Chapter 4. Results and Discussion --- Crops Team

4-1 Baseline survey of crop production and Farming Systems

4-1-1 Introduction

This was done in order to be able to generate with the local communities suitable management technologies for more intensive and sustainable utilization of inland valleys for rice-based farming systems by small-holder farmers. Emphasis was on helping local communities to articulate how they perceive a technology, so that the research and extension team can map these perceptions and understand the local people's point of view so that recommendations are formulated and technologies designed with prior knowledge of their acceptability to them.

The lack of participatory approach during technology development led to non-adoption of most of these promising technologies developed by scientists. Survey conducted however indicates that paradoxically, other new technologies not recommended by scientists have escaped from agricultural establishments and rapidly spread from community to community. This shows that if development is about people, projects and programs must be built around their needs and capacities if they are to be adopted. To ensure that the technologies developed would be adopted and implemented within the communities a multi–disciplinary farming system research team using the Farming System Research (FSR) approach was used as part of the initial characterization of the study area.

4-1-2 Hypothesis

The main hypotheses addressed were small scale farmers operate under difficult production conditions such as low fertility soils, lack of soil and water management practices, lack of proper farm implements etc., which cause low production and productivity, but are prepared to use agricultural technologies that meet their needs. Principles of farming systems research can help in the adoption of research recommendation generated by scientists

4-1-3 Materials and Methods

4-1-3-1 Overview of the Research Process

The main method used as research methodologies in developing the necessary soil management practices is based on the principles of FSR. The main principles of FSR are diagnosing problems, identifying promising solutions and setting priorities for research and extension (Shaner et al, 1982).

A farming system can be defined as "a unique and reasonably stable arrangement of farming enterprises that a household manages according to well defined practices in response to physical, biological and socio-economic factors and in accordance with house hold goals, preferences and resources. FSR is an approach to studying the farming systems and making proposals for development. Its usefulness and applicability are defined by the following characteristics: it,

- Views the whole farm as a system;
- Focuses on the inter-dependencies of the factors that are under, and out of control of the farm household.
- Aims at enhancing the efficiency of the farming system by improving the focus of agricultural research to generate and test better technologies appropriate to farmers.

In the FSR approach, the study team employed, among others, the following skills.

- use of multidisciplinary team members
- relying heavily on farmers' participation in the research process.
- use of indigenous knowledge in defining solutions to ranked problems.

To arrive at proposals for agricultural development in the study area, a sequence of activities were carried out by the team as shown in Figure 4-1.

Providing information that aid the development of relevant technologies for resource poor farmers is one of the main objectives of the studies. Technologies have been developed by research institutions but have not been adopted by farmers despite great efforts in extension. The non-adoption of such technologies may be as a result of their inability to meet the needs of resources poor farmers. It is in this context that the FSR approach was adopted.

4-1-3-2 Secondary data collection: Literatures and references

Secondary information gathering started in Kumasi, the regional capital by reviewing literatures and references from libraries in Kumasi, and Mankranso the district capital. Meetings were held with staff of several district and sub–district level of agricultural research agencies and institutes, extension and development agencies and non-governmental agencies (NGO). During such meetings information was gathered on perceived problems of the study area with reference to their mandate and activities. Secondary data gathering continued from the start to the end of the study.

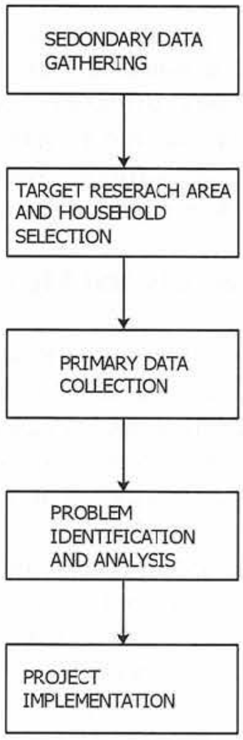

Fig. 4-1. Basic activities of the field study

4-1-3-3 Reconnaissance survey

A two–days reconnaissance survey was conducted on arrival at the site. From direct observations and informal discussions with some farmers and persons knowledgeable about the area, initial impressions were formed on the agricultural systems and biophysical characteristics of the area. Results of the survey and data from secondary sources served as bases for problem identification.

4-1-3-4 Household selection

The average number of households in the representative village was three hundred. Thus a sample size of thirty households from the village was found to be adequate. To have a representation from female-headed households in the selected groups, five female–headed households were included. To select households, household records were obtained from local extension workers. Using these records, households were randomly selected. Randomization was done by listing names of family heads on pieces of paper which were shuffled and 25 households were selected in addition to the selected 5 female–headed households. The unit of investigation was a household: The household was defined as persons' living together in the same house, eating from the same pot and managing the same farm activities.

4-1-3-5 Primary data collection

Primary data was collected through informal surveys using Participatory Rural Appraisal (PRA) methods. Reasons for adopting the PRA methods in this study were:

– more rapid and inexpensive means of understanding the system under study.

– clearer in–depth understanding of cause–effect relationship of a farming system.

– more genuine participation of the rural people in analyzing their problems and identifying possible solutions together with researchers.

4-1-3-6. PRA Exercise

During the PRA exercise at the study site, a group meeting was held with the selected household during which PRA exercises were undertaken. From each household, husband and wife were invited through the village chief. During the meeting, farmers were divided into three sub–groups (one woman and two men's group). Each sub-group had at least one scientist as a facilitator. Each sub-group constructed annual activities calendar, identified and ranked problems made a time–line analysis of development programs, wealth ranking and drew a resource map for the village. Annual activities calendar. During this exercise, farm operations were discussed and a sequence of annual activities was drawn on charts.

(i)Problem identification and ranking

The problems of both on–farm and off farm activities were identified. To assist farmers understand the problems they were ranking, symbols were used to depict each problem. Problems were then ranked according to their relative importance to farmers. Ranking was done using bean seeds. Each farmer was given thirty seeds and asked to distribute them according to his/her perception of the importance of the problem. The number of seeds each problem received determined Time-line analysis. This involved listing of development activities undertaken by government and NGO's in the village over the past two decades. The reasons for success or failure of each programme were discussed.

(ii)Resource mapping

Farmers drew two village maps (one past and one present including changes in natural resources. Reasons for changes were discussed.

(iii)Wealth ranking

Farmers were asked to sort out households in their communities into wealth categories. The criteria for the wealth ranking were identified as ownership of cocoa farms, land ownership, houses with galvanized iron sheet roofs and the ability to send children to school. Knowing the factors that were of value to farmers became more important than knowing the numbers of farmers in each wealth category. This meant that the recommendations generated could take into consideration their aspirations

4-1-3-7 Household Interviews

Household interviews were conducted days after PRA exercises. This was used to collect detailed information on household farm and non-farm activities to supplement information obtained during the PRA exercises. Households interviewed were those selected during sampling and had also participated in the PRA exercises.

4-1-3-8 Key informant Interview

Local residents who were identified as having great depth of knowledge about the study area were interviewed as key informants. This was necessary to collect further data on agricultural practices and production in the area. Key informants interviewed included, an NGO staff, the village chief, teachers, chief farmers, and Ministry of Agricultural staff in the area.

4-1-3-9 Farmers Forum

At the end of the first round of data collection, a one–day farmers forum was held at Adugyama (the district headquarters of the study area). The purpose of the workshop was to:

– Validate/confirm information collected from the field surveys;

– Get feedback or reactions on the major issues that emerged from the team' preliminary data analysis;

– Identify promising solutions to emerging issues;

Participants to the workshop included researchers, extension workers, farmers from the study villages, and representatives from the district assembly. During the workshop, presentations were made by the scientists on information collected about the study area and the issues that emerged during the study. Participants were divided into mixed groups of researchers, extension workers, farmers and NGO representatives. The groups were to prioritize the emerging issues and propose solutions. At the end of group discussions, a plenary session was held to compare and harmonize the rankings and the solutions. The solutions formed the basis for further research and recommendations.

4-1-4 Results and Discussion

Using the Farming System Research approach, detailed description of the study area especially the socio-economic setting and development programs in the area, and description and analysis of the farming systems, which included the farm activities, off–farm activities, household income and expenditure, problems and constraints and sustainability of farming system in the inland valleys were identified

4-1-4-1 Socio-Economic Setting of the Area

(i) Demography

Majority of the people in the area, as in other parts of the Ahafo-Ano district in Ashanti region, is farmers. Population figures indicate that the population of young people in their early twenties was very small compared with the older generation. This may indicate the incidence of rural-urban migration among the youth in search of jobs. This contributes to the shortage of labor during the peak of farming activities. The average family size is eight. Over one-third of the farmers are immigrants.

(ii) Household and Labor Organization

Decisions on labor organization in a household are made jointly by the man, wife and the their unmarried grown–up sons. House building and land preparation are mostly done by men, while planting, weeding and harvesting are shared by all household members. Household chores, such as cooking, fetching water and firewood, and taking children to clinics are done by women. Sale of rice, maize and animals are mostly done by men, while women sell other products like vegetables, plantains, cocoyam and cassava mostly on market days.

Hired labor is limited in the area especially during peak periods of farming activities (April-August). This is due to rural-urban migration of the youth in search of jobs in the cities especially Kumasi. Farmers have devised the community working groups (Nnoboa) system as a way of addressing the labor constraints in the area. Wages for hired labor range from $1-$2 per day (5hours period) excluding meals.

(iii) Economic and Social Infrastructure.
Mankranso the seat of government for the district, is connected to Kumasi the regional capital of Ashanti Region by a 30 km asphalt road and Sunyani the regional capital of the Brong–Ahafo Region by 80km road. This road passes through the study area from the 40km point at Adujama to 50km point at Asuadei. This is the major road in the district.

Roads from Mankranso to other towns and villages in the district are in bad condition. Most of the assess roads within the study area are foot parts. This makes it very difficult to transport agricultural inputs and food products to and from the farms. Extension Officers also find it very difficult to visit farmers during the growing period, which is also the raining period.

(iv) Education
Majority of the farmers has no formal education. Those who went to school had not progressed beyond junior secondary school. Only 5% of males and 2% of females had graduated from senior secondary school. Presently there is only one government assisted senior secondary school within the district and it is situated at Mankranso.

(v) Health
The district has one general hospital at Mankranso, ten health centers, four health posts and all the towns and villages within the district have immunization points. The hospital has one medical doctor. The only major hospital is in Kumasi the regional capital.

(vi) Marketing
Major marketing functions are performed in the area twice a week; Sundays at Adugyama market and Fridays at Kumasi market. Farmers bring their crops, small animals (goats, sheep, and chickens) and oil products to sell and also to buy their needs Rich farmers consume about 30% of their food crops (rice and maize) and sell the rest (70%) when prices increase. Middle-income families sell about 50% of their products, while poor families sell only about 10% or not at all. Poor farmers sell their products just after harvest, when prices are low since they are usually in need of money.

There are no stores or agencies that sell good seeds and pesticides in the area. Simple hand tools like cutlasses and hoes can be bought at Adugyama and Kumasi on market days or at some stores at Mankranso.

(vii) Credit.
Farmers usually need to have access to initial capital if they are to adopt or to develop

new agricultural technologies. Unfortunately majority of farmer in the area do not have access to credit. About 85% have never had access to credit for the past 7 years. For those who had, only 2.5% of them had the credit from the formal sector (banks). The rest had it from the informal sector (traders, relatives and friends).

(viii) Land Tenure System.

Land, especially that of upland, is not a major constraint to production. Share-cropping is the major tenure system in the area. There are two types of shared cropping. The first is a system with no fixed arrangement between the farmer and the landlord (usually a family member). The farmer, after harvesting his crops, gives the landlord a small part of his or her produce as a symbol of appreciation and also to show to the landlord that the land still belongs to him. In the second arrangement an agreement is made between the landlord and the tenant farmer before farm operations begin. This type of arrangement depends on the relationship between the two parties. The most common agreement is that the tenant farmer retains two thirds of the produce and the landlord the rest. In some cases part of the rent is collect in cash before planting while the remainder is collected after harvest.

(ix)Cultural Ceremonies and Customs.

The inhabitants of the area both natives and immigrants are traditionalists even when they are affiliated to a Christian or Moslem religion. They have a strong belief in their ancestors and gods and do nothing that will displease them. They maintain the traditions of their ancestors for fear of reprehensions from them. During marriage ceremonies exchange of gifts take place between the two families. The man is supposed to provide bride price that includes money, cloths, and drinks. The more one gives, the more one is respected by his in-laws. Funerals are held on Saturdays and sometimes on Thursdays for dead people within the community. It is a taboo to go to farm on Tuesdays and Fridays as a sign of respect for Mankran, Biem and Dwiyan Rivers.

4-1-4-2 Cropping Systems

The farming activities in the study area can be categorized into two main components: (i) Upland, lowland rice production and small livestock production. (ii) Household socio–economic activities, which include maintenance of the household social welfare and off–farm activities.

The main arable farming system in the area, based on the length of the fallow period and the input of labor, capital and technology are:

- Shifting cultivation: short period of cropping is followed by long fallow periods.
- Fallow system: Periods of cropping are followed by short fallow period.
- (Semi-) permanent cultivation: Fallow periods are very short or do not occur at all.

In practice the farming systems distinguished above are not distinctly separated. Within a certain area different farming systems occur.

(i) Upland cropping systems.

The main crops grown in the uplands are cereals – maize and rice; root and tubers – cassava and cocoyam; perennials – cocoa and citrus; and different types of vegetables. These crops are produced on small holders prepared by a slash-and-burn shifting cultivation method using simple hand tools like cutlasses and hoes.

Plantain intercropped with cassava, maize, cocoyam and maize intercropped with cassava are the most common and most widely practiced cropping system for the uplands. The cultivation period is between 18 months and 2 years involving a single crop of maize and cassava; with the latter harvested in the second year. For the plantain intercrop with the other crops, the cultivation period is between 1-6years depending on the crop husbandry practices of the farmer. Fallow periods vary between 2-12 years depending on the land holdings of the farmer and his family. Apart from maize most of the crops grown are local varieties.

Most farmers cultivate upland and lowland crops. Land preparation starts mostly in January in the dry season. Planting begins at the onset of the raining season (mid-March). Other crop husbandry activities like weeding and fertilizer application depend on the workload of the farmer (Fig. 4-2).

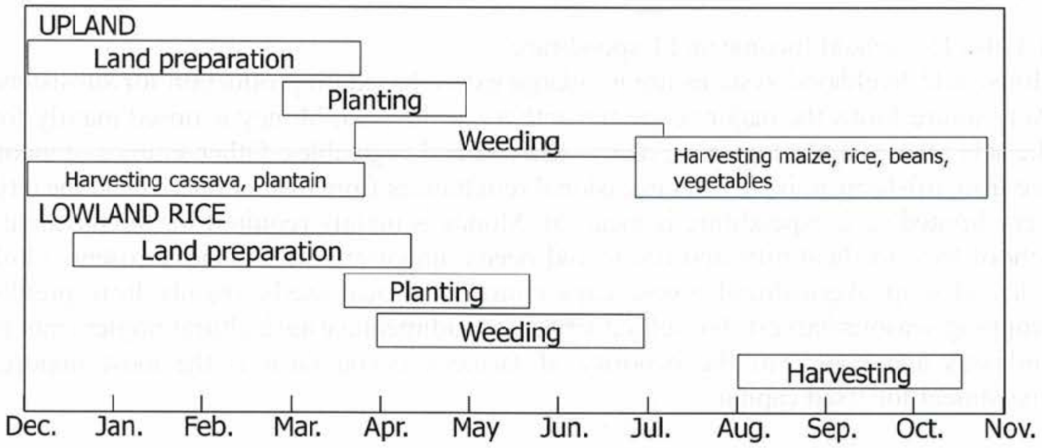

Fig. 4-2. Cropping calendar

Another cropping system in the uplands is the permanent type. It is used mostly in tree crops (cocoa, oil palm and citrus) cultivation. Tree crops holding are larger than those of the food crops, often been added to in successive years. During the establishment period of the tree crops, it is intercropped with plantain and annual crops until the canopy of the trees close.

The old plantations of cocoa, oil palm and citrus were established with traditional varieties. The new plantations are however established with improved varieties, which starts fruiting from the third year after planting. This sub-system provides, food to supplement household consumption requirements, money to purchase livestock, housing, to educate children and to cater for the medical needs of the family.

(ii) Lowland rice production.

Rice is cultivated in the lowlands either continuously or with a very short fallow period (1-2years) under slash-and-burn shifting cultivation method. Most of the inland valley bottoms are used for rice cultivation in the raining season. Majority (80%) of the farmers plant local varieties (mainly Asian origin of Oryza sativa, but sometimes African rice, Oryza glaberrima) which are either white or slightly red color which matures in 5 to 6 months. Yields of 0.5 to 1.5t/ha are obtained, depending on the crop husbandry practices of the farmer. The rest of the farmers cultivate mixed varieties of improved and local varieties. Rice is either dibbled or broadcasted during planting and weeded two to three times before harvesting. There is no water management and fertilizer application. Marketing outlets in the area are numerous. Rice is sold directly to itinerant middlemen who go to the area on market days. There is no price difference between the varieties grown, even though most consumers prefer the long white grain.

4-1-4-3. Animal Production

The main animals reared by the local farmers are sheep, goats and chicken despite the potential in feed resources from by-products and residues. The animals scavenge around homesteads. There are however well organized poultry farms in the area.

4-1-4-4 Off-farm Activities

The main off-farm activities undertaken in the area are basket weaving, palm wine tapping, distillation to produce local gin, dress making, and trading in food crops and small merchandise

4-1-4-5 Household Income and Expenditure

Household livelihood systems are to a large extent based on production for subsistence. Agriculture forms the major economic activity in the area. Money is raised mainly from the sale of cocoa, plantain, rice, maize, cassava and vegetables. Other sources of income are from off-farm activities and occasional remittances from distant relatives in the cities. Very limited cash expenditure is incurred. Money is mainly required for the payment of school fees, medical bills and household needs, important ones being kerosene, cloths, salt and soap. Agricultural investments consists of local seeds, mainly from previous cropping seasons harvest, household labor and rudimentary agricultural implements like cutlasses and hoes. For the majority of farmers, cocoa farm is the most important investment for fixed capital.

4-1-4-6 Analyses of Lowland Rice-cropping System.

The analysis of the problem tree of the inland valley bottoms (Fig.4-3) by the whole group indicated that there are both technical and social constraints to the utilization of the inland valleys. The technical constraints are water management, low soil fertility, weeds, and pests and diseases. The main social-economic constraints are lack of capital and labour. Proposed recommendations agreed on by both scientists, extension workers and the farmers were that, bunding and leveling of rice field was necessary for water and weed control, and utilization of organic manure is a cheaper means of maintaining soil fertility.

The project started with the above recommendations on farmers' fields in 1997. The adoption rate of the new technologies, which includes sawah system by the local farmers, is so high that other communities in Ghana are also adopting it. Farmers who used to obtain an average of 0.5 t/ha rice now obtain an average of 4.5 t/ha, an increase over 400%. The farming systems approach introduced in the Inland Valley Research Project had tremendously increased the adoption rate of the sawah technology introduced in the area. One important aspect also is that presently social and natural scientists are working as one team in the project.

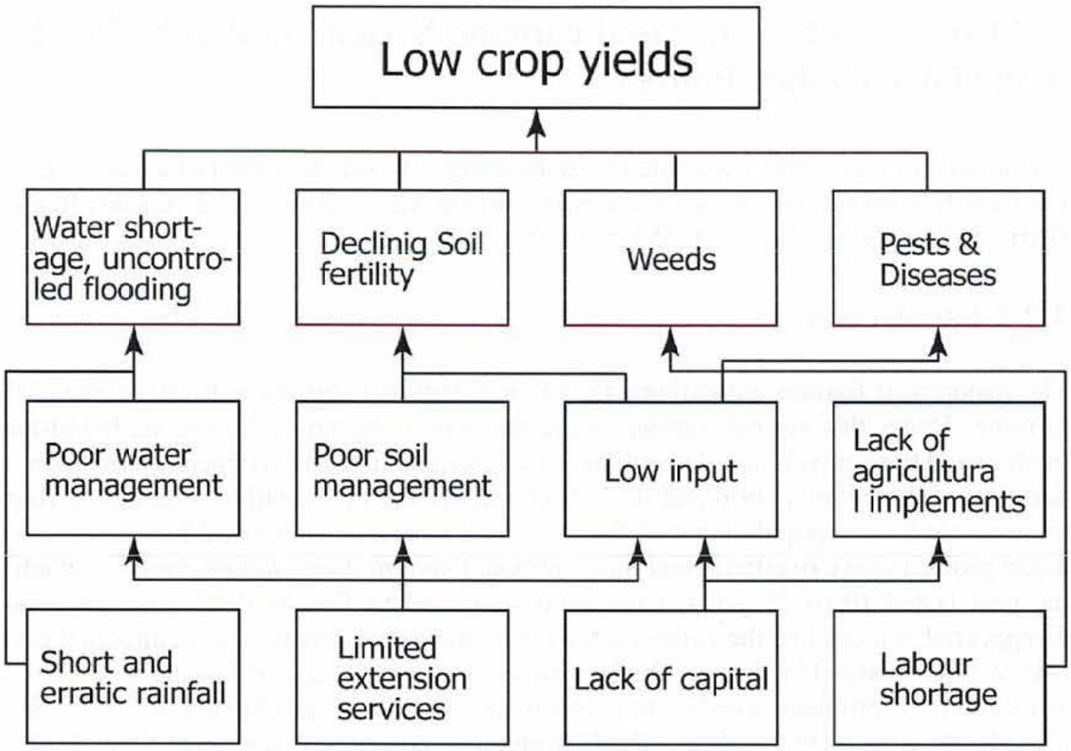

Fig. 4-3. The analyses of problem tree of the inland valley bottoms

4-1-5 Conclusion

The adoption rate of the soil and water management technologies, such as sawah system, that was developed with the farmers and the policy makers in the area indicated that the principles of farming systems research were useful tools to help researchers and farmer. This baseline survey indicated what they perceived as constraints to improvement of agriculture. It also was shown that some important features of improvement of farming systems in inland valleys may seem obvious to the local communities but go unnoticed by technology scientists. It also shows that FSR method is a stimulus for the local people to think through and articulate consideration, which may be important for technology designers to know about. This participatory method or technology generation also helps local communities to identify themselves with the new technologies, which are either generated or transferred to them.

4-2 Effect of a Sawah-Based Farming System on Rice Cultivation in the Inland Valley Bottom*

* This section was cited by Kwame O. Asubonteng (SRI) et al, "Effect of a Sawah-Based Farming System on Rice Cultivation in the Inland Valley Bottom the Ashanti Region, Ghana", Tropics, Vol.10, No.4, 555-564, 2001

4-2-1 Introduction

The majority of farmers are still practicing the traditional shifting cultivation method of farming. Under this system, farmers clear the native vegetation by the slash-and-burn method and then grow crops. The efficiency of shifting cultivation depends mostly on the duration of the fallow period and the nature and density of the fallow vegetation. Rapid increases in human population and the associated increases in demand for farmland and wood products have overburdened this traditional system. Long fallow periods, which in the past lasted 10 to 25 years, have been shortened to five or three years or almost disappeared in areas like the valley bottom sites in Ashanti, where rice is cultivated every two to three years. This has resulted in increasing degradation of farmland, increasing infestation of problem weeds, and declining yields and production of food crops (Atta-Krah et al., 1993). When food production targets are not met, food must be imported, especially rice, to meet rapidly increasing domestic requirements. It is estimated that 42% of the country's rice needs of 300,000 metric tons is imported (PPMED, MOFA, 1999), which is more than double the amount imported 10 years ago. The imports constitute a heavy drain on the country's meager foreign exchange reserves.

Inland valleys can contribute to the increase and stabilization of rice production. However, most farmers still use their traditional methods of cultivating rice in the valley bottoms. Farmers slash and burn their fields, dibble rice, and weed twice or thrice without water control or fertilizer application. The paddy yield obtained is often very low, 0.5 - 1.5 t ha^{-1} (Fig. 4-4). The detailed characterization and evaluation of the study site have revealed that even though valley bottom soils are slightly richer than those of the uplands, they are still low in nutrient reserves to support intensive rice cultivation. Water control and weed infestation are also major constraints to rice production (Asubonteng et al., 2001). Therefore, new farming systems, i.e. Sawah based rice farming, that attain both soil restoration/water conservation and high yield must be developed

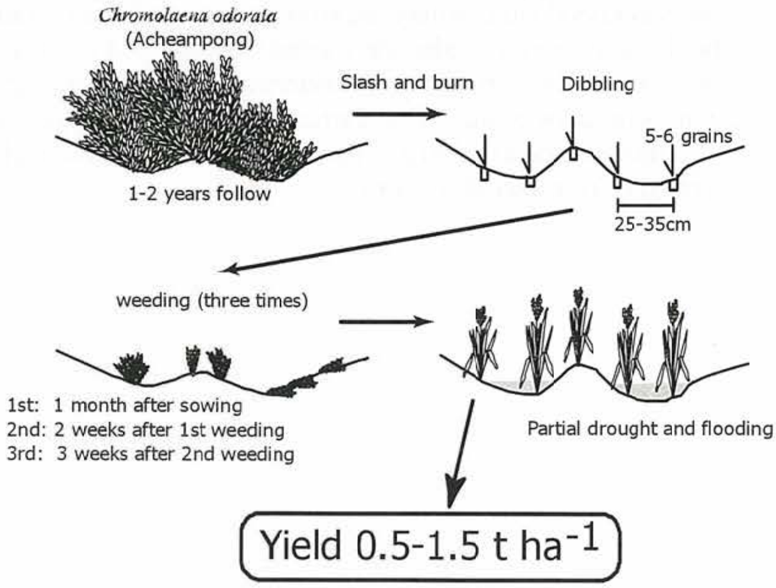

Fig. 4-4. Traditional rice farming practice in inland valley bottom of Ashanti region, Ghana.

to achieve effective and sustainable rice production (Wakatsuki et al., 1998).

Mineral fertilizers could be used to improve fertility management of these soils, and a large amount of literature on their comparative efficiency is available. (Djokoto and Stephens, 1961; Kwakye, 1975; De Datta et al., 1983; De Data and Buresh, 1989). The fact that farmers are relying on rain-fed field conditions makes the efficiency of the fertilizer very low. In addition, the high prices, high cost of handling, and poor distribution networks of inorganic fertilizers have resulted in serious setbacks in their use by small holder farmers who form the majority of the farming population.

Different sources of organic residues (cow dung, poultry manure, and decomposed rice straw) are available in farming communities in this area. These could provide nutrients as well as increase the organic matter, which would in turn help improve the nutrients reserve, especially N in the soil (Asubonteng, 1997; Asubonteng et al., 2001). Nutrient retention, weed control, and water management could also be improved in submerged fields, Sawah (Wakatsuki, 1994). The purpose of the present investigation was therefore to compare the sawah system with the traditional rain-fed lowland rice cultivation method of local farmers.

4-2-2 Materials and Methods: Comparison of rice cultivation practice in Sawah and traditional system

4-2-2-1 Study Area

The experiment was conducted at the Potrikrom site. The area has a bimodal rainfall pattern; the annual rainfall was 1363.1 mm during this experiment. The major rainy season lasted from mid-March to the end of July with a peak in July. The minor rainy season began in September and ended in mid-November. Relative humidity figures ranged between an average of 87.9% at 0900 hours to 62.8% at 1500 hours.

4-2-2-2 Experimental Site and Design

It was in an inland valley bottom, which was under a fallow for two years before initiation of the experiment. The soil type was Haplic Gleysol with low nutrient levels (Asubonteng et al., 2001). There was a split-plot design with a farmer's field and a sawah field as the main plots and six fertilizer treatments as subplots (Table 4-1). There were 4 replications for each treatment. Each subplot measured 5 m x 5 m. Bunds 50 cm high were mounted around the edges of each sawah plot in order to hold water (Fig.4-5). The sawah fields were bunded, leveled, and puddled with a power tiller.

Table 4-1. Fertilizer treatments in two experimental plots of farmer's rain-fed field and sawah field.

	Treatment	Application rate in dry weight (ha^{-1} $year^{-1}$)	Nutrient addition N	P_2O_5	K_2O
			(kg ha^{-1} $year^{-1}$)		
T1	Control		0	0.0	0
T2	Chemical fertilizer		45	30.0	30
T3	Chemical fertilizer		90	60.0	60
T4	Poultry manure	4 ton	81	28.0	36
T5	Cowdung	4 ton	57	6.4	36
T6	Decomposed Rice Straw	4 ton	31	2.8	72

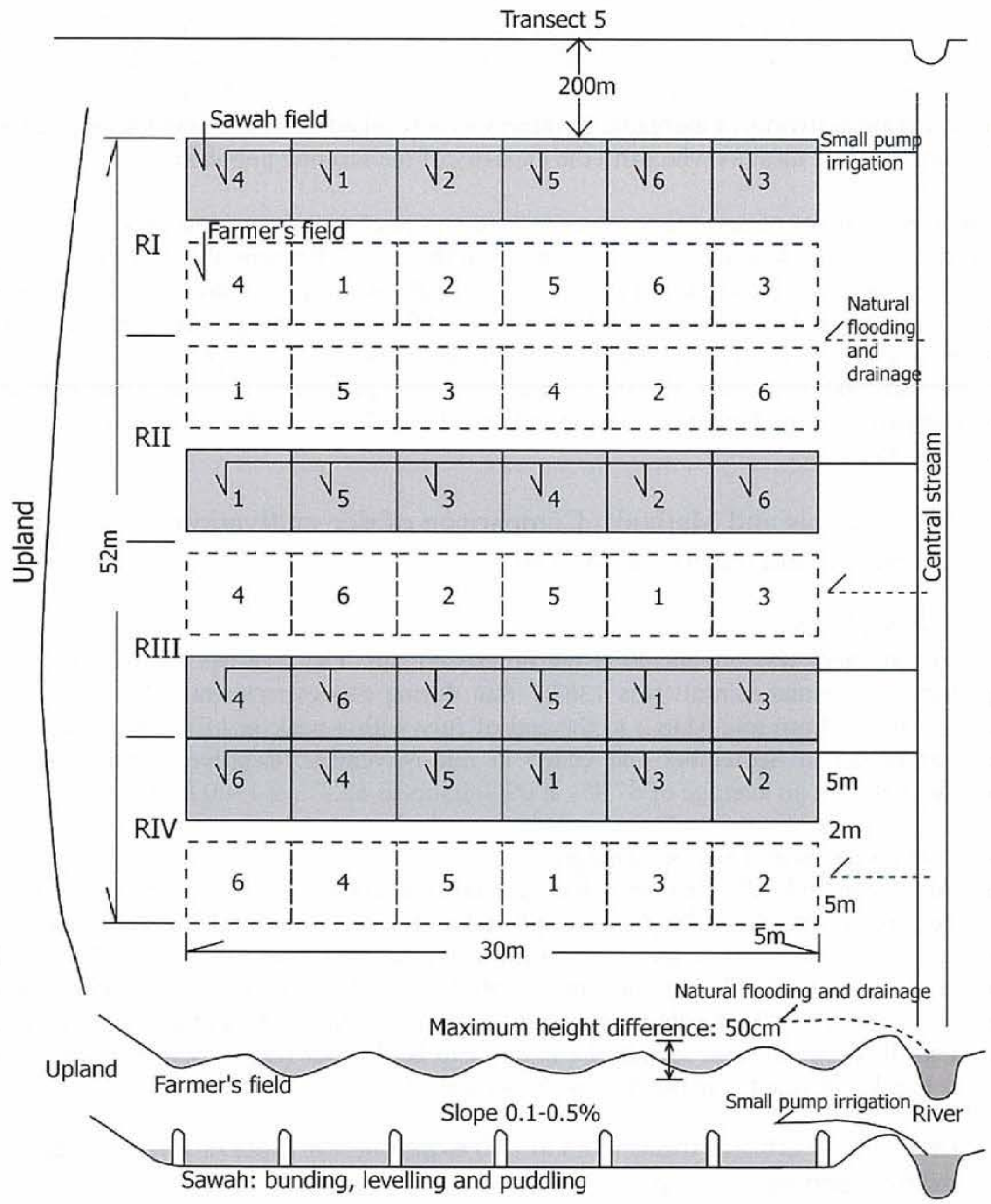

Fig. 4-5. The field experimental layout of experimental plot in Potrikurom site near the Transect 5.

When necessary, sawah fields were irrigated using a small hand pump to lift water from the river. In the field representing the farmers' rice cultivation practices the vegetation was burnt after slashing.

Organic manure was applied and mixed with topsoils three weeks before transplanting. The rice variety "*sikamo*" was used as the test variety and was transplanted at 20 x 20 cm spacing. T1 was a control plot in which no inorganic fertilizer or organic manure was applied. On T3, a basal application of 60 kg N ha^{-1} ammonium sulphate, 60 kg P_2O_5 ha^{-1} triple superphosphate, and 60 kg K_2O ha^{-1} muriate of potash were applied just before plowing and/or puddling for transplanting. Thirty kilograms of N ha^{-1} ammonium sulphate was applied for top dressing at the maximum tilling stage. T2 received only a basal application of 45 kg N ha^{-1}, 30 kg P_2O_5 ha^{-1}, and 30 kg K_2O ha^{-1} of the same types of fertilizers. Organic manure at a rate of 4t ha^{-1} (dry basis) was used.

Total N, P_2O_5, and K_2O contents of poultry manure, cow dung, and decomposed rice straw were 2.02%, 0.7%, and 0.9 %, 1.42%, 0-16%, and 0.9%, and 0.78%, 0.07%, and 1.8%, respectively. The increase in the amount of N and other nutrients as a result of various treatments is depicted in Table4-3. The local farmers' field type was weeded three times. The sawah fields received no weeding (Table 4-2). The number of productive tillers, the panicles, and the grain and straw yield were recorded and nitrogen uptake of the grain and straw was determined. The top 20 cm of the soil was sampled for analysis before fertilizer application.

Table 4-2. Comparison of sawah and farmer crop (rice) husbandry practices.

	1st week of Jun.	3rd week of Jun.	3rd week of Jul.	2nd week of Aug.	1st week of Sep.	1st week of Oct.	3rd week of Oct.
Farmers' field	Application of organic manure	Transplanting and basal application of inorganic fertilizer	Weeding	2nd weeding	3rd weeding Top dressing (T3)	-	Harvest
Sawah	Application of organic manure	Transplanting and basal application of inorganic fertilizer	No weeds	No weeds	Pick up weed Top dressing (T3)	-	Harvest
		Flooding of sawah field using small pump				Drain water from sawah field	

Organic manure: Poultry manure, Cowdung, Decomposed rice straw
Inorganic fertilizers: Ammonium Sulphate, Triple Super Phosphate, Muriate of Patash

4-2-2-3 Soil and Plant Analytical Methods

Soil pH was determined using a pH meter (with a glass electrode) with a soil-to-water ratio of 1:2.5, according to the methods described by the IITA (1979) and McLean (1982). Total carbon content was determined by the wet combustion method as described by Walkley and Black (1934). Total N content was determined using an N-C analyzer (Sumigraph NC-90A) as described by Geigher and Hardy (1971). Available P was determined by the Bray No.1 method (Bray and Kurtz, 1945). Exchangeable Ca, Mg, K, and Na were first extracted with ammonium acetate (1.0M NH_4Oac).

Contents of exchangeable K and Na were determined by atomic absorption spectrophotometry as described by Thomas (1982). Contents of exchangeable Ca and Mg were determined by inductively coupled plasma-atomic emission spectroscopy (Shimadzu ICPS 2000). Exchangeable acidity was determined by first extracting with potassium chloride (1M KCl) and titrating the extract with sodium hydroxide as described by McLean (1965). Effective cation exchange capacity (ECEC) was calculated as the sum of exchangeable cations (K, Ca, Mg, Na) and exchangeable acidity. Particle size analysis was conducted by the pipette method as described by Gee and Bander (1986).

4-2-3 Results and Discussion

4-2-3-1 Productive tiller and N uptake under sawah and farmers' field

Results of the soil analysis are given in Table 4-3. Although exchangeable Ca and Mg were nearly as rich as in the inland valley soils in West Africa (Issaka et al., 1997), the pH indicated that the soil was slightly acidic in nature, with medium organic matter and N content. The base saturation is very high (99.63%). The levels of available P and exchangeable K were low. The soil tested was Haplic Gleysol (Oda series), typical in the valley bottom in this area (Asubonteng et al., 2001). Table 4-4 gives the main effect of the farming practices (*sawah* and farmers' practice) on growth, yield components, and N uptake. Regardless of the type of treatments, grain and straw yield, effective tillers and agronomic efficiency, were significantly higher with the *sawah* method than the farmers' practice. It must be noted that even in the control plots under the *sawah* system, where there was no application of fertilizer, the grain yield was 2.5 t ha^{-1}. This was equal to the grain yield obtained in the farmers' plots where the recommended rate of fertilizer (N90 P60 K60) was applied.

Table 4-3. Chemical and physical properties of soil, Oda series, at the experimental site (0-20cm depth)

pH H_2O	Exchangeable cations: Ca	Mg	K	Na	Exch. Acid. Al + H	ECEC	Base Sat.
	cmol(+) kg^{-1}						%
5.4	11.91	1.47	0.13	0.07	0.05	13.63	99.6

Org. C	T-N	O.M.	C/N	Avail. P_2O_5	Sand	Silt	Clay
	%			mg kg^{-1}		%	
1.51	0.13	2.6	11.6	5.04	57.0	31.5	13.5

Table 4-4. Productive tillers, yield and N uptake under *sawah* (S) and farmers' field (F).

Treatment	Productive tillers ($stock^{-1}$)		Straw yield (t ha^{-1})		Grain yield (t ha^{-1})		N uptake in grain (kg ha^{-1})		N uptake in straw (kg ha^{-1})		N uptake in grain & straw (kg ha^{-1})		
	S	F	S	F	S	F	S	F	S	F	S	F	S-F
T1	8.8	5.5	4.5	2.2	2.5	1.5	42.3	25.6	25.5	18.1	67.8	43.6	24.2
T2	11.8	7.0	6.5	3.0	3.5	1.9	51.0	36.4	35.0	25.0	86.0	61.4	24.6
T3	17.5	10.5	9.6	4.1	4.9	2.5	86.7	50.3	53.2	35.5	139.9	85.8	54.1
T4	13.8	8.3	7.2	4.1	4.5	2.3	67.4	50.8	43.2	34.8	110.7	84.9	25.8
T5	12.5	7.8	6.7	3.8	3.9	2.1	60.4	46.0	40.1	30.0	100.5	76.0	24.5
T6	11.5	7.5	6.3	3.7	3.0	1.9	59.9	48.0	39.1	29.5	99.0	77.5	21.6
LSD 5%	1.1		0.28		0.3		1.8		2.5		6.7		
1%	1.5		0.38		0.4		2.5		3.3		8.9		

A possible explanation for the success of the *sawah* technology is that, due to leveling and bunding, water can be properly managed to increase fertilizer efficiency. In addition to this, flooding of paddy soil changes its soil chemistry for rice growth, including generally eliminating soil acidity problems (Ragland and Boonpukdee, 1987) by increasing soil pH. This contributes to the rise in P and N availability (Willet and Intrawech, 1988; Ragland and Boonpukdee, 1987). Irrigation water supply base cations such as Ca and K. The most important contribution of the sawah system is Nitrogen fixation under submerged condition, which reaches 20-100 KgN/ha in a growing season depending on the condition and management. Sawah also effective to trap fertile topsoils eroded from the upland (Geological fertilization) (See Chapter 2).

In contrast to that, in rain-fed conditions with no water management there are large changes in the chemistry of the soils due to the fluctuation in soil water with intermittent wetting and drying cycles. Even when there is a small undulation, as shown in Figure 4-4, the micro depression and crest accentuate the wetness and dryness. Wetting and drying cycles can cause large losses of N in the soil of a farmer's field. During drying phases in the soil, reduced forms of N, particularly NH_4^+, are nitrified to NO_3 (Sanchez, 1976). After soil flooding, as sometimes occurs in farmers' fields lacking water control, NO_3 may be lost by leaching or by de-nitrification to N_2 and N_2O gasses. Flooding and reduction of topsoil also increase P availability under the sawah system, which may have also contributed to the high rice yield.

4-2-3-2 Apparent agronomic N uptake efficiency, Agronomic uptake N efficiency, and Agronomic N efficiency under sawah and farmers Field

N uptake was more efficient and significant in treatments under the sawah system. The recommended rate of inorganic fertilizer for rice (N90 P60 K60) resulted in the highest uptake of N in both grain and straw (Table 4-4). In order to examine the effect of N fertilizer in the *sawah* system on grain yield, we calculated the apparent agronomic N uptake efficiency (AANUE), agronomic uptake N efficiency (AUNE), and agronomic N efficiency (ANE) of each treatment in both types of fields. The results are shown in Table 4-5. AANUE was defined as N uptake of grain and straw of T2 to T6 minus T1 per the amount of N addition of each T1 to T6. AUNE was defined as the increment of grain yield per the increment of N uptake of each treatment compared to the control. ANU was defined as the increment of grain yield per the increment of N addition of each treatment compared to the control. The equations are shown in Table 4-5.

Although even in the farmers' fields practice, N uptake is higher for all the treatments than it is in the control field, there was not much difference between the recommended rate of NPK and the organic residues (Table 4-4). When there is no water control, the uptake and the efficiency of both N fertilizers and organic manure applied remain limited. AANUE of T2, T4, T5, and T6 were similar in both types of fields. Following the greater application of N, P, and K fertilizers, T3 showed more efficient uptake in the sawah than in the farmers' field. The difference of N uptake of T1 between the sawah and farmers' field was 24.2 kg ha^{-1}. This shows, apart from the addition of N fertilizer, the effect of the sawah system itself in enhancing N uptake. If we calculated the AANUE of T2-T6 in the sawah system based on the T1 of the farmers' field, the value increased from 0.40-1.00 to 0.83-1.79, as shown in the parentheses in Table 4-4, which also shows the effect of the sawah system. In the farmers' field, AUNE of treatments T2-T6 were considerably smaller than the uptake N efficiency, 34.4 (grain yield/ N uptake in grain + straw), of the control plot in the farmers' field (Table 4-5). This means, in the present farmers' field condition, rice plant cannot effectively utilize both applied mineral and organic fertilizers.

Table 4-5. AANUE, AUNE and ANE.

Treatment	N add. ($kg\ ha^{-1}$)	⊿ Grain yield ($kg\ ha^{-1}$)		⊿ N uptake ($kg\ ha^{-1}$)		AANUE (N up./ N add.)		AUNE (Grain t / N kg)		ANE (Grain t / N kg)	
		S	F	S	F	S	F	S	F	S	F
T1	0	-	-	-	-	-	-	36.9**	34.4**	-	-
T2	45	1000	400	18.2	17.7	0.40 (0.94)*	0.39	55.1	22.5	22.2	8.9
T3	90	2400	1000	72.1	42.2	0.80 (1.07)*	0.47	33.3	23.7	26.7	11.1
T4	81	2000	800	42.9	41.3	0.53 (0.83)*	0.51	46.7	19.4	24.8	9.9
T5	57	1400	600	32.7	32.4	0.58 (1.00)*	0.57	42.8	18.5	24.6	10.6
T6	31	500	400	31.2	33.9	1.00 (1.79)*	1.08	16.0	11.8	16.0	12.8

⊿ Grain yield: Gf - Gc, where Gf is grain yield of the fertilized plot (T2 - T6); Gc is that of the control plot (T1).

⊿ N uptake: NUf - NUc, where NUf is N uptake in grain & straw of the fertilized plot (T2-T6); NUc is that of control plot (T1).

AANUE: Apparent Agronomic N Uptake Efficiency (⊿ N uptake / N add.)

AUNE: Agronomic Uptake N Efficiency (⊿ Grain yield / ⊿ N uptake)

* values in parenthese were calculated as (⊿ Nf uptake / N add.), where ⊿ Nf uptake is NUf - NUcf (NUc in fermers' plot).

ANE: Agronomic N Efficiency (⊿ Grain yield / N add.)

** Gc / NUc

N add.: N addition by fertiliztion (the values are the same as Table 1)

Under the *sawah* system with water control, both mineral and organic fertilizers gave higher grain yield and N uptake as well as higher AUNE, except for the rice straw treatment, T6, and the recommended fertilizer plot, T3. In the T6 treatment, P availability may be another limiting factor because of the small addition of P (Table 4-1) and the poor amount of available P in the soil (Table 4-3). In the recommended fertilizer plot of T3, this lower apparent agronomic fertilized N efficiency means that the amount of this N level may be close to optimum. ANE showed a similar trend to AANUE. This is the indicator for the economic production obtained per unit of nutrient applied. In every case, the sawah system had superior performance. ANE of the sawah fields were more than double those of the farmers' field. The biggest difference was 2.4 times in T3, which received the highest rate of chemical fertilizer.

In all the fertilizers treatments under the different crop husbandry practices, the inorganic fertilizer resulted in higher grain and straw yield under both systems, although it was not significantly different than treatments of poultry manure. Among the organic manures fertilizers, the maximum yield resulted from the application of poultry manure and the lowest yield, significantly, resulted from rice straw incorporation. This means that the soils used were deficient in not only N but also P, as shown in Tables 4-1 and 4-3.

4-2-4 Conclusion

The results and observations indicate that under the sawah system rice production can be increased more than 400% (Ave. 4.5t/ha) over what the local farmers now obtain (Ave. 1.0t/ha). As shown in Fig. 4-6, the sustainable high yield was realized by good water control through the installation of the Sawah system. Major advantages of the Sawah systems are (1) elimination of acidity and alkalinity by the submergence of top soil which develop anaerobic condition. This anaerobic condition assists to increase phosphate availability by releasing the ferrous ions. The submergence and anaerobic conditions also contribute to microbiological nitrogen fixation. The amounts of nitrogen fixation in Sawah systems are estimated as 20 – 200kg N per ha per year. In Japan the amount was estimated as 50-80Kg N per ha per year (Kyuma and Wakatsuki 1995, Wakatsuki 1997). Submerging condition of Sawah also very effective to control weed. The weed control is also another remarkable advantage of sawah system in tropical climate. In addition to these biochemical mechanisms to sustain the soil fertility, lowland sawah can also enjoy the geological fertilization in the watershed as described in the Chapter 2. Those special biochemical processes are considered to contribute short to medium term, 10-30 years, sustainability, while the geological fertilization is considered to contribute longer term(100 years), sustainability. This shows that if the sawah-based farming system is adopted in even 100,000ha of the 1,000,000ha of land in inland valleys suitable for rice cultivation, the country can be self sufficient in rice production.

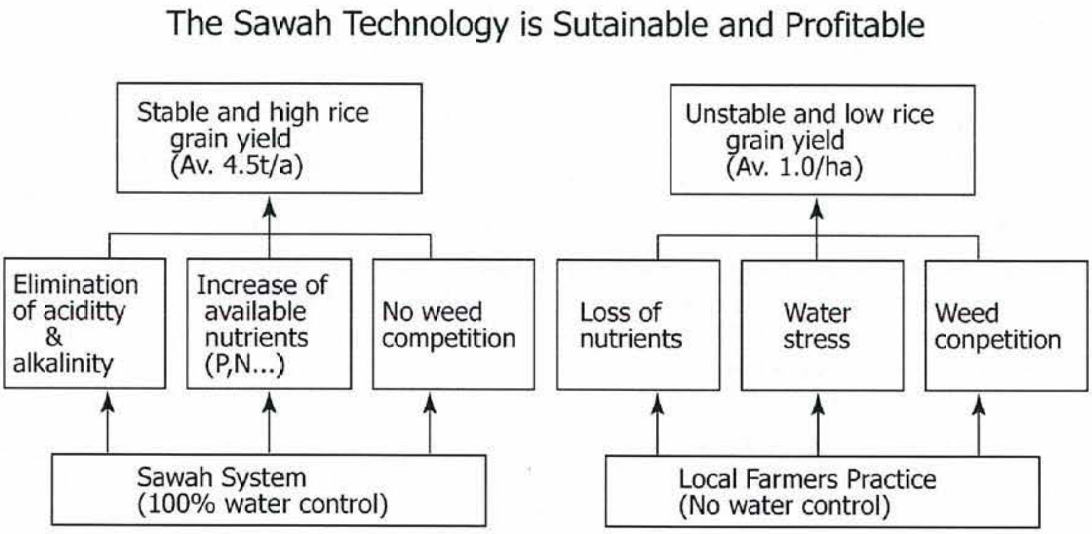

Fig. 4-6- Sawah Technology Analysis

4-3 Integrated Nutrient Management for Sustainable Rice Production In Valley Bottom Soils of the Sub-humid Tropics of Ghana

4-3-1 Introduction

Soil nutrients, especially nitrogen, are very important for rice production. About 63% of the nitrogen taken by rice originates from rapidly and easily decomposable organic nitrogen (Ando and Shoj, 1985). However, from available data (Asubonteng and Dennis, 1997), and the results of a detailed characterization of inland valley watersheds in the semi-deciduous forest zone in Ghana, the organic matter content in the valley bottom soils are generally low to sustain intensive rice cultivation (Asubonteng and Dennis, 1995). In order to increase and sustain the yield of rice grown on these soils, mineral fertilizers could be used to improve the productivity of these soils. A large amount of literature on the comparative efficiency of inorganic nitrogen is available (Djokoto and Stephens, 1961; Kwakye, 1975; De Datta *et al.*, 1983; De Datta and Byresh, 1989).

However, the high prices, high cost of handling and poor distribution networks of these inorganic nitrogen (N) fertilizers have resulted in serious setbacks in their use by small holders who form the majority of the farming population. Different sources of organic residues are available in these areas which can provide nutrients as well as increase the organic matter which would in turn help improve the nutrients reserves, especially nitrogen in the soil. In addition to biological N fixation integrated use of organic manures and inorganic fertilizers can contribute to the nitrogen content of rice soils as well as the increase in the long-term productivity (Meelu *et al.*, 1980; Gill and Meelu, 1982) and enhancement of ecological sustainability.

The main organic residues in the area are poultry manure (PM), rice straw (RS) and cow-dung (CD). Poultry manure is a good source of nitrogen, phosphorus and potassium and cow-dung or cattle manure is a very good source of nitrogen and potassium. The nutrient ratio of cow-dung is approximately 10:5:13 (NPK). For nitrogen, some 30% to 60% of the total N can be regarded as available (Kwakye, 1975; Flaig *et al.*, 1975). The availability of phosphorus (P) and potassium (K) corresponds to that of mineral fertilizers. The effect of P may even be better, because there is a gradual release of P from the organic fertilizers, which prevent possible P fixation as against the quick release of P from inorganic phosphate fertilizers.

Rice straw is another important source of organic matter. Incorporation of rice straw into submerged soil causes dramatic changes of chemical conditions of the soil and makes some plant nutrient elements like iron (in high pH soils) and phosphorus, more available to the rice plant, and its continuous application increases the soil nitrogen (Pannamperuma, 1980). Santiago - Ventura *et al.* (1986) reported that straw supplied N to the flooded soil rice system through the addition of N and promotion of N fixation. Hwang and Kim (1977) reported that the use of rice straw markedly increased the organic N, potash, and silica contents in soil as well as rice yields. Potassium in rice straw is also an important element for increasing yield (Oh, 1985).

Manure and compost also provide a stable supply of ammonium through slow nutrient release. The results of other work carried out in other parts of West Africa show that manures are as effective as mineral fertilizers and, in some cases, better for increasing crop yield (Obi, 1959; Dennison, 1961; Djokoto and Stephens, 1961; Lombin and Abdullali, 1977). Similar results have been obtained in other parts of the world. However, the low nutrient content of manure means that large quantities are required to produce comparable effects to those of mineral fertilizers.

The incorporation into soil of fresh organic materials including rice straw, results in the formation of organic acid (Rao and Mikkelsen, 1976;). Therefore, heavy application may lead to plant toxicity. Ryu *et al.,* (1971) reported a negative correlation between yield and organic content in imperfectly or poorly drained soils. The Sawah based rice production system, being introduced as a new technology in the inland valleys, will create a condition where rice soils would be flooded almost in the entire period of rice growth.

Based on these considerations the present investigation was carried out. The effects of the application of organic manure together with inorganic fertilizers on rice yield and N utilization by rice crop and the residual soil fertility were studied under sawah-rice based system in an inland valley in the semi-deciduous rain forest of Ghana.

4-3-2 Materials and Methods

4-3-2-1 Experimental site

The experiment was conducted at Potrikurom site in Dwinyan inland valley, which is the same site described in the above section 2 and 3. The experiment was conducted on a dark greyish brown silty clay soil, Haplic Gleysol (Oda series), a typical inland valley bottom in the area. (Asubonteng et al, 2000). The top 20 cm of the soils were sampled before fertilizer application for analysis. Soil samples were air dried, ground and passed through a 2 mm mesh sieve.

4-3-2-2Soil and Plant Analytical Methods

Soils were analyzed similar methods described in the previous section reaction, Chapter 4, 2. Nitrogen in the plant samples was also determined using an N-C analyzer (Sumigraph

NC-90A). Contents of micronutrients Cu, Zn, Fe and Mn were extracted in O.IN HCl according to the method of Viets and Brown (1965).

4-3-2-3 Experimental Design

The experiment (Table 4-6) was designed as randomized complete block with the following treatments: T_1, control; T_2, Urea; T_3, ammonium sulphate (Al/SO_4); T_4, A/SO_4 + Poultry Manure (PM); T_5, A/SO_4 + decomposed rice straw (DRS); T_6, A/SO_4 + cow-dung (CD); T_7, Urea + PM; T_8, Urea + DRS and T_9, Urea + CD. Inorganic nitrogen fertilizers were applied at the rate of 90 kg N ha^{-1} for sole urea and ammonium sulphate treatments (T_2 and T_3) and 45 kg ha^{-1} when they were applied in combination with organic manures (T_4 - T_9). The nitrogen fertilizers were applied twice (2/3basal + 1/3 at panicle initiation). A basal dose of 30 kg P_2O_5 ha^{-1} and 30 kg K_2O ha^{-1} were applied to the sole nitrogen treatments (T_2 and T_3). The organic manures at a rate of 3 tha^{-1} (dry basis) were incorporated into the soil 21 days before transplanting. Total N, available P and K and Zn contents of poultry manure, cow-dung and decomposed rice straw were 2.02, 0.07, 0.9% and 14 mg $kg^{-1;}$ 1,42, 0.16,0.9% and 10 mg kg^{-1}; and 0.78, 0.07, 1.8% and 4 mg kg^{-1} respectively. The increase in the amount of nitrogen and other nutrients as a result of various treatments is depicted in Table 4-6, too. The experiment was laid out in a randomized complete block design using four replications. Plot size was 5 m x 4 m and rice variety, sikamo was used as the test variety and was transplanted at 20 cm x 20 cm spacing. The number of productive tillers, grain and straw yields, 1000-grain weight were recorded. Grain and straw samples were analyzed for total N content to calculate Agronomic and N Recovery efficiencies (Mengel and Kirkby, 1987).

Table 4-6. Nutrient addition through organic and inorganic nitrogen source

Treatment	Dry weight of organic residue t/ha	Nutrient addition (kg ha^{-1})		
		N	P_2O_5	K_2O
T1 Control	-	-	-	-
T2 Urea	-	90	30	30
T3 Sulphate of Ammonia (A/So_4)	-	90	30	30
T4 A/So_4 + Poutry Manure (PM)	3	45+60.6	15+2.1	27
T5 A/So_4 + Decomposed rice straw	3	45+23.4	15+2.1	54
T6 A/So_4 + Cowdung (CD)	3	45+42.6	15+4.8	27
T7 Urea + Poultry Manure (PM)	3	45+60.6	15+2.1	27
T8 Urea + Decomposed rice straw (DRS)	3	45+23.4	15+2.1	54
T9 Urea + Cowdung (CD)	3	45+42.6	15+4.8	27

4-3-3 Results and Discussion

Results of the soil analysis indicated that the soil was slightly acid (pH 5.7) with moderate level of available phosphorus (7.40 mg kg^{-1}). Effective cation exchange capacity (ECEC) and base saturation were high (12 cmol (+) kg^{-1} and 96.77% respectively). Total nitrogen (0.08%) and organic matter (0.59%) were low. The soils were adequately supplied with Zn (3.5 mg kg^{-1}). Fe and Mn deficiencies was unlikely in the soil nor was there any likelihood of toxicity from these elements with the present values of the elements at 71.1 mg kg^{-1} Fe and 28.8 mg kg^{-1} Mn.

Table 4-6 depicts the increase in the amounts of various nutrients in the soils as a result of the application of N fertilizer alone or in combination with organic manures. Poultry manure application increased the nitrogen content by 60.6 kg ha^{-1}, phosphorus content by 2.1 kg ha^{-1} and potassium by 27 kg ha^{-1}. Cow-dung application increased the nitrogen content by 42.6 kg/ha phosphorus content by 4.8 kg ha^{-1} and potassium by 27 kg ha^{-1}. Decomposed rice straw also increased nitrogen content by 23.4 kg ha^{-1}, phosphorus by 2.1 kg ha^{-1} and potassium by 54 kg ha^{-1}.

The effect of the application of organic manures and inorganic fertilizers on the number of tillers, straw and paddy yield is shown in Figure 4-7 and Table 4-7. Regardless of the type of organic manures used in combination with the inorganic nitrogen fertilizer, the straw, paddy yield and effective tillers were higher and more significant than when inorganic nitrogen fertilizers were used alone. Ammonium sulphate application also resulted in a large number of productive tillers, as well as in a higher straw and paddy yield compared to urea. In the application of organic manures on paddy yield, the maximum yield resulted from the application of poultry manure and A/SO_4 (T_4). This was followed by application of A/SO_4 with cow-dung (T_6) and urea and poultry manure (T_7) respectively. The lowest yield was obtained when urea was combined with rice straw (T_8). The effect of the various treatments on straw yield was similar to their effect on tiller numbers. The maximum tiller number and straw yield were obtained by the application of A/SO_4 and poultry manure.

Table 4-7. Tillers, yields, N uptake and recovered, and agronomic efficiency as influenced by treatment combinations pf inorganic nitrogen fertilizers and organic manures

Treatments	Productive tillers (No)		Straw Yield (kgha-1)		Grain yield (kgha-1)		N uptake in Straw (kgha-1)		N uptake in Grain (kgha-1)		N recovered in grain and straw (%)		Agronomic efficiency kg paddy kg-1N	
T1	9.00	g	3000.0	d	1560.0	d	19.2	c	33.8	e	0.0		0.0	
T2	13.25	f	5000.0	c	2750.0	c	30.4	b	45.0	d	24.4	e	13.1	d
T3	15.00	e	5825.0	bc	3250.0	bc	33.3	ab	49.5	cd	29.7	de	21.0	c
T4	18.75	a	6975.0	a	4225.0	a	39.1	a	59.0	a	44.7	ab	25.2	ab
T5	16.25	cd	6125.0	ab	3700.0	ab	35.8	ab	51.9	bcd	49.3	a	31.2	ab
T6	17.75	ab	6575.0	ab	4006.3	a	37.8	a	57.1	ab	42.2	abc	25.1	ab
T7	16.75	bc	6337.5	ab	3968.8	a	38.2	a	54.9	abc	36.6	bcd	22.8	ab
T8	15.25	de	6025.0	abc	3581.3	ab	34.7	ab	51.0	bcd	47.2	bcd	29.6	ab
T9	16.50	c	6262.5	ab	3915.0	a	34.8	ab	53.3	abc	35.5	cd	24.1	ab
LSD 0.05	1.05		1065.2		653.0		6.9		7.1		9.0		8.6	

Means followed by the same letters are not significant at 5% level of significance.

Nitrogen contents in straw, grain and grain + straw were significantly affected by the various fertilizer treatments. N uptake in grain + straw was always significantly higher with A/SO_4 treatments than the urea treatments. Like the tiller number, grain and straw yield, the highest N uptake in both grain and straw was obtained when A/SO_4 was applied in combination with poultry manure (Table 4-8). In the contribution of various organic manures to N uptake, the additional uptake associated with the application of poultry manure was the highest, while the least contribution was by rice straw. Nitrogen recovery efficiencies were also significantly influenced by the various treatments. Nitrogen recovery efficiency in straw + grain was highest in the case of application of A/SO_4 with rice straw, followed by urea and rice straw and the lowest was by the incorporation of urea alone. Agronomic efficiency was also significantly influenced by the various treatments as shown in Fig. 4-8. Agronomic efficiency was also highest in application of A/SO_4 with rice straw followed by urea and rice straw. The nitrogen recovery and agronomic efficiencies, sulphate of ammonia treatments resulted in higher efficiency rate than those of urea (Table 4-8).

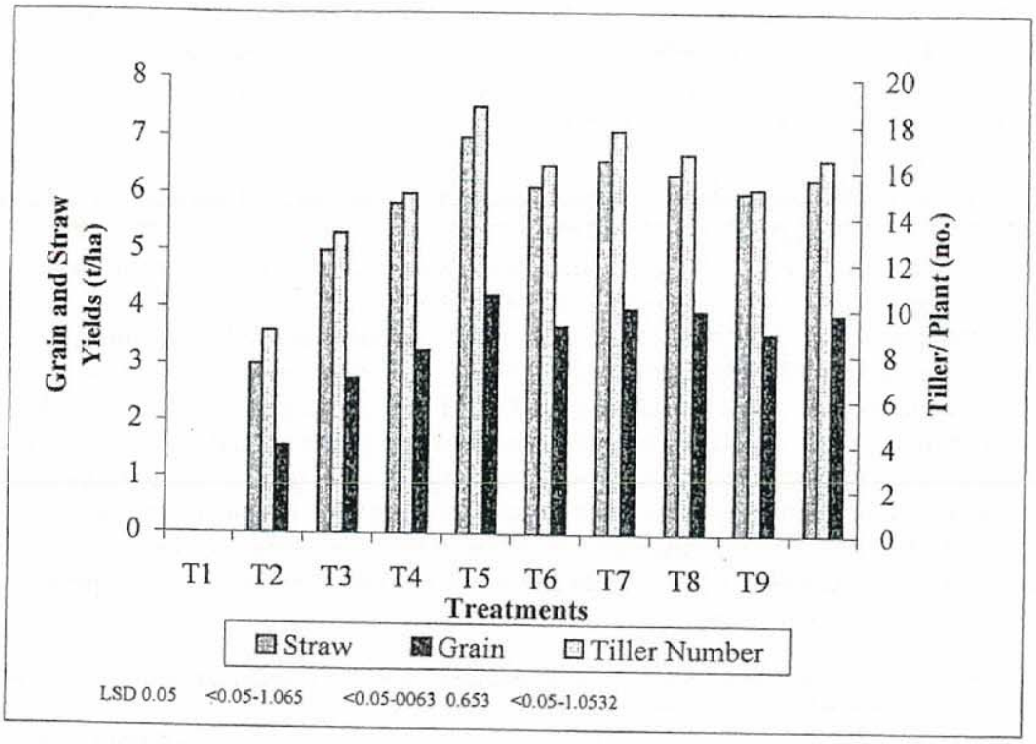

Fig. 4-7. Effect of the application of inorganic nitrongen fertilizers and organic manures on rice yield and tiller number..
T1 control; T2 urea 90 kgN/ha; T3 ammonuim sulphte (A/SO_4) 90 kgN/ha
T4 A/SO_4 45 kgN/ha + 3 t/ha Poultry Manure (PM); T5 A/SO_4 45 kgN/ha + 3t/ha Rice Straw (RS);
T6 A/SO_4 45 kgN/ha + 3 t/ha cowdung (CD); T7 Urea 45 kgN/ha + 3 t/ha PM;
T8 Urea 45 kgN/ha + 3 t/ha RS; T9 Urea 45 kgN/ha + 3 t/ha CD

The residual effect of organic and inorganic fertilizers on soil fertility indicated that both inorganic and organic sources increased the total nitrogen content in soil, the values being 10-81 and 8.1% of sulphate of ammonia and urea respectively. The increase in nitrogen content due to the application of poultry manure, rice straw and cow-dung were 18.92 - 21.45, 13.51 - 14.87, 16.21 - 17.57 % respectively.

All the fertilizer sources had a positive effect on the organic matter content of the soil. The increase in the organic matter content due to poultry manure, rice straw and cow-dung was 15.0 - 16.67, 8.33, 13.33 % respectively. The phosphorus was increased in treatments with OM incorporation and there was slight decrease of phosphorus content in treatment with inorganic N incorporation (Table 4-6). However, there was increase in potassium content. The increase in the K content was highest in the case of rice straw application (6.62 - 7.28 %). The larger number of productive tillers, higher straw yield and paddy yield, and higher uptake of nitrogen, N recovery, and agronomic efficiencies by straw, grain and grain + straw in the treatment of ammonium sulphate application alone than urea treatment were considered to NH_3 volatilization losses associated with the basal application of fertilizer in case of urea treatment. When the major portion of N in ammonium sulphate and urea was supplied in basal application much greater losses were recorded from urea compared to ammonium sulphate (Ferrante *et al.*, 1986). Ammonium sulphate, unlike urea, also contains a very important secondary major nutrient (sulphur) which is deficient in most Ghanaian rice soils. This may also explain why the yield component of rice under A/SO4 is higher than that of urea.

Table 4-8. Nitrogen uptake and recovery in rice as influenced by treatment combinations of inorganic nitrogen fertilizers and organic manures

Treatment	Nitrogen uptake (kg ha^{-1})						Nitrogen recovered (%)					
	Straw		Grain		Straw + Grain		Straw		Grain		Straw + Grain	
T1	19.71	c	33.76	e	53.47	e	0.00		0.00		0.00	
T2	30.39	b	44.99	d	75.39	d	11.87	c	12.49	c	24.35	e
T3	33.33	ab	49.53	cd	80.19	cd	15.13	bc	17.53	bc	29.68	de
T4	39.12	a	59.02	a	100.71	a	18.87	abc	27.63	a	44.73	ab
T5	35.75	ab	51.89	bcd	87.18	abc	23.45	a	25.69	ab	49.25	a
T6	37.79	a	57.11	ab	94.63	ab	18.51	abc	23.93	ab	42.17	abc
T7	38.20	a	54.85	abc	92.12	bc	17.51	abc	19.97	abc	36.60	bcd
T8	34.68	ab	50.98	bcd	85.76	bc	21.88	ab	24.14	ab	47.21	bcd
T9	34.84	ab	53.31	abc	88.15	bc	15.51	bc	20.03	abc	35.53	cd
LSD 0.05	6.93		6.93		7.50		7.75		8.67		9.02	

Means followed by the same letters are not significant at 5% level of significance.
T1 Control; T2, Urea 90kg Nha^{-1}; T3, A/So$_4$ 90kgNha^{-1}; T4, A/SO$_4$ 45kg Nha^{-1}, +3t/ha PM; T5, A/SO$_4$ 45kgNha^{-1} + 3t/ha DRS; T6, A/SO$_4$ 45kgNha^{-1}+ 3t/haCD; T7, Urea 45kgNha^{-1} + 3t/ha PM; T8, Urea 45kg Nha^{-1}+ 3t/haDRS; T9, Urea 45kgNha^{-1} + 3t/ha CD.
A/SO$_4$: Ammonium sulphate; PM: Poultry manure; CD: Cowdung; DRS: Decomposed rice straw

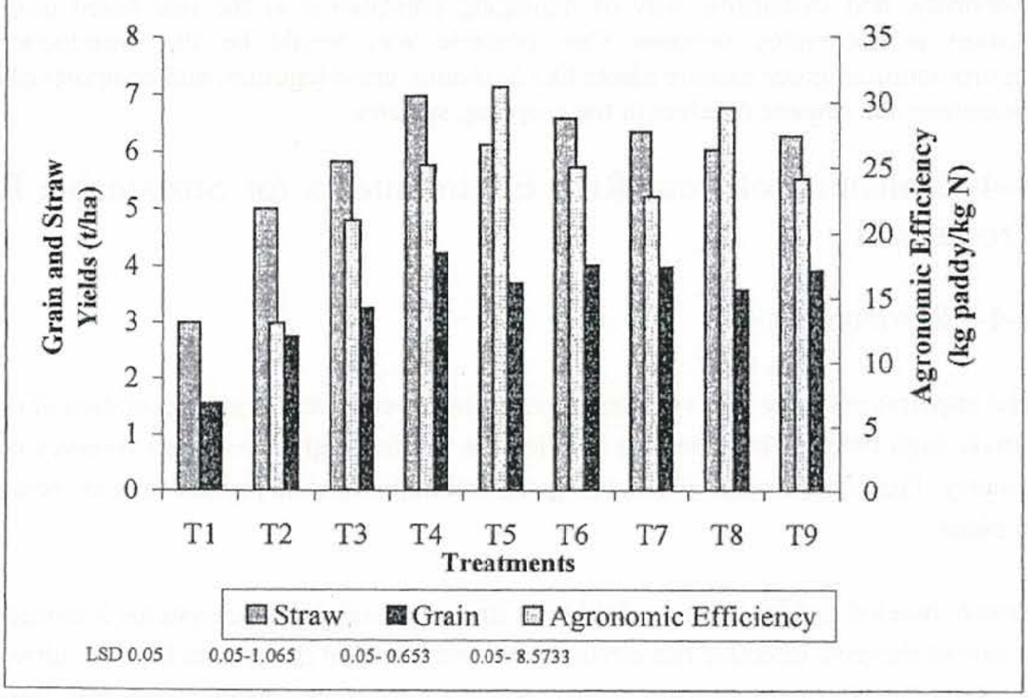

Fig. 4-8. Effect of the application of inorganic nitrongen fertilizers and organic manures on rice yield and agronomic N efficiency.
T1 control; T2 urea 90 kgN/ha; T3 ammonuim sulphte (A/SO$_4$) 90 kgN/ha
T4 A/SO$_4$ 45 kgN/ha + 3 t/ha Poultry Manure (PM); T5 A/SO$_4$ 45 kgN/ha + 3t/ha Rice Straw (RS);
T6 A/SO$_4$ 45 kgN/ha + 3 t/ha cowdung (CD); T7 Urea 45 kgN/ha + 3 t/ha PM;
T8 Urea 45 kgN/ha + 3 t/ha RS; T9 Urea 45 kgN/ha + 3 t/ha CD

The larger number of productive tillers, higher paddy yield, N uptake, by rice plant after the application of poultry manure and cow-dung are due to the higher supply of N compared with rice straw incorporation. Poultry manure and cow-dung supplied other micronutrients like sulphur. The increase in the content of N and other nutrients ultimately increased the rice yield and enhanced nitrogen utilization. The higher content of residual N in the case of poultry manure and cow-dung is related to the greater amounts of N supplied to the soil. The residual P was negative in organic N treatments because more phosphorus was absorbed than replaced by the fertilizers incorporated. The residual P was higher at treatments where organic residues were applied. This may be due to the fact that acids released during the decomposition of the organic manure may have helped in the solubilization of insoluble phosphorus in the soil thereby increasing the residual soil phosphorus. On the other hand, the incorporation of rice straw with a high content of potash enriched the soil with K compared to the other treatments as reflected by the high residual content of K in the soil after crop harvest.

4-3-4 Conclusion

The above results indicate that organic residues, if used extensively in the area in combination with inorganic nitrogen fertilizer under sawah system, will help farmers to increase their crop yield, profit margins and also maintain the fertility of the soil at a comparatively low cost. The negative P residual effect from the application of only inorganic N also indicates that it is important to introduce in the cropping system a systematic and sustainable way of managing phosphorus in the rice based cropping system in the valley bottoms. One possible way would be the introduction of incorporation of green manure plants like *Sesbania*, grain-legumes, and composts of rock phosphate and organic residues in the cropping systems.

4-4 Evaluation of Four Rice Environments for Sustainable Rice Production

4-4-1 Introduction

The importance of rice in the Ghanaian economy is very vital. High importation of rice to satisfy high demand have serious implication on the foreign exchange reserves of the country. Presently, various efforts to expand and improve yield per unit area are being put in place.

Sawah, bunded and leveled rive field with irrigation and drainage systems is considered as one of the most effective rice environment and has been the system for rice cultivation in Asia for decades. Its efficient nutrient replenishing mechanisms and intrinsic resistance to soil erosion has been reported (Kyuma and Wakatwuki, 1995) the very opposite is true for rice cultivation in West Africa in general and Ghana in particular. Water control is usually poor, erosion eminent and efficiency of fertilizer highly questionable.

This study compares the sawah system (bunded and leveled rice field with irrigation and drainage systems) on one hand and farmers environment (growing of rice under the prevailing natural conditions regarding topography and water control) on the other hand.

Between these two extremes, two other environmental conditions were included viz.; bunded semi-leveled (with a hoe) condition with no irrigation and bundedd with no leveling and irrigation.

The evaluation of sawah system along side the traditional Ghanaian system and other intermediate systems is imperative in understanding differences in rice yield, the causes of these differences and hence the need for farmers to improve the rice environment for increase and sustainable production.

4-4-2 Materials and methods

Experimental design and treatments.

The experiment was conductedd at Biemso No.1 and repeated at Potrikrom. A randomized complete block design was used with four replications at Biemso No.1 (Fig. 4-9) and three replications at Potrikrom (Fig. 4-10). Four rice growing environments were considered viz: Sawah – bundedd and leveled rice field with irrigation and drainage systems (S); Farmer's environment – no bunding or leveling (FE); Bunding with minimum leveling – bunded rice field, leveling was done with a hoe (ML) and Bunded non-leveled rice field – after bunding no leveling was done (NL). These rice growing environments were repeated with fertilization at 90 N-60P2O5-60 K2O kg/ha. A total of 8 treatments were therefore obtained: Sawah with fertilization (SF); Farmer's environment without fertilization (FENF); Bunding with minimum leveling with fertilization (MLNF); Bunding non-leveled with fertilization (NLF) and Bunding non-leveled with fertlization (NLNF).
Agronomic practices: Tox 3108-56-4-2-2-2 (local name – SIKAMO) was the rice test crop. The crop was spaced at 20x20 cm. All potassium and phosphorus and one-third of the nitrogen were applied after transplanting. Topdressing was done with the remaining nitrogen at panicle initiation. For the sawah treatments the plots were irrigated when necessary. Plants which were weedy were weeded and the number of times a plot was weeded were recorded. For the farmer's environment only the environment was considered not necessary farmer's practice-weeding was therefore done when necessary. Soil (bulk) samples were collected at 0-15 and 15-30 cm depths. Soil properties for the sites are presented in Table 4-9.

Laboratory analysis:

Soil samples were air-dried, ground and passed through 2 mm sieve. Soil pH (1:2.5) water) was measured with a pH meter with a glass eletrode according to the method described by Mclean (1982). Organic matter was determined by wet combustion (Walkely and Black, 1934). Flame photometer was used to determine exchangeable cations (calcium, magnesium and potassium) as described by Thomas, (1982) after extraction with 1.0 M ammonium acetate. Available phosphorus was by the method of Bray and Kurtz, (1945).

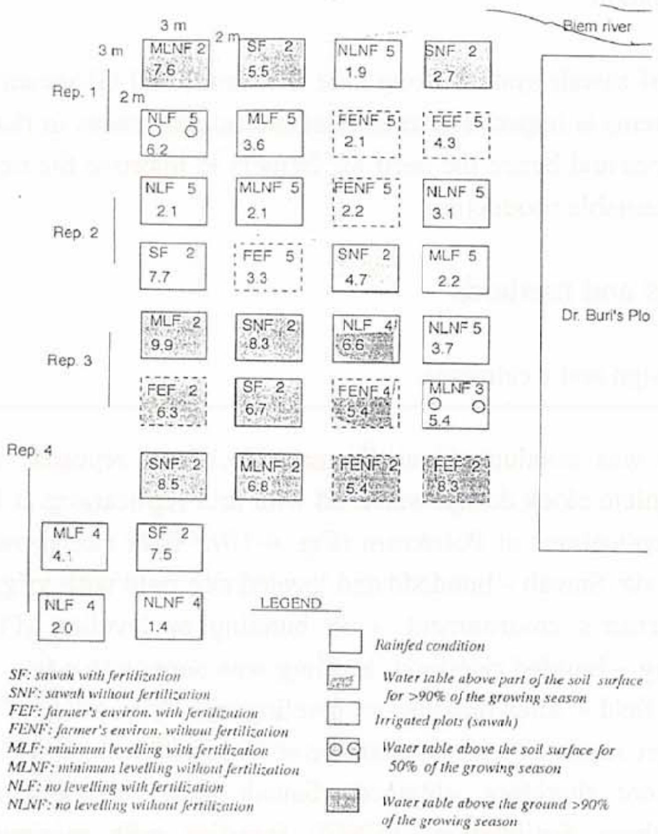

Fig. 4-9. Field layout at Biemso No.1 showing postion of each plot: Numbers with one decimal point show grain yield in t/ha while single numbers show frequency of weeding

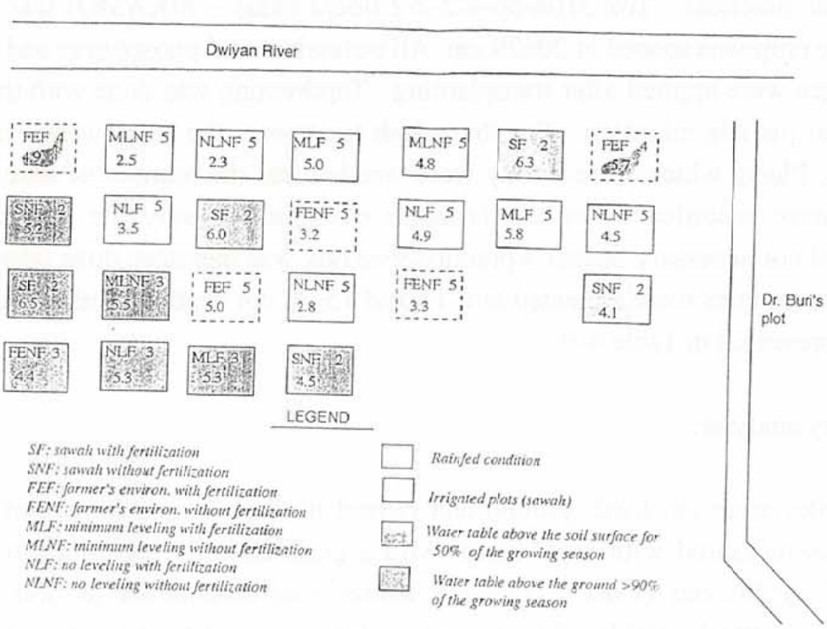

Fig. 4-10. Field layout at Potrikrom showing postion of each plot: Numbers with one decimal point show grain yield in t/ha while single numbers show frequency of weeding

Table 4-9. Initial soil (bulk sample) properties at Protrikrom and Biemso No1.

	Depth (cm)	Soil pH	Organic matter %	Exchangeable Cations[cmol(+)kg]			Bray No.2 P (mg/kg)
				Ca	Mg	K	
Potrikrom	0-15	5.7	2.61	6.20	2.28	0.42	1.8
	15-30	5.7	1.08	3.16	2.09	0.10	2.5
Biemso No1	0-15	5.6	1.94	4.20	1.65	0.15	4.3
	15-30	5.5	0.60	2.84	1.32	0.09	1.1

4-4-3 Results

Effect of rice environment on stover and grain yield

The effect of rice environment on stover and grain at Potrikrom are presented in table 4-10. Stover yield was similar for all the eight treatments. For grain yield ,NLNF treatment gave the lowest yield which was similar to FENF and MLNF. SF gave the highest yield which was significantly different than most of the treatments. Yield index was similar for all the treatments.

At biemso No. 1 stover yield was significantly lower for NLNF which was similar to FENF and MLNF (Table 4-11). Treatments NLNF and FENF gave significantly lower grain yield than SF and SNF. Unfertilized treatments generally showed poorer results than treatments.

Table 4-10. Effect of rice environment on stover and grain yield (kg/ha) at Potrikrom

Rice Environment	Stover	Grain	Grain/Stover(%)
SF	12,289.a	6233.2d	52a
SNF	8,595.5a	4583.3bc	64a
FEF	11,461.6a	5200.0cd	49a
FENF	11,884.5a	3616.7ab	31a
MLF	12,781.1a	5316.7cd	56a
MLNF	11,257.6a	4250.0abc	40a
NLF	12,674.8a	4533.3bc	40a
NLNF	6,565.1a	3166.7a	66a

Data are means of 3 replicates Means followed by the same letter (s) within a column are not significantly different 5% level DMRT.

The 1000 seed weight was not different treatments at Potrikrom (Table 4-12). SF, FEF and FENF produced significantly more tillers/hill than SNF and NLNF at Potrikrom. Yield components for fertilized treatments were relatively better than unfertilized.

At Biemso No.1, SF, SNF, MLNF and NLNF showed significantly higher 1000 seed weight than FENT, FENF treatment also gave significantly lower number of panicles/hill.

At the same site, NLNF gave significantly lower number of seeds/panicle than SF and SNF (Table 4-13).

Table 4-11. Effect of rice environment on stover and grain yield (kg/ha) at Biemso No.1.

Rice Environment	Stover	Grain	Grain/Stover(%)
SF	9999.6b	6822.0b	68a
SNF	8973.6b	6035.0b	67a
FEF	9729.3b	5556.4ab	57a
FENF	7376.8ab	3745.8a	50a
MLF	9762.9b	4933.1ab	51a
MLNF	8306.8ab	5465.4ab	65a
NLF	9467.5b	4256.8ab	45a
NLNF	4374.0a	2501.7a	57a

Data are means of 3 replicates Means followed by the same letter (s) within a column are not significantly different 5% level DMRT.

Table 4-12. Effect of rice environment on 1000 seed weight (g), number of panicles/hill and number of seeds/panicle at Potrikrom.

Rice Environment	1000 seed wt.	No. Pan/hill	No. of Seeds/Pan
SF	24.5a	10.9c	96.7
SNF	24.2a	8.7ab	91.0cd
FEF	25.0a	10.7c	82.7bcd
FENF	23.9a	10.7c	63.3a
MLF	24.5a	9.6abc	93.3cd
MLNF	24.5a	9.3abc	78.3abc
NLF	24.9a	10.1bc	76.7abc
NLNF	23.9a	8.1a	66.7ab

Data are means of 3 replicates Means followed by the same letter (s) within a column are not significantly different 5% level DMRT.

Table 4-13. Effect of environment on 1000 seed weight (g), number of panicles/hill and number of seeds/panicle at Biemso No.1.

Rice Environment	1000 seed wt.	No. Pan/hill	No. of Seeds/Pan
SF	26.9b	9.8b	99.3b
SNF	26.5b	9.4b	89.8b
FEF	25.7ab	10.2b	81.3ab
FENF	24.7a	5.6a	75.0ab
MLF	25.9ab	9.8b	87.0ab
MLNF	26.6b	9.1b	84.8ab
NLF	26.0ab	8.5b	73.3ab
NLNF	26.4b	8.9b	41.3a

Data are means of 3 replicates Means followed by the same letter (s) within a column are not significantly different 5% level DMRT.

Relationship between yield and yield parameters

of the three factors that determined rice yield, number of panicles/hill and number of seeds/panicles significantly correlated with grain yield at both sites (Table 4-14).

Table 4-14. Correlation coefficient relating selected parameters and rice grain yield

Rice Environment	1000 seed wt.	No. Pan/hill	No. of Seeds/Pan
Potrikrom	0.267	0.542^{***}	0.84^{***}
Biemso No1.	0.291	0.551^{***}	0.928^{***}

$^{***}P<0.001$

Of the three factors that determined rice yield, only number of panicles/hill and number of seeds/panicle significantly correlated with grain yield at both sites (Table 6).

Effect of water regime and rice yield

Figures 4-9 and 4-10 show the positions of each plot with regards to qualitative assessment of m water availability (ponding) throughout the growing season at Biemso No. 1 and Potrikron respectively. Plots that water ponded for most part of the season generally produced better grain yield, this was also true for plots that were irrigated. Weeding was lowest when water occurred above the soil surface for most part of the growing season.
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4-4-4 Discussion

Yield components that significantly influenced rice yield were number of panicles/hill and number of seed/panicle (Table 4-14.). These factors were influenced by water availability and to some extent fertilization (Table 4-12 and 4-13). Figures 4-9 and 4-10 clearly show that water (ponding) significantly affected yield components and hence rice yield. Plots that were under water for most of the growing season and irrigated plots showed higher grain yield. SF treatment ensured the availability of water and adequate plant nutrients and hence showed higher values of number of panicles/hill and number of seed/panicle at both sites. This explains why grain yield for SF was consistently higher. Control, NLNF treatment showed lower values for number of panicles/hill (Table 4-12) and number of seed/panicle Table 4-13) resulting in lower grain yields at both sites. For bunded non-leveled plots (NLF and NLNF) water gene rally move towards the bunds causing the middle portion to be relatively drier thus negatively affecting the performance of the crop. The crop was observed to bemost affected when fertilizer was not applied.

4-4-5 Conclusion

Based on general observations and the results of this experiment the following conclusions can be drawn. The crop prefers ponded environment; management that allow for proper water control is highly recommended. It is important to improve the fertility status of the soil. At least some leveling is required if bonds are constructed.

4-5 The effect of Organic and Inorganic Fertilizers on Rice growth and yield under "Sawah" within the Forest Agro-ecology of Ghana.

4-5-1 Introduction

Even though Ghana has the potential (over 700,000 ha of potential lowland sawahs with only 3% being currently used) not only to produce enough rice for local consumption but also for export, the country still imports large quantities of the crop annually to meet demand (only 3% of area currently used) Despite recent efforts at encouraging/promoting increases in production, rice yields per unit area are still far below average. Among identified causes for the low yields are declining soil fertility and the inability of farmers to use mineral fertilizers (due to high cost). Farmers therefore rely solely on natural soil fertility. For proper crop growth and optimum yields, the necessary nutrient must not only be present and available but must also be in balanced quantities.

In Ghana and indeed at the West African sub-regional level, environmental problems have led to more attention and emphasis being placed on not only cost effective and sustainable crop production systems but systems that are also environmentally friendly. Recent works by Buri et al (1996, 1998, 1999), Issaka et al (1996, 1997) and Weidmeijer and Andriesse (1993) have shown that not only are the rice growing environments of the West African sub-region low in inherent fertility but also are actually very deficient in some nutrients. Notably among such nutrients is soil sulfur, a major ingredient in rice nutrition. With the introduction of the "sawah" concept in Ghana, there has been an improvement in water conservation and utilization and hence improvements in nutrient retention under rice cultivation. In addition, organic fertilizer sources are quite common within southern Ghana. It is therefore possible to explore integrated nutrient management options, which will not only improve rice yields but also generally improve and/or maintain soil productivity.

The objectives of this study are therefore to (i) investigate the effectiveness in nutrient supply of common and available farm manure sources, (ii) investigate the extent to which sulfur deficiency, if any, affects rice growth and yield within the forest ecology and (iii) to possibly make nutrient management recommendations based on availability and affordability of such nutrient materials and sources.

4-5-2 Materials and Methods

Location: The experiments were conducted at three locations (Potrikrom, Biemso I, and Biemso II) all within the forest ecology. Trials at Biemso I and II were located on lands which were fallow for the previous season while the Potrikrom site had been previously put to rice.

Land preparation: After an initial land clearing and manual removal of stumps, site was ploughed and divided into four macro-plots (replications) at Potrikrom and Bienso I while Biemso II had only three replications. These were further divided to smaller plots (treatments). These micro-plots were then flooded and rotivated thoroughly using a power tiller.

Treatments: Three organic fertilizer types (Poultry manure, Cattle Manure, Rice Husk) were imposed at two rates (7.0 and 3.5 t/ha). Mineral fertilizer at three rates of NPK (120-90-90, 90-60-60 and 45-30-30) kg/ha as Urea and Ammonium sulfate were used. The design was an RCBD with four replications. Organic fertilizers were worked into the soil during land preparation at least three weeks before transplanting.

Transplanting: This was done manually at a square spacing of 20 cm x 20 cm and at three seedlings per stand. Seedlings were transplanted at 3-4 weeks after nursing. Weed control was mainly by water, even though there were a few handpicking of water-resistant weeds. Harvesting was by manually (by hand).

4-5-3 Results and Discussion:

Table 4-15 shows initial soil characteristic of the experimental sites (Potrikrom, Biemso I, Biemso II). Topsoil (0-15) cm was slightly acidic to slightly alkaline within a pH range of 5.4 to 6.5. Subsoil (15-30) cm also showed a similar trend. Organic matter, total N and available P levels were low for all locations even though Biemso II (freshly cleared land) comparatively showed higher levels of these nutrients.. Topsoil exchangeable Ca and Mg levels were relatively moderate while exchangeable K was low more particularly at Biemso I. Nutrient content of the organic fertilizers used is as shown in Table 4-16. Apart from organic matter, which was fairly high for all the organic nutrient sources, poultry manure showed much higher levels of other nutrients over cattle manure and rice husk.

Table 4-15. Some Chemical Properties of Soils of the Experimental Sites

	Depth		%	%	mg/kg	Exchangeable Cations {cmol (+)kg $^{-1}$}			
Location	(cm)	pH	OM	TN	Av. P	K	Ca	Mg	Na
Potrikrom	0-15	5.6	2.01	0.17	1.8	0.32	5.92	2.24	0.19
	15-30	5.7	1.37	0.09	1.45	0.1	4.16	2.08	0.08
Biemso I	0-15	5.4	2.16	0.13	3.95	0.1	3.68	1.6	0.19
	15-30	5.6	0.46	0.06	1.05	0.05	2.56	1.28	0.24
Biemso II	0-15	6.5	2.58	0.18	8.95	0.3	6.88	1.28	0.11
	15-30	6.8	2.11	0.09	1.65	0.09	5.12	2.24	0.2

	Depth				
Location	(cm)	%Sand	%Silt	%Clay	texture
Potrikrom	0-15	31	42	27	Clay loam
	15-30	41	36	23	Loam
Biemso I	0-15	34	40.5	25.5	Loam
	15-30	54.5	24	21.5	Sandy clay loam
Biemso II	0-15	66	26	8	Sandy loam
	15-30	63	29	8	Sandy loam

While fertilizer (organic or inorganic) application significantly affected tiller number, its effect on plant height was very minimal between the other treatments except the control. Tiller number was significantly affected by fertilizer application (Table 4-17). Mineral fertilizer at a higher rate of NPK (129-90-90) kg/ha gave the highest tiller number. Ammonium sulfate at this rate produced more tillers than Urea at this rate in two out of the three sites. However, there was not significant difference in tiller number between lower rates of mineral fertilizer and organic fertilizer whether solely or in combination (mineral and organic).

Table 4-16 Some Chemical properties of the Organic Fertilizers used in the Experiment

Organic fert. type	% O. M	% TN	% P	% K	% Ca	% Mg
Poultry Manure	23.08	2.6	0.61	1.09	8.45	7
Cattle Manure	17.71	1.12	0.59	0.4	0.56	6.87
Rice Husk	27.35	1.1	0.28	0.36	0.4	1.8

Table 4-17 Effect of Organic and Mineral fertilizers on Rice Tiller Number and Plant Height (cm)

	Potrikrom		Biemso I		Biemso II	
Treatment	Till. No	Plt Ht	Till. No	Plt Ht	Till. No	Plt Ht
Control	9.7a	114.3a	11.5a	118.5a	9.1a	95.6a
$N_{120}P_{90}K_{90}$ kg/ha as Urea	13.8bc	139.2b	16.8cd	138.8c	12.4b	113.0cd
$N_{120}P_{90}K_{90}$ kg/ha as A/S	14.9c	138.9b	17.8d	149.4d	12.4b	122.0e
$N_{90}P_{60}K_{60}$ kg/ha as Urea	12.9abc	133.9b	14.2bc	132.8bc	12.0b	111.9cd
$N_{90}P_{60}K_{60}$ kg/ha as A/S	12.1abc	136.7b	14.7bc	136.3c	13.0b	116.2de
Poultry Manure - 7.0 t/ha	13.7bc	135.4b	16.4cd	140.6c	12.5b	109.1bcd
PM (3.5 t/ha) + $N_{40}P_{30}K_{30}$ kg/ha -Urea	13.2bc	135.3b	15.9bcd	139.0c	12.2b	108.5bcd
Cattle Manure - 7.0 t/ha	12.7abc	129.9b	13.5ab	136.0c	10.7ab	102.6ab
CM (3.5 t/ha) + $N_{40}P_{30}K_{30}$ kg/ha -Urea	11.8abc	124.8ab	13.8ab	131.6bc	10.5ab	109.3bcd
Rice Husk - 7.0 t/ha	11.4ab	126.1ab	14.8bc	125.2ab	11.1ab	104.0bc
RH (3.5 t/ha) + $N_{40}P_{30}K_{30}$ kg/ha - Urea	13.2bc	126.6ab	16.4cd	138.8c	11.5ab	1086bcd

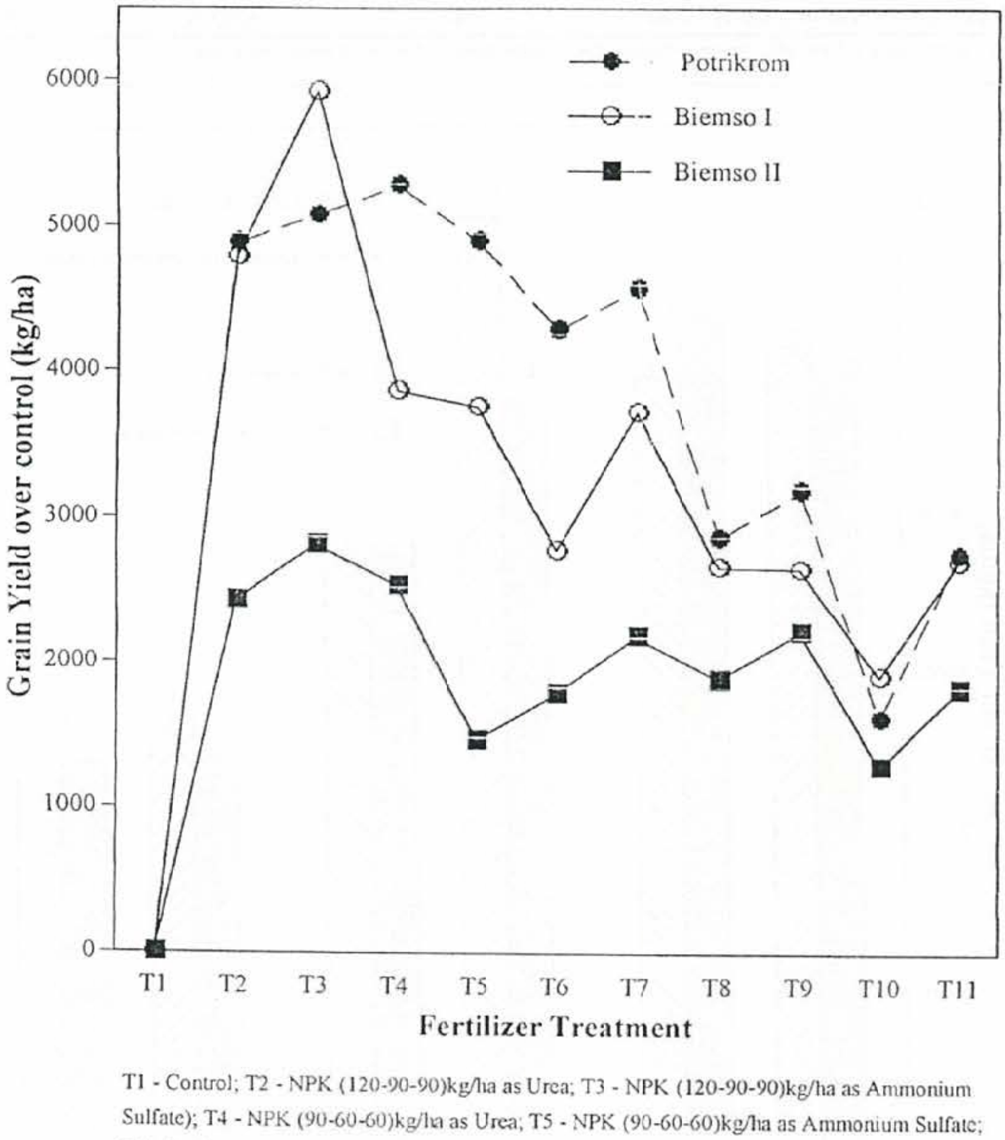
A/S - Ammonium Sulfate; PM - Poultry Manure; CM - Cattle Manure; RH - Rice Husk; Till. No. – Tiller number; Plt. Ht – Plant height.

Figure 4-11 shows the net effect of fertilizer application on rice grain yield (paddy) at the three location (valleys). Even though the pattern of fertilizer response was similar for the different valleys, greatest response was at Potrikrom, indicative of nutrient mining (previously cropped for several seasons to rice). The lower response to fertilization at Biemso II was partially due to initial water shortages, which probably affected early crop growth. In addition, soils of this site (Table 4-15) showed much higher initial nutrient levels than the other two sites.

Further observations from this study showed that rice grain responded positively and significantly to fertilization from both mineral and organic sources (Table 4-18). Mineral fertilizer at higher rates of NPK (120-90-90) kg/ha gave the highest grain yields whether as Urea or ammonium sulfate being the N source. However, at medium levels of mineral fertilizer (NPK 90-60-60) kg/ha, rice grain yields were comparable to higher rates of poultry manure (7.0t/ha) solely and lower rates of poultry manure (3.5 t/ha) in combination with lower mineral fertilizer rates (NPK 45-30-30) kg/ha. Poultry manure was, however, more effective in nutrient supply than both cattle manure and rice husk in the order poultry manure > cattle manure > rice husk.

Figure 4-12 shows the effect of sulfur fertilization on rice grain yield. It was only at

Biemso I and II that S application significantly affected rice grain yield for higher rates of NPK (120-90-90)kg/ha. The no response to S application at Potrikrom could be due to the provision of the element from earlier fertilization (location has been an experimental site). With continuos and intensive rice cultivation coupled with the non-existence of main S mineral fertilizers, S could become a limiting nutrient in the near future and therefore needs to be monitored. This seems to confirm earlier reports (Buri et al., 1999; Yamauchi, 1989; Kang et al., 1981; Aquaye and Kang, 1987; Enwezor, 1976) that sulfate S was quite limiting across the sub-region. With improvements in organic matter management, coupled with the tapping of traditional sources (precipitation and irrigation water), s problems may be minimized.



T1 - Control; T2 - NPK (120-90-90)kg/ha as Urea; T3 - NPK (120-90-90)kg/ha as Ammonium Sulfate); T4 - NPK (90-60-60)kg/ha as Urea; T5 - NPK (90-60-60)kg/ha as Ammonium Sulfate; T6 - Poultry Manure (7.0 t/ha); T7 - Poultry Manure (3.5t/ha) + NPK (45-30-30)kg/ha; T8 - Cattle Manure (7.0t/ha); T9 - Cattle Manure (3.5t/ha) + NPK (45-30-30)kg/ha; T10 - Rice Husk (7.0t/ha); T11 - Rice Husk (3.5t/ha) + NPK (45-30-30) Kg/ha

Fig. 4-11. Effect of fertilization on rice grain yield

Table 4-18. Effect of Organic and Mineral Fertilizers on Rice Grain Yield (kg/ha)

Treatment	Potrikrom	Biemso I	Biemso II
Control	1675a	3587a	1500a
$N_{120}P_{90}K_{90}$ kg/ha a Urea	6562.5d	8375e	3933.3def
$N_{120}P_{90}K_{90}$ kg/ha as A/S	6756.25d	9512f	4316.7f
$N_{90}P_{60}K_{60}$ kg/ha as Urea	6962.5d	7450d	4033.3ef
$N_{90}P_{60}K_{60}$ kg/ha as A/S	6575d	7337.5d	3900def
Poultry Manure - 7.0 t/ha	5962.5d	6362.5c	3283.3bc
PM (3.5 t/ha) + $N_{40}P_{30}K_{30}$ kg/ha -Urea	6250d	7300d	3683.3cde
Cattle Manure - 7.0 t/ha	4537.5c	6250c	3383.3cd
CM (3.5 t/ha) + $N_{40}P_{30}K_{30}$ kg/ha -Urea	4862.5c	6237.5c	3716.7cde
Rice Husk - 7.0 t/ha	3287.5b	5487.5b	2783.3b
RH (3.5 t/ha) + $N_{40}P_{30}K_{30}$ kg/ha - Urea	4425c	6287.5c	3316.7c

A/S - Ammonium Sulfate; PM - Poultry Manure; CM - Cattle Manure; RH - Rice Husk; 5% Level

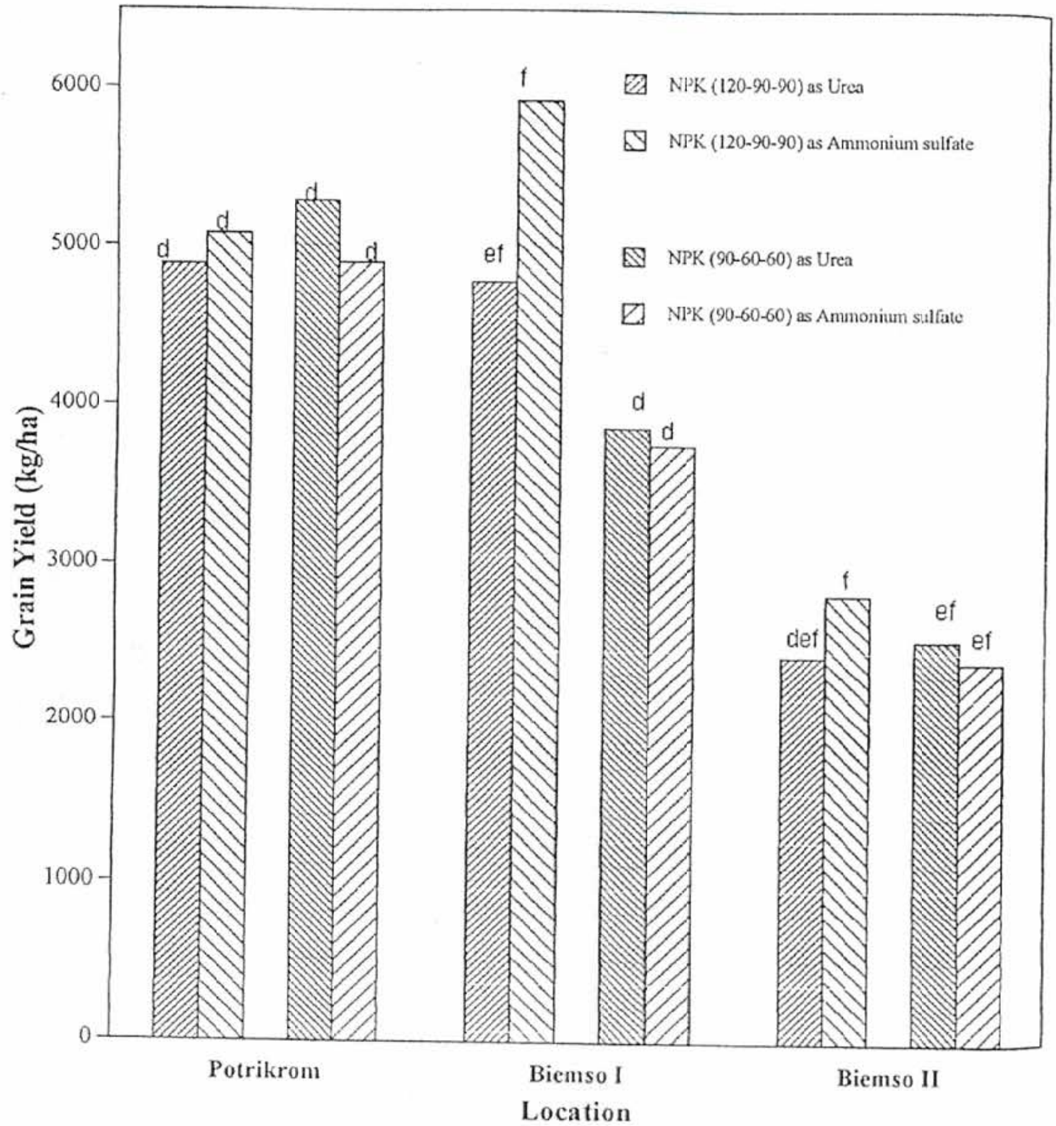


Fig. 4-12. Effect of sulfur fertilization on rice grain yield

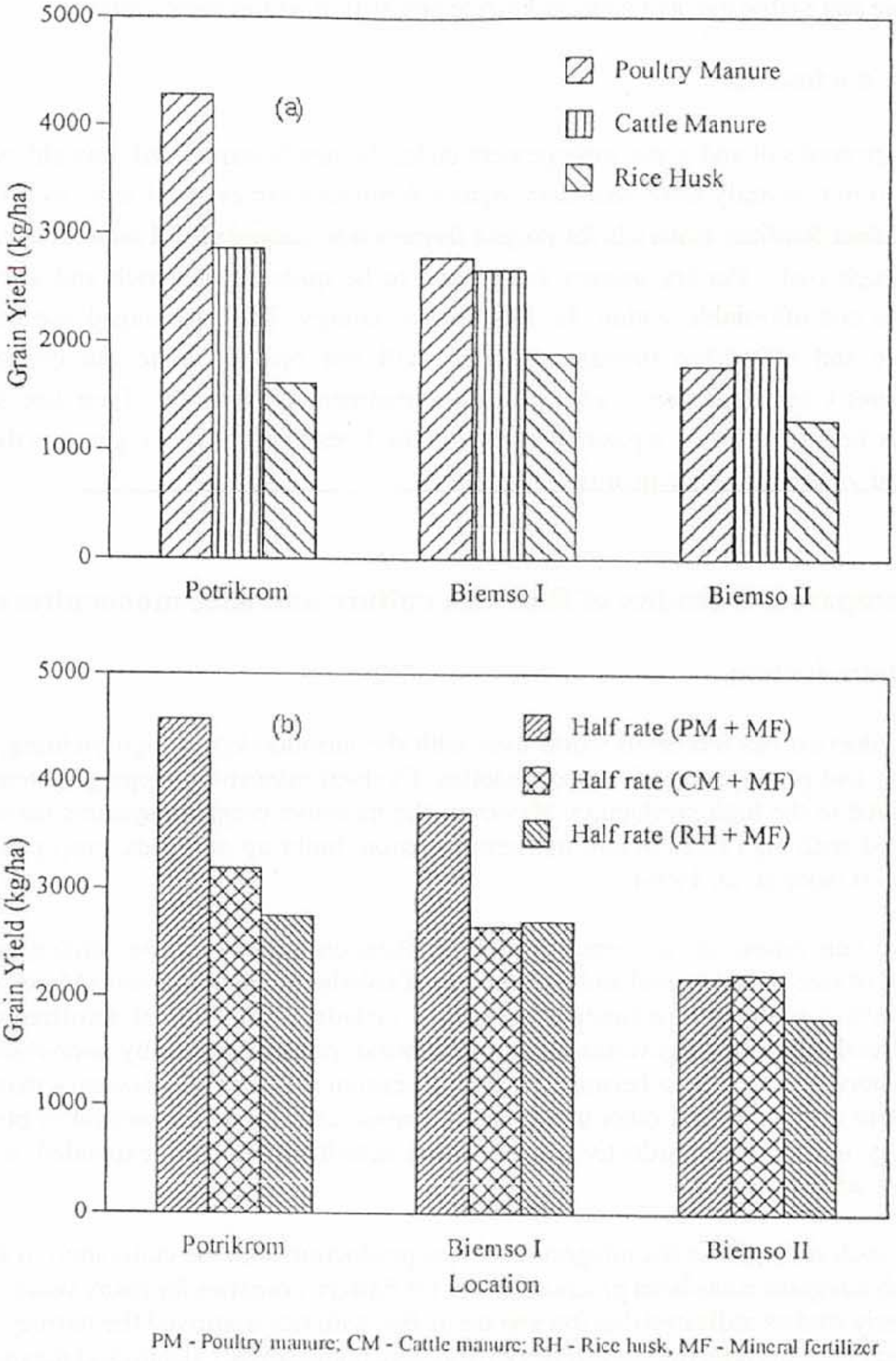


Fig. 4-13. Comparison of the effect of different organic manures alone (a) and combination of organic + mineral fertilizer (b) on rice grain

The net influence of the various organic fertilizer sources either solely or in combination is shown in Figure 4-13. Poultry manure gave the highest grain yield at two out of the three locations. This was followed by cattle manure and rice husk in that order. In combination with mineral fertilizers at lower rates, poultry manure again gave a higher yields over cattle manure and rice husk. This illustrates the potential of poultry manure as a reliable and viable nutrient sources for rice production within these valleys.

4-5-4 Conclusions

With improved soil and water management under the newly introduced ìsawahî system, results from this study show that farm organic fertilizer sources could serve as effective and efficient fertilizer materials for project farmers who cannot afford mineral fertilizers due to high cost. Poultry manure has shown to be quite nutrient rich and also very available and affordable within the forest agro-ecology. The encouraged use of such available and affordable organic materials will not only promote the concept of sustainability but their use is also indeed environmentally friendly. Their use should therefore be promoted for a positive change in the lives of peasant rice growers through increased yields and hence income.

4-6 Comparative Studies of Rice-fish culture and Rice monoculture.

4-6-1 Introduction

Rice production has increased world over with the introduction of high yielding, early maturing and photo-insensitive rice varieties. Evolved intensive cropping systems too have added to the high production. However, the intensive cropping systems have been associated with high rates of soil nutrient depletion, build up of weeds, crop pests and diseases- (Ghose et. al. 1996).

Intensive cultivation of rice requires high fertilization because of the limited genetic potential of rice varieties used and the creation of unbalanced soil nutrients (Manwan and Fagi 1989). Locally a combination of factors including spiraling of fertilizer prices coupled with removal of government subsidies make rice production by poor-resourced farmers non- viable. This is because the farmers cannot make all the necessary monetary investment to complement other inputs. The situation calls for an assessment of possible means by which total productivity of farming activities could be expanded without extensive additional cost.

Among such strategies is the integration of rice production with the cultivation of fish. Rice-fish integration has been practiced in the far Eastern countries for many years. Some of the early studies indicated that integration of fish with rice improved the fertility status of the land used through the availability of nitrogen, phosphorus, calcium and magnesium from fish dropping leading to increased grain yield of rice (Satari, 1962, Li, 1986). Fish culture in rice fields requires relatively small capital inputs and has a short pay back period (Ruddle, 1982). There is also the advantage of fish production in areas usually far removed from sources of fresh fish. A situation, which could enhance the nutritional status of the farmers. Finally the integration has the potential of expanding income generation by farmers.

In Ghana rice-fish systems research was started in 1998. The initial work evaluated:

i. Performance of fish and rice under organic and inorganic fertilization in the rice-fish system
ii. Evaluation of different stocking densities of fish in rice-fish integrated system.

Therefore it is important to test the feasibility of rice-fish system on-farm as an option for diversification.

The purpose of the present investigation was therefore to evaluate the influence of fish on yield of rice. It also assesses the relative economics of rice-fish culture and rice monoculture. The present study evaluates the influence of rice-fish culture on rice yields. It also assesses relative economics of rice-fish culture and rice monoculture.

4-6-2 Materials and Methods

The experiments were conducted at Biemso No. 1 site of Biem inland valley in Ahafo-Ano south district and at Nobewam site of Anum valley in Ejisu-Juaben district, all in Ashanti Region of Ghana. The two sites are located in the semi-deciduous rain forest. . The areas have bimodal rainfall pattern. The major rainy season stretches from mid-March to end of July. The minor season begins in the September and ends in mid-November. The annual rainfall and relative humidity during the experiment in these two locations are:

	Rainfall	Relative Humidity
Biemso No. 1:	1350 mm	87.5 % at 9:00 a.m., 62.8 % at 3:00 p.m.
Nobewam :	1280 mm	85.3 % at 9:00 a.m., 58.5 % at 3:00 p.m.

Eight cooperator-farmers were involved in the on-farm trial in each of the sites.
In Nobewam and Biemso No. 1 experimental plots were 50 x 20m and 50m x 20m, respectively. For the concurrent rice-fish culture, Peripheral trenches were dug and pond refuge excavated in a lower end of the plot to a depth of 1m. Each cooperator farmer had three plots representing the treatments, namely

1. Rice monocrop
2. Rice-fish concurrent culture
3. Rice-fish concurrent culture with manured refuge pit.

Rice fields were ploughed and puddled. Twenty one-day-old rice seedlings (variety:Sikamo(Tox 3108-56-4-2-2-2) were transplanted at spacing of 20cm x 20cm using 2 seedlings per hill. Inorganic fertilizers were applied as basal and at panicle initiation stage at the rate of 80kg N, 45 kg P_{205} and 45kg K_{20} per hectare. Fig 4-14 showed a design of fish pond in a Biemso No 1 sawah. Photo 4-1 showed a small fish

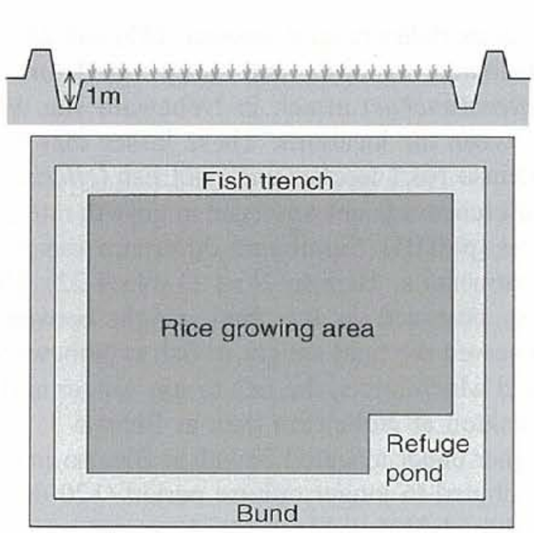


Fig. 4-14. The design of rice-fish farm

pond in a sawah at Biemso No.1 sawah

Fingerlings of Nile tilapia (*Oreochromis niloticus*) of average size 25g were stocked at 3000 fingerlings per hectare in the refuge pit. Stocking was done 15 days after transplanting in both the two sites. As per treatment some of the refuge pits were manured with poultry droppings at rate of 30kg/ha whereas supplementary feed of rice bran was applied to each pond at rate of 5kg/ha/week. The fish was harvested 10 days after harvest of the rice.

4-6-3 Results and discussions

Consistent evidence emerged from the two sites that introduction of fish into rice fields did not depress rice yields (Table4-19) the results confirmed the previous reports (J.N. Torres, *et al*, 1992; A. A. Fugi *et al*, 1992. However Khoo and Tan (1980), Mukhopadhay et al (1992) and Thongpan, *et al* (1992) reported increase grain yield of rice in fields stocked with fish. Regardless of type of treatment, tillering and test weight did not show significant difference. The total equivalent rice production was significantly higher in concurrent rice-fish culture by 0.32t-0.49t at Biemso No.1 and0.18-0.23t at Nobewam site than under rice monoculture. Similar trend was observed when the results from the two sites were pooled (Tables 4-20 & Table 4-21).

Table 4-19. Comparison of yield and yield attributes between rice monoculture and rice-fish culture on equivalent area occupied by the rice in the two systems

Treatment	Biemso No. 1			Nobewam		
	Tillers/m^2	Test weight(g)	Yield t/ha	Tillers/m^2	Test weight	Yield t/ha
Rice monoculture	275	27.4	4.4	266	25.6	4.2
Rice-fish culture	266	26.9	4.0	259	24.2	4.2
Rice-fish culture + manured sump	264	28.1	4.4	261	25.1	4.1
LSD	NS	NS	NS	NS	NS	NS
CV (%)			2.6			

Fish mortality ranged between 24% and 28% between the locations. These losses may be attributed to birds and snake predators at Biemso No.1 leeches and wild fish (*Hterbranchus)* attack in Nobewam site. Fish mortality ranged between24% and28% between the locations. These losses may be attributed to birds and snake predators at Biemso No.1 leeches and wild fish (*Hterbranchus)* attack in Nobewam site. Significant difference was not observed in growth rate of fish at both Biemso No.1 and at Nobewam sites ($p>0.05$). Significant difference was also not observed in final weight between the treatments at Biemso No.1 (Table 4-22). However, at Nobewam differences($p==0.03$) was observed in the final weight between treatments (Table4-23). The differences observed the final weight of fish at Nobewam might be due to low water level in the rice field which forced the fish to stay longer in the pit which was relatively richer in terms of plankton at Nobewam than at Biemso 1. Average final weight of fish at harvest was higher under irrigated Sawah at Biemso in both the treatments. This observation may be attributed to longer culture period (120 days) as fish in both sites was above 0.5g/day (Tables 4-22 & Table 4-23). Supplement feed of rice bran fed to the fish on weekly basis may have accounted for this high level of growth rate.

Table 4-20. Comparative Land Productivity between concurred Rice-fish culture and Rice monoculture in Biemso No. 1 and Nobewam site.

Treatment	Biemso No. 1 *Equivalent Rice Yield (t/ha)	Nobewam *Equivalent Rice Yield (t/ha)
Rice monoculture	4.74a	4.35a
Rice-fish culture	5.06b	4.53b
Rice-fish culture (+manured sump)	5.23c	4.58c
S. E.	0.126	0.52
CV (%)	7.11	3.25

*Fish yield in rice equivalent (kg) = Fish yield (kg) X Fish price ($) / Rice price ($)

Rice price = $0.29
Fish Price = $ 0.89/kg

Table 4-21. Comparative Land Productivity between concurrent Rice – Fish culture and Rice monoculture pooled over locations.

Treatment	Equivalent Rice Yield (kg)*
Rice monoculture	4.54a
Rice – fish culture	4.79b
Rice – fish culture (+ manured sump)	4.90c
S.E.	0.07
CV(%)	5.73

*Fish yield in rice equivalent (kg) = Fish yield (kg) X Fish price ($) / Rice price ($)

Rice Price = $ 0.29/kg
Fish Price = $ 0.89/kg

Tables 4-24 and 4-25 showed relative small capital inputs in culturing fish in rice fields. The observation confirms previous report by Ruddle, (1982); Compared to rice monoculture the integration of rice with fish gave higher net return. The percentage increase in revenue ranged between 5%-11% over rice monoculture between the two sites (Table 4-24 & 4-25). This is in conformity with the earlier reports by de la Cruz (1980), Fagarino (1985), Sevilleja and Lopez (1986) Arevalo (1987), Fermino (1992) and Dewan S (1992).

Table 4-22. Summary data on growth performance and yield of fish (Oreochromis niloticus) at Biemso site

Treatment	Initial wt (g)	Final wt (g)	Recovery (%)	Growth g/day	Gross wt kg/ha	Net wt kg/ha
Rice-fish	25	92.1	72.8	0.55	201.1	146.5
Rice-fish + manure in the sump	25	95.6	71.4	0.58	204.7	151.2
t prob. 5 %	-	NS	-	NS	-	-

Table 4-23. Summary data on growth performance and yield of fish (Oreochromis niloticus) at Nobewam site

Treatment	Initial wt (g)	Finalwt (g)	Recovery (%)	Growth rate g/day	Gross wt kg/ha	Net wt kg/ha
Rice-fish	25	80.2	74	0.55	178.9	122.1
Rice-fish + manure in the sump	25	86.6	76	0.69	197.4	137.7
t prob. 5 %	-	0.03	-	N.S.	-	-

Table 4-24. Comparative economics between Rice-fish system and Rice monoculture for one cropping season under irrigated *Sawah* (Biemso 1)

Cropping system	Production rice (kg/ha)	Fish (kg/ha)	Production cost (U$)[a]	Value of output (US $)	Net return (US $)	% increase from rice mono-culture.
Rice mono-culture	4,600	-	241	1,349	1,109	-
Rice - fish	4,410	201	256	1,461	1,206	8.7
Rice-fish (+ manured sump)	4,501	205	257	1,491	1,234	11.3

[a] Original values in Ghanaian cedis were converted to US $ at the rate of US $ = 6000 cedis as of year 2000

Table 4-25 Comparative economics between Rice-fish system and Rice mono-culture for one cropping season under irrigated Sawah (Nobewam)

Cropping system	Production rice (kg/ha)	Fish (kg/ha)	Production cost (U$ $)[a]	Value of output (US $)	Net return (US $)	% Increase from rice monocult.
Rice mono-culture	4,388	-	241	1,287	1,046	-
Rice - fish	4,150	179	256	1,366	1,111	6.1
Rice-fish + (manured sump)	4,088	197	257	1,364	1,107	5.8

[a] Original values in Ghanaian cedis were converted to US $ at the rate of US $ = 6000 cedis as of year 2000

4-6-4 Conclusion:

On-farm rice-fish culture trial was conducted at Biemso No. 1 under irrigated Sawah and at Nobewam (precisely at Anum valley irrigation project site) in the Ashanti region of Ghana during the main cropping season of the year, 2000. The objectives of the study were to evaluate the effect of fish on the growth and yield of rice and to assess relative economics of concurrent rice-fish culture and rice monoculture. The results indicate that the yield of fish did not significantly depress the yield of rice at both locations. The size of the fish increased from an initial weight of 25g to 80g at Annum valley and to 90g at Biemso No.1 site during the culture period of 100 and 120days, respectively. The net return from the rice-fish culture ranged from US$1,106.90 to US$1,233.80 whilst that of rice monoculture ranged from US$1046.40 to US$11108.60. Percentage increase in revenue from the rice-fish system over the rice monoculture ranged between 5 and 11%. These results suggest the rice- fish integration as a viable option for small and medium scale rice farmers in areas, which have reliable source of water for irrigation. The information obtained from the trial suggests the followings:

1. The presence of fish per se does not depress the yield of rice.
2. Integration of rice with fish could be a viable option for small and medium scale farmers to diversify and augment their income.
3. Rice-fish culture can serve as a source of fresh fish for the rural farmers and this enhance their nutritional status.

4-7 Agronomic activities in newly developed sawah at project site

4-7-1 Membership of Farmers Sawah Association at Biemso No.1

As part of the strategy to involve farmers in the technology development, testing and transfer, farmers association was formed. The initial membership was 16 on April 1999. Three if them however withdrew their membership by August 1999. The list of the remaining farmers with their ages and marital status are indicated below:

	Name	Age	Marital Status
1.	Leslie Osei Mensah	55	M
2.	Frank Oteng	35	M
3.	Anthony Duah	33	S
4.	Attah Poku Dickson	31	S
5.	Konadu Theresa (F)	31	S
6.	Kingsley Larbi	28	S
7.	Kofi Kyere	28	M
8.	Francis Yam Dabanka	26	S
9.	Tawiah Lawrence	25	M
10.	Comfort Serwaa (F)	25	S
11.	Kwabena Owusu	24	M
12.	Mercy Opoku(F)	22	S

(*F-Female M-married S-single*)

4-7-2 Main activities in the development of the new Sawah during 1999

The construction new Sawah which was to be under irrigation started on 24th May 1999 with clearing of the bush and de-stumping which involved thirteen (13) farmers. Originally, the total area of the SAWAH was to be 0.5 hectare. But farmers considering their numerical strength, decided to increase the area of the SAWAH so as to possibly increase their total output. One of the farmers however withdrew his membership due to ill health.

4-7-2-1 Bunding and Leveling

Bunding of the SAWAH started on 14th June,1999. A staff of Crops Research Institute was engaged to plough the land using power tiller (Daedong) as none of the farmer was familiar with its usage. At the time of leveling (7th July) the rains had subsided therefore water was pumped from the river to the fields through the canal for this operation.

4-7-2-2 Nursery Preparation and Transplanting

Nursery beds preparation and seed nursing commenced on 10th June, 1999. This was done every 3 days to ensure availability of seedlings of good age (21-30days) for transplanting. The first three SAWAH plots, which ready , were transplanted to rice on 8th July. Leveling and transplanting were completed on 10th and 11th August 1999, respectively.

4-7-2-3 Fertilizer Application

Fertilizer was applied as basal at the rate of 45kgN, 45kgP_2O_5,and 45kg K_2O per hectare. This was done at transplanting and sometimes 7 days after. The rest of the nitrogen was however applied at panicle initiation stage.

4-7-2-4 Water Management

At some stage of the SAWAH development, leveling and transplanting were done concurrently, which meant that water that was pumped was used for such operations. It was therefore difficult to manage the water effectively, especially in the already-transplanted plots. The situation however changed for the better when transplanting was completed. To effectively control weeds the water level was kept at between 5-10cm deep until 10 days to before harvest, by which time the water was drained.

4-7-2-5 Training of farmers

Before the training begun the farmers were taking on a field visit to Potrikrom SAWAH project site. Activities involved in the training included:

a) Nursery bed construction and management.
b) Transplanting and fertilization
c) Maintenance and the use of Power Tiller for ploughing and leveling.
d) Water management
e) Harvesting and threshing.

Farmers were taking through practices of preparing rice seed for nursing. They were also taught how to construct nursery bed, nurse rice seed and manage seedling ready for transplanting.

On the 8th and 9th of July, 1999, Mr. Tanaka, a JICA Expert from IDA-Ashiaman and two other staff of IDA were invited to Biemso No.1 site to practical train farmers the maintenance and use of power tiller for ploughing and move the soil for level the fields.

4-7-2-6 Field Visits

Seventeen Agricultural Extensionists were invited to the Project site where they were lectured on the principles and practices of the bush to basal fertilizer application of all the plots. The head-dyke, which was damaged, has been repaired and it is hoped that during the minor rainy season, there will be enough water in the river for irrigation. The Biemso SAWAH Farmers Association is new the Department of co-operatives for training in the management if such group.

4-7-2-7 Farmers' Day

Just before harvest of the rice crop, farmer's day was organized by the project in collaboration with the Ministry of Food and Agriculture for the Rice Farmers in Ahafo Ano South District. This was telecast nation-wide by Ghana Television and another private Television. By this program Rice Farmers who were not part of the project familiarized themselves with SAWAH farming technique. On December 1999, the SAWAH Rice Farmers at Biemso(1) won a national award for being best rice in the District.

4-7-3 Topsoil fertility characteristics and yield of 27 plots of Biemso No. sawah newly developed during 1999

Soils were sampled from each 27 plot. The position of the 27 plots is shown in Fig. 15 and 16 in pages 27 and 28, respectively. Similar soil samplings and analytical data are also shown in Table 3-6, 3-7 and Fig. 3-17. In each plot, 4 points were selected and 0-15 and 15-30cm depth was sampled after the harvest of rice. In each depth, the 4 samples were combined to one for physico-chemical analyses. The results were shown in Table 4-26. The plots No.1 to 7 included termite mounds that were destroyed to make the surface level at the beginning of Sawah development. Soil samples were collected similar way. The results were shown in Table 4-27. Table 4-28 shows the performance of rice on each 27 plot, including yield, plant height, and tiller number. Table 4-29 compared the performance rice between the areas of removed termite mound and normal sites.

Although total carbon, nitrogen and available phosphorous showed considerable differences between plots, levels of the exchangeable bases, such as Ca, Mg, K, and Na were relatively homogenous as shown in the Table 4-26. The rice performance at each 27 plot was not so big difference as shown in the Table 4-28. The highest was 7.3 and the lowest was 3.8 t/ha. As shown in the Table 4-27, soils in the plots of normal were rather heterogeneous in terms of carbon, nitrogen, exchangeable potassium and sodium, and available phosphorous. Those nutrients as well as exchangeable calcium and magnesium were higher in the normal site than removed termite hill sites. Topsoil pH was also lower in the site of removed termite hill than in those of normal sites. The sub-soils of plot No. 2 and 6, which belong to the site of normal, showed relatively high levels of exchangeable sodium and those soil showed relatively high soil pH as shown in the Table 4-27. This result is however not correspond to the results of the Table 3-5, 3-6 and Fig. 3-14 as described in the Chapter 3, in which the removed termite hills showed higher soil pH and higher exchangeable sodium. Therefore we have to monitor these soils carefully.

Photo 4-2 showed poor tillering on the removed termite soil at the center of No 5 plot of Biemso No1. The yield was however considerably higher in normal sites than in the area removed the termite hill. Photo 4-3 showed hetero-genous rice growing in sawah after initial development (Afreh's site). The differences are, however, decreased in 2nd and 3rd years after development of Sawah. Photo 4-4 showed azolla in a sawah of Biemso No.1. One of the benefit of sawah is that sawah system has various mechanisms of nitrogen fixations. This is an examples. Well managed sawah can fix nitrogen 50-200 Kg N per ha per year. Photo 4-5 and 4-6 showed termite mounds in sawah developed in Biemso No.1, where has maize cultivation and a small rest house. Photo 4-7 showed a sawah just after the completion of leveling by power tiller in Biemso No.1. Photo 4-8 showed transplanting.

Photo 4-9 showed newly developed sawah by new sawah group at Biemso No.1 at September 2001. The sawah are using the same irrigation canal to the old sawah at Biemso No.1 (see the Fig. 15).

Table 4-26 Soil chemical characteristic of Biemso No1 sawah site after harvest of rice crop

Plot No.	pH	Total C (g/kg)		Total N (g/kg)		Ca(cmol(+)/kg)		Mg(cmol(+)/kg)		K(cmol(+)/kg		Na(cmol(+)/kg)		P(mg/kg)	
		0-15cm	15-30	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30
1	6.1	10.21	3.90	1.01	0.50	4.57	2.60	1.09	0.90	0.08	0.05	0.10	0.08	2.01	1.18
2	6.5	7.50	3.40	0.87	0.56	4.83	2.30	1.46	1.24	0.07	0.04	0.08	0.07	2.25	1.09
3	6.9	16.10	7.10	2.25	0.92	5.50	3.30	1.25	1.00	0.07	0.05	0.14	0.10	2.75	2.00
4	6.4	10.12	3.42	1.42	0.87	4.26	1.92	1.18	0.85	0.08	0.04	0.09	0.10	3.10	1.19
5	6.2	11.73	5.98	1.20	0.74	4.50	1.75	1.23	0.91	0.07	0.05	0.15	0.20	1.96	2.53
6	6.5	14.28	1.68	1.34	0.30	4.53	1.81	1.15	1.00	0.08	0.06	0.16	0.12	8.46	2.73
7	5.3	8.11	3.15	1.03	0.52	3.05	1.19	0.84	0.71	0.06	0.04	0.10	0.20	2.10	0.95
8	6.1	10.42	3.28	1.80	0.67	4.57	2.70	1.20	1.07	0.05	0.04	0.20	0.18	3.15	0.85
9	8.9	4.00	2.79	0.63	0.47	6.02	3.71	0.91	0.62	0.05	0.03	0.15	0.10	2.79	2.58
10	7.2	7.35	3.10	1.30	0.42	5.40	3.20	1.18	0.98	0.06	0.05	0.10	0.08	6.10	2.10
11	5.9	8.10	2.10	1.01	0.53	3.95	1.97	1.14	1.00	0.05	0.07	0.13	0.16	4.32	1.01
12	8.3	3.90	2.10	0.50	0.49	5.74	2.75	0.91	0.49	0.06	0.03	0.22	0.20	3.26	1.55
13	6.8	4.87	1.98	0.84	0.33	5.15	2.80	0.96	0.91	0.05	0.06	0.18	0.10	2.13	1.72
14	5.8	7.40	2.56	0.90	0.52	5.00	2.40	1.03	1.04	0.07	0.06	0.10	0.09	6.20	1.90
15	6.9	10.03	2.30	1.08	0.47	4.53	2.70	1.07	0.97	0.06	0.04	0.10	0.10	1.00	2.35
16	5.8	14.28	1.72	2.10	0.30	5.20	3.17	1.02	0.83	0.06	0.05	0.20	0.10	5.20	2.10
17	6.1	3.01	1.37	0.36	0.28	4.40	2.70	0.75	0.50	0.07	0.03	0.10	0.20	2.01	0.94
18	6.0	9.82	3.90	1.01	0.64	4.80	2.10	1.21	1.06	0.06	0.05	0.09	0.10	1.36	0.10
19	6.2	7.23	3.15	0.90	0.34	4.50	1.98	0.77	0.81	0.09	0.06	0.10	0.07	2.50	1.30
20	6.1	9.53	2.97	1.21	0.42	5.10	2.01	1.00	1.10	0.08	0.04	0.16	0.10	2.10	1.10
21	6.9	3.24	1.80	0.79	0.22	5.04	3.40	1.04	0.89	0.09	0.05	0.14	0.20	2.30	1.05
22	6.5	11.75	2.80	0.84	0.45	4.54	1.87	1.13	1.11	0.06	0.03	0.10	0.10	4.88	1.44
23	5.9	6.21	2.14	0.60	0.31	4.94	2.11	1.17	1.09	0.06	0.03	0.12	0.08	4.17	1.49
24	6.2	6.24	1.70	0.82	0.21	4.87	1.78	1.02	0.89	0.07	0.05	0.18	0.10	1.72	0.94
25	6.0	5.19	2.10	0.74	0.33	4.87	2.30	1.09	1.00	0.07	0.04	0.20	0.22	2.10	1.24
26	5.7	7.32	3.20	0.94	0.40	4.49	1.95	0.96	0.97	0.08	0.06	0.10	0.07	2.00	1.20
27	6.3	12.40	2.10	1.60	0.26	4.95	2.15	1.01	1.00	0.06	0.03	0.20	0.10	4.10	1.20

Table 4-27. Soil chemical charastristic of Biemso sawah site after harvest of rice crop comparison between normal and removed termite hill sites

Normal Site (NMS)

Plot. No.	pH	Total C (g/kg)		Total N (g/kg)		Ca (cmol(+)/kg)		Mg(cmol(+)/kg)		K(cmol(+)/kg)		Na(cmol(+)/kg)		P(mg/kg)	
	0-15cm	0-15cm	15-30cm	0-15cm	15-30cm	0-15cm	15-30cm	0-15cm	15-30cm	0-15cm	15-30cm	0-15cm	15-30cm	0-15cm	15-30cm
1	6.1	7.25	3.40	0.87	0.76	4.83	2.06	1.83	0.83	0.19	0.09	0.10	0.07	1.25	0.78
2	7.8	9.89	5.20	1.01	0.60	5.50	2.30	1.24	1.10	0.06	0.05	0.08	0.78	7.19	1.19
3	7.5	6.35	4.10	0.91	0.52	3.05	2.10	1.15	0.91	0.07	0.07	0.12	0.13	3.26	2.01
4	6.1	13.10	7.50	1.30	1.00	4.57	1.97	0.84	0.49	0.08	0.05	0.10	0.10	2.25	1.19
5	6.0	16.90	7.32	3.34	1.14	4.49	2.10	0.78	0.62	0.80	0.06	0.09	0.10	2.58	1.01
6	8.0	11.51	4.10	1.18	0.47	5.15	3.20	1.02	0.69	0.10	0.16	0.10	0.91	8.46	2.92
7	6.9	10.84	5.90	1.20	0.70	3.95	2.15	1.21	1.00	0.06	0.05	0.20	0.17	2.36	2.51

Removed termite hill site (RAS)

Plot. No.	pH	Total C (g/kg)		Total N (g/kg)		Ca (cmol(+)/kg)		Mg(cmol(+)/kg)		K(cmol(+)/kg)		Na(cmol(+)/kg)		P(mg/kg)	
	0-15cm	0-15cm	15-30cm	0-15cm	15-30cm	0-15cm	15-30cm	0-15cm	15-30cm	0-15cm	15-30cm	0-15cm	15-30cm	0-15cm	15-30cm
1	5.9	5.31	3.24	0.69	0.44	1.93	1.11	1.81	0.80	0.05	0.04	0.08	0.09	1.06	0.58
2	6.5	6.35	5.21	0.72	0.32	2.42	0.82	0.75	0.70	0.05	0.05	0.07	0.10	2.53	0.50
3	5.6	4.40	2.45	0.54	0.42	1.10	0.60	0.69	0.78	0.03	0.04	0.09	0.08	1.11	1.55
4	5.2	7.80	4.20	0.98	0.51	0.62	0.70	0.92	0.88	0.04	0.03	0.12	0.11	1.42	2.10
5	6.4	4.50	3.25	0.36	0.30	1.56	1.62	0.91	0.79	0.06	0.05	0.10	0.16	2.84	1.70
6	6.2	4.89	2.18	0.76	0.52	2.10	1.20	0.51	0.49	0.07	0.07	0.11	0.09	2.55	3.89
7	5.1	5.71	2.82	0.65	0.35	0.94	0.78	0.58	0.50	0.06	0.05	0.11	0.10	3.01	1.50

Table 4-28. Rice yield, plant high and tiller number at each 27 plot

Plot No.	Plant height (cm)	Number of tillers (m^{-2})	Test weight (g)	Yield (ton ha^{-1})
1	150.8	365	2.6	6.0
2	130.0	255	4.2	6.3
3	144.4	320	3.3	6.0
4	125.4	325	5.9	6.8
5	125.4	312	4.3	5.0
6	130.2	320	4.3	6.5
7	135.0	275	3.0	4.5
8	112.6	295	2.4	6.8
9	139.0	300	4.6	5.8
10	115.0	335	3.2	5.8
11	152.0	395	3.1	5.8
12	142.0	195	3.4	4.5
13	139.0	210	3.9	5.0
14	128.0	235	6.3	5.5
15	135.0	300	3.1	4.8
16	130.0	225	3.9	5.0
17	119.0	210	6.5	3.8
18	129.0	250	4.1	4.5
19	132.0	280	5.4	7.3
20	124.0	175	10.6	5.8
21	125.6	260	4.2	4.8
22	135.0	225	4.5	5.8
23	102.8	200	6.5	3.8
24	118.4	245	5.7	4.8
25	124.0	220	5.3	4.3
26	126.0	290	4.7	4.5
27	138.0	265	3.9	5.0
Mean	129.9	270	4.6	5.4

Table 4-29. Performance of the rice crop on areas with removed termite hill and normal sites.

Plot.No	Plant height (cm)		Number of tillers (m^{-2})		Test weight (g)		Yield (ton ha^{-1})	
	RAS	NMS	RAS	NMS	RAS	NMS	RAS	NMS
1	98.6	130.4	265	255	2.1	2.6	3.0	6.3
2	125.4	153.0	285	312	3.1	4.3	3.3	5.0
3	109.0	142.0	170	195	0.6	3.4	3.4	4.5
4	121.0	139.0	300	410	4.7	4.6	4.5	6.8
5	115.0	133.0	150	320	3.2	4.3	1.8	6.5
6	107.0	135.0	220	300	2.2	4.0	3.5	4.8
7	118.0	132.0	225	280	5.8	5.4	3.6	7.3
Mean	113.1	137.7	230	296	3.1	4.0	3.3	5.9

.RAS-Removed termitehill site.
.NMS-Normal site.

Photo 4-1 Small fish pond in a Sawah of Biemso No.1

Photo 4-2 Poor tilling and columnar soil surface Structure of remove termite hill, at the center of plot No.5 of Biemso No1 Sawahs

Photo 4-3 Heterogeneous rice growth in Newly developed Sawah at Afreh's site

Photo 4-4 In addition to Azolla, Sawah has various N fixation mechanisms

Photo 4-5 and 4-6 Major caltivation and small rest house on Termite mound in Biemso No.1 Sawah

Photo 4-7 Just after the completion of leveling by power tiller

Photo 4-8 Transplanting at Biemso No.1

Photo 4-9. New additional sawah at Biemso No.1, September 2001

4-8 Comparing different rice planting/seeding methods under sawah

4-8-1 Introduction

The rice crop is unique among the many crop varieties because it is able to grow and produce good yield under different ecological and topographically varying environment. The physiology of the rice crop is suited to waterlogged as well as under upland conditions. The biotic and abiotic stresses imposed on the crop under these conditions are therefore also varied. There are different methods of seeding rice and this depends mostly under the ecology and the flooding situation of the circumstance rice farmers will dibble, transplant, drill or broadcast their rice at the beginning of the cropping season. Although there are many socio-economic factors, which govern the king of method used by a particular farmer or the farming community in a particular area, it is worth pointing out that each has its own merits and demerits. Under the African Sawah system, bunding of the land perimeter allows for waterlogging and therefore drastically changes the farming operations. Transplanting as a planting method is particularly favored. It has been recorded in the South-East Asian countries that transplanting normally out yields other crop establishment methods. The economic and sociological data that will allow for more systematic analyses for a better understanding of the planting methods are usually lacking. In the 1999 major season a study was carried out at Potrikrom under the project to evaluate the importance and the extent of the differences that may exist in the different methods. It was considered that this kind of study would provide the basis the future socio-economic study on the comparative advantage between the different methods under the rainfed sawah system.

4-8-2 Materials and Methods

4-6-2-1 Experimental site

The experiment was conducted at Potrikrom site. The experiment, which was laid out in complete randomized block design (RCBD), had 5 treatments, with four replications. The treatments were

1. Transplanting
2. Dibbling in rows of pre-germinated rice (PGR)
3. Dibbling at random of PGR
4. Broadcasting of PGR

The test variety, SIKAMO (Tox 3108-56-42-1-1) was planted at a seeding rate of 80kgha^{-1}, in micro-plots measuring 6×5m making a plot area of 30m^2. The transplanted and the treatment dibbled in row were done at a spacing of 20cm×20cm at 2 seeds or seedlings per hill per hill. Seeds were broadcast at 80kgha^{-1}. Each plot received basal application of potassium and phosphate fertilizers at rate 45 and 40kgha^{-1} respectively. Nitrogen was applied as Sulphate of ammonia (SA) at a rate 90kg ha^{-1}, but in two equal spilt applications of 45kg ha^{-1} 21days after seeding establishment (DSE) or seedling emergence as the case may be manual weeding was done at 28 and 48 DSE. Agronomic data were collected for plant height and number of tillers at maximum tillering stage (9weeks after seeding establishment). Yield data was collected at harvesting and calculated for the hectare.

4-8-3 Results and Discussions

Transplanted rice recorded the highest rice yield (4.98t ha^{-1}) which was significantly different ($p<0.02$) from the dibbling, at random (3.74 tons ha^{-1}) and broadcasting 3.94 tons ha^{-1} but not dibbling pre-germinated rice in rows (4.13 tons ha^{-1}) (Table 4-30). Similarly, there was significant difference in plant height between transplanted rice and dibbling rice at random and broadcasting rice. The number of tillers recorded no significant difference between the treatments. The result confirm the superiority of transplanting rice over broadcasting as a seeding method, but however failed to record any significant difference ($p<0.05$) when rice was dibbled in rows. Transplanting rice allows the selection of healthy and vigorous growing rice seedling over weak ones. Dibbling and transplanting does not have the advantage of prior selection. Plant health and vigour in the seed is left to chance when rice is direct seeded. Spacing and plant density are also under control under transplanting or under dibbling in rows. Random seeding and broadcasting does not have any of these advantages. The high and significant yield of transplanted rice and dibbling pre-germinated rice therefore conforms to known theories.

Table 4-30. Plant height (cm) number of tillers per hill and rice yields (ton ha-1) of SHIKAMO under different rice seeding methods (Potricrom.1999 main season)

	Plant height (cm)	Number of tillers (m^{-2})	Yield (ton ha^{-1})
1 Transplanting	126	12	4.98
2 Dibbling in rows PGR	120	12	4.13
3 Dibbling at random(PGR)	103	-	3.74
4 Broadcasting of PGR	110	12	3.94
Mean	115	12	4.2
LSD	14	1.84	0.76
Level of significance (p)	*<0.02*	*<0.8*	*<0.02*
CV(%)	7.98	2.3	11.34

(4) Conclusions

The study demonstrates the usefulness of transplanting and to some extend dibbling of pre-germinated rice. The is the need to examine the socio-economic importance of this crop establishment procedure and analyze how it fits into the culture and current practices of seeding in the project area. Farmers normally dibble at random at Potrikrom. Until the sawah is constructed and the method is appreciably adopted by the farmers it appears that dibbling will continue. Dibbling in rows to achieve the optimum planting density may be an important intervention.

4-9 Performance of Sikamo as affected by different inorganic and organic combination under rainfed conditions (Potrikrom,1999 Rain season).

4-9-1 Introduction

Conventional plant breeding procedures necessitate the utilization of chemical fertilizers in development high yielding varieties (HYV). This suggests that new varieties such as Sikamo will achieve their real genetic potentials only under good fertilization programs. Recent high costs of chemical fertilizers in the sub-region and in Ghana in particular, together with the gradual erosion in value of the local currency, (the cedi) against the major trading currencies like the US dollar, the British pound and the Japanese yen has adversely affected the costs of fertilizers. Farmers are therefore not able to apply the minimum fertilizer requirements that will meet the optimum yield potential of the rice, which is cropped.

In the project area however, farmers are encouraged to use legumes in their cultivation practices especially after the main season's rice crop. The stubble, which is left behind when incorporated, could be of some nutritional importance to the next rice crop. The extent to which incorporation of stubble from a cowpea crop will contribute to the nutrient requirements has not been examined. The literature however suggests that this could be important if it is carefully handled although the decomposition process itself also generates some organic acids into the soil. This could also be harmful to the rice plant. The study reported here was conducted in the main season of 1999 to assess the relative importance of using cowpea as an organic manure solely or in combination with the application of recommended rates of NPK-15-15-15 chemical fertilizer.

4-9-2 Material and Methods

The experiment was conducted at Potrikrom in the Dwinyan inland valley. The study was laid out in as a randomized complete block designed (RCBD) experiment with an eight (8) treatments with three replications. Plot size was 3m× 4 m. The rice variety, sikamo was used as a test crop and transplanted at a spacing of 20cm×20cm. The treatments are listed below

T1= Control
T2=100% Recommended N (inorganic)
T3=75% Recommended inorganic + 25% NPK
T4=50% inorganic N + 50% Poultry manure
T5=100% 100% Poultry manure
T6= 75% inorganic N + 25% cowpea variety
T7= 50% inorganic N + 50% cowpea variety
T8= 100% cowpea variety

The application of NPK was done to achieve 45 kg ha^{-1}, 45ka K ha^{-1} and 45 P $ha-^{1.}$ The was however topdressing with urea at 45 kg ha-1 at maximum tillering growth stage. The cowpea variety (Asontem), and poultry manure were dried to moisture content of 13.28%, and applied at 90kg ha^{-1}. Rice plant height and counting of the number of tillers per hill for each treatment were made at maximum tillering growth stage (9 weeks after transplanting) (WAT). At harvest rice yield was determined and calculated based on per hectare basis.

4-9-3 Results and Discussions

Significant differences (*$p<0.05$*) were recorded between the treatments in the plant height, number or tillers, and grain yield (Table 4-31). The application of 100% inorganic fertilizer (T2) recorded the highest plant height (149cm) although it was not significantly different (*$p<0.003$*) from T6, (75% inorganic fertilizer + 25% cowpea incorporation). The other treatments together with the control were all significantly different. The count of tillers per hill showed a similar trend although at a higher level of significance (*$p<0.001$*). Application of 100% chemical fertilizer recorded the highest grain yield 3.13 tons ha^{-1}which was significantly different from all the treatments except T2 (Table 4-30). The results underscored the established knowledge that the modern HYV respond to chemical fertilizer application that to organic amendments.

Table 4-31. Plant height (cm). Number of tillers per hill and yield (Tons ha-1) of Sikamo as affected by different inorganic and organic* combinations under rainfed conditions (Potrikrom.1999 Main season)

	Plant height (cm)	Number of tillers	Grain Yield (ton ha^{-1})
T1= Control	123	9	2.53
T2= 100% Recommended N (inorganic)	149	15	3.13
T3= 75% Recommended inorganic + 25% NI	123	10	2.63
T4= 50% inorganic N +50% Poultry manure	135	12	2.90
T5= 100% Poultry manure	131	9	2.10
T6= 75% inorganic N + 25% cowpea variety	142	12	3.06
T7= 50% inorganic N + 50% cowpea variety	117	10	2.06
T8= 100% cowpea variety	118	9	2.33
Mean	130	11	2.53
LSD	15.1	2.59	0.75
SE	4.98	0.85	0.25
Level of significance (p)	*<0.003*	*<0.001*	*<0.04*
CV(%)	6.63	13.25	16.52

*Cowpea variety = Asntem%N = 1.4% ; % moisture=13.2%
Application Rate = Cowpea dry weight = 90kg ha-1
Poultry manure = 90kg ha-1

4-9-4 Conclusion

In the first year of cropping, sole application of chemical fertilizers will be superior to use of cowpea or poultry manure or in combination with chemical fertilizers. It is recommended that the experiment be monitored over a longer time to assess the efficacy of the applied organic amendments or in combination with chemical fertilizers.

4-10 Screening Cowpea Lines/Varieties For Performance Under Residual Moisture Conditions After Main Season Rice

4-10-1 Introduction

Under carefully planned and executed cropping programmes, it is possible to cultivate cowpea varieties in the inland valleys after the main season rice crop. The advantages of reducing weed pressure and breaking the cycle of pest build-up has been discussed variously. Using legumes in the cropping programme allows for the addition of nitrogen to the soil while increasing total quantity of available food for the farm family. The type of cowpea variety that needs to be used however has to be carefully evaluated and the appropriate recommendation made with regards to the choice. Much work has been accomplished by CRI and the International Institute of Tropical Agriculture (IITA) in developing cowpea varieties for the different ecozones in Ghana. This project was undertaken to evaluate together with farmers the performance of cowpea lines/varieties at Potrikrom after the main season rice crop of 1998/1999.

4-10-2 Materials and Methods

Ten (10) cowpea lines/varieties were planted in un-replicated trial after rice was harvested. Table3 shows the list of the test varieties, which included a farmer variety. They were planted at a spacing of 50 × 50cm, each on a plot measuring $12m^2$. There was no fertilizer application, but chemical insect control was carried out. Data collected included:

-Days to 50% flowering
-Days to maturity
-Pod weight
-100 seed wt.
-yield

4-10-3 Results and Discussion

Ayiyi recorded the highest weed yield of 794 compared with the rest of the test varieties, although it took a longer time (29days) between the days to 50% flowering and maturity compared with 32days of Asontem. (Table 4-32). Ayiyi was second highest in seed yield together with $IT86^D$-791 (760 kg ha^{-1}). The lowest recorded seed weight was by $IT87^D$-885, although it recorded the highest 100 seed weight. Pod weight was highest in $IT86^D$-719 (1040 kg ha^{-1}), although it was not the highest yielder in term of seed weight. It appears that the cultivation of released varieties may have to be promoted since they performed.

4-10-4 Conclusions and Recommendations

The performance of the cowpea varieties clearly suggests that two crops can be successfully grown in the inland valleys. The recommended varieties of Ayiyi and Asontem performed well and may need to be used in replicated trials to ascertain their real statistical superiority. Sociological and sensory studies may need to support this evaluation for the choice of the appropriate varieties for the project.

Table 4-32. Yield and yield components of screened cowpea lines/varieties for performance under residual moisture after main season rice crop

Entry name	Plant (m^{-2})	Days to 50% flowering	Days to 50% maturity	Pod wt (kg ha^{-1})	100 Seed wt.	Yield (kg ha^{-1})
Ayiyi	10	41	70	889	15	794
IT×P46-1	9	47	71	815	17	760
Asnotem	9	43	69	865	16	703
IT871)-611-3	10	44	70	905	14	748
IT871)-885	9	45	70	823	21	620
Farmer's variety	9	50	76	833	16	650
IT861)-719	9	47	71	1040	15	760
IT871)-1951	10	45	69	934	16	784
IT871)-2027	8	47	72	941	15	827
VAL-B82	10	43	70	905	16	679
Mean	**9**	**45**	**71**	**905**	**16**	**733**
CV(%)	**11**	**2**	**2**	**11**	**2**	**12.6**