing us to accompany them on a field trip to Illiasa and other villages to observe salt intrusion barriers and water retention structures under construction. Mr. Fye's insights into soil classification were most valuable.

Appreciation is also expressed to the Assistant Director of Agriculture, Mr Sompo Ceesay, and to all of The Gambian researchers who contributed to our knowledge of Gambian Agriculture.

Finally, we thank the Chief-of-Party of the GARD project, Dr. Elon Gilbert, Mr. David Gibson, Project Administrator, Ms. Connie Taal, secretary, and Max Njie, expediter, for the support they provided in facilitating our work and making the short visit an interesting and rewarding experience.

SOIL FERTILITY PROGRAM

CURRENT PROGRAMS

FAO DEMONSTRATIONS

Fertilizer demonstrations have been conducted on maize, millet, sorghum, groundnut, rice, cotton, and vegetable crops by the FAO Fertilizer Project since 1981. From 1981 through 1984, a total of 76 maize, 47 millet, 110 groundnut and 53 cotton fertilizer trials were conducted. These were carried out on 24 mixed farming centers and replicated at Yundum and Sapu, using the standard FAO 8-plot design:

	0 - 0 - 0	
0 - 1 - 1	1 - 0 - 1	1 - 1 - 0
1 - 1 - 1	1 - 1 - 1	1 - 1 - 1
2 - 1 - 1	1 - 2 - 1	1 - 1 - 2

This design gives three rates each of N, P_2O_5 and K_2O while keeping the other two constant. The 1-1-1 treatment is the recommended rate and is common to each nutrient. In most of these experiments, excluding groundnuts, N was the most limiting nutrient. All four crops gave a response to the first K_2O addition, but the high K_2O treatment depressed yields more than did the high rate of N or P_2O_5. The reason for the yield depression is not obvious from the data but likely results from a nutrient imbalance. A complete plant analysis would help to resolve this question.

The control treatment (0-0-0) permits the calculation of net returns from fertilizer application. Net profit is calculated for each treatment. The maximum profit from each nutrient is estimated from a quadratic equation, $y = a + bx + cx^2$, where y = the rate of nutrient applied, x = net profit, and a,

b, and c are constants. Differentiating y with respect to x and setting the result to 0 gives $b + 2cx = 0$, or $x = - b/2C$. Substituting this value of x into the original quadratic equation gives the nutrient rate at which the most profitable return was obtained. The results for maize, millet, and groundnut are given in Table 1. The use of a quadratic equation involving only three points guarantees a perfect fit and is not strictly valid, but it is a useful approximation.

Yields were limited more by rainfall than by nutrients. When yield was separated by rainfall zone, the 1-1-1 treatment gave the highest yield for rainfall above 900 mm. Below 900 mm, the 2-1-1 rate was better. This is surprising because more leaching of N would be expected at higher rainfall and, therefore, more should be required. A similar effect has been observed in Senegal. However, other factors such as urea volatilization, rainfall distribution, and root distribution all influence nitrogen availability.

Table 1. Optimum fertilizer rates yield, net profit, and value/cost ratio for maize, millet, and groundnuts. [From FAO Fertilizer Project status report, GCPF/GAM/014/DEN]

CROP	OPTIMUM RATE $N+P_2O5+K_2O$	YIELD (COUNTRY AVG.)	NET PROFIT	VALUE/COST RATIO
	..kg/ha..	..kg/ha..	D*/ha	
Maize	73+39+36	2980	675	4.2
Millet	53+31+37	1525	249	2.7
Groundnut	18+27+31	2130	461	5.8

*1 Dalasi = $US 0.15, approximately, in March, 1986, but $US 0.22 when this study was conducted.

These studies show that regional fertilizer recommendations should be possible. As more data is collected, even more site-specific recommendations can be made.

In addition to the above standard fertilizer trials, various management practices such as ridging, fertilizer incorporation, plant population, and variety selection were demonstrated. These demonstrations should serve to stimulate interest in fertilizer use efficiency.

Demonstrations of fertilizer use and other inputs for vegetable production have been conducted in all six Divisions in cooperation with extension workers. Crops include beans, bitter tomato, cabbage, carrot, eggplant, lettuce, okra, onion, pepper, and tomato. Three fertilizer treatments were used. In 1983/84, the rates were 0-0-0, 76-30-30, and 152-60-60. These rates were cut in half in 1984/85.

The FAO project assisted in carrying out soil fertility experiments involving NPK for rice, N source and rate studies, P source and rate studies, and rice varieties. These experiments are discussed below.

NITROGEN SOURCE x RATE.

Nitrogen as 18-46-0, 26-14-0, prilled urea, urea super granules (USG) or calcium ammonium nitrate (CAN) were applied to maize at rates of 0, 40, 80, 120, and 160 kg N/ha. The N materials were incorporatd after broadcasting by hand hoeing. The highest yield (3275 kg/ha) was obtain with 112 kg N/ha as USG or 158 kg N/ha as 26-14-0. The lowest yield (2545 kg /ha) was obtained with 144 kg N/ha as CAN. In 1985, CAN gave the highest yield. Thus, it is necessary to conduct this kind of experiment for more than two years. Typical

response curves were obtained with CAN and prilled urea, but abnormal yield depressions were obtained with the other carriers at 160 kg N/ha. Although P and K were added at uniform rates to all plots, either element might have been insufficient at the high N rate. A plant analysis would help resolve this question.

Soil pH was depressed about 0.5 pH unit when N was applied. The influence of N rate on pH was not available, but high N could decrease pH and increase soluble Mn. Initial soil pH was 5.5. Extractable Mn was high (20 ppm).

PHOSPHORUS SOURCE x RATE.

Four rates of five phosphate materials were applied to maize (NCB) and three rates to groundnut at Yundum. The materials were phosphate rock from Burkina Faso, partially (15%) acidulated phosphate rock, partially acidulated (30%) phosphate rock, single superphosphate and triple superphosphate. Phosphate is mined as phosphate rock. The principal phosphate mineral in phosphate rock is apatite, $Ca_{10}X_2(PO_4)_6$, where X is OH, F, or CO_3. The solubility of phosphate rock increases as soil pH decreases. It is virtually useless above pH 5.6, owing to its low solubility. Consequently, phosphate rock is treated with H_2SO4 to make single superphosphate or with H_3PO4 to make triple superphosphate. In both of these fertilizers, the P is present as monocalcium phosphate $Ca(H_2PO_4)_2.2H_2O$, which is more than 90% water soluble. This is normally considered advantageous but may not be so in soils having a high P fixation capacity such as oxisols and ultisols. Partially acidulated phosphate rock is made by treating phosphate rock with a controlled amount of H_2SO_4. Solubility is intermediate between apatite and monocalcium phosphate.

For groundnuts, P_2O_5 was applied at rates of 10, 20, and 30 kg/ha. The highest yield was obtained with the partially acidulated phosphate rock at 30 lbs. P_2O_5/ha. It was not determined whether there was a significant source X rate interaction. If the yields for all sources are averaged, a normal P response curve is obtained.

Recovery of P is usually less than 15% in the year of application. The residual effects of these P carriers were studied in 1985 and will also be studied in 1986.

Four rates of P_2O_5 were applied to maize in 1984, 15, 30, 45, and 60 kg/ha. The highest yield was obtained with 30% acidulated phosphate rock at 45 kg/ha. Again, a normal response curve was obtained when yields for all materials were averaged.

When maize was grown in 1985 on plots to which different rates and sources of P_2O_5 had been applied in 1984, the highest yield was obtained with the residual effect of phosphate rock applied at 30 kg/ha. Averaged over all P sources, yields increased from 1160 kg/ha in control plots to 2050, 2630 and 2880 kg/ha where 10, 20, or 30 kg P_2O_5/ha had been applied in 1984. The interaction between P source and rates has not been analyzed as yet. Earleaf samples taken from these plots two weeks after silking will be analyzed at the Soil & Plant Analysis Lab, University of Wisconsin, for N, P, K, Ca, Mg, S, Zn, B, Fe, Mn, Cu, and Al to determine what factors other than rainfall might have limited yields.

N x K INTERACTION

The interaction of N and K on cotton and maize was investigated at Yundum in 1983, on cotton, maize, and rice in 1984 and on cotton, maize, rice, and groundnut in 1985. The data for 1985 have not been summarized and analyzed statistically thus far.

In 1983, N was applied to maize as urea at rates of 0, 60, 120, 180, 240, and 300 kg N/ha, and K_2O as KCl was applied at rates of 0, 50, and 100 kg/ha. The maximum yield was obtained with 50 kg/ha K_2O and 300 kg N/ha. Increasing K rates resulted in increased yield when N was applied at rates of 120 kg/ha or less. Yields were depressed, however, with 100 kg K_2O/ha when more than 120 kg N/ha was applied.

The 300 kg N/ha rate was omitted in 1984. The highest yield was obtained with 120 kg N and 100 kg K_2O/ha. Averaged over all N rates, grain yields were 1820, 2700, and 3340 kg/ha with 0, 50, and 100 kg K_2O/ha, respectively. The depression in yield when more than 120 kg N/ha was applied with 100 kg K_2O/ha suggests a nutrient imbalance.

Nitrogen as urea was applied to upland rice in 1984 at rates of 0, 50, and 100 kg/ha; K_2O was applied at rates of 0, 30, and 60 kg/ha. Response to K_2O was greatest when N was applied, and response to N was greater when K_2O was added. The highest yield was obtained with 100 kg N and 30 kg K_2O/ha.

Nitrogen was applied to cotton at rates of 0, 30, 60, and 90 kg /ha in 1983 and 0, 25, 50 and 75 kg/ha in 1984. Potash rate were 0, 30, 60, and 90 kg/ha in 1983 and 0, 30, and 60 kg/ha in 1984. In 1983, the highest yield was

obtained with 90 kg N and 30 kg K_2O/ha. Yields decreased when more than 30 kg K_2O/ha. was added. The highest yield of cotton in 1984 was obtained with 75 kg N and 30 kg K_2O/ha.

RECOMMENDED PROGRAMS IN SOIL FERTILITY

The following suggestions for soil fertility research are based on a review of available data and limited observations. Some may prove impractical in light of more experience but are presented for consideration.

NITROGEN

Data from all N rate studies should be summarized and reviewed. The general impression is that there is adequate information on simple N effects.

The most costly fertilizer input for cereals is N. Ways of improving N fertilizer efficiency should be studied. These include timing and placement, comparison of N carriers, and the use of legumes and farmyard manure (FYM).

Past work on N carriers left conflicting results between urea and CAN in different years. This work should be continued one or two more years to sort out the discrepancy. Comparisons should be restricted to urea, USG, and CAN, and one crop, possibly maize. Uptake of N from whole plants (above ground) at the dough stage should be used in assessing results.

Fertilizer cost and the effect of the carriers on soil acidification should be considered in evaluating the results. Urea is less expensive than CAN but results in greater acidification and must be incorporated. Compare carriers at four rates with and without incorporation.

Nitrogen as NO_3-N is subject to loss by leaching, volatilization and denitrification. The former can be studied by measuring NO_3-N in profile samples but volatilization and denitrification losses are difficult to measure without special equipment. Nevertheless, yield and N uptake data can be used to evaluate the net effect of fertilizer timing and placement. If N is applied too far in advance of the time that it is needed by crops , the risk of loss increases. If it is applied too late, yield will be reduced. The following treatments are suggested:

Source: urea (prilled)

Rates: 0, 50, 100 kg N/ha

Time: 1) all at planting

2) all at 3 weeks

3) all at 6 weeks

4) 1/2 at planting, 1/2 at 3 weeks

5) 1/2 at 3 weeks, 1/2 at 6 weeks

6) 1/3 at planting, 1/3 at 3 weeks, 1/3 at 6 weeks

7) 1/3 at 3 weeks, 1/3 at 6 weeks, 1/3 at 9 weeks.

All treatments should be incorporated. Measure N uptake and yield.

The maize agronomist and cultural agronomist will be investigating intercropping of maize and leguminous crops. Uptake of N by maize following groundnuts and cowpeas or other legumes should be compared with uptake of N by continuous corn. If the plots are wide enough, they can be split and three N rates (0, 50, 100 kg/ha) applied. It has been observed elsewhere that yield of maize grown in rotation are higher than when grown continuously regardless of amount of N applied.

Manure is widely recognized as a source of N and soil conditioner. In The Gambia, it is usually burned because it hardens during the dry season and is difficult to plow under. Where cattle are tethered in villages, the manure is burned. It could easily be piled in a compost heap at the edge of the tethering area. The composted manure crumbles easily and could be used in vegetable gardens as well as farm fields. Composting of manure and utilization could best be demonstrated by the extension service at the village level.

Continued use of N fertilizer leads to soil acidification as NH_4 oxidizes to NO_3^-: $NH_4^+ + 2O_2 \longrightarrow NO_3^- + 2H^+ + H_2O$.

In N rate studies, soil pH should be monitored, especially in experiments in which the same plots are used for the same treatments for several years.

PHOSPHORUS

The work on P rates and source over the past few years should be summarized and evaluated. There may be sufficient data for conclusions to be drawn concerning the most economical P source. Future research should concentrate on residual effects and P placement.

The residual effect of P fertilization can be studied on the former P source-rate plots. Ideally, these plots would be split, and three annual applications would be applied (0, 10, 20 kg/ha) in a band alongside and below the row. Uptake of P and yield should both be used to evaluate results. The availability of phosphate rock and partially acidulated phosphate rock should be evaluated as a function of soil pH. A low pH site should be selected (pH 4.0 to 4.5). A preliminary laboratory incubation study with local lime (kiln

baked oyster shells) should be conducted to determine what rates of lime are needed to raise the soil pH in increments of 0.5 pH unit to 6.5. The field pH plots should be large enough to include three P sources in a split-plot design. Soil pH at 4.0, 4.5, 5.0, 5.5, 6.0, and 6.5 would comprise the main plots, with PR, PR-30, and TSP as sub-plots. The P_2O_5 should be applied at rates of 0, 25, and 50 kg/ha the first year. Residual P availability could be measured in following years.

Soil pH should be monitored annually to determine the rate of reaction of locally available lime. These pH plots can be used to determine the availability of other nutrients as well as P, notably N, K, Ca, Mg, Mn, and Al with little additional work. Whole plants harvested near anthesis (silking for maize) must be dried and weighed for dry matter yield determinations. In the case of maize, ten plants per plot are weighed fresh at harvest. The plants are chopped with a cutlass, mixed, and a sample taken for analysis. To get maximum use from these samples, they should be sent to the Soil and Plant Analysis Lab, University of Wisconsin, for a complete elemental analysis. The cost (US $15.00/sample for N, P, K, Ca, Mg, S, Zn, B, Fe, Mn, Cu, and Al) is less than could be done locally even if equipment for individual element analysis were available.

The pH plots should be designed as long-term plots so that the influence of pH on other crops can be investigated in sequence. When leguminous crops are grown, the effect of soil pH on nodulation and N_2-fixation can be studied.

POTASSIUM

Response to K by maize, rice, and cotton was obtained in N x K factorial experiments in 1983 and 1984 and by maize, millet, groundnut, and cotton in FAO demonstrations. In most of these trials, high K rates depressed yields relative to intermediate rates. Nutrient imbalance appears to be the most likely explanation but K-induced Ca or Mg deficiency, disease enhancement by high N rates or deficiencies of other nutrients could also be involved.

An N^3 x P^2 x K^2 factorial experiment would help resolve the nutrient balance question. Adequate data is available at relatively low rates of these elements, but interactions at higher rates have not been studied adequately. The following rates are proposed for maize:

N	P_2O_5	K_2O
---------- kg/ha----------		
0	0	0
60	30	75
60	30	150
60	60	75
60	60	150
120	30	75
120	30	150
120	60	75
120	60	150
180	30	75
180	30	150
180	60	75
180	60	150

In addition to yield data, analysis of earleaf tissue at silking time should be used to study yield limiting factors. The above rates can be changed as warranted by results the first year.

SOIL TEST CALIBRATION

A soil test for available nutrients is not very useful until it is calibrated under field conditions. Two kinds of information are needed. First, the general shape of the response curve must be known for the major soil associations. For most nutrients, the curve will be similar to that of Figure 1. Other nutrients than the one in question must not limit yield. Response curves are generated from replicated plots under carefully controlled conditions.

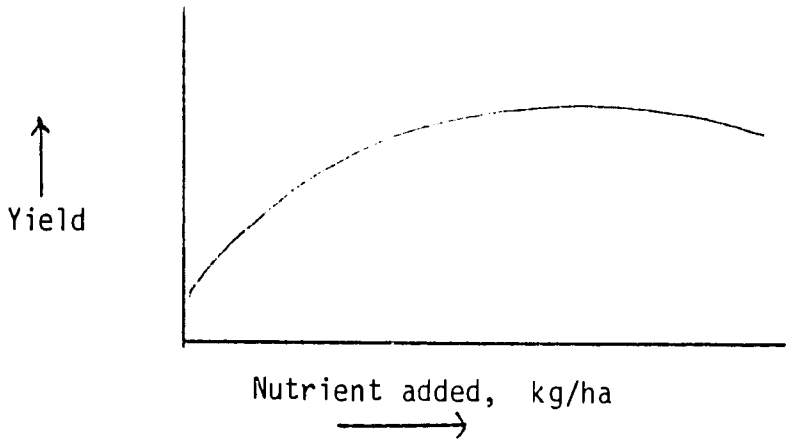

Figure 1. Typical nutrient response curve.

The second kind of information required is the yield expected at any given soil test level. Only two treatments are required. The first treatment is without the element being tested, the other includes that element. Both treatments include adequate amounts of other elements. A large number of sites having different initial soil test levels is needed, and these should include all of the major agricultural soils. At each site, the yield without the element being calibrated is expressed as a percentage of the yield obtained with that element. These values of % yield are plotted against soil test level as in Figure 2 (Nelson - Cate diagram).

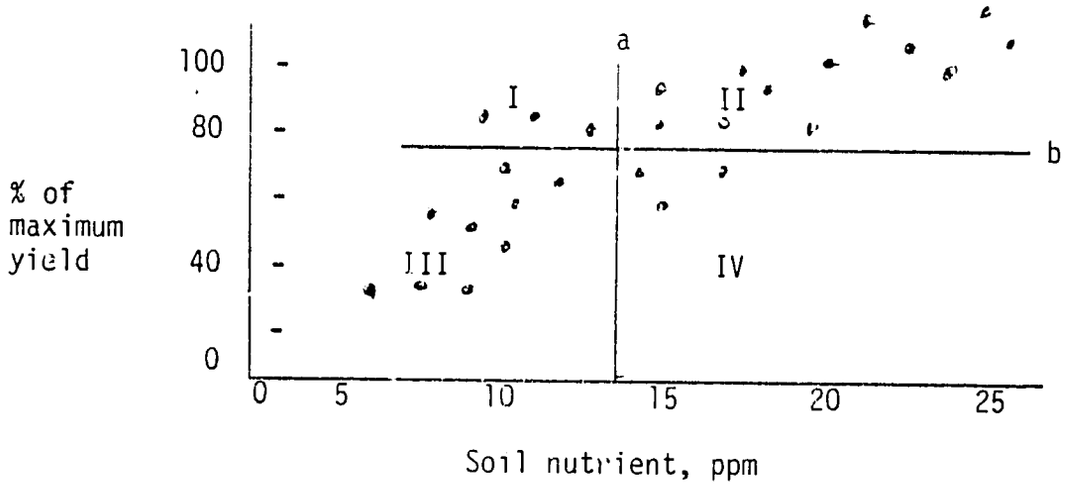

Figure 2. Percent of maximum yield attainable with a given level of available nutrient.

Lines a and b are adjusted horizontally and vertically, respectively, to give a minimum number of points in sectors I and IV. The intersection of line a with the x-axis represents the level of nutrient above which no further yield increase is expected.

This approach presupposes that the optimum amount of nutrient to be applied for maximum yield is known. This is not always the case, and some trial and error is required to determine rate of nutrients to be added.

Soil tests for P and K should receive first priority. Tests for other elements can than be calibrated as time and resource permit.

The mixed farming centers are located on soil representing 11 of the 24 soil associations of The Gambia. Calibration trials should be initiated at those centers where the soils are most typical of the association. Consultation with the soil survey section of the SWMU is needed to locate the best sites. Data from FAO fertilizer demonstrations and the ODA Land Resource Development study should supplement the calibration studies and permit some extrapolation of results to similar soils.

Soil test calibration presupposes that suitable extraction procedures are in use. Research to select an appropriate extractant involves laboratory and screenhouse work under controlled conditions. This should not be a high priority at this time. Procedures in use in other West African countries should be reviewed and those most appropriate for The Gambia adapted.

MISCELLANEOUS

Normal rainfall in The Gambia ranges from 800 to 1400 mm. Average rainfall at Sapu (7 years) from June to October, inclusive, is 930 mm; at Yundum (64 years) it is 1005 mm. Potential evapotranspiration during the same period is 580 mm at Basse (data not available for Sapu) and 565 mm at Yundum. Rainfall exceeds evapotranspiration each of these months except October. Thus, water shortages are due to lack of water storage in the soil rather than insufficient average rainfall. Rainfall distribution is another matter, however.

Measurement of water infiltration rates (Land Resource Study No. 22, 1976) gave values ranging from 0.8 mm/min to 2.0 mm/min on a colluvial soil and from 0.36 to 0.21 mm/min on a plateau soil. Rainfall intensities of 1.0 mm/min are common. If infiltration is slower than precipitation, runoff is inevitable.

Joint efforts between the SWMU, cultural agronomists, forage agronomists, soil physics, and soil fertility are needed to improve water infiltration rates. In addition to contour ridging, contour plowing, construction of water retention berms and tied ridges, improvement of soil tilth is essential. This can best be done by increasing soil organic matter. This will be a difficult task requiring long-term educational efforts to change traditional burning and grazing patterns. Establishment of grass-legume pastures along slopes in rotation with arable crops would improve soil tilth and water infiltration.

STAFF TRAINING

Soil fertility experiments with several crops have been conducted for many years. It is time for a thorough review of the data to determine what direction future research should take. Opportunities for complicated statistical analyses are limited in The Gambia. Access to relevant literature is also limited. It is recommended, therefore, that the Gambian soil scientist in charge of soil fertility research come to the University of Wisconsin for six weeks in February to March to review the soil fertility program in detail. He would have access to computer analysis of research data and should bring with him all field and lab data needed. Soil fertility specialists at the University of Wisconsin would be available for consultation, as would statistical consultants. Plans for field research for the coming growing season would be discussed.

The soil fertility counterpart at the University of Wisconsin (Kussow or Schulte) should visit the Gambia during the growing season to review the soil fertility program and observe nutrient problems.

SOIL TESTING AND PLANT ANALYSIS

IMPORTANCE:

Agricultural research in The Gambia has reached the stage where an active, functioning soil testing laboratory is vital to further development. Crop improvement programs, crop culture studies, intercropping studies, farming systems research, horticulture projects, soil reclamation projects,

land use/classification schemes and fertilizer trials should use test results as basis for site selection, fertilizer application, interpretation of results, etc. A well-designed variety trial, for example, might inadvertently select variety adaptable to low soil K or tolerant to Mn toxicity when correction these limitations would lead to selection of cultivars having a superior yield potential.

Although knowledge of optimum soil test levels for pH and various nutrients lacking for a wide range of soil conditions in The Gambia, this information will only be generated if there is an active soil testing program. Feedback from researchers and Extension personnel using soil test data should lead to refinements in interpretations and suggest areas where research is needed in soil test methodology and calibration. Eventually, as information about the chemical characteristics of different soil series is acquired, fertilizer recommendations can be made on a site-specific basis.

REVIEW OF PRESENT ACTIVITIES

ANALYTICAL CAPABILITY:

The soil testing laboratory at Yundum is reasonably well supplied with the basic equipment needed for soil testing (Table 2). Most of the equipment is in good condition or can be put into service with the acquisition of needed spare parts. The lab lacks a soil grinder. Grinding is done presently with a mortar and pestle manually. The lab is currently capable of analyzing soil samples for pH, organic C, available P, exchangeable K, Ca, Mg, and Na, electrical conductivity, extractable Zn, Mn, Fe, and Al, exchange acidity,

mechanical analysis (% sand, silt, clay) and cation exchange capacity. The laboratory is also capable of analyzing plant samples for N, P, K, and other elements, if needed.

Table 2. Equipment Available for Soil Testing in the Soil Laboratory, Yundum

	Item	Uses	Condition
1.	Flask shaker, Eberbach	Nutrient extraction, soil dispersion.	Good
2.	Atomic absorption spectrophotometer, Baird alpha 4	Analysis of Ca, Mg, Mn, Fe, Zn.	Good; needs air compressor, spare hollow cathode lamps.
3.	Flame photometer, EEL	Analysis of K, Ca, Na.	Needs lamps, air compressor; very old; should be replaced.
4.	Colorimeter Gerhardt	Analysis of organic carbon.	Good.
5.	Spectrophotometer, SP 600	Analysis of P, B.	Good.
6.	Spectrophotometer, Perkin-Elmer 35	Analysis of P, B.	Good; needs spare tungsten lamps.
7.	Kjeldahl digestion/ distillation unit	Analysis of N in plant tissue.	Good; needs set (8) of spare digestion tubes.
8.	pH Meter, Kent	Soil pH.	Good; needs electrode.
9.	Sieve shaker	Sand fractionation.	Good.
10.	Conductivity meter, portable	Electrical conductivity. (soluble salts)	Good; needs Ni-Cd batteries, battery charger.
11.	Mill, Wiley No. 4	Grinding plant samples.	Good; need spare set of knives.
12.	Drying oven	Dry soil/plant samples.	Good.

A chemical inventory was taken in December, 1985. From this inventory and a knowledge of chemicals needed for various analyses, a list of chemicals and labware needed for 1986 is being prepared. This list, along with spare parts for present equipment, will be included in the commodity list.

STAFF:

The Yundum soil testing laboratory is directed by Mr. Saihou Taal. who also has responsibility for soil fertility research and advising others in the Department on fertility-related concerns. Additional staff are listed in Table 3. The three Lab Assistants are temporary.

Table 3. Staff of the Soil Testing Lab., Yundum

Name	Position	Qualifications
Saihou Taal	Director	M.Sc.; Special courses in soil testing at Auburn University and IFDC.
Musa Ann	Analyst	B.Sc. (Reading Univ.)
Ada Gaye	Temporary (since 1981) Lab. Asst.	Sixth form; in-lab experience.
Samuel Jobe	Temporary Lab. Asst.	Fifth form; in-lab experience.
Sait Drammeh	Analyst	M.Sc. (Agric., USSR); Agric. Supt.
Sainey Kedta	Temporary Lab Asst.	Fifth Form; in-lab training.

Ms. Gaye has applied for B.S. training in economics and is likely to leave when given the opportunity.

RECOMMENDATIONS

ORGANIZATION:

Owing to changing personnel and division of the director's time between soil fertility research and laboratory activities, the lab is not well organized for rapid routine analysis It appears to be organized more as a research lab than as a routine service lab. At this stage of development, a service lab capable of doing a good job on a few analyses is preferable to a lab specializing in research and analyzing service samples as time permits. Routine analysis should be given top priority. Research into other procedures can be done during slack periods. Other interested parties might be allowed to use the lab for special analyses providing they contribute to the purchase of spare parts and chemicals they consume.

For a smooth-functioning lab, a person with at least a B.Sc. degree, preferably in Soil Science with a strong background in analytical chemistry, should be present in the lab during working hours to train junior staff, solve analytical problems and keep the samples moving through the various stages of analysis. He must perform each analysis personally and often enough to be able to recognize when results are erratic.

Lab supplies and chemicals should be inventoried monthly and a record kept of this inventory. Consumables should be ordered far enough in advance to prevent shortages from disrupting lab activities. Spare parts for analytical instruments should be anticipated and ordered to ward against prolonged breakdowns.

ANALYTICAL PROCEDURES:

A routine soil analysis including pH, organic C, P, K, and soluble salts should be performed on each sample. Detailed procedures for these analyses should written out and followed scrupulously. Once these procedures have been mastered, exchangeable cations (K, Ca, Mg, Na) and exchange acidity should be included. Samples should be analyzed in groups of 50 (or some other convenient number). The first sample in each group should be a "standard sample."

The standard sample is used for quality control. It is analyzed at least 25 times with different sets of samples and on different days. The results of 25 (or more) analyses are averaged and the standard deviation calculated. The mean is drawn as a horizontal line on graph paper with analytical result (e.g., pH) on the vertical axis and batch no. on the horizontal axis. Additional horizontal lines are drawn to indicate values + or - one standard deviation (SD) from the mean.

When measuring the pH of a batch of soil samples, the results for the standard sample is plotted on the control chart. If it does not fall within + or - 1 SD of the mean, the pH meter is re-standardized before the remaining samples are analyzed. A similar procedure is followed for other analyses.

The standard soil should be prepared in bulk with thorough grinding and mixing to insure homogeneity. A sufficient quantity of this standard sample should be prepared to last for at least two years. Changes in the standard sample upon storage are easily detected when plotted on the control chart. It may become necessary to re-calculate the mean and SD from time-to-time.

Soil pH should be measured in both water and in KCl, using a soil solution ratio of 1:2. Salt depresses soil pH by as much as a full pH unit. Therefore, an alluvial soil under the influence of salt intrusion will have an abnormally low pH. This effect is masked by measuring the pH in KCl. After a sufficient number of samples have been analyzed from throughout the country, it should possible to relate pH in water to pH in KCl by means of a regression equation. Thereafter, only pH in KCl will be needed in routine soil testing.

Eventually, tests for mechanical analysis (% sand, silt, clay) and acid sulfate characterization may be warranted on selected samples. For most routine work, hand-texturing by feel should be adequate. Diagnosis of possible deficiencies, or toxicities of B, Mn, and Zn is better done by plant analysis. Analysis of plant samples from research trials for N, P, and K should be available.

Procedures adapted for soil analysis should conform to standard procedures for this region unless research indicates that another procedure is preferable. At this point, the procedures used by the International Institute for Tropical Agriculture (IITA), Ibadan, are probably best suited for The Gambia and should be adopted. Thus, results obtained here can be compared with those of other West African countries.

An exchange of soil samples with IITA on a regular basis (every three months would help insure quality control in the laboratory.

EQUIPMENT AND SUPPLIES:

Soil sample preparation consists of drying, grinding and sieving to pass a 2-mm sieve. In the Yundum lab, soils are air dried and ground manually with mortar and pestle. This is satisfactory when only a few samples are analyzed. When large numbers of samples are processed, manual grinding and sieving are often done hastily, resulting in segregation of the soil sample and an inaccurate analysis. A mechanical soil grinder should be purchased. Grinding and sieving should be done in a sheltered area outside of the lab.

For handling large numbers of samples, soil trays are needed. These can be built locally. A simple solar dryer can also be built from local materials.

STAFF:

Junior staff salaries are low, and persons with sixth form education aspire to further training. Consequently, turnover is rapid. This necessitates constant training of new staff, resulting in a drain on the director's time and a reduction in reliability of analyses. It would be preferable to have three permanent junior staff paid a salary sufficient to discourage leaving for other employment. If that is not possible within the civil service system, then Agric. demonstrators with some field experience should be employed. These can be trained in specific lab procedures and would be supervised by a lab supervisor.

The present lab director, Mr. Saihou Taal, also has responsibility for soil fertility research in the field and advising other staff in agronomy, farming systems research and extension, crop protection, etc. on soil

fertility problems. These duties are likely to increase as staff become aware of the importance of soil testing in their trials. Work on calibration of soil tests in the field under different soil conditions will also occupy an increasing amount of time.

We believe it is important, therefore, to separate the duties of soil fertility research and lab supervision. It is our recommendation, therefore, that Mr. Taal devote all of his efforts to field research in soil fertility. Unfortunately, a person with experience in managing a routine service lab has not been identified.

It is recommended that Mr. Musa Ann be sent to the University of Wisconsin during the first semester of 1986-7 (August 25 through December 20). During this time he would take courses in soil fertility and analytical chemistry as a special student. He would spend half of his time in the Soil & Plant Analysis Laboratory of the University of Wisconsin learning to use routine procedures. He would assist in making racks and trays for routine analysis to be shipped to The Gambia upon his return.

Mr. John Peters, Director of the Soil & Forage Analysis Lab, University of Wisconsin, Marshfield, Wis., should come to The Gambia from January through April, 1987, as a Technical Assistant to assist Mr. Ann in setting up and organizing a service lab. By this time, necessary supplies and chemicals should have been ordered and received at Yundum so that no time will be lost when Mr. Peters arrives. Terms of reference for Mr. Peters are included as Appendix A.

Because a soil testing lab is vital to any soil fertility program, Mr. Taal should have an active voice in overall laboratory policy. It is proposed that a Lab Services Committee be appointed to set lab policy, review

analytical results, develop recommendations and insure efficient lab operation. The committee should be chaired by Mr. Taal and be represented by key users of lab services. Mr. Taal should have the opportunity of conducting research in the lab on analyses the lab is not prepared to handle on a service basis.

APPENDIX A

TERMS OF REFERENCE: JOHN B. PETERS, TECHNICAL ASSISTANT IN SOILS SCIENCE, JANUARY - APRIL, 1987.

BACKGROUND:

As a complement to the training program and long-term technical assistance provided under the GARD project, provision has been made for technical assistance in a variety of fields for short-term consultation with Gambian counterparts.

Soil analysis is a high priority area needing urgent attention in providing analytical capabilities for users in a wide array of agricultural activities. Fertilizer recommendations currently are made on a country-wide basis. Site-specific recommendations based on soil tests will lead to more efficient fertilizer recommendations. Crop improvement, plant breeding, soil fertility research, cultural agronomy, and other areas have reached the stage where soil analysis is vital to further advances.

SPECIFIC ACTIVITIES:

The technical assistant will assist the soils laboratory at Yundum to set up and operate a routine soil testing laboratory. Initially, the specialist will concentrate on tests for soil pH, organic carbon, available phosphorus, exchangeable cations, exchange acidity, and electrical conductivity. Once these are routinized, particle size analysis (% sand, silt, and clay) and analysis of plant tissue for nitrogen, phosphorus, and potassium will be undertaken.

The technical assistant will work closely with the lab supervisor, Mr. Musa Ann. It is proposed that Mr. Ann will spend the fall semester (1986) at the University of Wisconsin working in the UW Soil and Plant Analysis Laboratory. Supplies and equipment needed to get the Yundum lab functioning will have been ordered and should be delivered prior to the technical assistant's arrival. The technical assistant will also work with soil fertility staff to develop soil test interpretations and recommendations.

QUALIFICATIONS OF TA:

John Peters received a B.S. degree in Soil Science from the University of Wisconsin-Stevens Point, 1976, and a M.S. in Soil Science from the University of Wisconsin-Madison in 1978. He served as Assistant Superintendent of the University of Wisconsin's Marshfield Experiment Station from March, 1978, to December, 1984. From January, 1985, to the present he has been director of the UW Soil and Forage Analysis Laboratory, Marshfield. This lab analyzes approximately 10,000 soil samples and 20,000 forage samples annually. Mr. Peters was instrumental in reorganizing this lab, introducing new analytical procedures, and a quality control system. In addition to supervising the Soil and Forage Analysis Lab, Mr. Peters coordinated a forage sample check/certification program for approximately 20 commercial and public forage testing labs. He is budgeted 45% as a soil extension specialist, handling soil fertility problems for North Central Wisconsin. He conducts research in liming and soil fertility problems.