EXPERIENCE AND ACHIEVEMENTS WITH INTEGRATED PLANT NUTRITION SYSTEMS (IPNS) IN THE INTEGRATED SOIL FERTILITY AND FERTILIZER MANAGEMENT PROJECT (SFFP) IN BANGLADESH [1]

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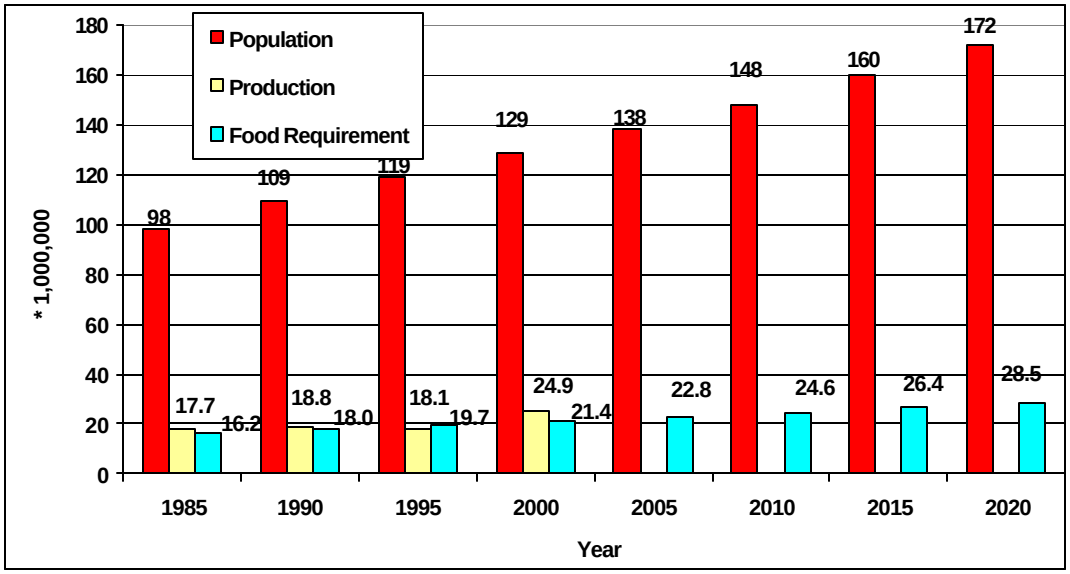
INTRODUCTION

This paper describes the objectives and achievements of the Integrated Soil Fertility Management Project (SFFP) in Bangladesh, and will more specifically elaborate on the Integrated Plant Nutrition Systems (IPNS), which SFFP embraced as its strategy and disseminated through its activities. The paper will first give a brief background of agriculture and soil fertility status in Bangladesh. The IPNS concept in the Bangladeshi environment and in the context of SFFP will be explained. The background, objectives and activities of SFFP will be described, and some of the experiences and achievements with IPNS activities in demonstration, training and in research activities highlighted.

CHALLENGES FOR AGRICULTURE IN BANGLADESH

The challenge for present day agriculture in Bangladesh is to meet the food requirements of a huge and still growing population (presently 130 million, projected to reach 170 million in 2020, see also graph 1). Bangladesh has attained foodgrain self-sufficiency during the last couple of years thanks to a national foodgrain production increase of 33% from 1990 to 2000. Presently the challenge is to ensure and sustain general nutritional security and food safety for all. See further Graph 1 for the projected population increase and food requirement, as well as the foodgrain production of the last 15 years.

Figure 1. Projected population, food requirement (Mt) and foodgrain production (Mt), 1985 - 2020.



[1] Paper presented at the Regional Workshop on Integrated Plant Nutrition Systems (IPNS) development and Poverty Alleviation, FADINAP, Bangkok, 18-20 September 2001.

The increased food requirement must be achieved considering decreasing available agricultural land, which is due to increased area needed for human settlement and physical infrastructures, and loss of agricultural land to water / river erosion. See table 1 for the change in cultivated area and total holding size and land distribution.

Table 1. Change in the selected parameters influencing land use and agricultural development

Parameters	1983-84	1996-97	% Change
Number of total farm holdings	10,045,299	11,798,242	+17.4
Small farms ('000)	7066	9423	+33.3
Medium farms ('000)	2483	2078	-16.3
Large farms ('000)	496	297	-40.1
Absolute landless ('000)	1198	1815	+51.5
Homestead area (ha)	391087	533771	+36.48
Cultivated area (ha)	8160957	7194874	-11.83
Average farm size (ha)	0.81	0.61	-24.7

Note : Small farm: 0.02-1.008 ha; Medium farm: 1.01-3.03 ha; Large farm: 3.04 ha and above
Source: BBS, Agricultural Census, Govt. of Bangladesh, 1983/84 and 1997

From this table it becomes apparent that total agricultural land and average land holding size per family are decreasing and % smallholdings are increasing. The only way to increase agricultural production for the burgeoning population is through increased production per unit area and crop intensification on the existing available agricultural land.

Total agriculture productivity growth during the last decades has reportedly come through cropping intensification (now at around 180% against 150 % in 1983, Karim and Iqbal, 2001), rather than increase in production/ha. National Production figures of the main crops (rice) has fluctuated much because of climatic influence throughout the years. In general, however, the average production /ha of main crops remained rather stagnant according to statistics of Bangladesh Bureau of Statistics (BBS). This trend of stagnating yields has sometimes been attributed to declining soil fertility, although it is likely that other factors are into play (decrease of varietal vigour, physical land degradation, etc.).

SOIL FERTILITY STATUS IN BANGLADESH

The present status and future development of soil fertility is the crucial factor for the necessary and sustainable crop production increase from limited suitable agricultural land area. In general, it can be stated that Nitrogen is deficient in almost all soils in Bangladesh. Available Phosphorus content in most of the upland soils varies from very low to low and Sulphur from low to medium (M.S. Islam, 2000). Exchangeable Potassium is low in sandy and silty clays to medium-high in calcareous soils and alluvial sediments. Calcium and Magnesium supplies are quite satisfactory, and some Zinc and Boron deficiencies have been identified. Acidic soils cover a large area (about 60%) of Bangladesh. Soil salinity in the coastal areas of Bangladesh is a major constraint for successful crop production especially during the rabi (winter – dry) season. It is important to address these soil fertility constraints in an integrated way, in order to achieve continued increased and sustainable crop production in an environmentally friendly manner.

ORGANIC MATTER CONTENT

One of the main elements in sustaining soil fertility is the organic matter content of the agricultural soils. The organic matter content of most soils in Bangladesh is considered as low (<1.5 %) and has in most soils declined over the years, according to recent studies, though this trend is not seen everywhere, see also fig 2.

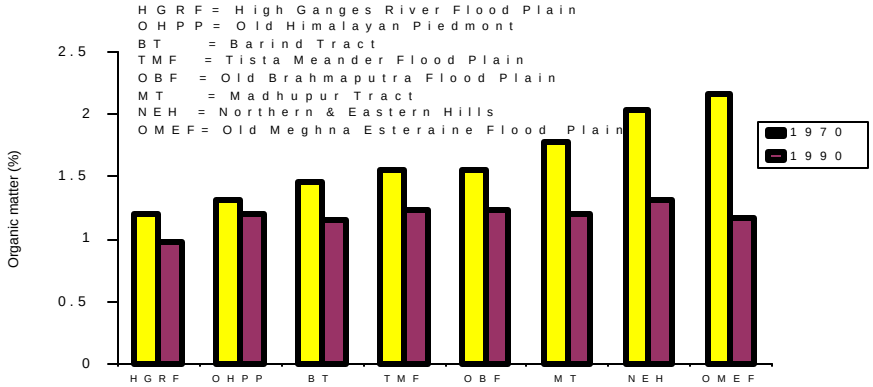
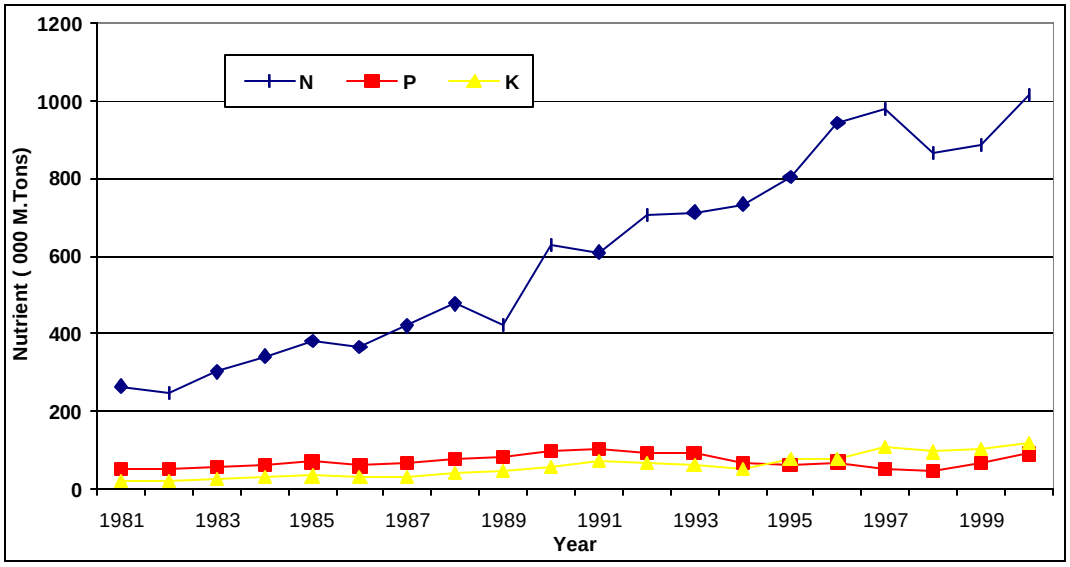


Fig. 2 Changes in organic matter content in some major AEZ of Bangladesh during 1970-90 (Karim et al. 1994)

The total availability of organic matter that can be added to the soil is also reported to be declining (M.S. Hoque, 2000). Because of the replacement of bullocks by power tillers the number of cattle and amount of cowdung is declining on most farms. Animal manures and crop residues are increasingly being used as fuel instead of being added to the soil. The only increasing trend can be seen in poultry manure, which is ava ilable in areas where the upcoming poultry industry in thriving.

FERTILIZER USE IN BANGLADESH

The use of chemical fertilizers in Bangladesh agriculture started in 1951 with the import of of Ammonium Sulphate. Fertilizer use became more popular with the introduction of high yielding varieties and is still gaining popularity with the increasing intensity of cropping (see Fig. 3).



From the graph the preference for Nitrogen as opposed to the other major and secondary nutrients is obvious. According to current statistics, the farmers of Bangladesh use only 179 kg nutrients (N:141, P:13, K:17 and S+Zn+B+others: 8 kg)/ha/year, while the estimated removal is around 250-300 kg ha/year. This is creating an imbalance that also becomes apparent at National level, see table 3.

Table 3. Plant Nutrient Balance Sheet of Bangladesh.

Nutrients	**Input Supply ('000 tons)**	**Removal ('000 tons)**	**Balance ('000 tons)**
Nitrogen (N)	1198	1322	(-) 124
Phosphorus (P)	149	159	(-) 10
Potassium (K)	399	1316	(-) 917
Total :	1746	2797	(-) 1051

Source: Karim et al. (1994)

These examples show the apparent nutrient mining which is currently going on in Bangladesh, especially for N and K, and which is aggravated by the increasing cropping intensity and the use of use of High Yielding Varieties that take up even higher quantities of nutrients that are not being replaced.

IPNS IN BANGLADESH

To counteract the above mentioned problems and take up the challenges, the Integrated Soil Fertility and Fertilizer Mana gement Project (SFFP) has adopted the Integrated Plant Nutrition Systems as its strategy. IPNS in the context of Bangladeshi agriculture is defined by SFFP as follows (adopted from FAO):

> ***IPNS is the management of all available plant nutrient sources to provide optimum and sustainable crop production conditions within the prevailing farming system.***

INTEGRATED SOIL FERTILITY AND FERTILIZER MANAGEMENT PROJECT (SFFP)

Background

The Integrated Soil Fertility and Fertilizer Management Project (SFFP) can be seen as a follow up of the earlier FAO support to fertilizer projects implemented in Bangladesh from 1975 to 1990. The DANIDA funded Project started from 1st July 1993 for a 5 year period. After a bridging period (1998-2000) a new Project was formulated, again for a period of 5 years. From 1st July 2000, SFFP-II is a "Component" under the DANIDA Agricultural Sector Programme Support (ASPS). SFFP phase II will continue and expand the activities of the first phase, focusing on development and testing of improved soil fertility and fertilizer management practices, and training of extension staff, fertilizer dealers and farmers. SFFP-II has National coverage, i.e. it is operating in all 64 Districts though annually incorporating around 155 Upazilas (out of a total of 460).

Objectives

All Components of the DANIDA Agricultural Sector Programme Support refer to the same **Development Objective**:

- *Optimised, integrated and sustainable agricultural production for improved living conditions.*

The **Immediate Objective** of the SFFP component is:

- *Male and Female farmers apply area specific improved plant nutrition and cropping pattern recommendations.*

Target group

The primary target group is smallholder farmers, men and women, cultivating less than 2.5 acres of land. The indirect target group consists of agricultural extension officers, who will be trained to demonstrate appropriate IPNS technologies to the farmers.

Strategy

The component design for phase II is based on a continuation of the strategy applied under phase I, i.e. *Support to research-extension co-operation; Training of extension staff; and Demonstrations on farmers fields.*

Outputs

The SFFP component addresses four problem areas in relation to soil fertility and fertilizer management:

- Farmers' knowledge and fertilizer management practices;
- Extensionists' knowledge and extension practices;
- Private fertilizer dealers' knowledge and extension capacity
- Development and testing of specific nutrient and cropping pattern recommendations by research.

Activities

Field Demonstrations

A total of 90776 field demonstrations have been implemented by SFFP from 1993 - 2000. The different types of demonstrations conducted were: cropping pattern based balanced use of fertilizer, green manure, preservation of farmyard manure and BNF demonstrations.

Block Demonstrations

A block demonstration covered an area of 1.2-2.0 ha with around 10-15 farmers following the same crop production and fertilizer plan for a year. Farmers training, including women's activities and training, are important elements of the block demonstration activity. A total of 2029 Block Demonstrations have been implemented during 1994 – 2000, with an estimated 27800 farmers involved.

Training

Human Resource Development in SFFP started with training of extension and research officers. It goes on to train upazila staff and block supervisors and eventually farmers, men and women, through demonstration farmers training and field days. Training focused on dissemination of technologies related to soil fertility management and IPNS, as well as proper implementation of SFFP field activities. A total of 3600 officers, 55000 BS and 200000 farmers received training during 1993 – 2000. At field and block demonstrations Field Days have been organized, with an estimated 1,8 million farmers participating. Local, private fertilizer retailers are trained at upazila level. The private retailers are familiarized with soil fertility problems, learn about the importance of integrated and balanced plant nutrition practices and are thereby able to provide better service to farmers concerning

fertilizer management. Posters, pamphlets, books, manuals and training material, videos, calendars, etc. related to soil fertility issues and IPNS are continuously produced by SFFP.

Research-Extension-Farmer Linkage

A total of 114 experiments at 279 sites were conducted by the main crop research institutions (6), mainly trials for updating of fertilizer recommendations, and development of appropriate IPNS practices, concentrating on on-farm research.

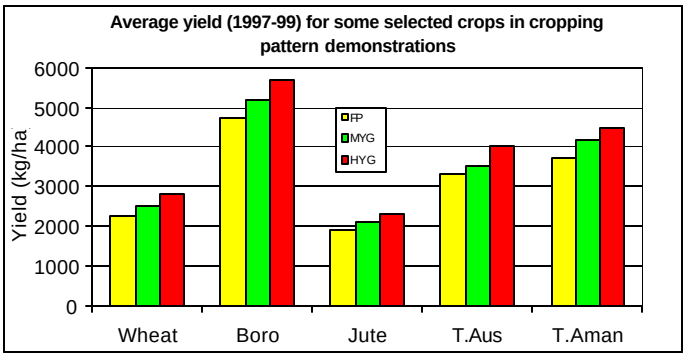
Monitoring

SFFP activities are continuously monitored, internally and externally. Part of the M&E set-up are baseline surveys and impact studies. Already conducted impact studies gave a positive impact of SFFP activities in terms of changes in awareness of soil fertility management, cropping patterns, yields, and income of farmers. Data from demonstration activities are collected and stored in a specially developed database, and subsequently analysed.

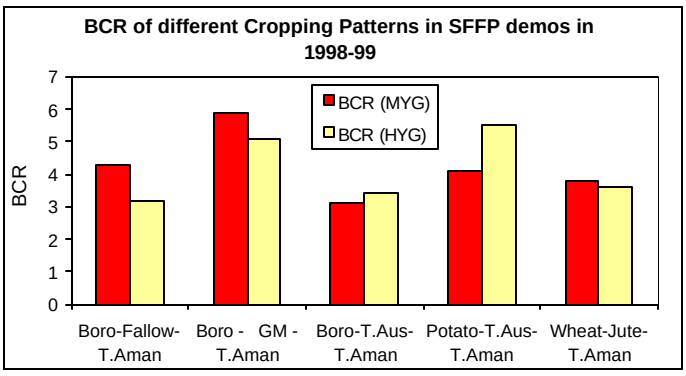
EXPERIENCE AND ACHIEVEMENTS FROM SFFP ACTIVITIES

balanced fertilizer use

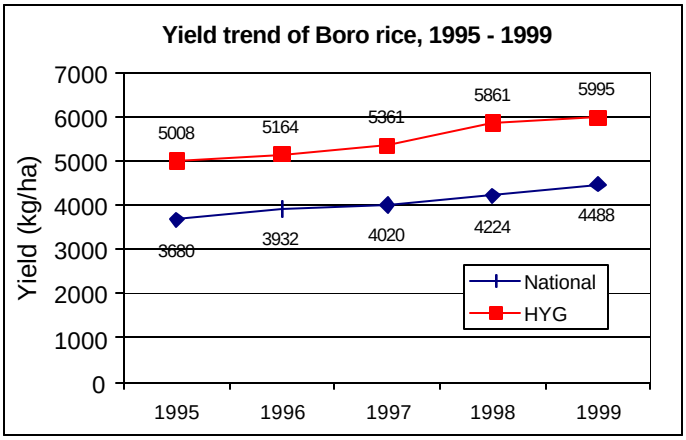
From 1993-2000 a total of 48317 cropping pattern based balanced fertilizer demonstrations were implemented by the Department of Agricultural Extension (DAE), with the objective to demonstrate balanced fertilizer recommendations in existing cropping patterns. These Demonstrations were laid out in existing cropping patterns for a whole crop rotation. The "General recommendations for AEZ based cropping patterns" from the BARC Fertilizer Recommendation Guide were followed. Field days were held in these demonstrations, and an estimated 1 million farmers were thus acquainted with the cropping pattern based balanced fertilizer concept. Some selected results are as follows:



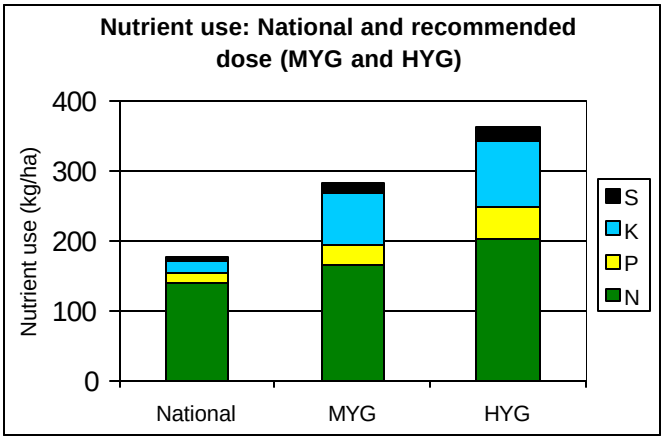
This graph shows the consistent yield increase of the fertilizer recommendation of High Yield Goal (HYG) over Moderate Yield Goal (MYG) over Farmer's Practice (FP) in SFFP Cropping Pattern field demonstrations.



This graph shows the Benefit Cost Ratio (BCR) of fertilizer recommendation is above 2 in all selected cropping patterns, both for targeted Moderate Yield Goal (MYG) as well as High Yield Goal (HYG). BCR's in cropping patterns Boro rice -green manure – Aman rice, and Potato – Aus rice – Aman rice are the highest.



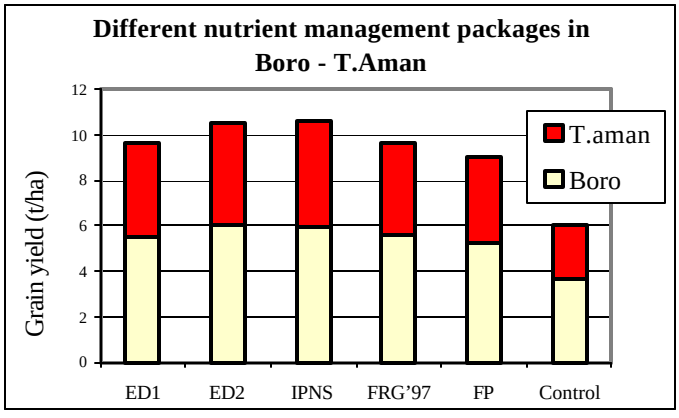
This graph shows the yield trend of Boro (winter) rice from 1995 to 1999, both for National Statistics as well as per HYG fertilizer recommendation. The graph shows that with a balanced fertilizer recommendation a substantial yield increase can be achieved under farmers' conditions, see the difference between the National and HYG yields (on average 24%).



This graph compares National fertilizer sales, and the fertilizer recommendation for Boro – T.aman rice (by far the most common cropping pattern). It shows that the National fertilizer sales are far below the average total nutrient recommendation for either MYG or HYG. It also shows that nutrient sales are unbalanced towards Nitrogen, as compared with the MYG and HYG recommendations.

The recommended balanced fertilizer recommendation based on Agro-Ecological Zone (AEZ) as used by the Block Demonstrations farmers gives more balanced nutrient doses, higher yields and net returns than in neighbouring farmers' similar cropping patterns.

Research also shows the positive effect of cropping pattern balanced fertilizer use, both in terms of yield as well as in the apparent nutrient balances.



This graph shows the results (grain yield) of the Boro rice – T.Aman rice cropping pattern from experiments conducted by the Bangladesh Agricultural Research Institute (ED = Estimated Dose based on soil test; FRG = fertilizer Recommendation Guide; FP = Farmer's practice). Nutrients applied either following AEZ basis recommendation or location specific soil test basis resulted in similar grain yield of rice. IPNS and ED2 (high dose nutrient) gave highest yields. High doses of nutrients (ED_2) were found less profitable and lowest B:C ratio was with IPNS because of high price of

organic manure. The apparent nutrient balances were strongly negative for soil N and K in all treatments, with the IPNS treatment gave the least negative nutrient balances.

Use of organic matter

The benefits of using organic materials in crop production in Bangladesh are obvious and well-known. The main sources of organic materials that could be used in crop production are animal manures, farmyard manures, composts, green manures and crop residues. The use of these organic materials has its limitations under Bangladeshi conditions in terms of available quantity and quality. The graphs below show the influence of cowdung and green manure on Boro (winter) and Transplanted Aman (summer) rice, respectively. It also shows that part of the nutrients from inorganic fertilizers can be substituted by plant nutrients form organic sources.

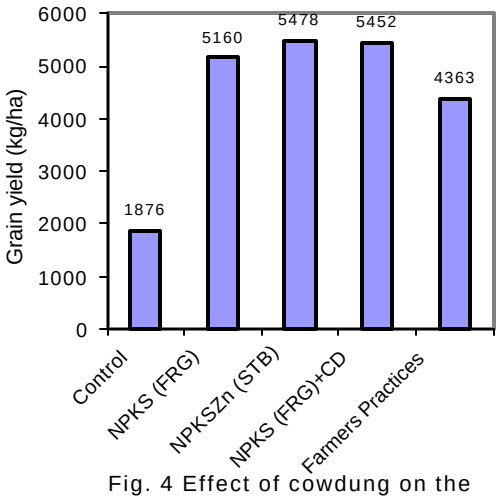


Fig. 4 Effect of cowdung on the yield of Boro rice

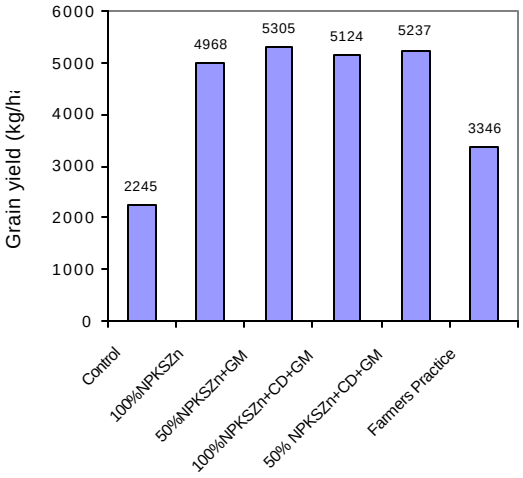
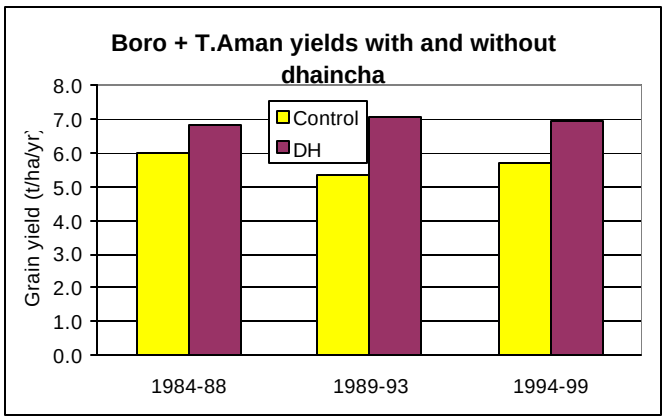


Fig. 5 Effect of green manure and cowdung on yield of T.Aman rice

SFFP implemented Farmyard Manure (FYM) preservation demonstrations according to the following lay-out. A total of 17220 structures have been erected from 1995 – 2000, and it is estimated that some 180000 farmers have visited field days and have been acquainted with this activity. In the SFFP Block Demonstrations the preservation of farmyard manure in this way is a special activity conducted by women. Farmers are interested in this type of activity but find it sometimes difficult to erect and maintain these structures (e.g. during monsoon).

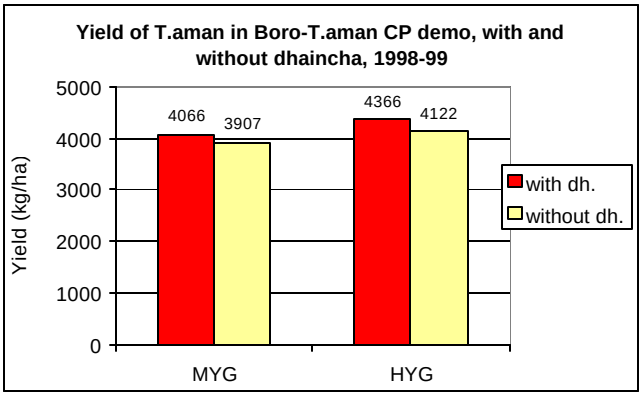
Use of Green Manure

The incorporation of green manures in the cropping patterns for adding biomass (organic matter) and nitrogen (through Biological Nitrogen Fixation) to the soil is known in many areas of Bangladesh. Cowpea, sunhemp, mungbean and dhaincha (*Sesbania aculeata*) are some of the crops used as green manure. Mungbean is in some regions of Bangladesh used as a "brown manure": the mungbean pods are harvested and the stover is incorporated in the soil before the following crop (usually transplanted aman rice). Dhaincha is the most commonly known green manure crop, although it is also used for other (fuel, sticks) purposes.



The graph shows the results of a long-term experiment conducted by Bangladesh Rice Research Institute (BRRI). Throughout the depicted periods, the plots where dhaincha was incorporated showed higher rice yields (Boro + Aman) than the plots without dhaincha (no fertilizers applied). Yields of control showed somewhat declining trend, yields of plots with dhaincha incorporation remained stagnant.

SFFP conducted 19717 dhaincha demonstrations from 1994 – 2000, where the objective was to demonstrate the effect of dhaincha incorporation on the following transplanted aman crop.



In the SFFP cropping pattern demonstrations dhaincha was often included in the selected cropping patterns. This graph shows the effect of dhaincha incorporation in a Boro – T.Aman cropping pattern on the yield of the following transplanted aman. Yields of T.Aman after dhaincha incorporation are higher than without dhaincha in the pattern.

Inclusion of a suitable green manure in the cropping pattern faces some constraints at farmer level. The most widely practiced green manure (dhaincha) has some limitations as regards to adaptability to water stress and flooding. It is also difficult for farmers to forego a harvestable crop in the pattern for inclusion of a green manure, which yields no direct benefits.

Biological Nitrogen Fixation

Research and demonstration results show the positive effects of the use of specific rhizobium inoculum in legume crops, as in experiments conducted by the Bangladesh Agricultural University. Best results give inoculum with recommended dose of P, K and S, as can be seen in below graphs.

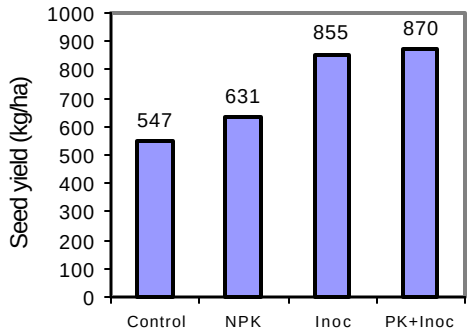


Fig. 1 Effect of inoculation and chemical fertilizer on lentil

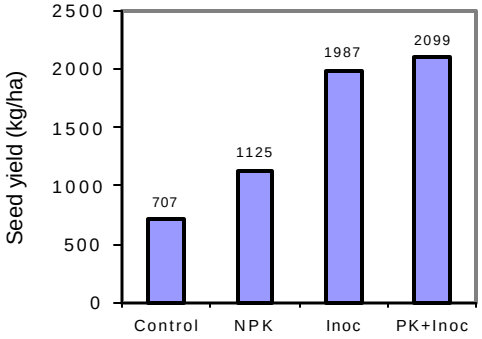
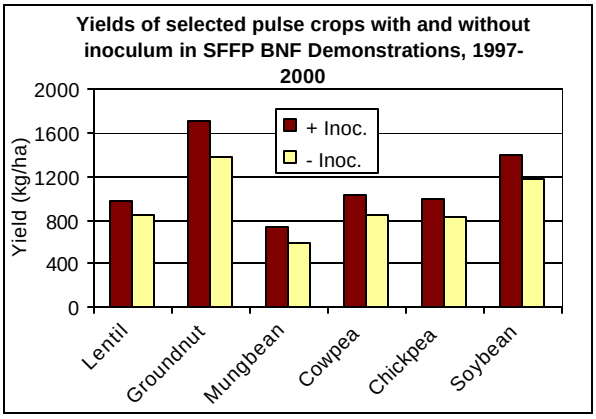


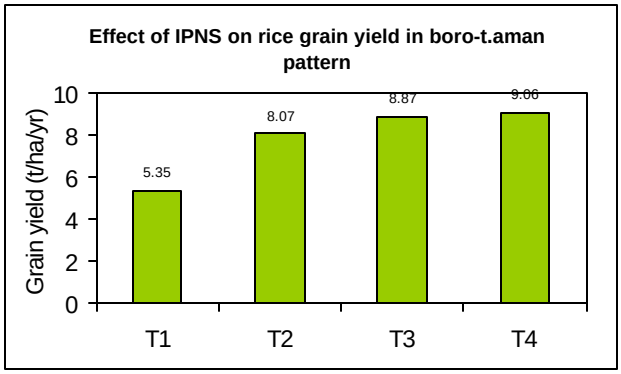
Fig. Effect of inoculation and chemical fertilizers on soybean



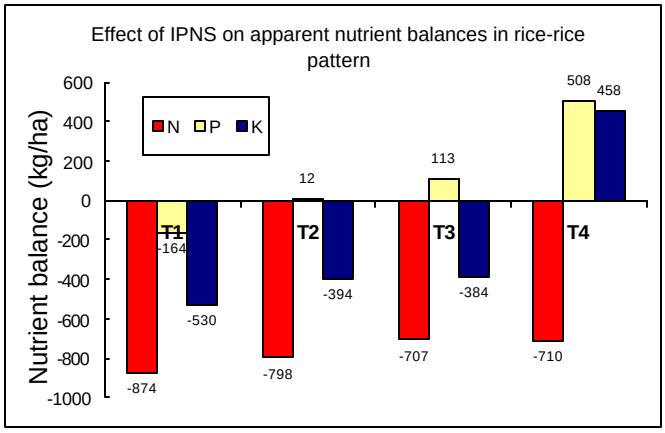
SFFP has implemented a total of 44545 BNF demonstrations with inoculum during 1995 – 2000. These demonstrations with crop specific inoculum in different legume crops give also positive results, as shown in this graph. This picture does however not apply throughout Bangladesh. Response to added inoculum is in some case not apparent. This seems to be mainly due to the quality, storage, transport and application of the inoculum. A major constraint for the uptake of this BNF technology at farmer level is the non-availability of legume specific inoculum in rural markets. At present a private company in Bangladesh is trying to set up a distribution and marketing network for inoculum in Bangladesh.

Research on Integrated Plant Nutrition Systems

The Soil Science Division of BRRI has been working on INM options for rice-based cropping patterns for the last 15 years, including trials sponsored by SFFP.



In this graphs one can see an increased yield in a boro – t.aman rice cropping pattern with T4, which is the IPNS treatment with cowdung and rice husk ash, with a lower inorganic fertilizer rate (2/3 recommendation). T3 is the full fertilizer dose, T2 the 2/3 dose and T1 the control.



This graph shows that the application of CD and ash (T4) contributed positively to the apparent soil P and K balance sheets. The apparent positive balance of P in soil due to the application of CD and ash indicated that these organic residues could eliminate the need for applying inorganic P fertilizer for a rice-rice cropping pattern.

TRAINING MATERIALS ON IPNS

Diverse training & extension material has been developed during SFFP Phase I. The list includes:

- Guidelines for implementation of Field and Block Demonstrations;
- Pamphlets and leaflets on SFFP activities and special topics (soil sampling, Green Manure, etc.);
- Three calendars for DAE staff and others, highlighting simple soil fertility messages;
- A flipchart on integrated soil fertility management;
- SFFP has been instrumental in producing the updated "BARC Fertilizer Recommendation Guide 1997".
- Diverse training materialhas been produced, e.g. the Resource Manual on "Integrated Soil Fertility and Fertilizer Management".
- Two videos for use by extension Department: on soil organic matter management and on balanced fertilizer use for use by the extension department;
- Slide series + booklet on plant nutrient deficiencies,
- Block Supervisor Fertilizer Recommendation and IPNS Guide.

CONCLUSIONS

Agriculture in Bangladesh faces the challenge of necessary and sustainable production increase from its limited land resource to provide food self-sufficiency for the country and nutritional and food security for all. Maintenance and possible improvement of soil fertility is the crucial element in achieving this. Presently the organic matter content of the main agricultural lands is reported to be declining and nutrients balances are negative for the main nutrients, especially N and K. The Integrated Plant Nutrition Systems (IPNS) approach, which combines the addition of plant nutrients from organic and inorganic sources, is the way to address these challenges and provide the pre-conditions for sustainable and environmentally friendly production increase. The Integrated Soil fertility and Fertilizer Management Project (SFFP) has since its inception concentrated on IPNS in its training, extension and research activities. SFFP concentrated on the main elements that make up IPNS in Bangladesh:

- **Balanced fertilizer use**: Balanced fertilizer recommendations based on cropping patterns, either on AEZ or soil test basis, are beneficial to smallholder farmers in respect to improved yields, increased income and less nutrient mining.
- **Preservation and use of organic materials**: Adding organic material, from e.g. animal manure, farmyard manure, compost, crop residues, counters the declining organic matter content of main soils, as well as increases yield of main crops. The use of these organic materials has, however, its limitations under Bangladeshi conditions in terms of available quantity and quality.
- **Use of green manure crops in cropping patterns** : Inclusion of suitable green manure in the predominant cropping patterns would assist in sustaining yields and soil fertility. The uptake of this technology at farmers level is still limited due to technical, environmental and socio-economic factors.
- **Biological Nitrogen Fixation through the use of inoculum in legume crops** : A promising technique that may add nitrogen to the cropping pattern, provided the crop residues of the leguminous crop are incorporated after harvest (as green or "brown" manure). Availability at local farmer's level of good quality inoculum is a constraint.

SFFP has supported and disseminated these IPNS elements through its respective activities and by producing relevant training & extension material. SFFP is now trying combinations of these IPNS elements in its research, field and block demonstration activities.

RECOMMENDATIONS

The following recommendations are derived from the experiences of SFFP. They are specific for Bangladesh and some even for the SFFP activities itself. It is thought, however, that other participating countries in this Workshop may learn from these experiences.

- Ensure proper, practical, technically sound, socially acceptable, economical and environmentally friendly fertilizer recommendation based on cropping patterns;
- Obtain better insight in decomposition of organic materials and their nutrient release pattern, so that they can be easily incorporated and accounted for in plant nutrient recommendations;
- Investigate and show the combined effect of all IPNS elements in agricultural crop production in research and demonstration activities. This should be area and even farm specific;
- Participatory approaches in research (Participatory Technology Development – PTD), extension (Farmers' Field Schools, etc.) and training will be more effective to disseminate the IPNS messages to the large farming community.
- More emphasis is needed on the whole farm approach, taking into account the inter-linkages between the different elements on the farm (e.g. crop-livestock);
- More emphasis on the farm economic consequences of the proposed recommendations / interventions, especially the costing of additional organic matter, labour, etc.;
- Continued attention to the rural women, trying to bring real benefits to them (not only increased workload), as well as try to involve them into the mainstream agricultural extension activities.
- Availability at local level of crop specific inoculum for legumes needs to be ensured;
- Other forms of BNF need to be investigated, as well as Biofertilizer for increased phosphate availability (phosphate solubilizing bacteria, fungi).

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