THE EVALUATION OF NITROGEN-FIXATION EFFICIENCY IN BAMBARA GROUNDNUT (*VOANDZEIA SUBTERRANEA*, THOUARS) GERMPLASM

A proposal submitted by:

The University of Maryland Eastern Shore
Princess Anne, Maryland

To:

The Agency for International Development
Washington, D.C.

Research Grant Program for
Historically Black Colleges and Universities

J. G. Wutoh - Principal Investigator
R. B. Dadson - Co-Principal Investigator
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ABSTRACT OF RESEARCH PLAN

THE EVALUATION OF NITROGEN-FIXATION EFFICIENCY IN BAMBARA GROUNDNUT (*VOANDZEIA SUBTERRANEA*, THOUARS) GERMPLASM

The proposed project is designed as a regional project involving the College of Agriculture of the University of Liberia and the Liberian Department of Agriculture, and the Ministries of Agriculture of the Republics of Togo, Upper Volta, Niger and Senegal. The objective of the project is to improve the grain yielding and soil nitrogen fixing abilities of bambara groundnut (*Voandzeia subterranea*, Thouars) grown predominantly in the dry zones of equitorial Africa. Improved efficiency of nitrogen fixation is expected to increase the yield of the bambara groundnut crop and also contribute nitrogen to the soil medium for ensuing crops in areas where the cost of artificial nitrogen fertilizer is prohibitive. Laboratory and field work will be done at the University of Maryland Eastern Shore Experiment Station to screen the rhizobia from Africa and other sources in field experimentations in Senegal, Togo, Liberia, Upper Volta and Niger which countries represent a wide spectrum of climatic and soil conditions. It is expected that effective and appropriate rhizobia strains will be developed for specific lines or cultivars for commercial use in tropical and subtropical agriculture. Linkages will be sought between the University of Maryland Eastern Shore agricultural research staff and the agricultural research personnel of the respective institutions in Senegal, Liberia, Togo, Niger and Upper Volta, where the Bambara groundnut is an important crop. An educational component to train at least one student from a participating country at the masters degree level will be instituted in order to establish a continuing link for the program in Africa.

Budget, First Year 1983-84

	Research Grant
1. Salaries and Wages	
J. G. Wutoh, P.I., 5%, 10 mo.	2,039
R. B. Dadson, Co-P.I., 5%, 10 mo.	1,286
C. Brooks, Co-P.I., 5%, 12 mo.	1,373
Graduate Student, 12 mo.	6,822
Total Salaries and Wages	11,520
Fringe Benefits (as applicable)	1,880
Subtotal Personnel	13,400
2. Material and Supplies	
Field and Lab	2,500
3. Communications (postage, telephone, cable)	400
Reproduction and printing	100
Reference Materials	100
4. Travel	
Domestic (meetings, conferences, observational visits)	500
Subtotal Operating	3,600
Total Direct Costs	17,000

Budget, Second Year 1984-85

	Research Grant
1. Salaries and Wages	
J.G. Wutoh, P.I., 5%, 10 mo.	2,290
R.B. Dadson, Co-P.I., 5%, 10 mo.	1,401
C. Brooks, Co-P.I., 5%, 12 mo.	1,483
Graduate Student, 12 mo.	6,978
Total Salaries and Wages	12,152
Fringe Benefits (as applicable)	2,248
Subtotal Personnel	14,400
2. Materials and Supplies	
Field and Lab	2,500
3. Communications (postage, telephone, cable)	400
Reproduction and printing	100
Computer Time	200
4. Travel	
Domestic	400
Subtotal Operating	3,600
Total Direct Costs	18,000
Grand Total	35,000

RESEARCH PLAN

EVALUATION OF NITROGEN-FIXATION EFFICIENCY IN BAMBARA GROUNDNUT (VOANDZEIA SUBTERRANEA, THOUARS) GERMPLASM.

Introduction:

Voandzeia subterranea (L) Thouars, commonly known as bambara groundnuts, is the third most popular pulse crop among Africans. The plant grows very well in rainforest areas and also in cool moist highlands. However the most distinctive characteristic of bambara groundnut is its ability to produce a greater yield than peanuts and cowpeas under extreme drought and poor soil conditions. In addition, it is known to have a reputation for resisting most tropical pests and diseases. (Cobley, 1956; Mundy, 1914; Holm and Marloth, 1940).

Bambara is the name of a district on the Upper Niger near Timbuktu (Holm and Marloth, 1940) and the crop named after it is probably of West African origin (de Schlippe, 1956). It is believed to have been found in the truly wild state in the N.E. Nigeria-N. Cameroon region (Kew Bull., 1963).

Alternative English names for this crop are Earth Nut (Cobley, 1956; de Schlippe, 1956) and Ground-Bean (Smartt, 1959). However, in Rhodesia it is most commonly known by its African name of Nyimo (chiShona) (Wild, 1952) or Ndhlubu (siNdebele) (Valentine, 1963). In the Republic of South Africa, it is called Njugo Bean (Holm and Marloth, 1940). It is also known as Congo goober, earth pea, baffin pea, Madagascar groundnut, voandzoa (Madagascar), epi roui (Yoruba), okpa otuanya (lbo), juijiya (hausa), nzama (Malawi), nlubu, njugu mawe (Swahili).

Bambara nuts must have been grown and used as a pulse for centuries in most of Central Africa and they are now commonly found throughout the continent and in the Malagasy Republic. They are a valuable and nutritious food used by large sections of the equatorial African population. The plant is also found in parts of tropical Central America where it must have been introduced by the slaves at the time of the great slave trade (Cobley, 1956). In Western Java the beans are also eaten by the natives and known to them under the name Katjang bogor (Buitenzorg Beans), doubtless because the plant was introduced by the Botanic Gardens at Buitenzorg, (Greshoff, 1970).

Although it produces a nutritious food and is cultivtaed throughout Africa--from Senegal to Kenya and from the Sahara to South Africa and Madagascar--the bambara groundnut remains one of the crops most neglected by science. Stigmatized a "poor man's crop," the plant has never been accorded a large-scale breeding and research program. Yet empirical evidence and fragmentary research results suggest that it is a crop with much promise. As one of the two most drought-tolerant cultivated legumes, it deserves to be taken far more seriously. Furthermore, despite the lack of research, its commercial use in Africa is increasing.

Objectives:

The scientific approach to be used to accomplish the program objectives is classified under three broad areas in which the application of laboratory, greenhouse and field experiments are paramount.

The objectives are:

(a) Collection and Evaluation of *Voandzeia subterranea* (L) Thouars germplasm for high yields and other essential agronomic characters.

(b) Evaluation of N-fixation efficiency of NifTAL and other available *Rhizobium* strains among the *Voandzeia subterranea* germplasm.

(c) Collection, isolation and evaluation of *Rhizobium* bacteria from nodules obtained from test plants grown in native African soils.

(d) Establishment of effective and appropriate *Rhizobium* strains for specific lines or cultivars for commercial use in tropical and subtropical agriculture.

Justification:

This project, which is to be a regionally focused project, is highly desirable to improve the grain yielding and soil nitrogen fixing ability of bambara groundnut grown predominantly in the dry zones of Senegal, Togo, Liberia, Niger and Upper Volta, all in equitorial Africa. Improved efficiency of nitrogen fixation will increase yield of the current bambara groundnut crop and also contribute nitrogen to the soil medium for the ensuing crop. Presently there is no large scale research program on bambara groundnut anywhere in the world in spite of the significance of the crop in the farming systems of countries in Africa. Since the cost of fertilizer is prohibitive in most African countries, the identification of germplasm with highly efficient nitrogen fixing ability will provide a means of supplying a cheap source of nitrogen for the overall benefit of increased crop production.

Of all plants used by man, only the grasses are more important than the legumes. However, while enormous resources have been expended in recent decades on grasses like rice, wheat, corn, sorghum, and barley, among the legumes only soybeans and peanuts (groundnuts) have received much attention. Yet it is the family Leguminosae (of which bambara is a tropical example) that shows most promise for producing the vastly increased supplies of vegetable protein that the world will need in the near future. In developing countries especially, cultivation of legumes is the best and quickest way to augment the production of food proteins.

Of the thousands of known legume species, less than 20 are used extensively today. Those in common use include peanuts, soybeans, peas, lentils, pigeon peas, chick-peas, mung beans, kidney beans, cowpeas, alfalfa (lucerne), sweet clover (Melilotus species), other clovers (Trifolium species), and vetches. The remaining species, most of which show great promise, are little used as yet, and many of them are almost unknown to science.

Initiation of this work is appropriate now since the University of Maryland Eastern Shore (U.S.) and some of the agricultural institutions in the African regions have expressed a willingness for cooperation in agricultural research. The proposed project will involve field trials in Togo, Niger, Liberia, Senegal and Upper Volta. Trials will be conducted in Zambia where University of Maryland Eastern Shore (UMES) agronomist, Jagmohan Joshi, on an AID Project and will be entirely responsible for the conduct of the tests. UMES since 1980 has received a USAID Title XII strengthening grant to prepare the faculty to participate in international agriculture programs. In addition, the University of Maryland Eastern Shore is also well situated to conduct this research by virtue of available facilities and location.

CHARACTERISTICS OF THE BAMBARA GROUNDNUT PLANT:

The genus, Voandzeia, belongs to the tribe Phaseoleae of the family Papilionaceae (or the Leguminosae, subfamily Papilionoideae which contains one species, Voandzeia subterranea (L) Thouars, the Bambara groundnut) (Hepper, 1970).

It forms pods and seeds on, or just beneath, the ground, similar to peanuts (Arachis hypogea). To achieve this the flower stalk elongates, and as its bulbous tip pen(`tes the soil, it creates a tunnel through which the fertilized flowers, ached a few centimeters behind the tip, are drawn into the soil. The pods are round and wrinkled and each contains one or two seeds. The seeds are round (up to 1.5 cm diameter), smooth, and when dried, very hard. They may be cream, brown, red, mottled, or black-eyed in color.

The plant itself occurs in both erect and prostrate types. It grows best in climates similar to those used for growing peanuts, maize, or sorghum. It needs bright sunshine, high temperatures (at least 4 frost-free months), and frequent rains in the period between sowing and flowering. But the bambara groundnut is one of the most adaptable of all plants and tolerates harsh conditions better than most crops. For example, it yields food under conditions too arid for peanuts, corn, or sorghum. (Bambara is actually a district near Timbuktu on the Sahara Desert's southern fringe). Thus the bambara groundnut as a legume particularly suited for hot, dry regions where growing other pulses is risky. The plant will also grow in rainforest areas and also grows in cool, moist highlands in Zimbabwe.

The bambara groundnut tolerates poor soils. On worn-out soils it can yield more than peanuts. In fact, nitrogen-rich soils are to be avoided because they stimulate the plant to produce too much leaf at the expense of the pods and seeds.

The plant has a reputation for resisting pests and diseases. It is less susceptible to diseases than peanuts, perhaps because it has been grown only in isolated, backyard gardens in mixed cultivation with other similarly isolated plants. Since the bambara groundnut buries its fruits in the soil, they are safe from attack by the flying insects that severely limit or destroy pulses like cowpeas and beans whose pods remain in the air. Rodents and crickets may damage the plant, however.

Though widely assumed to be a low yielder, there is substantial evidence to show that, with good management, the bambara groundnut can match yields with even the most productive legumes. Apparently the quoted yields reflect low-density populations because African farmers intercrop bambara groundnut with other crop plant. Johnson, 1968, reports yields in excess of 2,000 kg of shelled seeds per ha. These were from six independent trials in several Central African countries. A 1969 report from Ukiriguru Experiment Station, Tanzania, records yields up to 2,600 kg per ha. Various other documents refer to experimental yields in excess of 3,000 kg per ha. Highest yields seem to be produced mainly by slow-maturing (140-150 days) cultivars.

The crop is cultivated with methods similar to those used for growing peanuts. It takes 3-6 months to mature, depending on climatic conditions and cultivar type. The timing of harvest is less critical than with peanut; bambara groundnuts can be harvested early or late without serious loss. Usually they are eaten immature (i.e., before becoming too hard), but when roasted or boiled even the mature beans are edible. Ripe or immature, they are sweet and pleasant to eat and contain 14-24 percent protein and about 60 percent carbohydrate. Sometimes the roasted seeds are ground into a nutritious flour that can be incorporated into many dishes. The seed protein has more methionine (nutritionally an essential amino acid) than is found in other grain legumes.

The plant is also useful in crop rotations, for it contributes nitrogen to the soil which benefits subsequent crops.

In summary, this is a nutritious, rugged plant for growing where other crops do poorly--in hot, disease-laden regions where soil fertility and rainfall patterns are variable.

Some relevant agronomic drawbacks:

The bambara groundnut nodulates freely, but specific Rhizobium strains that are exceptionally effective in promoting growth have been found in experiments at NifTAL in Hawaii. For best growth, it requires high temperatures and abundant sunshine. Good soil drainage is essential, and the crop has to be planted in loose, light soils to facilitate the Rhizobium in its small, spherical root nodules and to enhance development of the buried seeds. Careful cultivation is needed; the flower stalks are weaker than those of peanut and cannot penetrate a hard soil crust. Loose soils also make it easier to dig up the pods.

Despite the plant's general healthiness, some disease organisms known to attack it are fusarium wilt, leaf spot, root-knot nematode, and a virus. These infestations are usually serious only in seasons or areas of high rainfall.

Though the crop can be found in vastly different environments in Africa, there are indications that individual cultivars are not in themselves very adaptable. High-yielding types from one location may fail when grown elsewhere. Tanzanian cultivars have yielded poorly in Zambia, for example. Indeed, some from northwestern Tanzania have proved unsatisfactory in the drier climate and different soils of central Tanzania. The most effective research on this crop in a given African locality may therefore be that which concentrates on selecting and improving local cultivars. Researchers outside Africa should endure that any cultivars tested come from appropriate climates.

SIGNIFICANCE OF THE PROJECT AND RESEARCH REVIEW:

The bambara groundnut is an ancient African legume crop ranking third in importance only after cowpeas and peanuts.

The crop is very important to the rural poor in most of Africa, and potentially so important elsewhere in the tropics, that the improvement of its germplasm (for higher yield, protein and digestibility) and the agronomy of its production both deserve intensive study.

Virtually no attention has been devoted to the crop by plant breeders and agronomists. However, fragmentary results suggest that the crop has a good potential for high yields even under the traditional farming system where conditions may be considered too poor for peanuts (Amuti and Pollard, 1974; Doku and Karikari, 1971; Holding and Lowe, 1971; Karikari, 1971; Masterson and Sherwood, 1974; Rachie and Roberts, 1974; and Vincent, 1970). Bambara is grown in areas of high temperature, scanty rainfall and on a variety of soils ranging between yellow alluvial soils of lacustrine origin to red laterites (Doku, et al., 1969; and Duke et al., 1977). It thrives in a pH range of 5.0 to 6.5 (Duke et al., 1977), but tolerates pH as low as 4.3 (Denarie et al., 1968).

In the cultivation of bambara groundnut it is usually recommended to inoculate a new field with soil from an old field in which the crop has been previously planted (Doku, 1969), although it has also been observed that there is no real need for inoculation (Hepper, 1970).

The ability of the plant to produce good crop under dry land conditions and the reasonably high yields obtained without fertilizers makes it a cheap crop to grow and a very valuable food item in dry areas.

Improvement in the nitrogen fixing ability of the plant is expected to enhance the fertility of the soil to benefit subsequent cropping in those countries where artificial fertilizers have a high cost.

Chemical composition:

Chemical analyses of cultivated bambara reported by Rassel (1960) shows the crop to be of comparable value to *Arachis* and *Vigna*. There is no reference to wild types which may be a source of variability needed for breeding.

The principal early analyses were carried out by Balland (1901); Greshoff (1906); Boname (1909); and Sornay (1913). More recent data based on improved techniques have also been reported, especially by Adriaens et al. who worked with *Voandzeia* of Congo origin. Other useful information is given in a table published by FAO. Rassel (1960) reported the following comparative figures for *Voandzeia*, *Arachis* *Vigna* (probably *V. sinensis*):

Composition of seed of *Voandzeia subterranea*, *Arachis hypogaea* and *Vigna*. Rassel, 1960).

	V. subterranea	*A. hypogaea*	*Vigna*
cal/100g	365	546	34
Protein	17-7	25-6	23-6
Oil, %	6.3	43.3	1
Ca, mg	73	52	7
Fe, mg	7.6	1.9	5
Vitamin A, I.U./100g	30	30	4
Thiamine, mg/100g	0.28	0.84	0.9
Riboflavin, mg/100g	0.12	0.12	0.1
Niacin, mg/10g	2.1	16.0	1
Ascorbic acid, mg/100g	trace	nil	2

The total carbohydrate content of bambara groundnut seed is about 60%. K content is high, comprised about half of the total mineral matter; P is also 17-20% of the mineral matter. The content of nitrogenous constituents in whole *Voandzeia subterranea* is about 20% of the dry matter. In samples collected from 18 localities in Africa and Madagascar the seed cost was found to contain only 5% nitrogeneous matter, the germ 46.81% and the cotyle 17-1-24.61% (Ammann 1907). The amino-acid contents of African and Madagascar origin were very slight.

In analyses of air-dry leaves of Voandzeia reported by Holm and Marloth (1940), the following were found: wter 10.76%, ash 7.30%, cellulose 42.20%; oil 2.42: sugar + starch 31.41% albuoids 5.91%. The leaves are said to be valuable stock food (Stanton, et al. 1966).

Environmental requirements:

Soil - Well-drained sandy loams are suitable for Voandzeia, with moderate yields being obtained from soils too poor for Arachis. N-rich soils tend to produce too much leaf (Holm and Marloth 1940). Although it does not grow well on low-lying land in Chad (Niqueux 1957), excellent yields are obtained in the Lac Alaotra basin of Madagascar on yellow alluvial soils of lacustrine origin, on the well-drained muddy, sandy soils of the west coast, as well as on the lateritic clay of the Hauts-Plateaux (Dufournet 1957). Most reports indicate that calcareous soils do not suit Voandzeia but P- and K-rich soils are beneficial (Dufournet 1957). Soils with pH in the range 5-6.5 are preferred (Mullins 1962).

Climate - Voandzeia is not grown above about 5200 ft. and is absent from high altitude regions of Africa, such as Ethiopia. From its altitude limitations, it follows that Voandzeia cannot stand cold conditions; in South Africa, for example, it can only be grown in areas with a frost-free period of at least 3-5 months and with high temperatures during that time (Holm and Marloth 1940). At Lac Alaotra, Madagascar (alt. 786 m), in the growing period (January-May) over many years, the mean maximum temperature was 27.7 C, the mean minimum 167.6 C, the general mean 22.1 C and the absolute minimum 5.5 C (Dufournet 1957). A rainy season of 4-5 months is suitable, at least in Madagascar, best results being obtained with 900-1200 mm rainfll. Yields are reduced by high rainfall, hence Voandzeia is not grown in the forest zone of Africa. Voandzeia and cultivated species of Vigna tolerate drought better than Phaseolus species (Stanton et al. 1966).

Cultivation:

Fertilizers and Inoculation - Manurial trials have been carried out, especially at Bambey, Senegal (Taubert 1953), but results have been inconclusive. Applications of 60 kg superphosphate/ha or 40 kg sulphate of ammonia/ha shortly after sowing have been reported as economic by Stanton (1966). In most places a certain amount of fertilization of the crop results from the burning of cleared natural vegetation. In Kwango, Congo, 500 kg lime/ha increased yields, but was not an economic treatment (Rassel, 1960). In field trials in Madagascar, inoculation with Rhizobium gave yield increases equivalent to the application of 60 kg N/ha.

Yield:

Comparison of yields is complicated by the fact that yields in different countries may be expressed differently, e.g. in such units as "bags", and in terms of shelled or unshelled seed. Percentage weight of shells to whole fruit varies from 13 to 19% for Madagascar and from 19.5 to 38% for African varieties (Ammann 1907). Irvine obtained figures of seed yields from various countries, e.g. Congo (Kahemba) 350-650 kg/ha; Chad and Cameroun 500 kg/ha; Dahomey 450-650 kg/ha; Nigeria (Ogoja Province) 254-400 lb/ac. Yields of 1000 kg/ha have been reported on several occasions, and from Malawi and Rhodesia very high yields of 26700 and 3000 kg/ha, respectively (Stanton, et al. 1966). There are 600-900 seeds per lb (Purseglove 1968).

Uses:

The main use of Voandzeia is of its seed for human consumption. The fresh semi-ripe seeds are more palatable than the hard ripe ones, though less nutritious (Sornay 1913); sometimes both the young seeds and the young whole pods are washed and boiled in salty water and in soup (Taubert 1953). Both ripe and unripe seeds are roasted (Taubert 1957). Freshly ripe seeds are first par-boiled to soften the tough seed coat for removal and the remainder is thoroughly boiled. Seeds dried to low moisture content are difficult to cook (Tisserant 1953) and some authors consider they can be cooked satisfactorily only when ground after long soaking (Sornay 1913) or when boiled for 4-6 hours (Colonial Plant and Animal Products 1954). Roasting the seeds is frequent in Africa, and in N. Ghana they are roasted in wood ash, soaked in salted water, and dried. Voandzeia seeds are often mixed with other foods. In Madagascar they are added to meat stew with rice or with a spinach and other vegetables (Dufournet 1957). In South Africa and other countries they are boiled with maize and sorghum (Quin 1957). In Sokoto Province, Nigeria, the mashed seeds are said partly to replace cereals, while in Ogoja Province they are mixed with palm oil and condiments, wrapped in banana leaves and boiled. Voandzeia flour may be made from roasted (Calziel 1937) or unroasted seed. A kind of porridge or paste is made from the flour by mixing it with oil or butter (Colonial Plant and Animal Products 1954); Niqueux (1957 and Wildeman (1905). Cakes or balls are also made from the flour, sometimes mixed with maize (Holm and Marloth 1940). In Rhodesia the roasted meal has been used as a coffee substitute.

The leaves may be used as fodder and are readily eaten by cattle and game (Quin 1957). Tardieu (1953) advises the growing of it in Senegal so that the foilage can be left in the field after harvest at the end of the rains as a forage for donkeys and horses. The seed is also used as animal feed, the coarser parts of the meal being fed to pigs and poultry (Dufournet 1957), but some authorities do not consider it suitable for this purpose (Dunstan 1908).

Nodulation Studies:

The NifTAL Project (Hawaii) has identified specific Rhizobium strains that are reported to be exceptionally effective in promoting nodulation, growth and yield of bambara groundnut (Anon 1979). Work at Legon, Ghana, indicated that bambara groundnuts will nodulate with Rhizobia from another bambara plant, peanut, soybean, and from the soil but not from cowpea and lima bean nodules (Doku 1969).

Successful introduction of any legume requires concomitant attention to normal agronomic criteria and to the associated root nodule bacteria. This is particularly important in the tropics because the normally slow-growing, Alkali-producing, peritrichously-flagellated rhizobia that inhabit tropical soils (The "cowpea" type of Rhizobium-Bisset, (1959); Ezedinma, (1964); Norris, (1956) may not nodulate the introduced legume. Such rhizobia have in common the ability to nodulate Vigna unguiculata and a variety of other hosts (Allen and Allen, 1939), although different hosts vary tremendously in their capacity to nodulate with various rhizobia (Norris, 1956). Hosts like Macroptilium atropurpureum, M. lathyroides and v. unguiculata are extremely unspecific in their rhizobial requirements (Norris, 1967), others like Centrosema pubescans, lablab and glycine javanica possess strain specificity of an intermediate type (Norris, 1967), while Leueaena leucocephala (Trinick, 1968), Lotononis bainseei (Norris, 1958) and G. max (Norris, 1967) are highly specific. Rhizobia able to nodulate a particular host or host groups may vary in N2-fixing effectiveness from wholly ineffective to maximally efficient.

As rhizobial research that goes hand-in-hand with plant introduction has inoculant production as its ultimate aim, it is necessary to note all the above with a plant of unknown rhizobia requirements. Many strains of rhizobia must therefore be tested on the host under bacteriologically-controlled conditions. Such experiments serve two functions-to identify elite strains suitable for further experimentation, and to elucidate the rhizobial requirements of the host (Broughton and John 1980).

Ikram and Broughton (1979) have reported on the effectiveness of different rhizobia isolates on the winged-bean Psophocarpus tetragonolobus (L) DC. They isolated rhizobia from fourteen different genera of legumes and tested them for their N-fixing effectiveness with Psophocarpus tetragonolobus in standard Leonard jar trials. Isolates from all plants except Pithecellobium jiringa were able to form nodules with P. tetragonolobus although a wide range of effectiveness among the different rhizobia was demonstrated. Thus P. tetragonolobus may be considered promiscuous with respect to its rhizobial requirements. Based on this experiment, a group of rhizobia comprising three elite strains, a moderately effective strain and two strains of low effectivity were selected for further study.

Broughton et al. have determined the efficiency of different isolates of rhizobia on Centrosema pubescens Benth and obtained good correlations between plant weight parameters and nitrogenase activity.

Though most tropical pasture and grain legumes form nodules when inoculated with rhizobia from the so called ."cowpea miscellany", they do demonstrate a range of symbiotic characteristics. This is becoming increasingly evident and important as new varieties and species are being brought into commercial use (Graham and Hubbett 1976).

Host specificity has been reported by Doku (1969). In a cross-inoculation experiment using crushed nodules from cowpea (Vigna unguiculata), groundnut (Arachis hypogea), bambara groundnut (Voandzeia subterranea), lima bean (Phaseolus lunatus) and soybean (Glycine max.), it was found that soybean did not nodulate with Rhizobia from any of the other species while its Rhizobia nodulated with all species. Cowpea and lima bean, on the other hand, nodulated with Rhizobia from all species, but their Rhizobia nodulated only with each other. Groundnut and bambara groundnut nodulated with Rhizobia from all species except cowpea and lima bean, and their Rhizobia also nodulated with all species except soybeans.

THE ACETYLENE-ETHYLENE ASSAY FOR N2-FIXATION IN LABORATORY AND FIELD EVALUATION

In the laboratory, N2 fixation by living organisms has been measured by Kjeldahl analysis, N-enrichment assayed by mass spectrometry, and N-incorporation assayed by radioactive counting; Na fixation by nitrogenase (N2ase) in cell-free extracts has been measured by N-enrichment, N-incorporation, micro-Conway diffusion technique coupled with titrimetric or colorimetric analysis of NH3, and N-2--H2 uptake or H2 evolution assayed manometrically. These methods are relatively insensitive except for the N method, and its application is extremely limited because of its short half-life (10 minutes). Of these procedures only Kjeldahl analysis has been used to appreciable extent for estimating N2 fixation in field samples, but the method is insensitive and time-consuming. The Acetylene-Ethylene Assay is now a standard method for N2 fixation determination.

Hardy et al. (1968) have demonstrated the methodology, characteristics and application of the sensitive C2-H-2-C2-H4 assay for N2 fixation by nitrogenase preparations and bacterial cultures in the laboratory and by legumes and free-living bacteria *in situ.* Their assay was based on the N2ase-catalyzed reduction of C2H2 to C2H4, gas chromatographic isolation of C2H2 and C2H4, and quantitative measurement with a H2 flame analyzer. As little as 1 umole C2H4 could be detected, providing a sensitivity 10 -fold greater than was possible with N analysis.

A simple, rapid and effective procedure utilizing syringe-type assay chambers is described for the analysis of C2H2 reducing activity in the field. Applications to field samples included an evaluation of N2 fixation by commercially grown soybeans based on over 2000 analyses made during the course of the growing season. Assay values reflected the degree of nodulation of soybean plants and indicated a calculated seasonal N2 fixation rate of 30 to 33 kg N2 fixed per acre, in good agreement with literature estimates based on Kjeldahl analyses. The assay was successfully applied to measurements of N2 fixation by other symbionts and by free living soil microorganisms, and was also used to assess the effects of light and temperature on the N2 fixing activity of soybeans. The validity of measuring N2 fixation in terms of C2H2 reduction was established through extensive comparisons of these activities using defined systems, including purified N2ase preparations and pure cultures of N2-fixing bacteria.

With this assay it now becomes possible and practicable to conduct comprehensive surveys of N2 fixation, to make detailed comparisons among different N2-fixing symbionts, and to rapidly evaluate the effects of cultural practices and environmental factors on N2 fixation. The knowledge obtained through extensive application of this assay should provide the basis for efforts leading to the maximum agricultural exploitation of the N2 fixation reaction.

PRELIMINARY STUDIES AT THE UNIVERSITY OF MARYLAND EASTERN SHORE

In preliminary tests the effectiveness of rhizobia strains to nodulate bambara groundnut were evaluated. The plants were grown in nutrient solution in a Leonard jar assembly, a set of which had nitrogen added, but plants were not inoculated and another set with no nitrogen and no rhizobia strains added. The strains 32H1 and CB756 obtained from the Cell Culture and Nitrogen Fixation Laboratory, Beltsville Agricultural Research Center (USDA), and AH169, AH1000, CP651, SG309 and Tal437 obtained from the NifTAL Project and MIRCEN, Hawaii freely nodulated bambara groundnut. Dry matter production, percent nitrogen and protein were higher inoculated than nitrogen and uninoculated treatments. The strains AH169, AH1000 and CB756 appeared to be more effective in terms of nodulation, dry matter and percent nitrogen. This would suggest variability in rhizobia strain effectiveness and would warrant further studies and screening to determine an effective host-strain compatibility.

METHODOLOGIES:

A large collection of bambara groundnut germplasm is being assembled for this work. Requests for more seeds have been sent to researchers in Mali, Malawi, Nigeria, Tanzania, Togo, Upper Volta and Zambia where the greatest variation of the crop is known to occur. Stock seeds received will be obtained from the USDA Cell Culture and Nitrogen Fixation Laboratory, Beltsville; Department of Microbiology, North Carolina State University, Raleigh, NC; and NifTAL Project, Hawaii. Indigenous rhizobia will be collected from various sites at the University of Maryland Eastern Shore.

A. EVALUATION OF THE RHIZOBIUM STRAINS

I. Greenhouse and growth chamber studies.

In screening for superior nodulating ability of bambara groundnuts and *Rhizobium* strains which are effective in the fixation of nitrogen, seeds of the bambara groundnut will be planted in sterilized vermiculite in sterilized bottles and trays in the greenhouse and in growth chambers at UMES and in the host countries. A Leonard jar assembly with vermiculite as the growth medium in the bottle and nutrient solution in the jar will be autoclaved at 121 C for two hours. Seeds will be prechecked for percent germination and enough of them surface-sterilized to produce three seedlings on planting. Surface sterilizatrion of the seeds will be accomplished by immersion in a 3% solution of sodium hypochlorite for 10 minutes and then rinsed with 6-8 changes of sterile water. The seeds will be allowed to imbibe sterile water for about an hour and after two rinsings transferred aseptically to water-agar plates, and incubated at 26 C until radicles are about 1 cm long. Three well-spaced holes in the rooting medium will be made to a depth that will accomodate the pregerminated seeds 1 cm below the surface. 2-3 ml of the appropriate *Rhizobium* culture will be dispensed around the pregerminated seedlings prior to the addition to sterile gravel over the surface of the rooting medium.

Strains of rhizobia to be tested will be cultured about 7-9 days prior to their use by inoculating them into 20 ml of yeast manitol (YM) broth (as described by J. M. Vincent) contained in 100 ml conical flasks and incubated at 26 C on a rotary shaker. The media to be used in liquid form is described by Keyser and Munns, 1979 and is as follows: Basal solution: mannitol 10 g/liter; salts (uM) MgS04300, CaC12300, ferric EDTA 100, KC1 10, MnC12 1, ZnS04 0.4, CuC12 0.1, Na2Mo04 0.02, Co (N03)2 0.002, distilled water. The nitrogen components will be amended to reflect higher levels required by the experiment.

Each treatment combination will be replicated four times.

Parameters to be recorded are days to nodule formation, nodule numbers, size, dry matter and nitrogen fixation measured by the acetylene reduction assay at first flowering, full flowering and beginning of podding and grain filling to give an indication of the relative nitrogenase activity in the different treatments at the time of the assay.

Frequent observations will be made of plant vigor and foilage color.

2. Pot Experiments

Based on the greenhouse studies a number of the most promising *Rhizobium* strains that has shown effective nodulation, will be subjected to further screening in 12-inch pots of non-cultivated soil with different Voandzeia lines. The same parameters used for evaluation in the greenhouse studies will be applied. The procedure here is similar to the Leonard jar experiment; seeds will be inoculated at sowing using the *Rhizobium* strains and the inoculated seeds rolled in acid-purified talc. The seeds will be germinated in the greenhouse and watered with nitrogen-free solution when necessary. Each tretament will be replicated five times and records of nodule formation, nodule nuimbers, size, distribution, dry matter and nitrogen fixation measured at firt flowering, full flowering and beginning of podding and grain filling.

3. Field Trials

Field trials following the greenhouse and pot evaluation, will be carried out during the growing season in both the African countries and the U.S. Total nitrogen and plant dry matter of the *Voandzeia* lines will be used as criteria for effective nodulation.

The bet ranked strains from the pot experiment will be used for the field evaluation. A randomized complete-block design with treatments replicated four times, will be used.

Sampling of five designated plants will be done in the early growing period to record nodule size, number color and distribution. Representative samples will be selected for serotyping, and the roots of the *Voandzeia* lines will be washed and dried to determine total plant dry weights.

At maturity, the rest of the plants will be harvested and the grain yield determined.

Procedure outlined in "Practical Exercies in Legume/*Rhizobium* Technology" NifTAL publication, 1979 by P. Sonasegarn, H. Hoben and J. Halliday, will be followed in the collection, isolation and evaluation of nodules from test plants grown in native African soils.

EVALUATION OF THE AGRONOMIC CHARACTERISTICS OF THE VOANDZEIA LINES

effectiveness of the Rhizobium isolates on the Voandzeia lines will be d in terms of the following:

above ground plant weight (leaves and stems)-- Total Dry matter above ground.

root total dry matter yield

i) total Nitrogen contents of the foilage and stems

flowering time

podding time

pod size

seed weight per plant

i) maturity date

number of stems per plant.

plant height and spread

root length

distribution of nodules on roots (whether localized or generally spread from top to bottom)

i) dry weight of nodules per plant

nitrogen content of plant nodules

protein content of seed

shelling percentage % of seed to unshelled

shell thickness

matter determinations.

leaves and stems of five selected plants will be harvested at the te time and oven-dried at 80 C for 72 hours and weighed to determine atter contents. Roots, seeds and nodules per plant will be similarly

nitrogen content determinations and compositional analysis.

foilage, stem, nodules and seeds of five selected plants will be used content determination by the Kieldahl digestion to be followed by the tion of NH_4 by an automatic N-analyzer.

Field Tests:

Following the initial laboratory and greenhouse screening, field experiments will be initiated to test the responses by bambara groundnut cultivars with specific rhizobium cultures under natural conditions both in equitorial Africa (Togo, Niger, Zambia and in the USA.

Analysis of variance will be performed on each parameter at each sampling time and differences compared using Duncan's Multiple Range Test.

Facilities and Equipment:

Research facilities at UMES to be used for this work are greenhouse and laboratory space, growth chambers, field plots, gas chromatograph with flame ionization detector.

Facilities needed at UMES will be additional pots, tanks and trays for solution culture, chemical and laboratory supplies.

Training:

Four African graduates with B.S. degrees in various areas of agriculture and microbiology have been identified for future training at the University of Maryland. Of the four, only one or two will be selected to do a masters level degree work in agronomy/microbiology as an integral part of the program. The candidate trained will continue the bambara work in an African country to be determined.

PERSONNEL SUPPORT:

A. R. B. Dadson (10% time) Ph.D., Research Associate, Plant Breeding, Genetics (20 years research experience.) Current research include: (1) Genetic control physiology of resistance, cultural practices regarding H. zea damage to soybeans. (2) Evaluation of soybean germplasm to stress tolerance and biological efficiency. (3) Tactics for management of soybean pests complexes and (4) Nitrogen-fixation in Bambara Groundnut.

B. J. G. Wutoh (10% time) Ph.D., Associate Professor, Plant Breeding Genetics, Cell Biology (25 years research experience.) Current research include: (1) Nitrogen-fixation in Bambara Groundnut (2) The Culturing and Toxigenesis of Marine Dinoflagellates, (3) Isolation, Purification and Biochemistry of Biological Active Substances from Marine Dinoflagellates, (4) Physiological, Pharmacological and Toxicological Investigations of Marine Dinoflagellates, and (5) Effects of Toxins on Microorganisms.

C. Carolyn B. Brooks (5% time) Ph.D., Research Associate, Microbiology with ten years research experience. Current research include: (1) Entomopathogens of soybean pests (2) Development of microbial pesticides and (3) Studies in N2-fixation.

INSTITUTIONAL UNITS AND RESPONSIBILITIES:

The responsibilities of UMES are the provision for greenhouses and growth cabinets for evaluation of bambara germplasm and variability in nitrogen fixation.

The reponsibilities of the African Institutions will be: (1) assist in the collection of Bambara germplasm, (2) field evaluation of variability in N2-fixation and (3) collection of nodules for Rhizobium isolation and development.

A total of half a hectare (1 acre) of land will be required for the field trials in ech of the two host countries.

IMPACT OF THE PROJECT:

The identification of variability in nitrogen fixation of bambara groundnut will aid breeders in Africa to produce cultivars which can give high yields and contribute more nitrogen to improve the soil for subsequent crops. Farmers in the bambara growing regions of Africa will realize higher yields from the crop, and increase their food protein resources, obtain higher income and enjoy better standards of living. The countries will import less nitrogen fertilizers for their crops and save foreign currency for other needs.

PUBLICATIONS:

It is expected that a number of technical publications will be produced during or at the end of the project. Presently one publication is anticipated to be titled "Selection of suitable *Rhizobium* strains for nitrogen fixation efficiency and yield in *Voandzeia subterranea* Thouars". Such a paper is to be published in the jouranl Applied and Environmental Microbiology.

RESEARCH TIME TABLE AT UMES AND IN WEST AFRICA

Activity	1983 Fall	1984 Winter	1984 Spring	1984 Summer	1984 Fall	1985 Winter	1985 Spring	1985 Summer	1985 Fall
ollect and assemble bambara groundnut germplasm from Niger, Senegal, Liberia, Cameroon, Kenya, Mali, Nigeria, Togo, Zimbabwe, Zambia; and *Rhizobium* strains from NifTAL; N_2-Fixation Lab., Beltsville, NSCU, Raleigh, N.C.	←	— AFRICA	—	—	—	—	—	—	→
Seed increase and screening of bambara groundnut germplasm and identified strains of *Rhizobium* as well as native rhizobia for high nodulation and N_2-fixation in the greenhouse.	←	—	—	—	—	—	—	—	→
Field testing and screening of bambara roundnut germplasm and efficient strains of *Rhizobium* as well as native rhizobia for high nodulation and N_2-fixation.			← USA	→ USA; ←→ AFRICA			← AFRICA / USA	→ AFRICA / USA	
Exchange of rhizobia between U.S. and African collaborators for testing.						←	—	—	→
Project Evaluation and Reporting					←→				←→
Preparation of Final Report									

COLLABORATIVE ARRANGEMENTS

Initial contacts have been established between the University of Maryland Eastern Shore and the research institutions and/or the Departments of Agriculture of Senegal, Upper Volta, Liberia, Ivory Coast, Togo, Niger and Cameroon through their individual Embassies in Washington, D.C. At this stage no commitments by the University have been made.

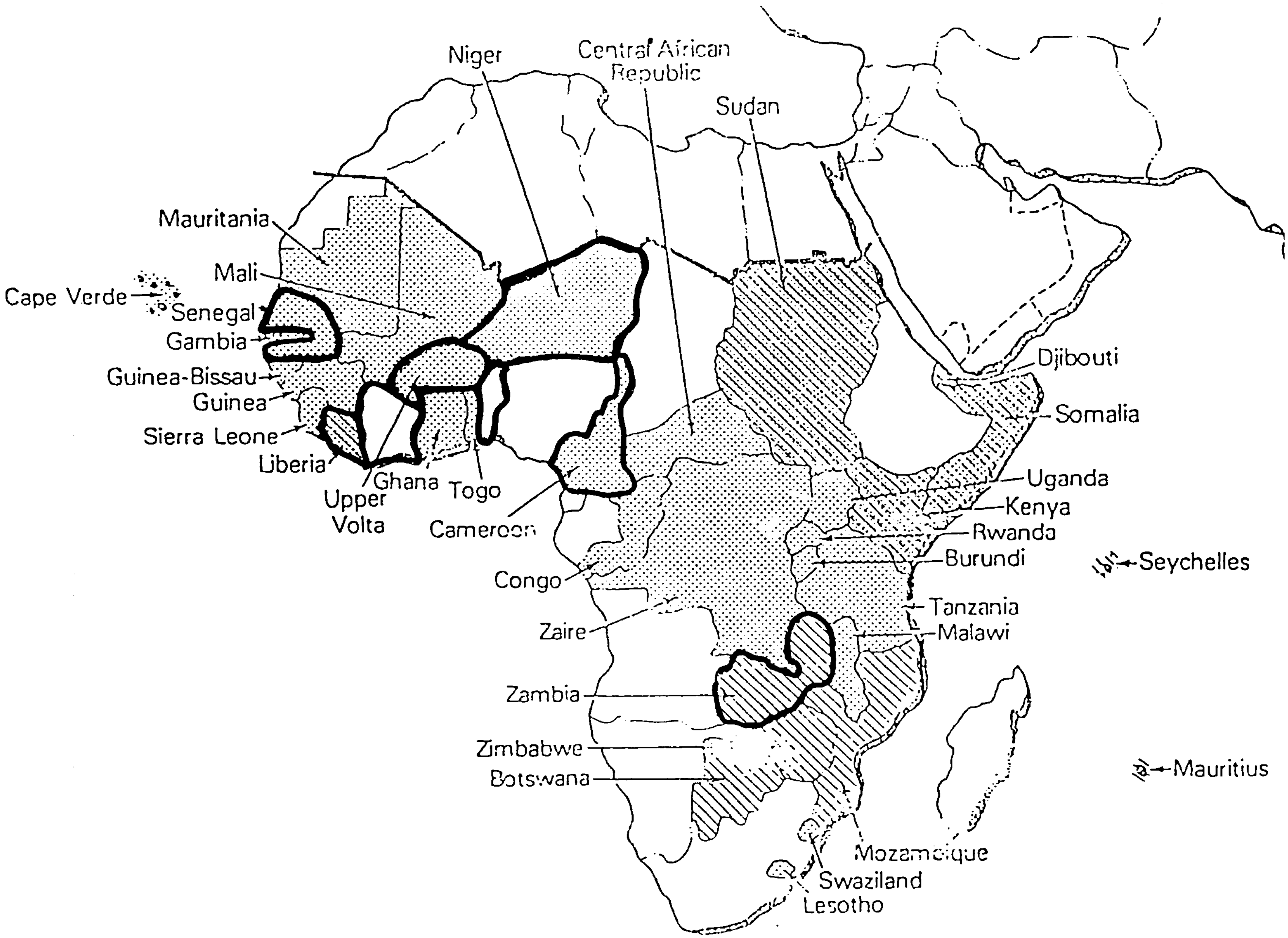
It is expected that each country, through the local research staff, will be responsible for the provision of plots for the experimental field tests, labor, land preparation, planting and harvesting of the bambara crops.

It is proposed that a direct contact with scientists of the collaborating countries will be made through a visit in order to establish an early working relationship with them and to allow them to participate in the detailed research planning and to draw up a work agreement. Administrative approval has been obtained through the chief administrative officer of the university. Research administrative agreements will be officially negotiated by the Head of Agricultural Research in the Cameroon and the Research Director and Dean at the University of Maryland Eastern Shore.

Collection of germplasm will be done in all the above African countries but it is expected that field tests of germplasm will be done only in Niger and Togo. These two countries have been selected to give variability in climatic conditions as determined by the latitudes of the two countries that lie approximately within close longitudes.

Data developed together with germplasm materials will however be shared with all interested scientists of all African countries for further testing and their results will be further tested at the University of Maryland.

Germplasm collection will be done in Zambia and field tests conducted there through a working arrangement personnel currently involved in a major project in Zambia.



MAP OF AFRICA SHOWING COUNTRIES MARKED IN RED THAT ARE INVOLVED IN THE PROJECT.

LINKAGES BETWEEN RESEARCH, EXTENSION AND FARMERS

Cooperation between research workers and extension personnel and feedback of information from farmers are essential to the development of this project which is primarily a research activity, but depends on the extension staff and services of the cooperating countries to disseminate information in the future to farmers -- the ultimate users -- of recommended cultivars with specific rhizobia.

Extension workers need practical and proven recommendations to be able to demonstrate successful and profitable technical innovations to farmers if the project is to be successful. Research is needed to develop the technology, to identify possible constraints to its adoption and to anticipate second generation problems arising from the use of new technologies. In each of the cooperating countries, research is viewed as a vital national resource both to raise productivity in the short term and to prepare and orient the long-term transformation of a society to meet future exigencies. It is a strong link between the present and the future.

Agricultural research is primaily concerned with providing answers to the problems confronting agricultural development and the farmer. These problems limit better crop practices and production. These problems may be due to varieties, diseases, insects, weeds, lack of plant nutrients, poor soils, improper crop stands and/or date of planting, among many possibilities. It is the aim of this research to minimize, eliminate or render these limiting factors less troublesome to farmers.

The adoption of recommended new varieties or cultivars is the final measure of the success of the research-extension partnership. The essential first step to adoption is to bring about an awareness among the farmers of the real benefits such practices will provide.

It is known that research stations in the cooperating countries organize field days to which extension staff are invited to see the current research programs and recommendations put to use. Extension workers, using these experiences, establish demonstration plots in their areas which endeavor to show farmers the superiority of the practice. These activities are crucial component of the extension process. Demonstrations, if based on solving farmers problems, help convince the farmer of the desirability of the recommended practice and also help motivate others to adopt the ideas. Practical demonstrations are the crux of the extension program. Their impact is widened and intensified through strong educational programs for farmers centered around these demonstrations by research station open days and through rural training centers and farm institutes.

It is expected that the end result of this project will be similar to the aforementioned concepts.

FACULTY INVOLVEMENT IN INTERNATIONAL DEVELOPMENT

The faculty of the University of Maryland Eastern Shore (UMES) have had a varied experience in agriculture and related sciences at the international level. About ten percent (10%) have spent time abroad in developing countries working with USAID with a host government or as a consultant.

The University of Maryland Eastern Shore is currently cooperating with the University of Illinois and Southern Illinois University in a multimillion dollar program of research and extension in Zambia under an USAID contract.

During a six year period Dr. Joseph Wutoh, Associate Professor of Biology, was both Director of the Animal Research Institute and Director of the Angelo Farm Corporation (Research Division-Crops) in Ghana. Prior to that he worked for the Government of Ghana as a tropical legume and forage specialist for five years and spent time in Puerto Rico and other African countries working on legumes and forages.

Dr. Dadson, currently the Acting Director of the Soybean Institute at the University of Maryland, and an expert in tropical agriculture, visited some Universities in West Africa in February, 1981, to initiate discussions of possible linkages between our campus and the various Universities in research, instructional and extension areas of agriculture and related sciences.

Because of the location of the University in a rural/farming community, work with small farmers, and experienced faculty and staff, the campus is in an optimal setting to provide technical assistance to universities/institutions in developing countries in undertaking research, education and training needs and problem resolution. Areas of assistance by UMES are in agriculture (crops and small animals), farm management, human nutrition, aquaculture and fisheries, and related rural development programs important to improvement of quality of life. For example, a collaborative research project on the winged bean has been underway for two years between the University of Peradeniya, Sri Lanka, and UMES plant scientists. Short-term participant training has been provided for Egyptian research scientists in soybean production and processing and in agricultural biochemistry and nutrition.

CURRICULUM VITAE

PERSONAL DATA

Name	Joseph G. Wutoh
Date of	
Marital Status	Married
Wife's Name	Valerie Wutoh
Children	Loreen (21), Jeffery (19), Tony (17), Michael (15), David (13)
Citizenship	U.S.A.
Race	Black

I. EDUCATION

A.	Degree	Ph.D.
	Institution	University of Queensland, Australia
	Date Degree was Granted	1964
	Major	Plant Breeding and Cyto-genetics
B.	Degree	B.Sc. (Honors)
	Institution	University of Wales, U.K.
	Date Degree was Granted	1958
	Major	Agricultural Botany (Plant Breeding and Genetics)
C.	Degree	B.Sc.
	Institution	University of Wales, U.K.
	Date Degree was Granted	1957
	Major	Zoology, Botany
	(Minor)	Agriculture (Rural Science)

ADVANCED STUDIES

D.	Degree	Diploma in Spanish
	Institution	University of Queensland, Australia
	Date Degree was Granted	April, 1964
E.	Degree	Diploma in German
	Institution	University of Queensland, Australia
	Date Degree was Granted	May, 1963
F.	Degree	Diploma in Scientific Russian
	Institution	University of Queensland, Australia
	Date Degree was Granted	May, 1963
G.	Degree	Working knowledge in French (No Degree)
	Institution	Institute of Foreign Languages, Bribane, Australia
	Date	1963

JOSEPH G. WUTOH

I. EDUCATION (Continued)

ADVANCED STUDIES (Continued)

H. Field of Study	Research in Forage Breeding (USICA Participant)
Institution	Penn State University University Park, Pennsylvania
Year	1960
I. Field of Study	Research in Forage Breeding (USICA Participant)
Institution	University of Puerto Rico, Puerto Rico
Year	1960

II. EXPERIENCE IN HIGHER EDUCATION

A. Rank/Academic Status	(i) Associate Professor
Name of Institution	Horn Point Environmental Laboratory Cambridge, Maryland
Nature of Work	Research
Duration of Appointment	1981-Present
Rank/Academic Status	(ii) Director and Associate Professor
Name of Institution	University of Maryland Eastern Shore Princess Anne, Maryland
Nature of Work	Biomedical Research and Teaching
Duration or Appointment	1970 - Present
B. Rank/Academic Status	(i) Vice Chancellor for Academic Affairs
Name of Institution	University of Maryland Eastern Shore Princess Anne, Maryland
Duration of Appointment	1972-1975
	(ii) Director of Research and Grants 1972-1973
	(iii) Research Coordinator for CSRS/USDA Programs for 1890 Land Grant Institutions and Tuskegee Institution 1971-1973
Name of Institution	University of Maryland Eastern Shore
Name of Work	Research and Academic Administration
Duration of Appointment	1972-1975

EXPERIENCE IN HIGHER EDUCATION (Continued)

C. Rank/Academic Status	Vice President for Research, Development and Training
Name of Insitution	INTAFED, Inc. (Institute of Tropical Agricultural, Fisheries and Economic Development, Inc.)
Nature of Work	Consultant, research and development planning, and training of research scientists and extension and development staff
Duration of Appointment	1977 to Present
D. Rank/Academic Status	Assistant Professor of Biology
Name of Institution	University of Maryland Eastern Shore
Nature of Work	Teaching Biology
Courses Taught	General Biology, Zoology, Genetics, Vertebrate Embryology, Comparative Vertebrate Anatomy, Physiology, Invertebrate Zoology
Duration of Appointment	1970-1972
E. Rank/Academic Status	Director
Name of Institution	Mianjelo Products Corporation Accra, Ghana
Name of Institution	Research and Development in fisheries and fisheries technology; (Biology and management of fresh water and estuarine fish; harvesting and presentation of fresh water and marine fish by temperatur variation and smoking; development of fish meal for livestock; fish migration in fresh water environments).
Duration of Appointment	1969-1970

III. EXPERIENCE OTHER THAN IN HIGHER EDUCATION

Rank/Academic Status	(i) Director
Name of Institution	Animal Research Institute Accra, Ghana
Duration of Appointment	1964-1970
	(ii) Research Specialist
	Department of Agriculture Accra, Ghana
	Research and Development in Legumes, Forage and Pastures
	1958-1960

IV. PUBLICATIONS

1. Evaluation of Soybean Varieties for Corn Earwormamage; Abstract of Techn. Papers. Eastern CSA (Canadian Society of Agronomy/Northeastern Branch, American Society of Agronomy. 1975, p. 36.

2. Evaluation of Commerical Soybean Varieties for Leaf-feeding resistance to H. zeae; Soybean Genetics Newsletter, Vol. 3, 1976 pp 43-46.

3. Battling the Pod Worm; University of Maryland Graduate School Chronicle, Vol. 9, 1975. pp. 16-17.

4. Breeding Soybean Varieties Resistant to Pod Worm; Soybean Research Review by BAC (Beltsville Agriculture Center, and University of Maryland). 1975, p. 15.

5. Corn Earworm Resistance in Soybeans - World Soybean Research Conference March 3, 1975.

6. European Corn Borer on Soybeans - Genetics Newsletter, Vol. II, 1975. p. 23.

7. Screening Technique for Leaf Feeding Resistance to Corn Earworm - Soybean Genetics Newsletter; Vol. II, 1975 pp. 24-26.

8. The Development of Agriculture in Ghana; Department of Agriculture, Accra, Ghana, Nov., 1966.

9. The Breeding System and Some spects of the Genetics of Glycine Javanica; Ph.D. Thesis, University of Queensland, Australia.

10. Effects of Photoperiod and Temperature on Flowering in Glycine Javanica; Austr. Jour., Exptal. Agric. and Animal Husbandry 8:544-547, 1968.

11. The Inheritance of Flowering Time, Yield and Stolon Development in Glycine Javanica; Austr. Jour. Exptal. Agriculture and Animal Husbandry 8:317, 1968.

12. Combining Ability in Glycine Javanica; Austr. Jour. of Agric. Res. 19:411-418, 1968.

13. The Chromosome Numbers in the Genus Glycine L.; Nat. London, Vol. 202, 1964.

14. A Hemolytic principle associated with red tide dinoflagellate - Gonyaulax monilata, Clemons, G. P., J. P. Pinion, E. Bass, D. V. Pham, Mary Sharif and J. G. Wutoh. Toxicon (18), 323 (1980).

15. Insecticidal Activity of Gonyaulax (Dinophyceae) cell powders and saxitoxin to German Cockroach — Clemons, G. P., D. V. Pham, J. P. Pinion and J. G. Wutoh, J. Phycology (16), 305 (1978).

IV. PUBLICATIONS (Continued)

16. Biological and Economic Evaluations of Microwave Heated full-fat soybeans in broiler diets — Journal Poultry Science Association.

17. The physiological effects of marine Algal Toxin on Chickens Proceedings — 7th Annual Biomedical Symposium, Atlanta University Center, Atlanta, Georgia; April 6, 1979.

18. Tolerance levels of Copper for marine invertebrates. Proceedings — 7th Annual Biomedical Symposium, Atlanta, Georgia; April 6, 1979.

19. The Comparitive Bio-Gel P-4 Column Chromagraphic Characteristics of *Gonyaulax tamarensis* and *Gonyaulax monilata* (Two Marine dinoflagellates) Relative to their toxicities in Homeotherms and Paikilatherms. Proceedings — 5th Annual Biomedical Symposium, Xavier University, Louisiana.

20. The University of Maryland Curriculum Development: Concepts and Program Related to the Future University of Maryland, Princess Anne, February, 1975, p. 532.

V. PROFESSIONAL ACTIVITIES

A. Membership

1. American Institute of Biological Sciences
2. American Society of Agronomy
3. Crop Science of America
4. Phi Kappa Phi

B. Other Offices Held

1. Member, National Land-Grant University - EPA - USDA, Coordinating Committee for Environmental Quality Research, Monitoring and Extension Education (1972-1974).

2. Member, President's Advisory Committee for Graduate Studies and Research, University of Maryland (1972-1975).

3. Member, Northeastern Agricultural Experiment Station Directors Association (1972-1974).

4. Member, Somerset County Maritime and Industrial Committee.

RESUME

Robert B. Dadson

ACADEMIC BACKGROUND

Name of Institution	Diploma	Degree	Date
Achimota School, Ghana	W.A.S.C.G1 C.H.S.C.	—	1956 1958
University of Ghana, Ghana	---	B.S.(Agr.) London	July, 196
McGill University, Montreal, P.Q., Canada	—	M.S. Agronomy)	June, 196
McGill University, Montreal, P.Q., Canada	---	Ph.D. (Plant Breeding & Genetics)	June, 196
Nuclear Energy Centre, Caesacia, Rome	Induced Mutation Techniques for Plant Breeding & Disease Resistance	--	Oct., 197

PROFESSIONAL EXPERIENCE

Professional Position	Institution	Date
Research Associate	University of Maryland Eastern Shore	1/82 to date
Visiting Research Scientist	University of Maryland Eastern Shore	9/79 - 12/81
Lecturer	University of Ghana, Legon	9/71 - 9/79
Principal Agricultural Officer	Ministry of Agriculture, Ghana	9/70 - 9/71
Senior Agricultural Officer	Ministry of Agriculture, Ghana	9/69 - 9/70
Agricultural Officer	Ministry of Agriculture, Ghana	9/62 - 9/69

PROFESSIONAL ACTIVITIES

1. Ghana Science Association
2. Crop Science Society--ASA
3. Agronomy Society--ASA

LIST OF PUBLICATIONS AND OTHER SCHOLARLY ACTIVITIES

(see attached, please)

List of Publications

1. R. B. Dadson. 1966. Response of certain forage species in pure and mixed seedings to irrigation. M.Sc. Thesis presented to Agronomy Department, Faculty of Graduate Studies, McGill University, Montreal, P.Q., Canada.

2. R. B. Dadson, J.M.D. Bastien and J.S. Bubar. 1967. Studies on inter-specific hybridization between *Trifolium* species and *T. pratense*. In Proceedings of the thirteenth annual meeting of the Canadian Society of Agronomy held at Macdonald College, P.Q. Canada. June 1967 p. 35-70.

3. R. B. Dadson, 1969. Interspecific hybridization between some perennial *Trifolium* species and *T. pratense*. L. Ph.D. Thesis submitted to Dept. of Agronomy, Faculty of Graduate Studies McGill University, Montreal, P.Q. Canada. (Dissertation Abstract Internat. 1970 30, iiiB, 2988-B).

4. R. B. Dadson, J.S. Bubar and N.C. Lawson, 1969. Environmental and pre-pollination treatment effects in the inter-specific hybridization of some *Trifolium* species. Technical paper presented at the 1969 joint meeting of the NE Branch, American Society of Agronomy, Canadian Society of Agronomy, Canadian Society of Soil Science at Cornell University, Ethaca, New York. June 1969 (Abstracts, NE Branch ASA p.4).

5. R.B. Dadson. 1975 Crop production: The desire to achieve national self-sufficiency. *Universitas*. 4, 162-174.

6. Ghana, Ministry of Agriculture. A project proposal for cattle development in Ghana. A report prepared under my leadership by a team of Senior Agricultural Officers in 1971 for the Ministry of Agriculture, Republic of Ghana and submitted to the World Bank.

7. R. B. Dadson and K.B. Boakye-Boateng. 1974. The influence of grass mulch on emergence, growth, and yield of soybeans, *Glycine max* (L). Merr. *In* Soybean, production, protection and utilization. *Ed.* by D.K. Whigham INTSOY Series 6, 69-76.

8. R. B. Dadson. 1975. The Effect of row width on yield and other characteristics of soybean, *Glycine max* (L) Merr. Paper presented at World Soybean Research Conference held at University of Illinois at Urbana-Champaign.

9. R. B. Dadson. 1976. Measures to increase cropy yield. A contribution to seminar on the development of the agricultural sector of Ghana with particular reference to the national economic plan 1975-1980. Accra, 5p.

10. R. B. Dadson. 1976. Screening and evaluation of soybean cultivars at Legon. *In* Proceedings of the University of Ghana, Council for Scientific and Industrial Research Symposium on Grain Legumes. *Ed.* by E. V. Doku, Univ. of Ghana, Legon, Ghana. p. 71-77.

11. R. B. Dadson. 1979. Effects of irradiation on certain characteristics of Shallots (Allium ascalonicum). In Induced Mutations for Crop Improvements in Africa. A Technical Document of the International Atomic Energy Agency, Vienna, 1979. AEA-TECDOC-222.

12. R. B. Dadson. 1981. Physical factors affecting stand establishment: Moisture, Mulching and Soil Texture. In Proceedings on Conference on Soybean Seed Quality and Stand Establishment. Colombo Sri-Lanka 25-31 January 1981. INTSOY Series 22, 96-101.

Projects Supervised

1. Inheritance studies on some pod and plant characters in Capsicums. W. Manu* 1973.

2. The effect of spacing and nitrogen fertilizer on flowering, nodulation and yield of groundnuts on the Accra Plains. P. O. Asibey*, 1973.

3. The effect of different spacings and varying levels of nitrogen on grain and its components and other agronomic characters of surghum, variety Dwarf hegari. T.E.O. Asamoah* 1974.

4. The effect of inoculation, nitrogen and phosphorus on certain plant characters and yield of soybean. Glycine max (L) Merr. G. Acquaah*, 1975.

5. The effects of plant population and fertilizer on the growth on yield of soybean. A. Ampomah*, 1976.

6. Influence of variation in inter-row and intra-row spacings on some plant characters and yields of soybean. Glycine max (L) Merr. F.K. Kjiu*, 1977.

7. Effect of TIBA (2,3,5-Triiodobenzoic acid) on certain plant characteristics and yield of determinate and indterminate cultivars of soybean G.K. Abutiate*, 1977.

8. The effects of weeds on the yield and certain characters of soybean (Glycine max) (L) Merr. E. Asiedu*, 1977.

9. Genetic Studies on F_1, F_2 and two backcross generations of four intercrosses of soybean (Glycine max (L) Merrill) G. Acquaah*, 1979.

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*Student

Association with International Organizations

1. Cooperator in Ghana in a Regional Research Project with International Institute of Tropical Agriculture, Ibadan, Nigeria, on soybean and tropical food legumes. 1973-1979.

2. Cooperator in Ghana in International Soybean Evaluation Studies with International Soybean Program based at University of Illinois, Urbana-Champaigne, Illinois. 1973-1979.

Membership in Professional Associations

1. Ghana Science Association 1971 to date.

2. Accra Branch of Ghana Science Association 1971 to date.

3. Crop Science Society of America 1975-1979, 1982 to date.

4. American Society of Agronomy 1975-1979, 1982 to date.

Other Professional Activities

Chief Examiner for Ordinary and Advanced Level Examinations in Agriculture for the West African Examination Council, 1972-1979.

RESUME

Carolyn B. Brooks

ACADEMIC BACKGROUND

Name of Institution	Degree	Date
Tuskegee Institute	B.S. (Biology, Chemistry)	Aug., 1968
Tuskegee Institute	M.S. (Cell Biology, Biochemistry	Aug., 1971
Ohio State University	Ph.D. (Microbiology)	Dec., 1977

PROFESSIONAL EXPERIENCE

Professional Position	Institution	Date
Research Associate (Microbiology)	University of Maryland Eastern Shore	2/81 to date
Research Associate (P.I./Acting Program Director)(Biology/ Biochemistry, Nutrition)	Kentucky State University	2/80 - 2/81
Research Associate/Lecturer Electron Microscopist	Kentucky State University	9/77 - 2/80
Prequalification Experience		
Graduate Teaching Associate Microbiology	Ohio State University	9/74 - 9/75
Research Technician (Hemoglobin Research)	V.A. Hospital	5/72 - 8/73
Science Teacher (Biology, Chemistry, Physics, Earth Sc.)	Alabama Board of Education	9/71 - 4/72
Graduate Teaching Associate (Gen. Biol./Lab.)	Tuskegee Institute	9/69 - 8/71
Science Teacher (General Sc./ Chemistry)	Alabama Bullock County Board of Education	9/68 - 6/69

PROFESSIONAL ACTIVITIES

Beta Kappa Chi
Society of Protozoologists
American Society of Tropical Medicine and Hygiene

HONORS AND AWARDS

Dissertation Year Fellow of National Fellowship Fund, Ford Fellowship Foundation, Atlanta, Georgia

Ohio State University, Graduate Fellowship Recipient

Tuskegee Institute, 4 year undergraduate scholarship recipient

PUBLICATIONS

"A Cytological and Cytochemical Study of Physiological Regneration of Stentor niger.". Unpublished Master's Thesis, Tuskegee Institute, Tuskegee, AL, August, 1971.

"An Electron Microscopic Study of In Vitro Attachment and Phagocytosis of Plasmodium berghei by Peritoneal Macrophages." Unpublished Ph.D. Dissertation, Ohio State University, Columbus, OH, 1977.

"A Study of the Role of the Surface Coat in the In Vitro Attachment and Phagocytosis of Plasmodium berghei by Peritoneal Macrophages." Infection and Immunity 20:827-835. June, 1978.

"Hair as an Indicator of Nutriture and Tissue Stores of Zinc, Copper and Magnesium in Rats." Submitted for Publication.

"The Role of Macrophage-Cytophilic and Opsonic Antibodies in the Elimination of Malarial Parasites in the Rat." Presented at the 1977 Conference of Tropical Medicine and Hygiene.

"Plasmodium berghei: The Role of the Merozoite Capsule in Resistance to Phagocytosis." Presented at the 58th Conference of Research Workers in Animal Diseases. 1978.

"The Effect of Dietary Zinc, Copper or Magnesium on Hair and Tissue Mineral Concentrations of Rats." Presented at the Third Biennial Research Symposium of Historically Black Land Grant Colleges and Universities. 1980.

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(Personal Communication between R. B. Dadson and E. V. Doku).

Appendix

BRIEF DESCRIPTIONS OF THE FIVE PARTICIPATING AFRICAN COUNTRIES*

Senegal:

Senegal, a country about the size of Nebraska, has a population of 6,033,000 people. Life expectancy there is about 44 years. The per capita GNP is about \$500. It is a country which is poor in natural resources, over-dependent upon a single crop (peanuts) for revenue, burdened by high population growth and beset by frequent drought. Its economy is dependent on agriculture, as 76% of the labor force is agricultural. The major cash crop is groundnuts, and the major subsistence crops are millet and rice.

Most of the country has low, rolling plains with savanna vegetation suitable for legume crop development. In the southeast, plateaus rise about 500 meters above sea level and marshy swamps are interspersed with tropical rain forest. Two well-defined seasons result from northeast winter winds and southwest summer winds. From June to October the annual rainfall in the city of Dakar is only about 24 inches; further south, about 60 inches of rainfall. Temperatures range from 63^{o} - 82^{o} F.

Senegal's commitment to democracy and human rights and desire for peaceful resolution of conflicts in Africa and the Middle East is influential toward African opinion and complements U.S. policy objectives in the region and in international fora. Therefore, it is in the interest of the U.S. for Senegal to become an economic success, which would indeed include much improved agricultural productivity and a healthier and better-nourished agricultural work force.

Niger:

The African country of Niger is about three times the size of California, and has a population of about 5.4 million people. The life expectancy is about 44 years. The per capita GNP is about \$340. Niger is one of the world's least developed countries hampered by droughts, pest attacks, poor links to the sea, low adult lit-racy rate and a young population which is generating tremendous pressure upon an inadequate education system. However, Niger has much growth potential and has made positive progress resulting from uranium-derived revenues and external donor assistance. The Government of Niger has accorded priority to economic development, particularly toward achieving food self-sufficiency and has achieved improved living standards for its people.

Most of Niger's economic growth during 1975-80 was due to investment revenues from Niger's mining sector (i.e. Uranium). Still 91% of the labor force is agricultural. The major subsistency crops are millet and sorghum and the major cash crops are groundnuts and cowpeas.

The terrain is about two-thirds desert and mountains and one-third savanna. The climate is hot, dry and dusty. During the rainy season (June-September) only 4-32 inches of rain is received annually.

The U.S. and Niger have both expressed their common concern with the threat posed to regional security by Libya. The U.S. has demonstrated commitment to Niger by increasing economic assistance. Niger has consistently taken positions in international fora which are supportive of U.S. concerns. The goals of the A.I.D. program in Niger are linked to the stated priorities of the Niger Government, one of which is to achieve food self-sufficiency.

Liberia:

About 2 million people live in Liberia, a country about the size of Pennsylvania. Life expectancy is 53 years and the per capita GNP is $540. About 70% of Liberia workforce is engaged in agriculture, but agricultural productivity is very low. This is attributable to poor soils and to pography, inadequate adaptive research to develop financially attractive improved technological packages for small farmers, lack of an effective extension service, inadequate marketing access and facilities and poorly defined agriculture priorities and policies.

Liberia has a relative abundance of natural resources such as iron ore and other minerals, rubber, timber, and diamonds. Their major subsistance crop is rice and the major cas crops are coffee and cocoa beans.

Liberia lies within the tropical rain forest belt and has distinct wet and dry seasons. The rainfall which occurs largely between April and November accumulates to about 150-170 inches annually. Along the coast the rain may exceed 200 inches yearly. The average annual daily temperature is about $80^{\circ}F$.

The U.S. and Liberia are close friends with unusual cultural and historical ties, dating back in 1847 with the arrival of ex-slaves from the U.S. The U.S. also has strategic rights at the airfield and port and the most important concentration of U.S. Government communications facilities in Africa. Also, black Africa's second largest block of U.S. private investment is in Liberia. U.S. objectives are to help establish economic and financial stability and investor confidence and to support return to stable, democratic civilian rule by 1985.

Togo:

Togo is about the size of West Virginia and is inhabited by about 2,783,000 people. The per capita GNP is about $390, and life expectancy is about 48 years. Most of the people work as farmers but production is mall-usually only enough to feed their families. Agriculture is a mainstay of the Togolese economy, employing 80% of the labor force. The major subsistence crops are yams, cassava and corn and the major cash crops are cocoa, beans and coffee. Togo's agriculture tended to stagnate during the past decade due to bad weather, low producer prices, a lack of small farm incentives and poor agricultural policies. The Togo Government is placing renewed emphasis on agriculture and is complementing its efforts to increase production with investments in support facilities.

The Togo mountains divide Togo into two regions. East and south of the mountains the land descends across a sloping plateau to a low, sandy coastal plain. The plateau is covered with tall grass and clumps of hardwood trees. It is drained by the Mono River. The coastal plain has swamps, lagoons and coconut and oil palm forests. The climate is tropical (average temperature is about 81°F). The rainfall annually is about 40 inches in the North and 70 inches in the South.

Upper Volta:

The population of Upper Volta is about 6,208,000. The life expectancy is only 39 years and the per capita GNP is $240. Although the economy of the country is dependent on agriculture, the variable climate and the small percentage of output passing through markets in a subsistence-oriented agricultural system, lead to wide fluctuations in agricultural output and uncertain prospects for economic growth. The major subsistence crops are sorghum, millet and corn. The major cash crops are groundnuts and cotton.

Mediocre soils and deforestation in relatively densely populated areas limit the potential for agricultural growth. Upper Volta is a high plateau, watered by Camoe, Volta and Oti Rivers. Most of the country endures a cool dry season, a hot dry season and a hot wet season. In the far north the climate is dry and desert-like. In the south, the land is green with forests and fruit trees. The annual rainfall is about 40 inches in the south and less than 10 inches in the extreme north and northeast.

The U.S. is interested in maintaining good relations with Upper Volta which has a history of moderation in international affairs. U.S. program goals are to assist this nation to obtain food self-sufficiency and security, and a higher quality of rural life in a context of self-sustaining economic growth.

*Much of the information describing the African countries was obtained from: "Agency for International Development-Congressional Presentation Fiscal Year 1984". Anex I Africa.