Annual Report

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for

Sustainability of Post-Green Revolution Agriculture: The Rice-Wheat Cropping System of South Asia

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University of Hawaii

by

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EXECUTIVE SUMMARY

Major contributions in the 2000-2001 project year to the soil constraints listed in the SM-CRSP program, and in other areas that are not so neatly categorized were:

1. Nutrient Management

Nitrogen:

- Studies have shown that straw mulch can increase crop recovery of fertilizer N, i.e. N use efficiency, in flooded rice. The mulch lowers floodwater pH and reduces N losses by ammonia volatilization. Adoption of this technology by resource poor farmers could increase rice yields at low N input levels.

Phosphorus:

- P efficient wheat lines have been identified in Bangladesh. This breeding program is expected to lead to reduced needs for inputs of P fertilizer, which is an expensive import for Bangladesh and Nepal, is not always available or affordable for farmers and may be of questionable quality.

Micronutrients:

- On-farm trials have demonstrated that micronutrient enriched seed of rice and wheat can successfully overcome soil micronutrient deficiencies. Micronutrient enriched seed may be more effective than soil treatment with micronutrients because resistance/tolerance to root pathogens is increased.

- As a result of SM-CRSP research, the Nepal national wheat breeding program has adopted a screening procedure for genetic susceptibility to sterility caused by B deficiency.

Multiple Nutrients:

- Research has demonstrated that K and Zn deficiency is widespread in the Nepal Terai, and has developed the basis for a strategy for targeting nutrient management programs.

- Soil fertility status survey data has documented the generally low fertility conditions in rice-wheat production areas in Bangladesh and Nepal and data is being analyzed within a GIS framework.

2. Soil Acidity

- Experiments have demonstrated significant yield response to liming of acid soils in Bangladesh for both rice and wheat. The research has high potential impact since 50% of soils in Bangladesh and many areas in Nepal are acid. Liming is not currently practiced in Bangladesh and little is used in Nepal.

3. Soil Degradation

- Multi-location testing, using solarization of soil as a diagnostic tool, has shown that soil biology is a major constraint to productivity of rice and wheat. Mechanistic research is pointing to reduction in soil-borne pathogens as the primary causal factor. Following surveys of plant parasitic nematode populations, current research is concentrating on the role of the root-knot nematode *meloidogyne graminicola* in the rice-wheat cropping system.

- Deep tillage (sub-soiling) on fine textured soil prior to rice has been found to benefit wheat yields whether soil is puddled for rice or not. Deep tillage does not affect rice yields. The combination of deep tillage with no-tillage surface seeding for timely establishment of wheat can substantially increase wheat and rice-wheat system yields.

4. New Technologies for the Rice-Wheat System

- The use of permanent beds has shown promising preliminary results for both rice and wheat.

- Elements of the system of rice intensification (SRI), an unconventional approach to rice production, were evaluated. Use of single seedling transplants increased yields and gave stronger plants that resisted lodging.

- Use of "healthy seedlings" gave yield increases of about 30% for transplanted rice. The concept is an application of our work on soil biological constraints and utilizes soil solarization and vitavax seed treatment.

5. Improving Grain Legume Productivity

- On-farm trials have documented that B deficiency is probably a widespread constraint to productivity of lentils and chickpeas in Bangladesh and Nepal.

- Seed treatment strategies to improve emergence and reduce seedling mortality of lentils and chickpea were developed in Nepal and are being evaluated in farmer fields.

6. Transfer of Surface Seeding Technology

- Surface seeding of wheat is being successfully transferred in the Central-Terai region of Nepal where heavy textured soils often remain fallow after rice.

7. Agricultural Linkages to Nutrition and Health

- Research on how farmer decision making affects family nutrition and health has been completed and Kaafee Billah is writing his PhD thesis.

- The field component of research on linkages between soil quality, crop quality and child nutrition and health has been completed by PhD candidate Anne-Marie Mayer.

PROJECT OBJECTIVES

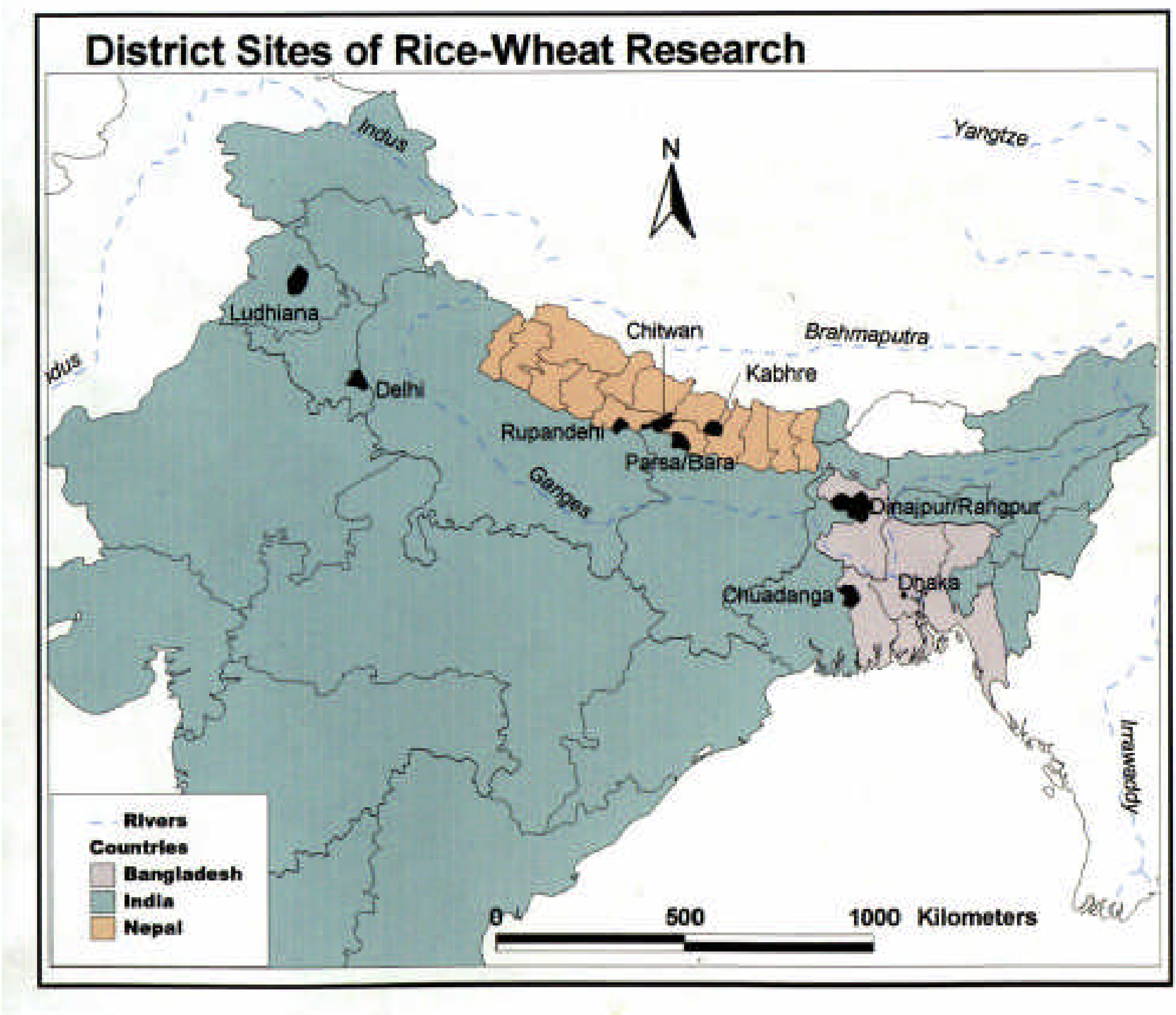
1) To identify constraints and opportunities to improve production in rice-wheat cropping systems of the IGP and adjacent hill regions.

2) To develop and promote adoption of improved tillage, crop establishment, and water management practices for rice-wheat systems.

3) To overcome nutrient and soil acidity constraints to crop production in soils of the Indo-Gangetic Plain.

4) To improve the agronomic and economic sustainability of rice-wheat cropping systems and the nutrition and health of farm households.

5) To use information systems and modeling as tools for improving land use and management decision making.



I. Nutrient Deficiencies

Specific information about soil nutrient deficiencies is limited in the Eastern part of the Indo-Gangetic Plain (IGP) and farmers here are often applying less than recommended rates of fertilizer. The efficiency of nitrogen use in the cropping system is generally poor. It is difficult to avoid volatilization losses in the rice paddy, either as ammonia or by denitrification. Surface application of urea for wheat also leads to ammonia volatilization and losses on the order of 50% are to be expected with this practice. Deficiencies of K are appearing in the Terai region of Nepal and in Bangladesh, and the prevalence of micronutrient deficiencies (at least Zn, B, and Mo) is also increasing in these countries. The goals of our program in Bangladesh and Nepal are to characterize macro- and micro-nutrient nutrient status of soils in the rice-wheat regions and to develop a range of options to overcome any deficiencies. Limited work is also being carried out in India. Strategies that are being investigated to cope with inadequate nutrient supply include:

- fertilization with inorganic and/or organic nutrient sources;
- development of cultivars of crops that have nutrient efficiency traits, i.e. increased ability to acquire nutrients from soils;
- designing cropping systems and management practices to increase acquisition and recycling of nutrients through crop residues or (legume) green manures; and
- enriching seeds with nutrients.

Activities that we report on for the 2000-2001 project year are:

1. Soil fertility surveys.
2. Evaluation of improved nutrient management practices.
3. Rice and wheat yield response to K, Zn and other micronutrients in the Nepal terai.
4. Breeding for P efficient varieties of wheat.
5. Boron and Crop Sterility.
6. Performance of rice and wheat seeds enriched with micronutrients.
7. Integrated nutrient management.

1. Soil Fertility Surveys

Soil fertility surveys to identify nutrient constraints to crop production in the region have been completed for Dinajpur and Chuadanga districts, Bangladesh and Rupandehi district, Nepal. This work was extended to the Chitwan district of Nepal (central Terai) during Spring 2000. Soil samples were collected from 190 sites and each sampling location was geo-referenced for use with GIS. Colleagues in the NARC Soils Division - GIS Unit are in the process of assembling soil nutrient maps from the survey analyses. Results from the analyses are summarized below together with results from Chuadanga and Dinajpur, Bangladesh for comparison.

Despite similarities in soil pH, total N and C between Dinajpur and Chitwan district soils (Table 1), available phosphorus levels are substantially higher in Chitwan compared to Dinajpur. Unlike other soils in the Nepal Terai, Chitwan district soils appear to have ample available potassium. Of the micronutrients, zinc and copper levels are above critical levels and are similar in magnitude to Chuadanga soils. Managanese levels are on the low side in Chitwan compared to the Bangladesh districts.

Table 1. Comparison of Soil Fertility Status (0-20 cm) in Chuadanga and Dinajpur Districts, Bangladesh and Chitwan District, Nepal

Parameter	Chuadanga n = 77		Dinajpur n = 60		Chitwan n = 190		Critical Level
	Mean	Range	Mean	Range	Mean	Range	
pH	7.4	6.0-8.1	5.4	4.4-7.0	5.4	3.6- 7.3	--
Total N (%)	0.08	0.04 - 0.13	0.09	0.04 - 0.17	0.11	0.01 - 0.27	0.12
Total OC	0.8	0.3 - 1.3	1.1	0.4 - 2.2	0.98[9]	0.2 - 2.8[9]	--
P (mg/kg)	9.7[1]	1.7 - 33.2	3.9[2]	0.8 - 32	71.4[1]	13 - 261	10.0[7]
K (mg/kg)	107[3]	39 - 191	71[2]	30 - 385	123[3]	35 - 539	47
S (mg/kg)	8.9[4]	5.0 - 15.7	--	--	--	--	10.0
Zn (mg/kg)	1.3[5]	trace - 4.4	0.51[2]	0.17 - 1.9	0.95[5]	trace - 6.9	0.6[8]
Cu (mg/kg)	3.8[5]	1.6-7.2	0.49[2]	0 - 1.6	2.4[5]	trace - 22.8	0.2
Mn (mg/kg)	33[5]	17-66	14[2]	1.3 - 57	11[5]	0.1 - 39	1
B (mg/kg)	0.021[6]	0.012- 0.028	0.042[6]	0.011- 0.157	--	--	0.20

[1] Olsen P extract
[2] Morgan's extract,pH 4.8
[3] 1 N NH_4OAc (pH 7) extract
[4] $Ca(H_2PO_4)_2$ extract, $BaSO_4$ turbidity
[5] 0.05N HCl and DTPA extract
[6] $BaCl_2$ hot water extract
[7] For Olsen P
[8] For DTPA Zn
[9] Organic matter/2

Ten random soil samples from the Chitwan survey were extracted and analyzed at Cornell for available (hot-water extractable) soil B with ICP. As expected levels were quite low ranging from 0.021 to 0.048 ppm with this method, while results from the NARC azomethione-H and AA analysis were roughly 10 times greater. Given the low soil B levels and the poor precision of the azomethione-H and AA method below10 ppm, the NARC results for soil B are not considered accurate and are not reported.

Spatial extrapolation of data (Table 2) collected from 50 farms in Birganj Upazilla (Thana), in Dinajpur district, Bangladesh in 1999-2000 was used to prepare maps of soil nutrient status and crop yields etc to facilitate data analysis within a GIS framework. Examples of this are shown in figures 1 and 2, where soil nutrient status and farmer nutrient inputs, respectively, are compared with wheat yield categories for the 1999-2000 season. The surface for wheat yield categories is not shown. Figure 1 shows that wheat yields appear to decline with increasing total N and available P but increase with exchangable K. Total N is clearly not a good indicator of N availability in these soils and yields did increase with increasing N inputs. Possibly the decline in yield with increasing P availability is linked to low soil Zn status and a need for balance between these two nutrients. The positive relationship between yield and K supply suggests that K is limiting yields and this interpretation is supported by the good relationship between farmer inputs of K and yield. Yields were well correlated with farmer N inputs, but not with P inputs, reflecting the generally adequate soil P status.

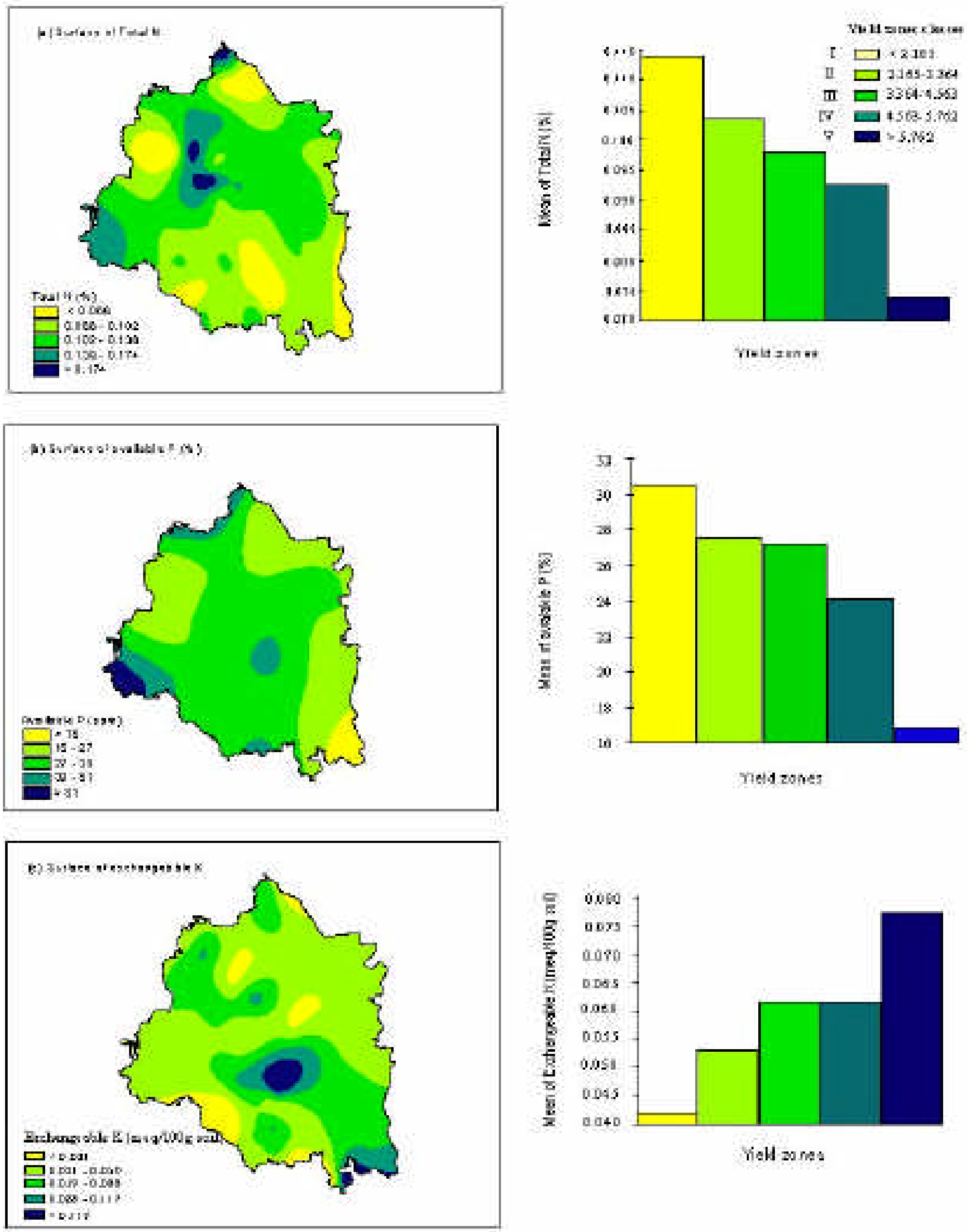


Figure 1. Relationships between soil nutrient surfaces and wheat yield zones in Birganj Upazilla, Bangladesh.

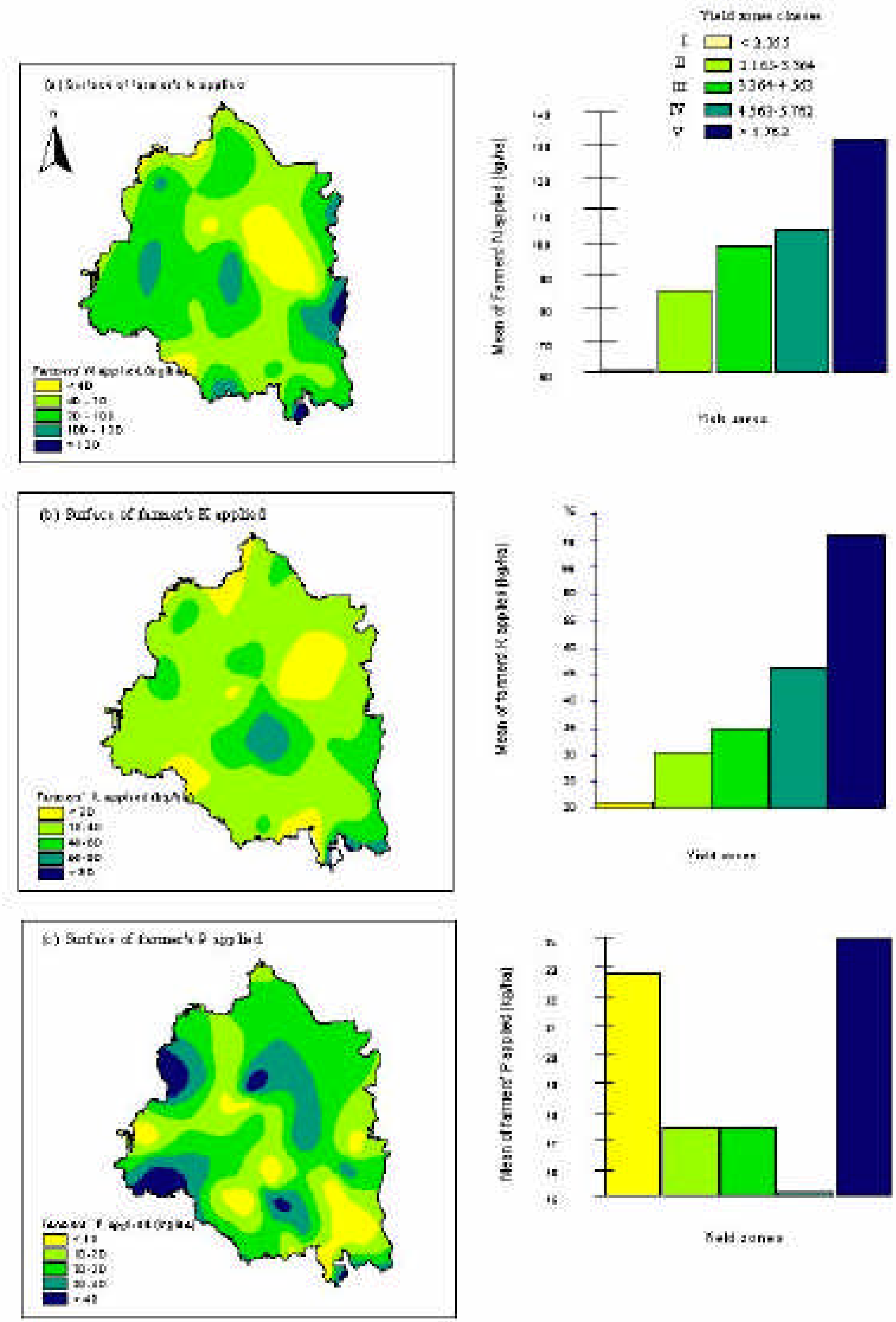


Figure 2. Relationships between farmer nutrient inputs and wheat yield zones in Birganj Upazilla, Bangladesh.

Table 2. Summary of data collected for 50 farms in Birganj Upazilla, Dinajpur District, Bangladesh, 1999-2000.

Parameter	No.	Min	Max	Mean	SD	CV (%)
Grain yield (t/ha)	50	1.38	6.31	3.62	1.00	27.61
Farmers' N applied	50	27.28	121.80	89.06	21.26	23.88
Farmers' P applied	50	0.00	44.62	17.25	13.34	77.34
Farmers' K applied	50	0.00	100.00	35.45	15.09	42.56
Soil pH (1:2.5 soil: water)	50	4.14	5.33	4.60	0.24	5.29
Total N (%)[1]	50	0.05	0.19	0.10	0.03	29.21
Organic C (%)[2]	50	0.55	2.02	1.09	0.33	29.89
Available P (ppm)[3]	50	3.53	59.50	27.12	15.92	58.70
Exchangeable K (meq/100g)[4]	50	0.03	0.12	0.06	0.02	40.12
DTPA Zn (ppm)[5]	50	0.32	2.99	1.02	0.52	51.05
Hot water extractable B (ppm)[6]	50	0.01	0.07	0.03	0.01	40.70

[1]Wet digestion, micro-kjeldahl distillation
[2]Walkley –Black wet digestion
[3]Bray P, NH_4F extraction and colorometric determination
[4]Neutral 1 N NH_4-acetate extraction and flame photometric determination
[5]DTPA extraction and AA determination
[6]Hot water extraction and colorometric determination

2. Evaluation of Improved Nutrient Management Practices

The need for "balanced nutrient inputs" is often cited as a major constraint to rice and wheat productivity. A series of on-farm nutrient management trials were initiated to compare yields obtained when average farmer practice, regional recommendations and soil test based recommendations were followed. Note, however, that soil testing is not widely available to farmers. As expected, wheat yields in nine on-farm trials in Dinajpur district, Bangladesh were increased by an average of 0.5 and 1.1 t/ha (12 and 29%) when regional and soil test based fertilizer recommendations, respectively, were followed (Figure 3). However, yields and responses to higher nutrient inputs were lower on five farms at Chuadanga.

The variability in farmer yield with best nutrient management at Dinajpur is striking. The difference in yield between the best two farmers and the average of the other farmers was 1.2 t/ha, which is slightly higher than the response to following soil test based recommendations. Similar results were obtained in Rupandehi district in the Nepal Terai, where responses to K and Zn were found, but these were mostly less (0.6 to 1.5 t/ha) than the difference (1.6 t/ha) between the best farmer and the average farmer (see following section). Understanding and overcoming the reasons for the variabilty in farmer yield is at least as important as following nutrient management recommendations and is the subject of research in the coming year.

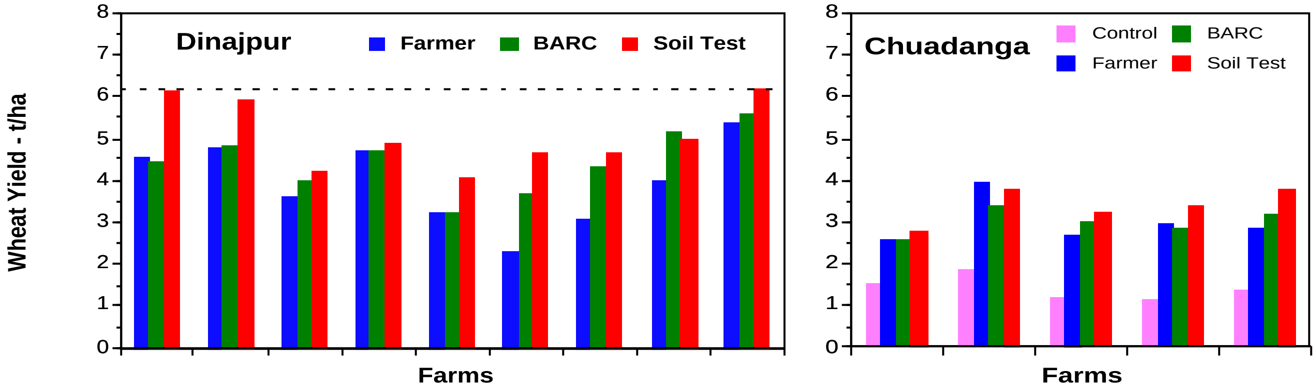


Figure 3. Wheat yields on farms in Dinajpur and Chuadanga districts, Bangladesh in 1999-2000 for average farmer, regional, and soil test based recommended nutrient inputs.

3. Rice and Wheat Yield Repsonses to K, Zn and Other Micronutrients

Crop yield responses to additions of K and Zn were evaluated through a series of trials in the Terai of Nepal. Responses to K and/or Zn were observed for both rice and wheat, but these varied as a function of soil texture and between years. Figure 4 shows mean data over two years for 13-15 farms per crop (nominally 5 farms for each texture grouping) in Rupandehi district.

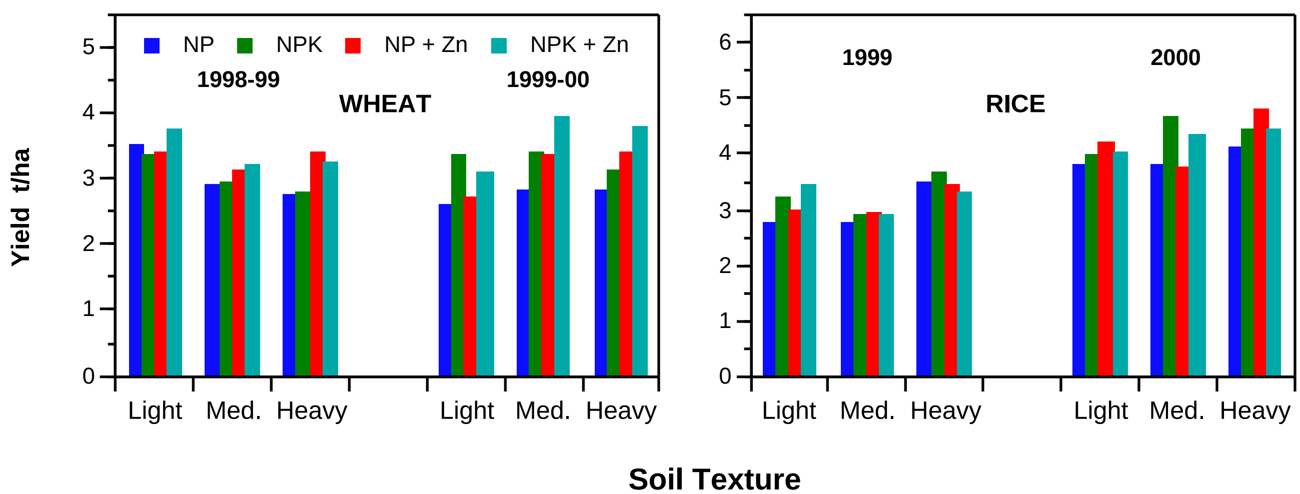


Figure 4. Response of rice and wheat to Zn and K fertilization on farms in Rupandehi district, Nepal in 1999 and 2000.

Yield responses tended to be greater for wheat than for rice. Overall, wheat grown on light textured soils responded to K only, while responses to both K and Zn were found on medium textured soils. Zinc deficiency became progressively more important as soil texture became finer. K and Zn were equally important in rice yield responses. Average data obscures the variability in both yield and yield response between farms. Rice yield increased by 30% (0.83 t/ha) on 6 of 11 farms where a response was observed in 1999 and by 26% (0.93 t/ha) on 7 of 14 farms in 2000. Similarly, yield responses with wheat averaged 43% (1.0 t/ha) on 5 of 13 farms in 1998-99 and 42% (0.87 t/ha) on 12 of 15 farms in 1999-2000. The frequency of response to these nutrients was highest on light textured soils.

In the 1998-99 wheat season the average yield response to K on light textured soils and to Zn on heavy textured soils was 0.58 and 0.61 t/ha, respectively, compared to 1.48 t/ha on soils where response to both K and Zn were observed (Figure 5). The highest return from nutrient management programs would come from targeting medium textured soils with both K and Zn fertilization.

The data in Figure 5 again highlight the variability in yield amongst farms. The average response to best K and Zn nutrient management was 0.86 t/ha, while the difference in yields between the best two farmers and the rest was 1.41 t/ha.

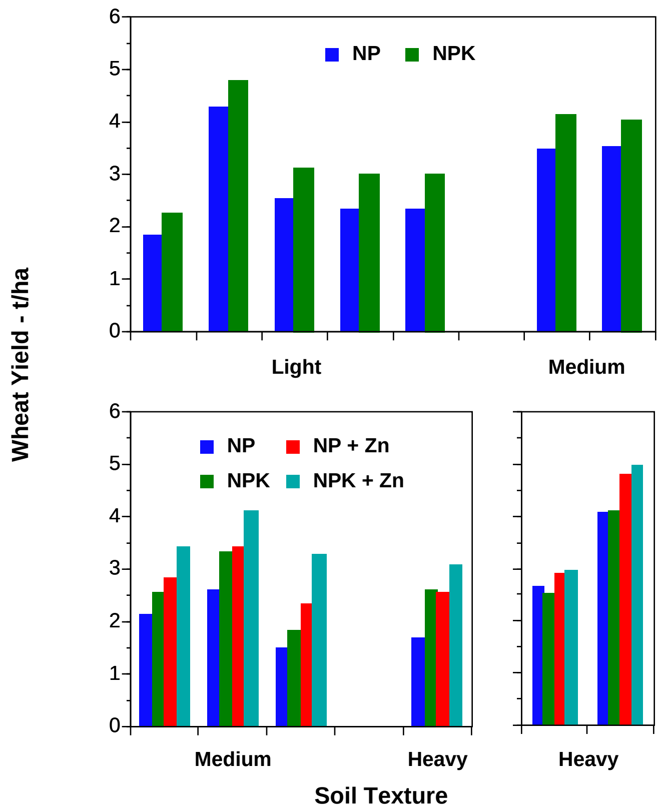


Figure 5. Effect of K and Zn fertilization on wheat yield on 13 farms in Rupandehi district, Nepal in 1998-99.

Zinc additions increased rice yields by an average of 20% (0.61 t/ha) on four of nine farms in Parsa district in 1999. Additional spraying with multiplex, a complete micro-nutrient mixture, had a small impact on only two farms. In the same area in 2000, yield responses to Zn and to additional micro-nutrients were observed on five of six farms. Yields were increased by 18% (0.66 t/ha) with Zn alone and by an additional 25% (1.06 t/ha) with complete micro-nutrients giving an overall increase of 48% (1.72 t/ha). Similarly additions of Zn increased wheat yields by an average of 45% (1.4 t/ha) on 4 of 5 farms in 1998-99 and by an average of 23% (0.4 t/ha) on 2 of 5 farms in 1999-2000.

Overall, these results suggest that K and Zn deficiencies are fairly widespread in the Terai and that other micronutrient deficiencies also exist. A more complete characterization of soil nutrient status is needed in Nepal.

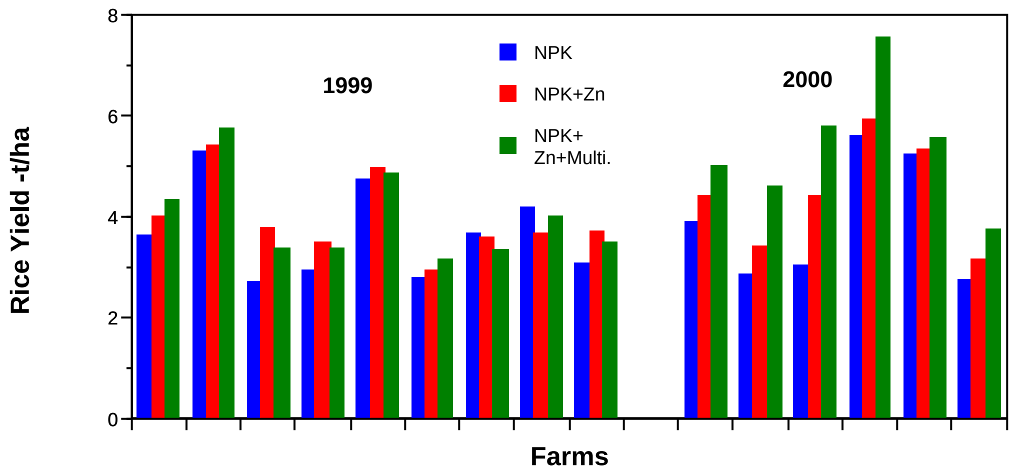


Figure 6. Effect of Zn and complete micro-nutrient fertilization on rice yields in Parsa district, Nepal in 1999 and 2000.

4. <u>Breeding for Phosphorus Efficient Wheat</u>

In the rice-wheat system, additions of phosphorus fertilizer are usually needed to correct P deficiency with wheat but not rice because P availability increases under flooded conditions. In 1998 a breeding program was initiated in Bangladesh to select wheat varieties for phosphorus efficiency. This new breeding strategy is expected to lead to reduced needs for inputs of P fertilizer, which is an expensive import for Bangladesh and is not always available or affordable to farmers.

To date the program has screened more than one hundred and thirty wheat lines at two P deficient sites in Bangladesh for phosphorus efficiency. From the screening trials, twenty one lines (including the current standard, Kanchan) have been tested further in Preliminary Yield Trials (PYT). From the PYT's, four lines (Attila, BAW 936, BAW 923, Mayoor) plus Kanchan (the standard variety) and a sensitive check, Wuhan, were selected for the Advanced Yield Trials (AYT) at four research station sites. Three lines (Mayoor, BAW 923, BAW 936) plus Kanchan as a check were also evaluated on five farms.

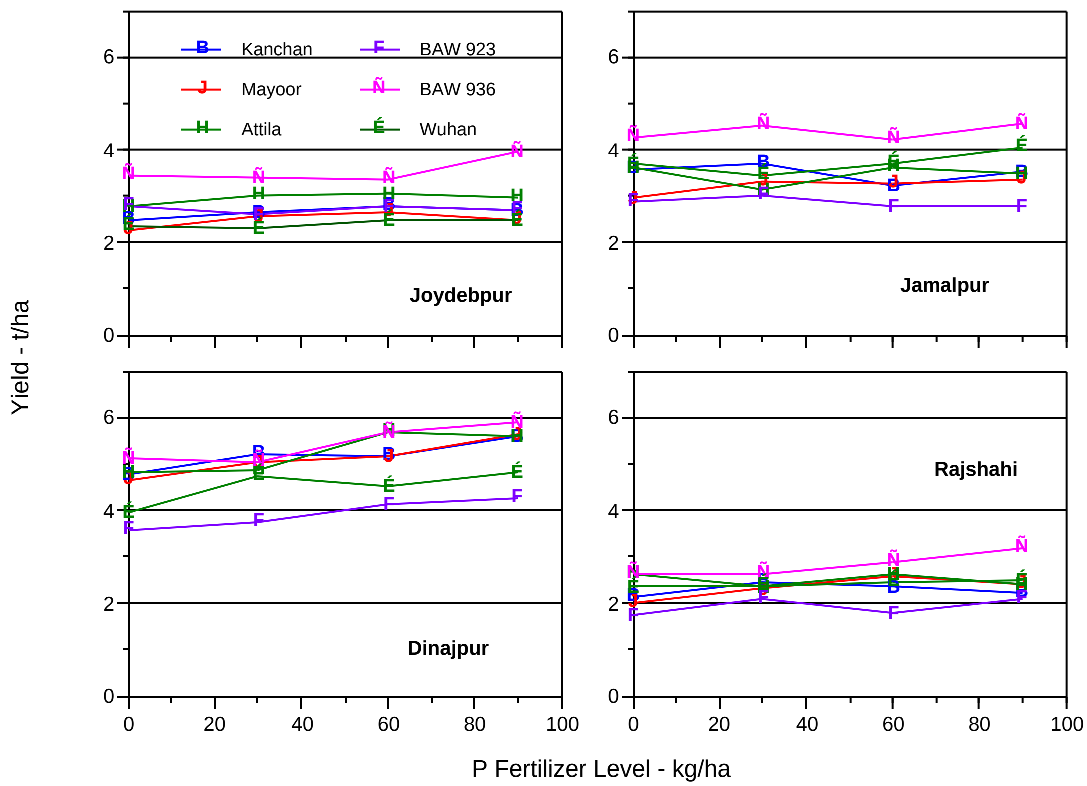


Figure 7. Advanced Yield Trials with P efficient wheat lines at four research station sites, Bangladesh, 1999-2000.

BAW 936 (also known as Shatabdi) performed the best in the AYT's at all sites followed by Attila and Mayoor (figure 7). All lines were relatively unresponsive to applied P fertilizer at Joydebpur and Jamalpur and only slightly responsive at Dinajpur and Rajshahi. Yields were generally lower at Rajshahi compared to the other sites. Performance of all lines was better on farms in Rajshahi district (figure 8) than on the research station. However, responses to P inputs were again slight. In contrast, yields on Dinajpur farms were not as good as at the research station and were more responsive to P inputs.

Assuming that the farmer field trials were managed similarly to the station trials, we hypothesize that the differences in performance between selected varieties at the Dinajpur station and farmer fields may have been due to other nutrient deficiencies. Soils in the Dinajpur/Rangpur area were found to be deficient in K, Zn and B as well as P and quite responsive to both K and Zn inputs (see Soil Fertility Surveys section). Not as much is known about the Rajshahi soils, but micronutrient deficiencies have been noted in maps compiled by the Soils Resource Development Institute (SRDI).

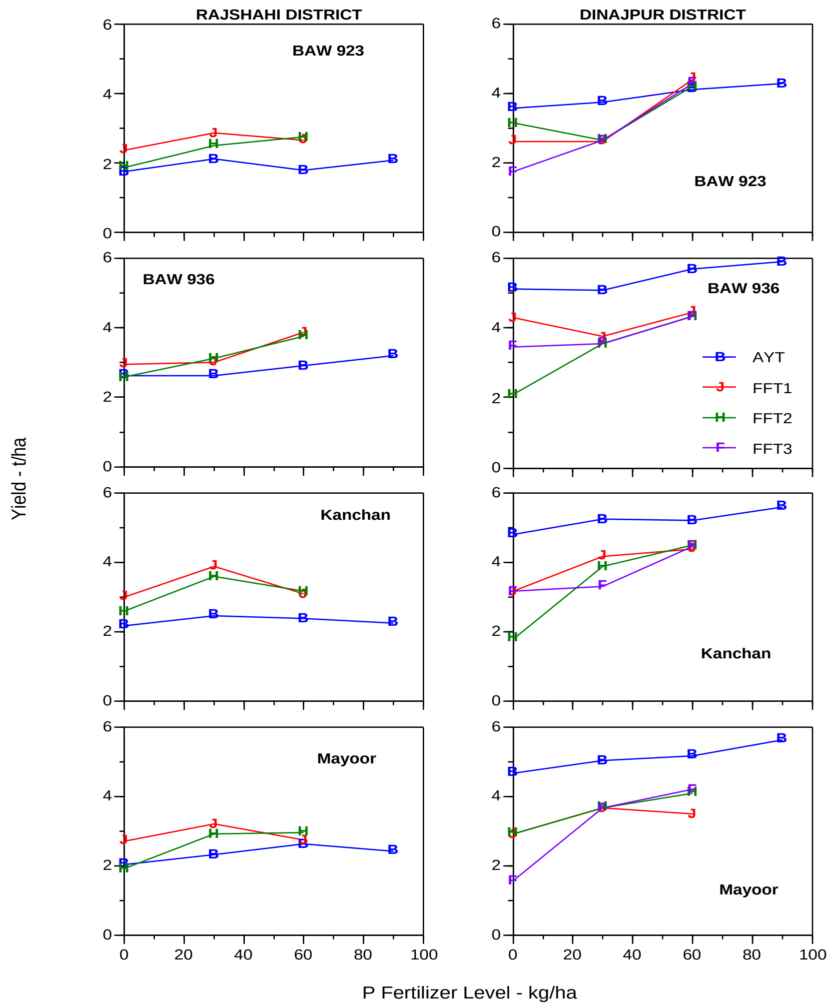


Figure 8. Farmer field trials with selected P efficient wheat lines in Dinajpur and Rajshahi districts, Bangladesh, 1999-2000.

5. Boron and Crop Sterility

A. <u>Wheat</u>

Work in previous years has confirmed that soil, environmental (fog) and genetic factors contribute to sterility in wheat. However, we believe that B deficiency is the fundamental underlying cause of sterility. Soil B supply is an obvious factor, while B transport is limited when fog reduces transpiration. Thirteen of thirty lines in the Nepal national breeding program were found to be genetically susceptible to B deficiency and the Nepal breeding program has now introduced a screening program at a B deficient site to address this factor.

(i) <u>Screening Bangladesh Wheat Lines</u>: Screening for genetic susceptibility in Bangladesh is using shading to guarantee "fog". The critical time for B deficiency is during pollen tube

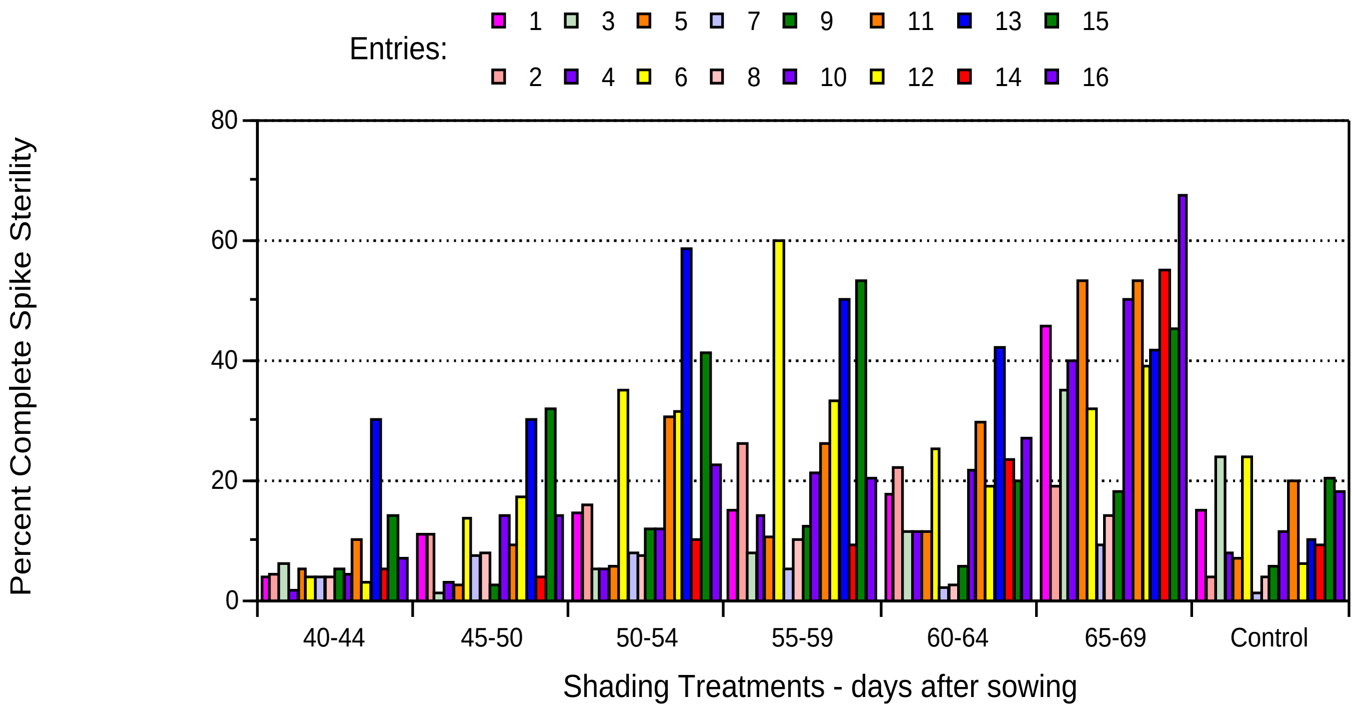


Figure 9. Effect of shading for five day periods on sterility in sixteen wheat lines, Joydepur, Bangladesh, 1999-2000.

formation and shading between 55-65 days led to the highest sterilty in the standard Kanchan variety. Sixteen wheat lines were evaluated in the 1999-2000 season. The time of shading that induced maximum sterility varied amongst varieties as a function of differences in plant development. Only three of the sixteen wheat lines, entries 7,8 and 9, exhibited good resistance to sterility, suggesting that genetic susceptibilty to B deficiency is also widespread in the Bangladesh wheat breeding program.

(ii) <u>Survey of Sterility on Farms in NW Bangladesh</u>: A third survey of wheat sterility on farms was undertaken March-April 2000 in Rangpur-Dinajpur districts (figure 10). As in the previous

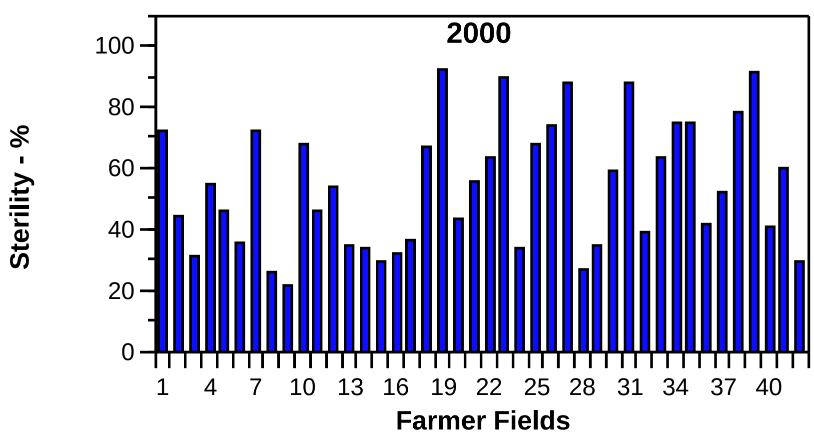


Figure 10. Incidence of sterilty in wheat on farms in Rangpur and Dinajpur districts, Bangladesh.

year, sites were geo-referenced for use with GIS at a later date. Kanchan was the dominant variety, although Gourab, Sourav and Protiva, three newly released lines, were found on a few farms. Sterility was quite high, with 62% of the 42 samples showing sterility >40%. Work is underway to compile the data from all three years and map the observed sterility in these districts.

B. <u>Chickpea</u>

Although the B status of soils in Chuadanga district is generally low, previous on-farm trials with chickpea showed little if any response to B or other micronutrients. Soil analyses showed that the trial sites had unexpectedly high levels of B, and it is likely that the farmers added manure to these sites. However, a trial in 1999-2000 showed the expected large response to B and smaller, but significant, responses to Cu, Fe and Mn (figure 11). No response to Zn or Mo was observed.

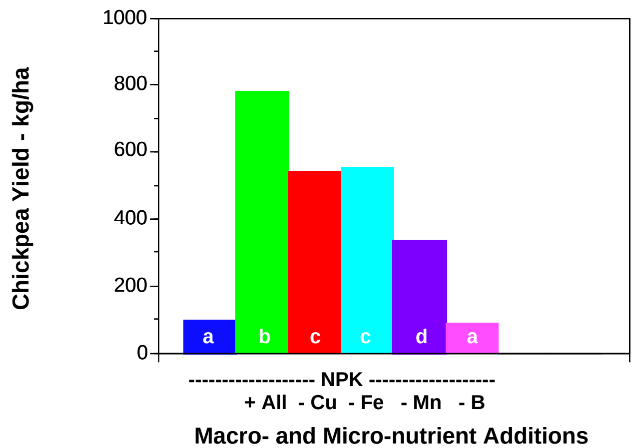


Figure 11. Response of Chickpea to micro-nutrients at Chuadanga, Bangladesh.

6. Evaluation of Micronutrient Enriched Seed of Wheat and Rice

Our hypothesis is that micronutrient enriched seed will provide yield benefits compared to micronutrient fertilizers due to greater initial supply to seedlings and by increasing seedling resistance to soil borne pathogens. Previous research has demonstrated that seed enrichment with Zn (2-3x), Mo (6-20x) , Cu (3x; rice only) and Ni (10-25x) can be achieved by foliar or soil application of micronutrients. Enriched seeds of wheat had higher seedling emergence and better early growth compared to control unenriched seed and farmer seed in a range of soils. The yield response observed when enriching BR 32 rice with micronutrients was also achieved using micronutrient enriched seed without additional micro-nutrients. Research has now shifted to broader evaluations of yield response with micronutrient enriched seeds in farmer fields and to seed enrichment of other varieties of wheat and rice. Preliminary evidence suggests that micronutrient efficiency is lacking in newer varieties of rice and wheat.

(i) <u>On-Farm trials with Micronutrient Enriched Seed of Kanchan Wheat</u>

A total of forty-seven on-farm trials with micronutrient enriched wheat seed have been carried out in three thanas over the last four years. In this year, response to enriched seed was seen on seven of the nine farms, whereas response was only observed on one of nine farms in the previous year. The marked difference in results between years suggests marginal nutrient deficiencies that may or may not be expressed depending on environmental conditions. Over all four years, a yield increase of 24% (0.69 t/ha) was seen with a frequency of one in four trials. Farmer seed performed as well as unenriched control seed generated on the research station in all but three of the forty-seven trials, indicating that farmer seed quality is not a major issue.

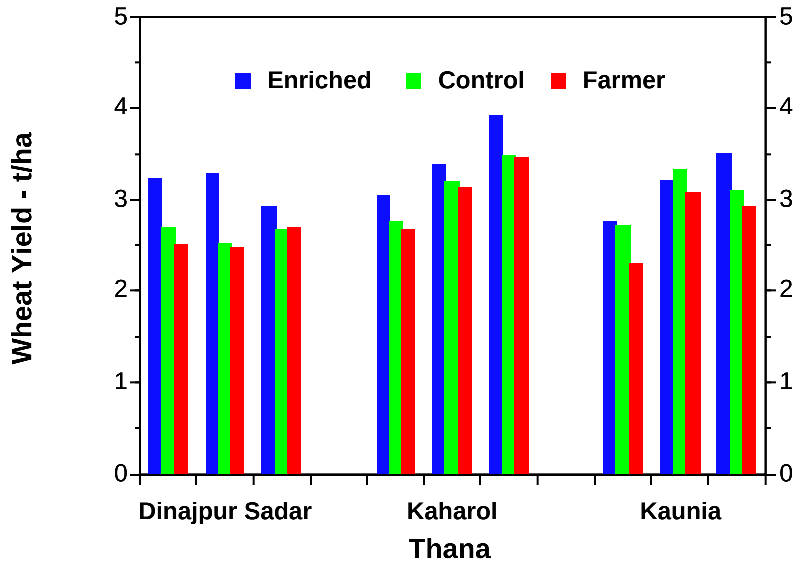


Figure 12. Effect of micronutrient enriched seed on yields of Kanchan wheat in NW Bangladesh, 1999-2000.

(ii) <u>On-Farm trials with Micronutrient Enriched Seed of BR-32 Rice</u>

Micronutrient enriched BR 32 seed gave significantly higher yields in ten of fourteen on-farm trials during the 2000 aman rice crop season (table 3). Compared to last years on-farm trials, the yield response to micronutrients whether in seed or the soil was moderate in Dinajpur and Rangpur districts. Despite good responses at farms 3, 7 and 8, the average response for the area was only 13%. In contrast, micronutrient enriched seed increased yields by an average of 21% in Chuadanaga district. Mixed results were obtained when comparing the effectiveness of micronutrient enriched seed with soil applied zinc; the latter was as effective as using micronutrient enriched seed at Dinajpur/Rangpur but not at Chuadanga. Lower rice yields in Dinajpur/Rangpur may have limited treatment effects.

Table 3. Effect of micronutrient enriched seed and soil micronutrient treatments on yield of BR 32 rice in Bangladesh.

District	Farmer	Enriched Seed	Zn in Soil	Zn + Mo in Soil	Unenriche d Seed	Response %
		------------------ Rice Yield t/ha ------------------				
Rangpur	1	2.12	2.33	2.35	2.11	0 - 11
Rangpur	2	2.92	2.83	2.79	2.88	-
Dinajpur	3	3.01	3.15	3.29	2.63	14 - 31
Dinajpur	4	3.28	3.43	3.08	2.93	5 - 17
Dinajpur	5	3.07	2.72	2.78	2.55	7 - 20
Dinajpur	6	3.53	3.36	3.83	3.25	3 - 18
Dinajpur	7	3.68	4.02	3.71	3.21	15 - 25
Dinajpur	8	3.39	2.85	3.38	2.70	6 - 25
Mean - D/R		**3.13**	**3.08**	**3.15**	**2.78**	**13**
Chuadanga	9	3.52	3.26	--	2.76	18 - 28
Chuadanga	10	3.65	2.94	--	2.65	11 - 38
Chuadanga	11	4.97	4.51	--	4.21	7 - 18
Chuadanga	12	4.36	3.88	--	3.73	4 - 17
Chuadanga	13	3.88	3.61	--	3.50	3 - 11
Chuadanga	14	4.38	4.24	--	3.64	16 - 20
Mean - C		**4.13**	**3.74**		**3.42**	**21**

Trials were also undertaken at the Wheat Research Station to enrich additional varieties of rice with micronutrients. Recently released, aman varieties BR 33, 37, 38 and 39 were grown on replicated plots with and without foliar application of micronutrients.

Overall yields (2.5 t/ha; figure 13) were substantially below expected yield potentials for these varieties (4-6 t/ha), which may have been due to mealy bug infestation throughout the area. However, significant positive yield responses were observed for BR 33 (17% over control) and BR 37 (23% over control) to foliar application of micronutrients. On the other hand, BR 38, an aromatic variety, showed a negative response to micronutrients, while BR 39 was unaffected by the sprays. These results suggest that achieving the potential yields of BR 33 and BR 37 may be difficult without proper management for the widespread soil micro-nutrient deficiencies in Bangladesh, whereas BR 38 and BR 39 are less sensitive to these soil problems.

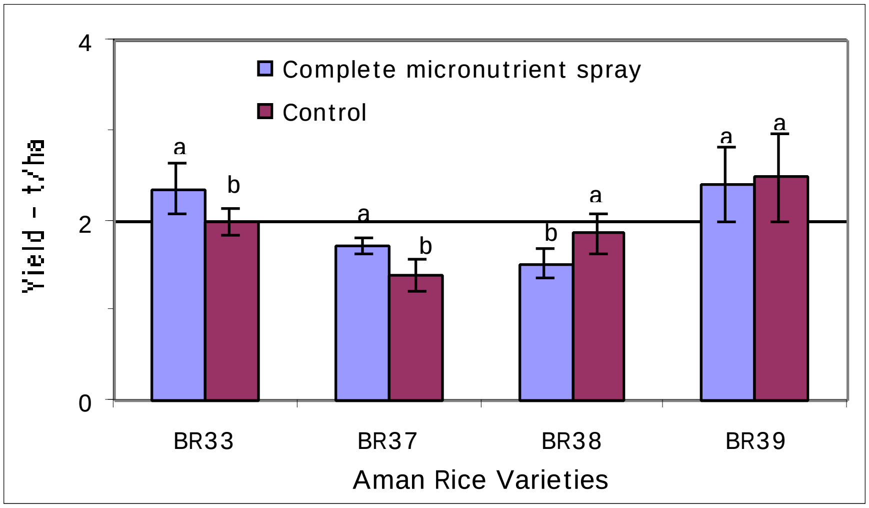


Figure 13. Effects of foliar application of micronutrients on yields of several rice varieties at the WRC, Dinajpur, Bangladesh

7. Integrated Nutrient Management

(i) Legume Green Manures

Following on previous work at Punjab Agricultural University, six on-farm trials with three legume green manure species have been initiated in two districts in Punjab, India. Data from these trials are not currently available.

(ii) Use of Straw Mulch to Improve N use Efficiency in Flooded Rice

Straw mulches are being investigated for their potential to improve N use efficiency in rice by reducing ammonia volatilization. The hypothesis being evaluated is that CO_2 generated by decompositon of the straw will counteract daytime increases in floodwater pH caused by algal utilization of CO_2. Impacts of mulch on floodwater pH were found to vary with mulch rate and mulch type, with wheat straw being more effective than rice straw. Mulch increased rice yield in some experiments but not others, and improved N use efficiency. Incorporation of straw did not have the same benefits as the mulch, presumably because of slow transport of CO_2 from soil to floodwater.

Two experiments were carried out at the BRRI research station at Joydebpur in the boro (winter) season in 1999-2000 and again in the aman season in 2000. One experiment used a range of different N and mulch rates and the second compared mulching with straw incorporation with limited N and straw rates. In the boro season, mulch increased rice yields in one experiment (site 1) with BR 29 but not in a second experiment (site 2) with BR 28 (figure 14). The reasons for the different results are not known. In the experiment with BR 29, the yield achieved with mulch was 23% (1.3 t/ha) higher than that without mulch and at half the N rate. The low mulch rate (1.5 t/ha) combined with the high N rate (120 kg/ha) was ineffective, presumably due to more rapid decomposition of the mulch. The recovery of N by the crop was increased from 15% to around 40% (figure 14). Floodwater pH was reduced in the initial 20 days or so of the experiment and mulch rates above 1.5 t/ha significantly reduced weed biomass for the first weeding.

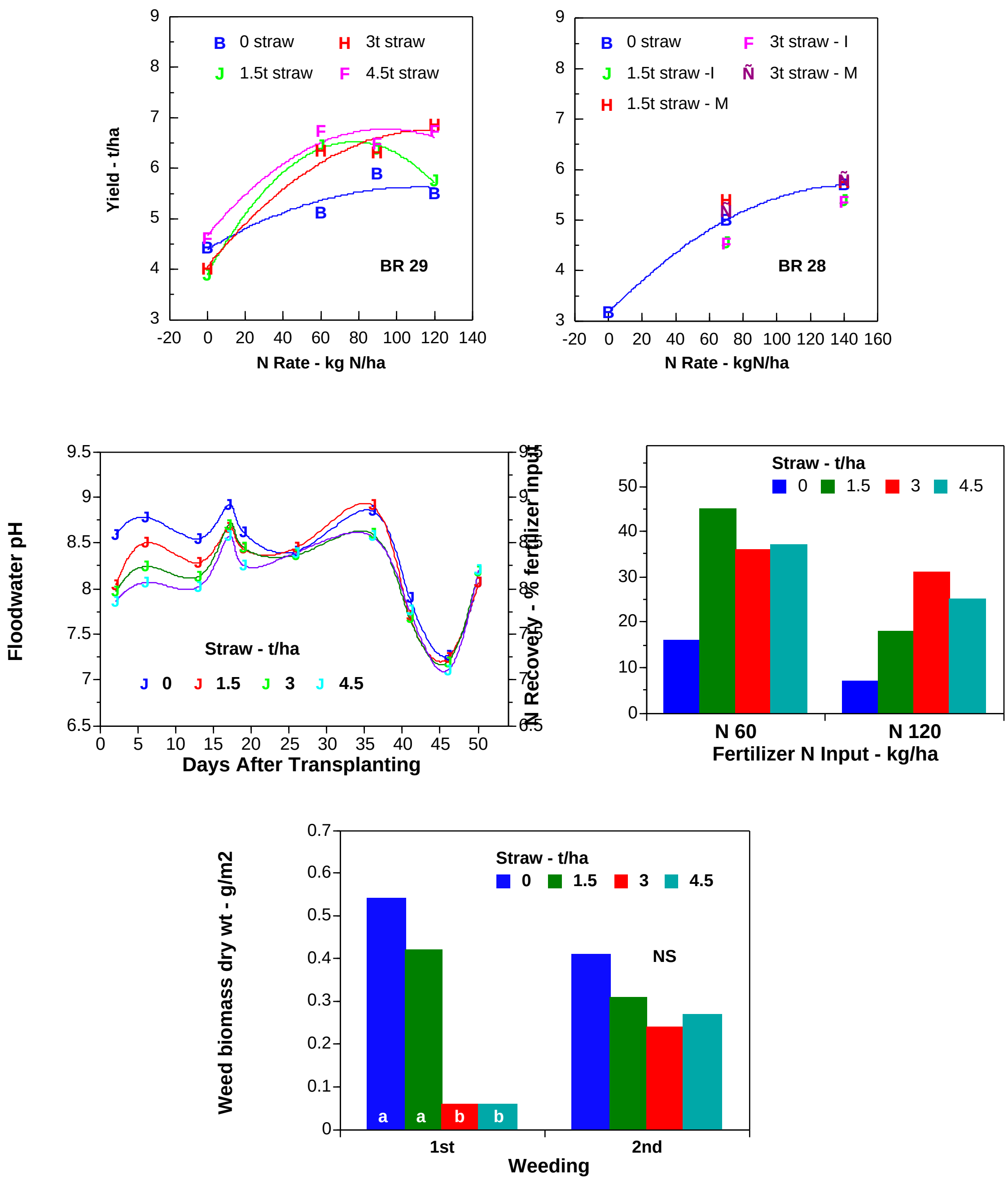


Figure 14. Effects of rice straw mulch on boro season rice yields (upper); floodwater pH and fertilizer N recovery (middle); and weeds (lower) at Joydebpur, Bangladesh.

Similar results were obtained in the aman season experiments, with grain yield responses being found at site 1 only) and with the mulch losing effectiveness at high N rates (Figures 15 and 16). Crop yield response to N was less in the aman season than in the boro season at site 1 and no response to N was observed at site 2. The effect of mulching is perhaps better evaluated on farmer sites where soil N supplying capacity is likely to be lower.

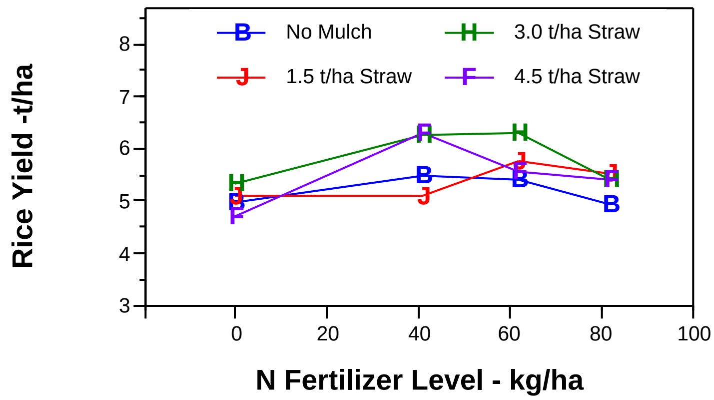


Figure 15. Effect of wheat straw mulch on rice yields at site 1 in the aman 2000 season at Joydepur, Bangladesh.

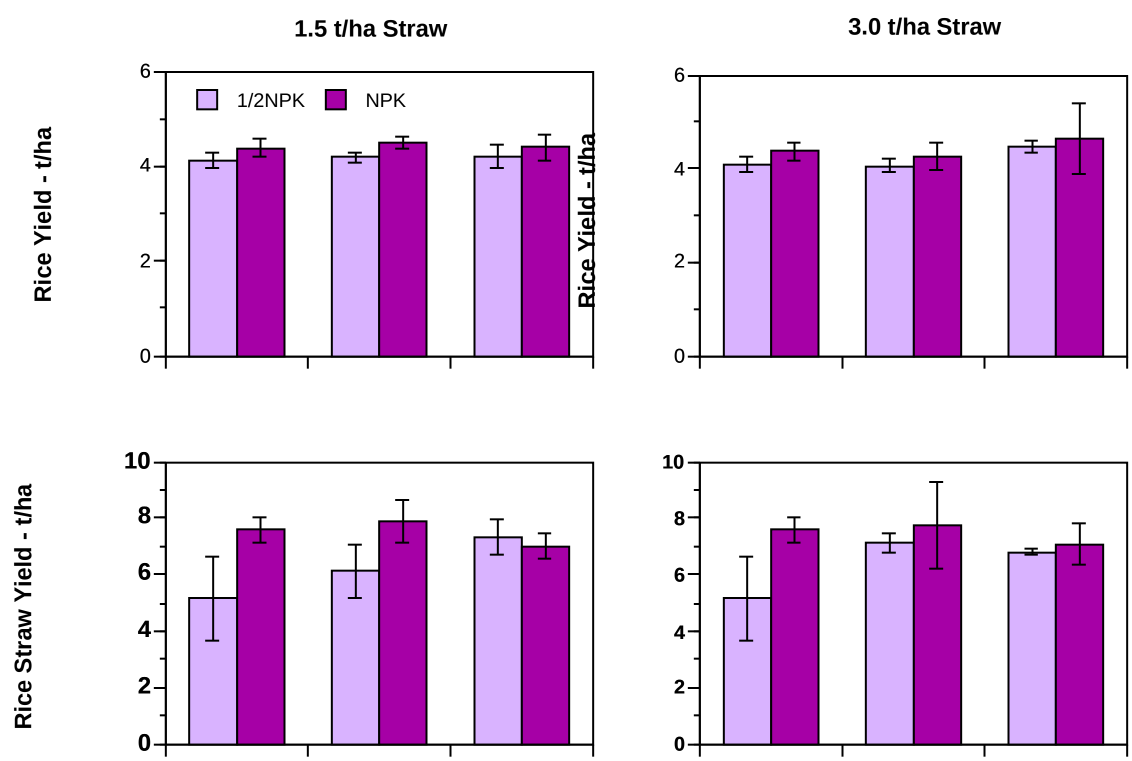


Figure 16. Effect of wheat straw management on rice grain and straw yields at site 2 in the aman 2000 season at Joydepur, Bangladesh.

A third experiment with straw mulch was carried out in the summer (aman) season at Rampur, Nepal. Flooding caused some straw movement between plots. Nevertheless, mulching at 3 t/ha gave an 18% (0.6 t/ha) yield increase at the full NPK rate. Mulching with local weeds (Cassia and Ipomea), which is practiced by some farmers did not give yield benefits.

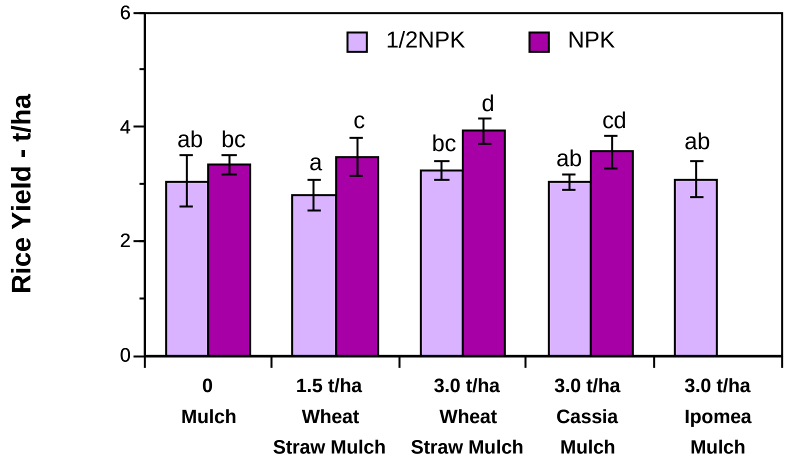


Figure 17. Effect of mulching with wheat straw and local weeds on rice yields at Rampur, Nepal, summer season , 2000

The reside management experiment at Bhairahawa, Nepal, where a yield response of rice to mulch was first observed (in 1998), did not show any significant effect of mulch in 1999 or in 2000. This experiment does not have a reduced N treatment and yields in the last two years have been higher than in the first year, which was probably the only year that N was limiting yield.

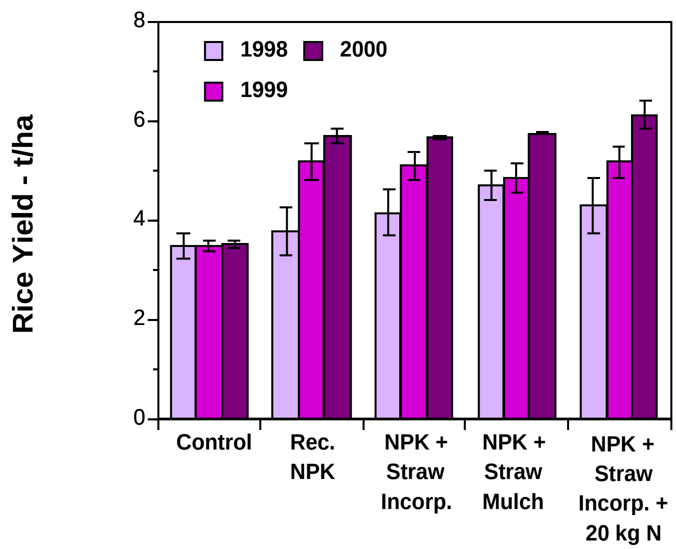


Figure 18. Effect of wheat straw management on rice yields at Bhairahawa, Nepal.

Straw management treatments were altered to include straw mulch in a tillage experiment on a light textured soil at Dinajpur, Bangladesh, where continuous flooding is not maintained. The mulch treatment replaced a straw burned treatment. The mulch resulted in a significant yield increase compared to either straw removal or incorporation. The yield increase was 19% (0.59 t/ha) compared to the straw removal treatment.

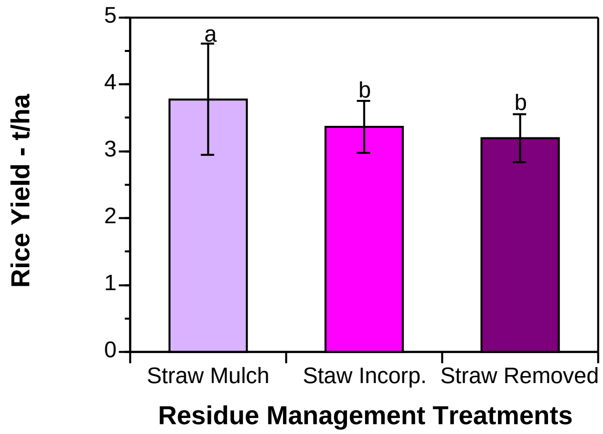


Figure 19. Effect of wheat straw management on rice yields at Dinajpur, Bangladesh, aman season 2000

The most encouraging aspect of the mulch studies is that mulch clearly has the potential to increase yields and improve N use efficiency at reduced N input levels. The greatest impact of the technology should be to increase yields obtained by resource poor farmers who often use only 60 or so kg N/ha. Using straw as a mulch competes with other uses but possibly this can be compensated for by higher straw productivity. Another disadvantage is the labor requirement for chopping and placement. Participatory on-farm trials planned for the coming project year will evaluate agronomic and socio-economic aspects of the mulch technology.

For farmers in the high yielding, mechanized parts of the IGP, mulch should reduce fertilizer cost for rice and water cost for wheat, and provides a productive use alternative to burning. When coupled with reduced tillage practices, mulching should increase soil organic matter contents and improve agricultural sustainability.

(iii) Coupling Straw Mulch with Surface Seeding of Wheat

Surface seeding of wheat on light textured soils is considered inappropriate because surface soil dryness hinders germination and seedling establishment. An experiment at Rampur, Nepal, utilized straw mulch in combination with a pre-sowing irrigation. All treatments received mulch in order to ensure good establishment. The mulch was then removed from the no-mulch treatment plots. Maintaining mulch reduced weed pressure and increased wheat yields considerably (figure 18). Timing of N application was also included in the study. The split application of N, with half at crown root initiation (CRI) and half at 40 days after sowing (DAS) gave the best result. For this N regime, mulch increased yield by 38% (1.25 t/ha) compared to the no-mulch treatment.

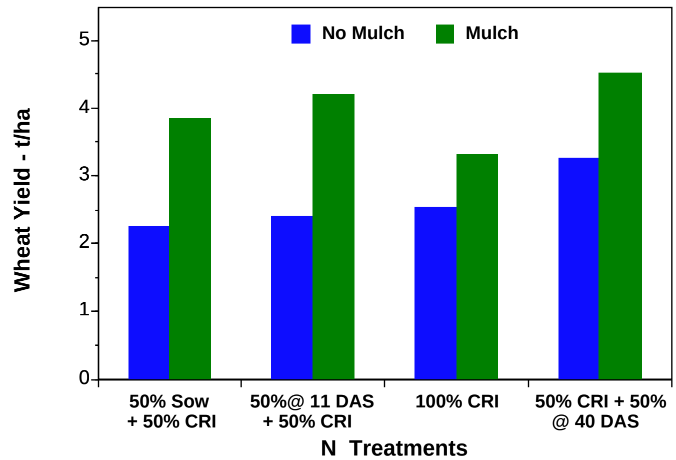


Figure 19. Effect of straw mulch and timing of N application on wheat yields at Rampur, Nepal, 1999-00.

II. Soil Acidity

Acid soils are found mainly in the eastern part of the Indo-Gangetic Plain, i.e. in West Bengal, Bangladesh, and the mid-hills region and parts of the Terai of Nepal, where cropping is intensive and monsoonal precipitation is high. The soils have low organic matter content, resulting in poor buffering capacity and low nutrient contents. Liming of soils is not practiced. in Bangladesh and is limited in the other areas. Liming experiments were initiated in Bangladesh because of concern that interactions with micronutrient availability (B, Zn, Cu, Mn will be reduced at higher pH, but Mo availability will be increased) could be important given the prevalence of micronutrient deficiency problems in the region. The intent of the experiments was to raise the pH of aerobic soil to about 6 and to include an over-liming treatment.

Experiments were carried out at the Wheat Research Center (WRC) and on farms in Birganj and Kaunia thanas. Treatments were two lime rates and a suite of nutrient combinations. Lime was added prior to the rice crop only. Lime had a significant ($p < 0.05$) impact on yields of both rice and wheat (figure 20). In 1999, rice yields were increased by 27 and 10% (1.03 and 0.58 t/ha) at research center and farm sites, respectively, with no evidence of over-liming. In 2000, lime rates were doubled and a suggestion of over-liming was seen at a new field site at the WRC. In 1999, yields of the following wheat crop were increased by 35 and 27% (0.97, 0.96 and 0.89 t/ha), at the WRC and farm sites, respectively.

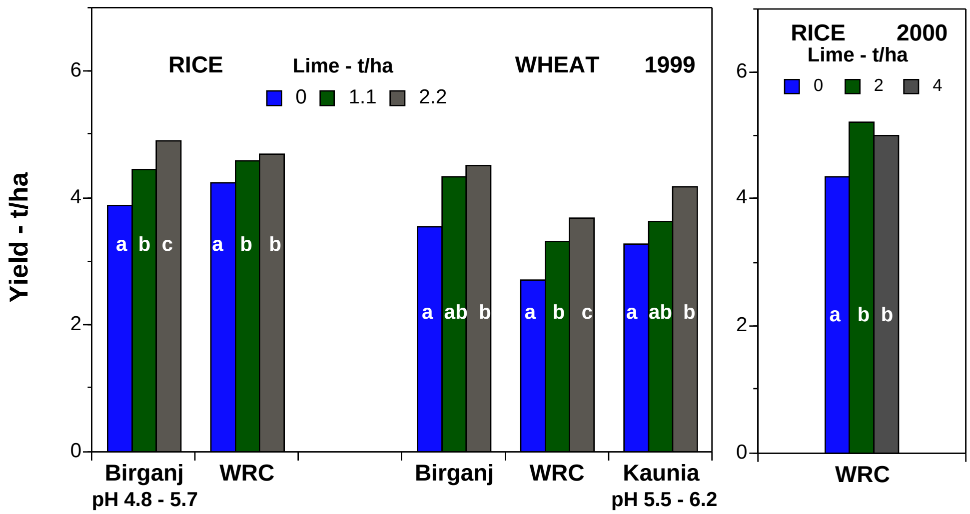


Figure 20. Effects of lime on yields of rice and wheat across nutrient treatments in NW Bangladesh, 1999 and 2000.

Effects of nutrients on yields of rice and wheat were also observed (figure 21). Responses in rice were seen with P, Mg and B depending on site and year. Responses in wheat were to Mg at the research center and to P and the combination of Zn and B at the farm sites. The response to Zn occurred at the low lime level at Kaunia and the high lime level at Birganj, while the reverse was true for B (figure 22). However, the micronutrient responses were not due to over-liming because yields always increased relative to the no lime treatment.

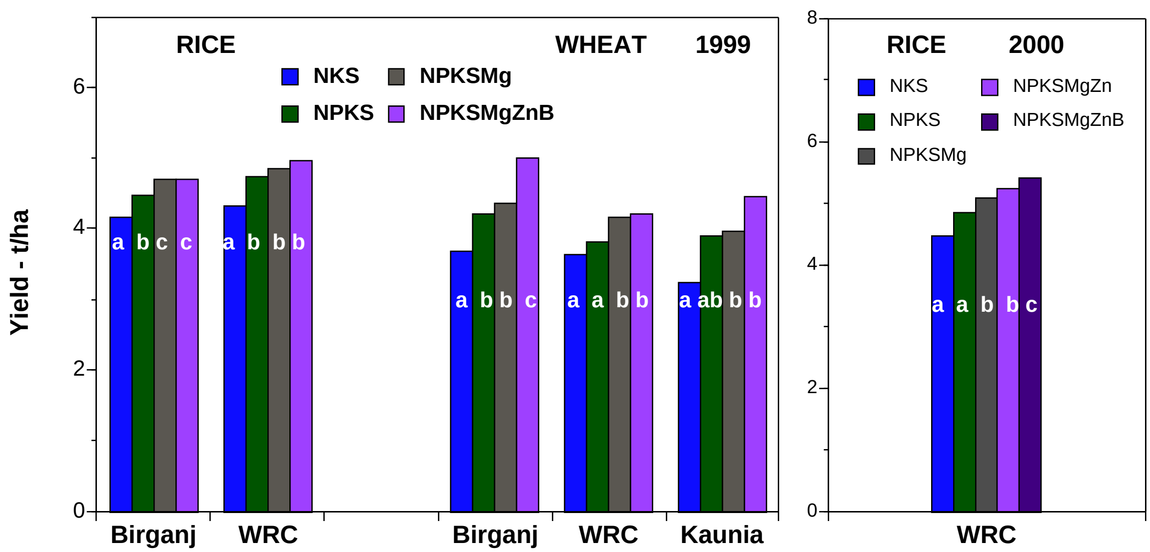


Figure 21. Effects of nutrient treatments on yields of rice and wheat across liming rates in NW Bangladesh, 1999 and 2000.

For the on-farm experiments with wheat, liming at the high rate was equivalent to adding NPKS fertilizer without lime Figure (22). It is uncertain that this result would persist as the increase in pH would be expected to initially enhance availability of P from sorbed forms and N, P and S through solubilization and mineralization of soil organic matter.

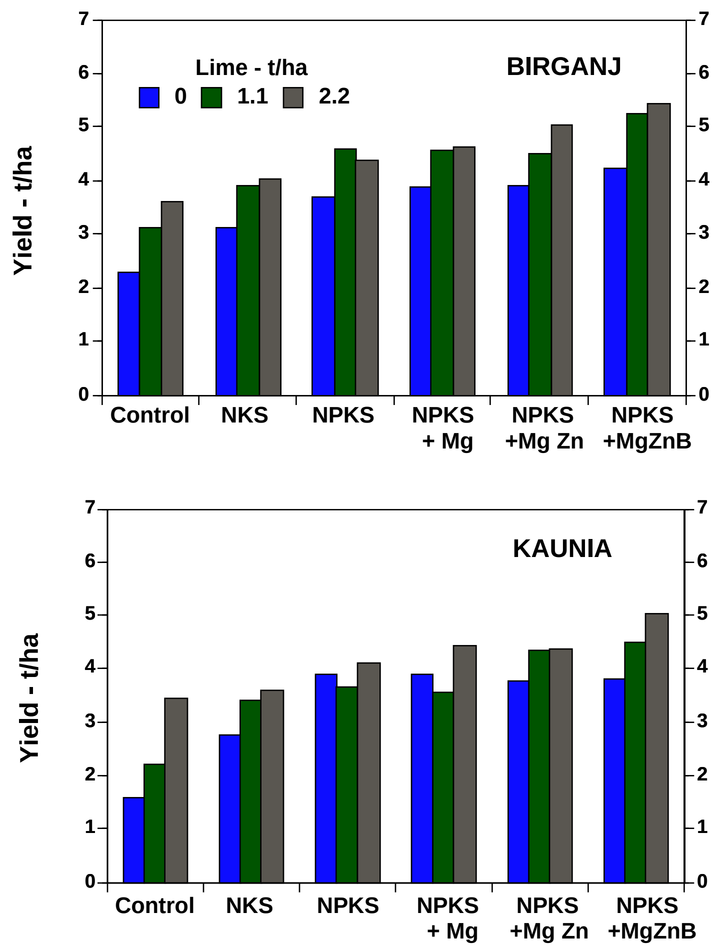


Figure 22. Effects of lime and nutrient treatments on yields of wheat on two farms in NW Bangladesh, 1999-2000.

III. Soil Degradation

A. Physical Degradation

Puddling of soils for rice production destroys soil aggregates and creates pans that can restrict root penetration. Although puddling is considered beneficial for rice, the poor soil structure that it creates interferes with the timely establishment of wheat and often leads to poor crop stands and growth. There is also interest in direct seeding of rice because of projected labor shortages for transplanting. These factors led us to implement several tillage experiments in Nepal to improve the soil environment for wheat and to include different plant establishment techniques for both rice and wheat. The experiment at Bhairahawa and one at Khumaltar that is the focus of PhD program of Andrew McDonald are the remaining experiments. We report on the Bhairahawa experiment only.

The experiment has two tillage practices prior to rice (deep and normal), two rice crop establishment techniques (puddling and transplanting, and direct seeding with rotovator/drill attachments to a Chinese tractor) and two wheat establishment techniques applied to each rice plot (surface seeding without tillage, and Chinese rotovator/seed drill). Crop yields over the duration of the experiment are summarized in Table 4 and figure 23.

Table 4. Effect of Tillage and Crop Establishment Practices on Rice and Wheat Yields

Treatment	---------------- Grain Yield (t/ha) -------------						
	Rice 1997	**Wheat 97-98**	**Rice 1998**	**Wheat 98-99[2]**	**Rice 1999**	**Wheat 99-00[2]**	**Rice 2000**
NT- TPR- CSD	5.97a[1]	2.20a[1]	4.40a[1]	2.88	4.27a[1]	1.99a[1]	5.03a[1]
NT- TPR- SS	*	4.02b	4.75a	2.38	4.40a	2.78b	4.95a
NT- DSR- CSD	5.92a	2.52a	4.89a	2.88	4.89a	2.63a	5.03a
NT- DSR- SS	*	4.33b	5.04a	3.49	4.91a	3.13b	5.30a
DT- TPR- CSD	6.28a	2.37a	4.59a	3.40	4.87a	3.14a	4.85a
DT- TPR- SS	*	4.33b	4.19a	3.17	4.94a	3.00b	4.93a
DT- DSR- CSD	5.62a	2.57a	4.89a	3.26	4.44a	2.79a	5.04a
DT- DSR- SS	*	4.44b	5.17a	3.18	4.71a	3.23b	5.11a

NT = normal tillage; DT = deep tillage; TPR = transplanted rice; DSR = direct seeded rice;
CSD = wheat planted by Chinese Seed drill; SS = surface seeding of wheat * No previous wheat tillage treatments
[1] values in columns followed by the same letter are not significantly different at $p < 0.1$
[2] see complete statistical analysis

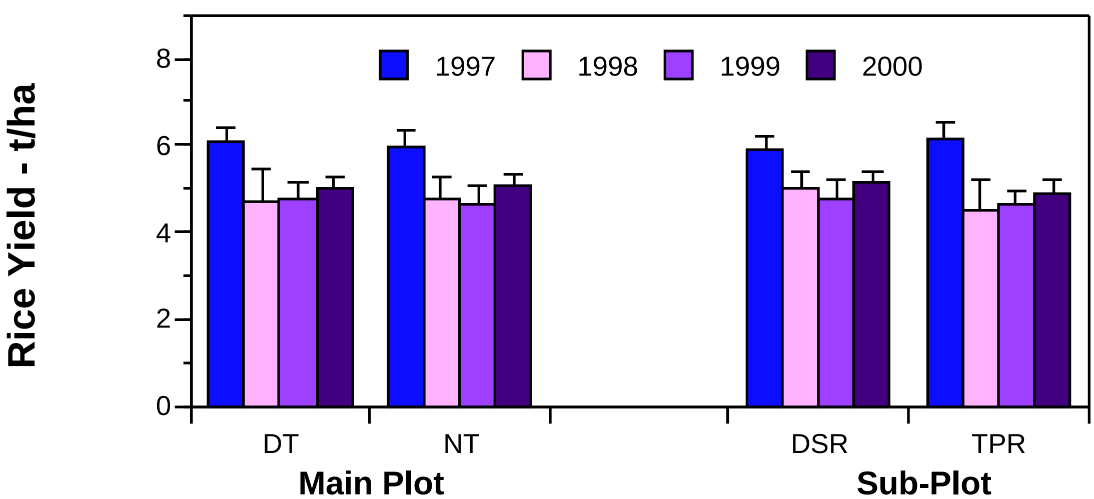


Figure 23. Effects of tillage and crop establishment practices on rice and wheat yields at Bhairahawa, Nepal.

(i) Rice: No effect of any of the tillage or planting treatments on rice yields has been seen as long as chemical weed control is practiced. However in weedy check plots, there was a small but significant impact of weeds on rice yields in the 2000 season; yields in the DSR plots were reduced by 10% due to an increased number and biomass of weeds relative to the TPR plots. Nevertheless, overall yields from the weedy checks (5.04 t/ha±0.5) were not different from the chemically controlled plots (5.03 t/ha±0.2), which suggests that weed pressure at this site is not particularly high.

(ii) Wheat: Like results from last year, deep tillage prior to rice increased yields of wheat by 16% (0.41 t/ha) over normal tillage (figure 24). Deep tillage appears to benefit wheat whether or not soil was puddled for the previous rice crop. Wheat yields were especially reduced with normal tillage and soil puddling.

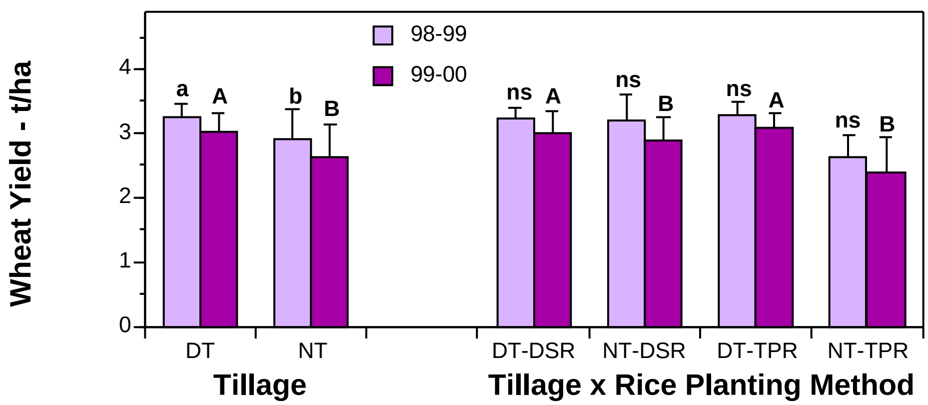


Figure 24. Effects of deep tillage and crop establishment practices on wheat yields at Bhairahawa, Nepal.

Soil conditions in the1999-2000 season were wet enough to delay wheat seeding by the Chinese seed drill relative to suface seeding. As a result, surface seeded wheat yields were 15% higher than wheat planted by the Chinese seed drill (figure 25). Surface seeding has increased wheat yields in two of the three years of the experiment. The combination of deep tillage and surface seeding provides a strong combination of practices to increase wheat yields in heavier textured soils.

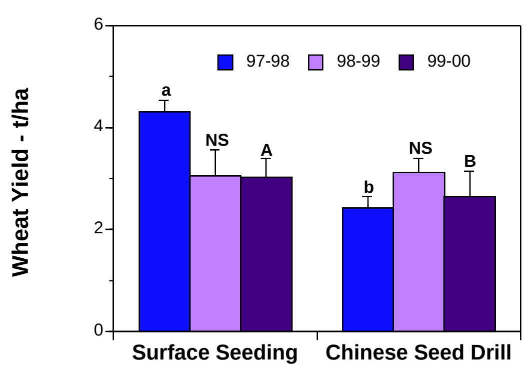


Figure 25. Effects of crop establishment practices on wheat yields at Bhairahawa, Nepal.

B. Biological Degradation

1. Mechanisms of Solarization Response

The experiment at Bhairahawa, Nepal comparing solarization with soil treatment with furadan insecticide and an untreated control as main plots, then ±seed treatment with vitavax as sub plots and ± sprays with tilt for control of foliar diseases was continued with basamid replacing furadan and looking at the residual effect of solarization. Unfortunately, the soil was not aerated sufficiently after treatment with basamid and wheat seedlings were killed. Nevertheless, the residual effect of solarization increased wheat yield from 3.3 to 4.2 t/ha. Vitavax and tilt treatments had smaller but still significant effects, increasing yield from 3.4 to 3.7 and 3.3 to 3.8 t/ha, respectively.

Survey results have shown that the root knot nematode *Meloidogyne graminicola* is the most abundant parasitic nematode in the rice wheat system. Root galls are observed in many rice nurseries, but these disappear when the seedling is transplanted into flooded soil and it is assumed not to be a problem. However, high populations of the nematode are still found in rice roots when soil is flooded, leading us to question whether this nematode has a major impact on rice yields. It is eliminated or drastically reduced by soil solarization treatments. We have initiated a program to determine the role of *Meloidogyne graminicola* in the rice wheat system. This topic is the subject of the PhD thesis research of Jon Padgham and is a major part of the research program of Ramesh Pokharel, a collaborating nematologist at IAAS, Rampur.

2. Soil Borne Pathogen Surveys

Surveys have continued during the past year. The isolation of nematodes has progressed well, however we are finding that fungal isolates from rice and wheat roots are not pathogenic. In order to address this issue and to coordinate amongst different groups working in the region, a two day workshop was held during January 2000 in Nepal involving scientists from the IGP region, CABI International, CIMMYT and Cornell.

IV. Socio-Economic Activities

Socio-economic assessments on a few technology packages were undertaken during the 1999-2000 project year;

1. <u>An economic comparison/evaluation of boro rice and wheat in North West districts of Bangladesh</u>: Farmer surveys were conducted at 250 farms in the Dinajpur Sadar, Birganj, Kaunia and Pirgachha areas of Bangladesh. Economic data were collected for both boro rice and wheat in addition to technical aspects such as tillage, turnaround time, nutrient and nutrient management for both crops. As a single crop, boro rice gives higher yields, gross returns (28,422 Taka/ha vs 19,155 Taka/ha) and margins (8,316 Taka/ha versus 7,792 Taka/ha) compared to wheat, T. aman, T. aus or jute. But at a cropping pattern level, wheat based cropping systems out-compete boro based systems by 2,246 - 3,022 Taka/ha in gross margin. This is primarily because variable costs for boro rice represent 70% of gross returns (mostly for

irrigation), whereas wheat costs are only 59% of gross returns. Also recently wheat has been receiving a higher price than rice. Despite wheat-based patterns having higher gross margins, farmers still cultivate boro because their main family food grain is rice, not wheat. Rice also has a much higher social status than wheat.

2. Effect of liming and nutrient management on Rice-Wheat productivity in acid soils: The economics of lime and nutrient treatments were estmated using data from an existing lime experiment at Birganj, Bangladesh. Treatments used for this experiment were:

L_o = no lime		T1 = no fertilizer	T4 = rec. NPKS + Mg
L_1 = 1 t lime/ha	and	T2 = rec. NKS fertilizer	T5= rec. NPKSMg + Zn
L_2= 2 t lime/ha		T3 = rec. NPKS	T6 = rec. NPKSMgZn + B

If the total cost for liming were paid in one year, then 1 t/ha lime with NKS gave the highest marginal rate of return (gross margin/marginal costs x100). If the cost of lime is split over 3 years, then one t/ha lime without any fertilizer gave the highest marginal rate of return. We believe this result may be a reflection of the higher yield response to lime at the initial stages and should be re-evaluated after another couple of years.

V. Related Activities

A. New Technologies for the Rice-Wheat System

New or emerging technologies for the rice-wheat system have been researched in the last year and to some extent in previous years. These include bed planting, the system of rice intensification (SRI) and the concept of using healthy seedlings for transplanted rice. These technologies are discussed separately as they do not fall under a single constraint to production.

1. Permanent Raised Beds

Bed planting has been developed in Mexico as a conservation tillage management tool to improve water use efficiency and reduce herbicide use in wheat. It should also increase N use efficiency as N can be placed in soil between rows rather than on the soil surface. Permanent beds in the rice-wheat system will offer the opportunity to improve soil tilth for wheat in heavier textured soils. However, it also means that rice will be grown in an unconventional manner.

Work was initiated at Ranighat, Nepal during the 1999-2000 wheat season. Various types of seed drills were used to establish wheat on beds and on the flat. Average yield on the beds was 95% (2.14 t/ha) higher that that on the flat. No significant differences were found between the various planting methods.

An experiment with rice was carried out at the BARI Research Station, Rajshahi, Bangladesh in the aman 2000 season. Beds (75 cm wide x 15 cm high x 24 m long) were established by hand in a silt soil. Five replicates of five treatments were installed: i) conventional transplanted rice (TPR) on the flat 30 days after direct seeding; ii) direct seeded

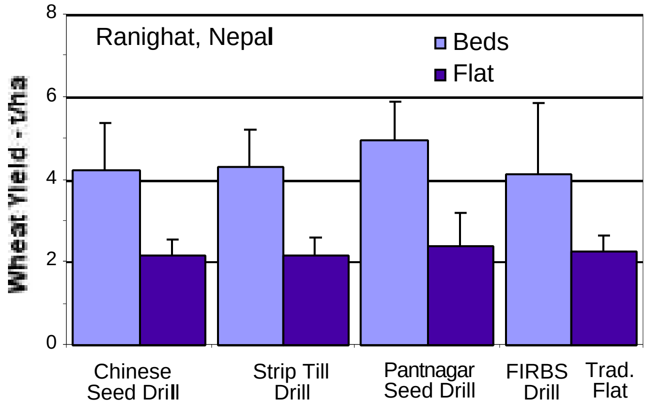


Figure 26. Effect of production on raised beds on wheat yields, Ranighat, Nepal 1999-2000.

rice (DSR)-2 rows per bed; iii) DSR-3 rows per bed; iv) TPR equally distributed across bed and furrows 30 days after DSR; and v) conventional TPR on the same day as DSR with 30 day old seedlings.

Heavy rainfall and flooding about a 1/4 of the way into the season, caused the beds to collapse due to the lack of structure in the soil. Nevertheless, rice yields from the DSR bed treatments were significantly greater than from the conventional transplanted treatments. Yields from the two and three row DSR bed treatments were 45 and 61% (1.64 and 2.21 t/ha), respectively, higher than conventional practice (figure 27). Transplanting across the bed and furrow gave similar yields to conventional practice. Tillers/m^2, panicles/m^2, plant height, straw yield and total dry matter followed the same pattern as yields. Two unexpected results were found:

- sterility (unfilled grains/panicle) was significantly lower in the DSR treatments than the TPR treatments and was correlated with yield ($r^2 = 0.59$)
- grassy weeds were significantly less in the DSR treatments than the TPR treatments, although weed pressure was not high

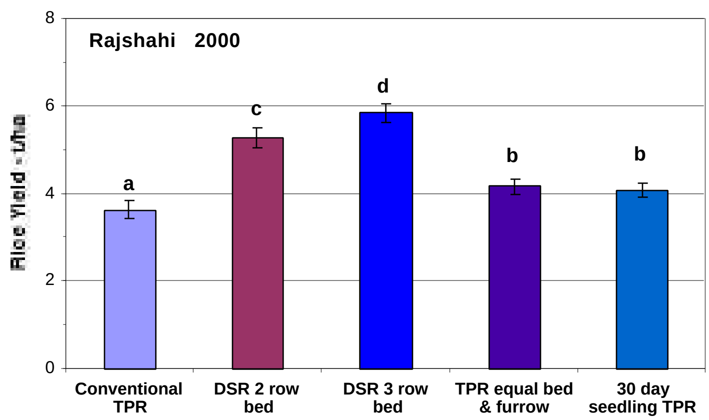


Figure 27. Effect of bed planting on yields of rice at Rajshahi, Bangladesh, aman season, 2000.

Work with beds has been expanded to a third site at the WRC, Dinajpur, Bangladesh. Trials at Ranighat, Nepal include both legumes and wheat in the current winter season.

2. The System of Rice Intensification

Developed by a French priest in Madagascar and promoted by a colleague at Cornell, the system of rice intensification (SRI) challenges many of the accepted approaches to growing lowland rice. The system uses young, single seedlings that often are planted at wider spacing than normal. Compost is used as the source of nutrients and soils are not continuously flooded, especially in the first part of the growth cycle. We have evaluated single seedling, seedling age and seedling spacing elements of the SRI method over several seasons at various sites in the mid-hills region of Nepal and at the BRRI research station at Joydebpur in Bangladesh. In our initial trial at Sipaghat in 1998, a spacing of 20x20 cm and a seedling age of 20 days gave the highest yield (figure 28, upper). A similar result with spacing was found at Joydebpur in 2000 (figure 28, upper). More comprehensive experiments were carried out on two farms in the Kathmandu valley and at the NARC Khumaltar research center in 1999 and 2000.

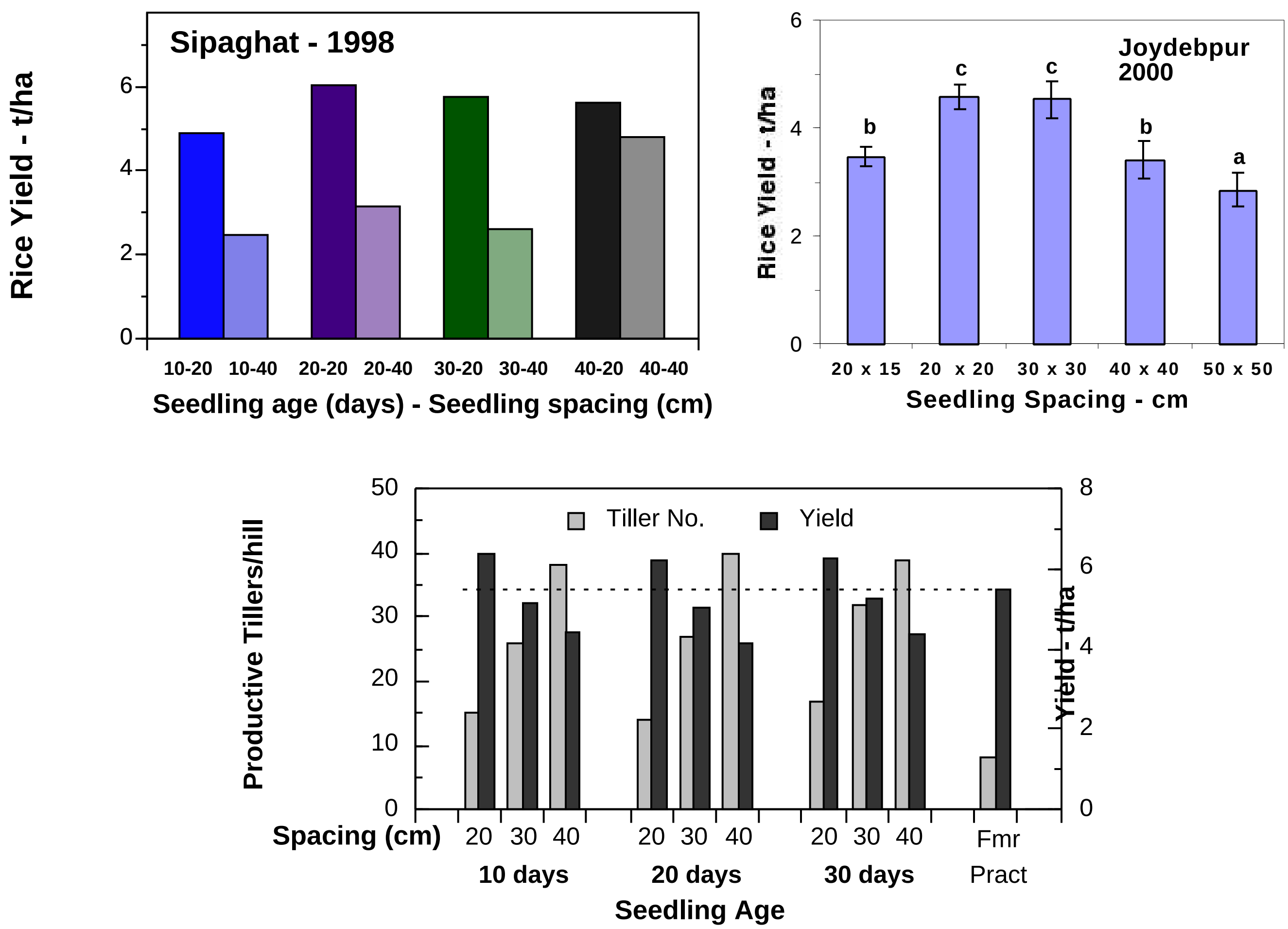


Figure 28. Rice yields with SRI practices at Sipaghat, Nepal and Joydebpur, Bangladesh (upper) and at the NARC research station, Khumaltar, Nepal (lower).

Representative data from 1999 is shown in the lower graph in figure 28. No effect of seedling age on crop yield was observed, but yields increased as spacing was narrowed to 20x20 cm. The number of tillers increased with spacing but interception of solar radiation decreased at wider spacings. The best SRI yields averaged 16% and 12% higher than farmer practice for Khumal 4 and Taichung 176 varieties, respectively. Single seedling plants resisted lodging better than with farmer practice, being slightly shorter and stronger. This observation is important as lodging prevents crop yield potential from being achieved for many rice varieties grown in the eastern IGP. Most farmers will not grow dwarf varieties because straw is a valued commodity.

3. Healthy Rice Seedlings

Our previous research has shown that substantial increases in rice yields can be achieved with solarization of soil. However, this practice is not feasible for large land areas. One practical application could be for rice nurseries. We have commonly observed that rice transplants have galling and discoloration of roots and appear to be of poor quality.

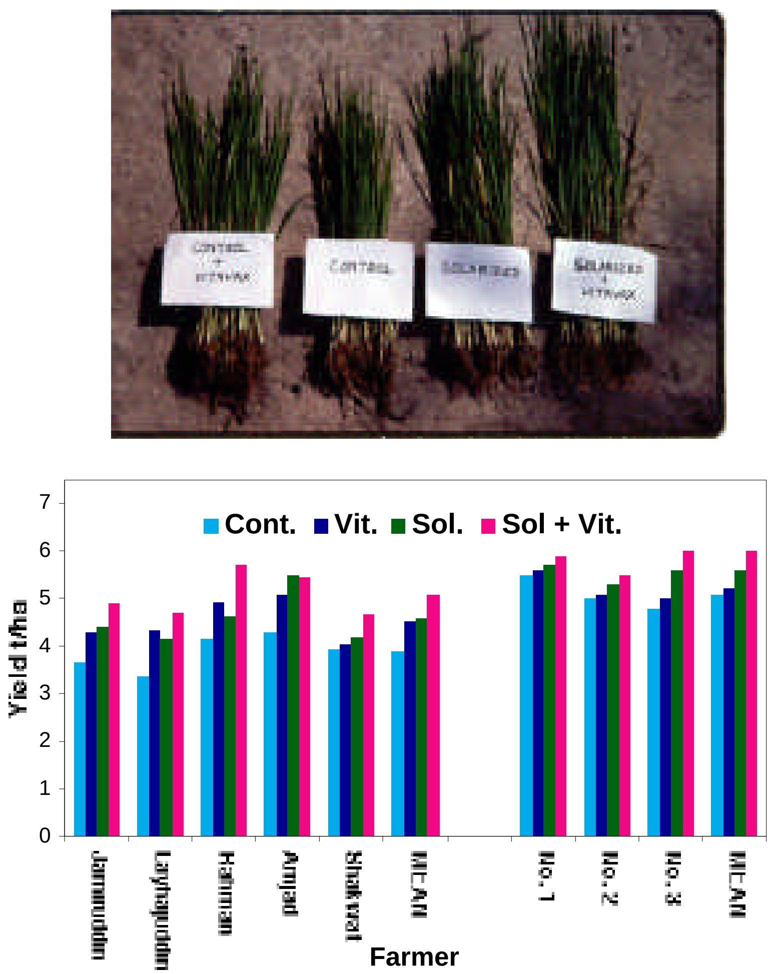


Figure 29. Effects of soil solarization and vitavax seed treatment on growth of rice seedlings (upper) and subsequent rice yields (lower) at two locations in Bangladesh.

Research was initiated to establish the benefit of producing "healthy seedlings". Three options were investigated; solarization of nursery soil, seed treatment with vitavax fungicide and the combination of soil solarization and vitavax. Both soil solarization and vitavax increased seedling height, but the tallest seedlings were with the combination of the two treatments (figure 29, upper). Similar results were obtained with yield, with the combination treatment increasing yields 30% at two different locations in Bangladesh (figure 29 lower). Overall, soil solarization was more effective than vitavax but effects varied by individual site.

B. Improving Grain Legume Productivity

Improving grain legume productivity would yield economic and health benefits to farm families. Unfortunately, the green revolution has by-passed grain legumes and production has essentially been stagnant since the 1960's. There are many bio-physical and some infrastructure constraints to grain legume production, including:

- high disease pressure at seedling stage and later in the growth cycle
- many pests
- micronutrient deficient soils that may cause sterility and constrain N fixation
- poor availability of improved varieties

In the past year we developed a program focussed on lentil and chickpea in the Chitwan Valley in the Terai of Nepal. This region was selected because it is a traditional region for these crops and the soils have many chemical and biological constraints to productivity.

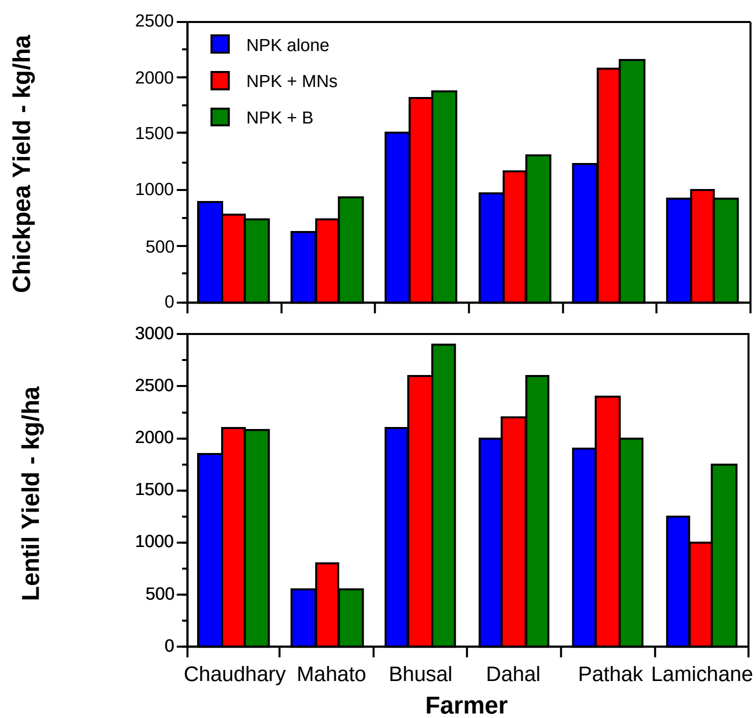


Figure 30. Response of lentil and chickpea to micronutrient treatments on farms in the Chitwan Valley, Nepal, 1999-2000.

A trial, designed to evaluate response to micronutrients and crop rotation, was established on twelve farms. Seedling mortality was extremely high on six of the twelve farms and little or no yield was realized. Crop growth was better on the other six farms, and responses to a complete suite of soil applied micronutrients and to boron by itself were found (figure 30). Yield response with chickpea was exclusively to B (seen on 4 of 6 farms), whereas other micronutrients appeared to play a role in lentil productiviy on two of the six farms.

To address the seedling mortality issue, a series of seed treatments were evaluated in a pot experiment with soils from two of the sites where seedling mortality was high. The seed treatments included chemical fungicides (vitavax and bavistin), three bio-control fungi (*Trichoderma harzianum, Trichoderma viride* and *Gliocladium virens*), and combinations of each bio-control fungus with half the rate of vitavax. All treatments had a substantial effect on seedling emergence and seedling survival over the 30 day experiment (figure 31). These treatments are being evaluated in field experiments on two farms with high disease pressure in the current season. A modified set of treatments is also being evaluated on 17 farms in collaboration with the NGO Local Initiatives for Biodiversity, Research and Development (LI-BIRD).

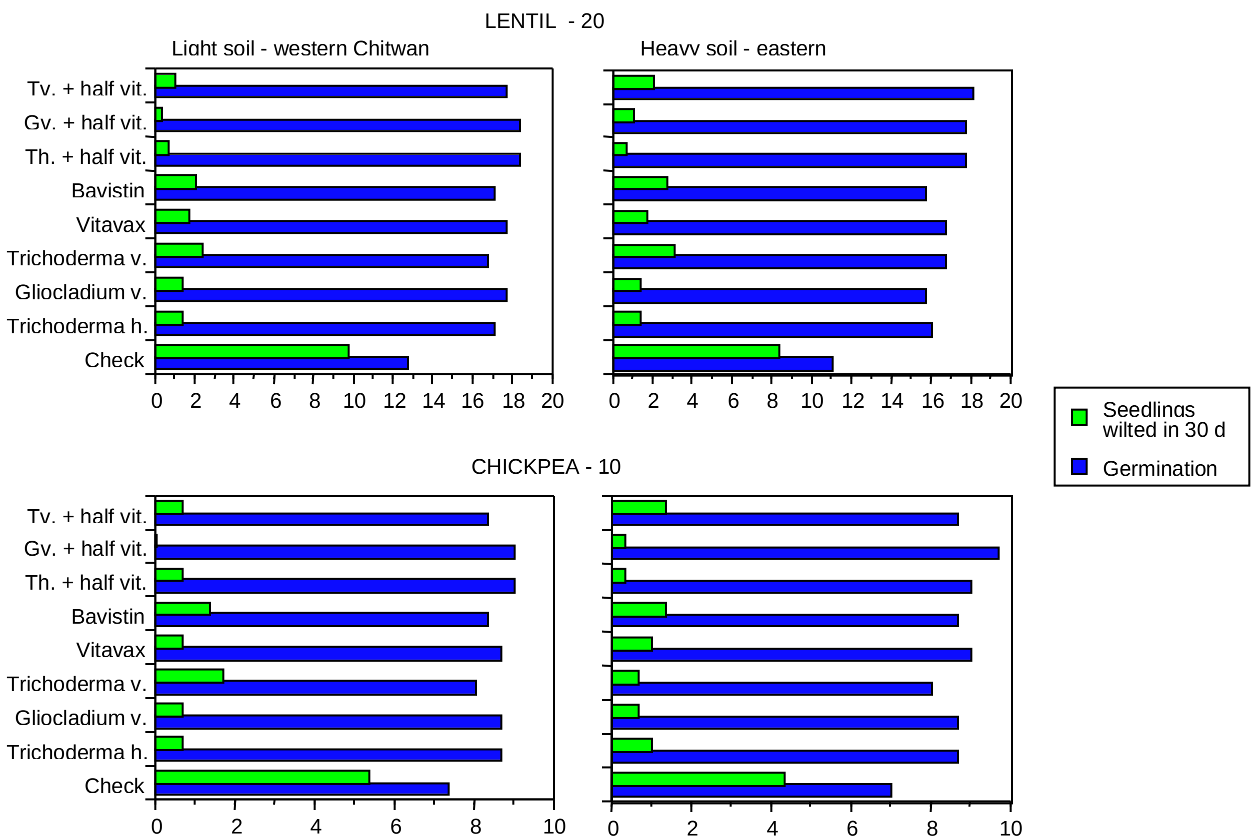


Figure 31. Effects of seed treatments on emergence and seedling survival in a pot study at Rampur, Nepal.

C. Transfer of Surface Seeding Technology

During the 1998-99 wheat season, relay and surface seeding of wheat was demonstrated on a total of 1.5 ha of land in villages of five VDCs (Village Development Committees) in Dhanusha and Parsa districts. In the 1999-2000 wheat season, 125 ha of land that would otherwise be fallow was planted by more than one hundred and fifty farmers in Raghunathpur VDC. To enhance technology adoption and to compare results between farmer seed and seed from the research station, a hundred farmers were given seed to plant 1000 m^2. Three 1 m^2, randomly selected micro-plots were harvested from fields of seventeen farmers to determine crop yields (Table 5). Mean yields with station and farmer seed were 2.03 and 1.34 t/ha, respectively, indicating that seed quality may be a factor.

Table 5. Farmer surface seeding trials in Raghunathpur VDC, Nepal 1999-2000.

Farmer	Farmer Seed		Research Station Seed	
	Variety	Yield t/ha	Variety	Yield t/ha
S.K. Tripathi	Unknown	1.39	Rohini	3.10
B. Gami	-		NL 297 Bhrikuti	1.71 1.37
S. Roniyar	Unknown	1.03	-	
B. Mahato	UP 262	1.13	Bhrikuti	1.55
M. Yadav	UP 262	1.55	Bhrikuti	1.71
S. Shrestha	Unknown	1.72	Bhrikuti	2.90
U. Katuwal	Unknown	0.51	NL 297	2.40
I. Miya	Unknown	2.06	Bhrikuti	4.08
B. Gami	Unknown	0.68	Bhrikuti	1.45
D. Raut	-		NL 297	1.51
T. Karki	-		Bhrikuti	1.03
B. Nayak	Unknown	1.21	-	
R. L. Purbe	-		Rohini	1.53
S.L. Dal	Unknown	1.72		
V. K. Sah	Unknown	2.41		
A.B. K-C	Unknown	0.57		
R.Ka;war	Unknown	1.50		
Mean		**1.34**		**2.03**

D. Environmental and Varietal Influences on the Nutritional Quality of Rice and Wheat: Nutritional Consequences for Children in Bangladesh

This study is the PhD thesis research of Anne-Marie Mayer. The research focused on the following research questions:

- What are the characteristics of the different varieties of rice and wheat?

- Who grows and consumes which varieties of rice and wheat? Why?
- How do the nutritional qualities of rice and wheat vary with soil parameters, agricultural practice and choice of variety?
- How is overall nutrient intake related to nutritional quality of rice?
- How is nutritional outcome related to nutritional quality of rice and the whole diet?
- What are the differences in rice variety, diet and health between different villages practising different types of agriculture?

Four villages were selected in different parts of Bangladesh that varied in terms of cropping systems, rice varieties grown and predominant soil type. In each village a sample of 40 households were selected with at least one child aged between 2 to 10 years. During the pre-harvest season a survey was carried out in these households. The survey included the following components:

- Dietary assessment by 24 hour recalls, food frequency and infant feeding practice,
- Nutritional assessments: anthropometry, hemoglobin by finger prick blood sample, urine iodine analysis, hair samples for zinc and other minerals,
- Children's health assessment and household infant and childhood mortality, stool samples for determining intestinal infections,
- Socio- economic status measures including land ownership, education, rice self sufficiency, food expenditure and occupation,
- Agricultural practice including rice and wheat varieties chosen and grown,
- Samples of unpolished and polished rice from households, and
- Samples of salt for iodine analysis.

Samples of rice, wheat and soil were collected at harvest time from survey villages and surrounding areas. In order to measure the effect of processing on nutritional content of rice, samples before and after parboiling and milling were also collected. Chemical analyses of rice, wheat, soil, salt and hair will be carried out at Cornell University. Urine and stool analyses have been completed in Bangladesh; urine samples have also been stored frozen in Dhaka for possible future arsenic analysis. Data input from survey data was completed in Bangladesh and further data cleaning will take place at Cornell. The data will be analyzed and the thesis written over the next 10 months. Dr Tarun Biswas carried out the children's health assessments and will analyze these data.

E. Human Resources Development

The following training/NARS enhancement opportunities were supported by the SM-CRSP during Project Year 4:

- M.A. Saifuzzaman (BARI) traveled to Nepal in April 2000 to present a seminar to NARC scientists on wheat sterility research in Bangladesh and to visit wheat sterility experimental sites in Nepal.
- Dr. D.N.S. Paul and Z.U. Ahmed (BRRI) were invited participants at the Fifth GISDECO seminar held at the International Rice Research Institute in the Philippines, 2-3 November 2000.

- S.P. Banu (BARI), A.Shaheed (BARI), M.A.Al-Amin (BARI), Dr. M.A. Nahar (BRRI), M.A. Begum (BRRI), R.R.Pokhrel (IAAS), Dr. S.M.Shrestha (IAAS), S.Sharma (NARC) and D.B. Gharti (NARC) attended a working group meeting in Kathmandu, Nepal 16-18 January 2001. The objective of the meeting was to asess progress made to date on soil health studies conducted in Nepal and in Bangladesh with Cornell support and to develop linkages/synergies with existing DFID sponsored soil health projects in India and Pakistan.

F. Publications

Devare, M.H. 2000. Effect of tillage, rice establishment and solarization on crop parameters in the rice-wheat system of Nepal. Ph.D. Dissertation. Cornell Univ. Ithaca, NY. 170 pp.

Duxbury, J.M. 2000. Addressing nutrient deficiencies and efficiencies in the rice-wheat cropping system. FAO/IAEA Consultants' Meeting on Integrated Soil, Water and Nutrient Management for Sustainable Rice-Wheat Cropping Systems in Asia, 23-25 August 2000. Rome, Italy.

Duxbury, J.M. 2000. Long-term yield trends in the rice-wheat cropping system: Results from experiments and northwest India. *In* P.K. Kataki (ed.) The Rice-Wheat Cropping System of South Asia: Trends, Constraints, Productivity & Policy Issues. J. Crop Production. 13. No.2 In press.

Kataki, P.K., P.Hobbs, and B. Adhikari. 2000. The rice-wheat cropping system of South Asia: Trends, constraints and productivity - A prologue. *In* P.K. Kataki (ed.) The Rice-Wheat Cropping System of South Asia: Trends, Constraints, Productivity & Policy Issues. J. Crop Production. 13. No.2 In press.

Kataki, P.K., S.P. Srivastava, M. Saifuzzaman,, and H.K. Upreti. 2001. Sterility in wheat and response of field crops to applied boron in the Indo-Gangetic Plains *In* P.K. Kataki (ed.) The Rice-Wheat Cropping System of South Asia: Efficient production management. 13. No.2 In press.

Lauren, J.G., R.Shrestha, M.A. Sattar, and R.L. Yadav. 2001. Legumes and diversification of the rice-wheat cropping system. *In* P.K. Kataki (ed.) The Rice-Wheat Cropping System of South Asia: Efficient production management J. Crop Production. 13. No.2 In press.

Paul, D.N.S., Z.U. Ahmed, M.S. Kabir, G.M. Panaullah, J. Lauren, and J.M. Duxbury. 2001. A GIS assessment of the scope for increasing the productivity of rice-wheat systems in Bangladesh. Proceeding of the Fifth GISDECO Seminar. 2-3 November 2000. Int. Rice Res. Instit. Los Banos, Philippines. In press.

VI. Collaborators

A. Country

Country	Name	Discipline	Institution
Bangladesh	Razzaque, Dr. M.A.	Agronomy-DG	BARI
	Chaudhury, Dr. N.H.	National Rice-Wheat Coordinator	BRRI
	Ahmed, Z.U.	Soil Chemistry	BRRI
	Begum, Ms. M.A.	Plant Pathology	BRRI

Country	Name	Discipline	Institution
Bangladesh	Baksh, M.E.	Agric. Economics	BARI
	Bodruzzaman, M.	Soil Chemistry	BARI
	E-Elahi, Dr. N.	Agronomy-Farming Systems	BRRI
	Hassan, Dr. N.	Human Nutrition	Dhaka Univ.
	Hossain, M.I.	Agronomy	BARI
	Kamal, Dr. (Mrs.) N.Q.	Entomology	BRRI
	Mannan, M.A.	Entomology	BARI
	Mustafi, Dr. B.A.A.	Agric. Economics	BRRI
	Nahar, Dr. (Mrs.) N.	Plant Pathology	BRRI
	Panaullah, Dr. G.M.	Soil Fertility	BRRI
	Parvin, Banu, Mrs. S.	Plant Pathology	BARI
	Paul, Dr. D.N.S.	Statistics	BRRI
	Rahman, M.A.	Soil Fertility	BARI
	Salam, Dr. M.A.	Plant Breeding	BRRI
	Samad, Dr. M.A.	Plant Breeding	BARI
	Saifuzzaman, M.	Plant Physiology	BARI
	Shaheed, M.A.	Plant Pathology	BARI
	Talukdhar, A.M.H.S.	Agronomy	BARI
India	Gupta, Dr. R.K.	Soil Science, Facilitator Rice-Wheat Consortium	RWC-CIMMYT
	Yadav, Dr. R.L.	National Rice-Wheat Coordinator	ICAR
	Arora, Dr.C.L.	Soil Chemistry	PAU
	Chaudhury, Dr. M.H.	Soil Physics	PAU
	Gajri, Dr. P.R.	Soil Physics	PAU
	Jead, Dr. (Mrs.) N.	Plant Pathology	PAU
	Pannu, Dr. P.P.S.	Plant Pathology	PAU
	Singh, Dr. Bijay	Soil Chemistry	PAU
	Singh, Dr. Y.	Agronomy	G.B. Pant Univ.
	Singh, Dr. Yadvinder	Soil Chemistry	PAU
Nepal	Joshi, D.	Soil Science-Executive Director	NARC
	Pathick, D.S.	National Rice-Wheat Coordinator	NARC
	Adhikari, C.	Agronomy	NARC
	Basnet, Dr. K.B.	Agronomy	IAAS
	Bhandari, D.	Plant Pathology	NARC
	Dahal, K.R.	Agronomy	IAAS
	Gami, S.K.	Soil Science	NARC
	Gharti, D.B.	Plant Pathology	NARC
	Giri, G.S.	Agronomy	NARC
	Maskey, Dr. (Mrs.) S.M.	Soil Science	NARC

Country	Name	Discipline	Institution
Nepal	Pandey, S.P.	Soil Science/GIS	NARC
	Pokharel, R.R.	Plant Pathology	IAAS
	Ranjit, Mrs. J.D.	Weed Science	NARC
	Sah, Dr.S.C.	Soil Science	IAAS
	Sharma, (Mrs.) S.	Plant Pathology	NARC
	Shrestha, Dr. R.K.	Soil Science	NARC
	Shrestha, Dr.S.M.	Plant Pathology	IAAS
	Shrestha, Ms. R.	Legume Agronomy	NARC
	Subedi, Dr. A.	Social Sciences	LI-BIRD
	Tripathi, J.	Agronomy	NARC
	Upreti, H.K.	Agronomy	NARC
	Yadav, Dr. D.N.	Agronomy	IAAS

B. Collaborating U.S. Institutions

Name	Department/Discipline	Institution
Abawi, Dr.G.	Plant Pathology	Cornell Univ.
Bellinder, Dr. R.	Fruit & Vegetable Science	Cornell Univ.
Bergstrom, Dr.G.	Plant Pathology	Cornell Univ.
Baveye, Dr.P.	Crop & Soil Science	Cornell Univ.
Combs, Dr. G.	Nutritional Science	Cornell Univ.
Duxbury, Dr. J.	Crop & Soil Science	Cornell Univ.
DeGloria, Dr.S.	Crop & Soil Science	Cornell Univ.
Feldman, Dr.S.	Rural Sociology	Cornell Univ.
Kyle, Dr.S.	Agric. Economics	Cornell Univ.
Lauren, Dr.J.	Crop & Soil Science	Cornell Univ.
Latham, Dr.M.	Nutritional Science	Cornell Univ.
Lee, Dr. D.	Agric. Economics	Cornell Univ.
Obendorf, Dr.R.	Crop & Soil Science	Cornell Univ.
Riha, Dr. S.	Crop & Soil Science	Cornell Univ.
Uphoff, Dr. N.	CIIFAD	Cornell Univ.
Welch, Dr.R.	Plant Physiology	US Plant, Soil & Nut. Lab
Kataki, P.	Seed Physiology	Cornell-Nepal Site Coordinator
Meisner, Dr. C.	Agronomy	CIMMYT-Cornell Bangladesh Site Coordinator

C. Other Collaborating Institutions

Name	Discipline	Institution
Bridge, Dr. J.	Plant Pathology	CABI Bioscience, U.K.
Duveiller, Dr.E.	Plant Pathology	CIMMYT-Nepal
Hobbs, Dr.P.	Agronomy	CIMMYT-Nepal

C. Other Collaborating Institutions (cont'd)

Name	Discipline	Institution
Gaunt, Dr.J.	Soil Chemistry	Rothamsted Exp. Station, U.K.; DFID Project Director
Fuchs, Dr.G.	Physician	ICDDRB
Halderness, Dr.M.	Plant Pathology	CABI Bioscience, U.K.
Johansen, C.	Legume Agronomy	Consultant
Ladha, Dr.J.K.	Soil Microbiology	IRRI
Ortiz-Ferrera, Dr.M.	Plant Breeding	CIMMYT-Nepal
White, Dr.J.	GIS/Modeling	CIMMYT-Mexico

D. Graduate Students

Name	Country of Residence	Discipline	Degree	Status
Cornell University				
Kaafee Billah	Bangladesh	Agric. Economics	Ph.D.	Dissertation preparation; research in Bangladesh
Tarun Biswas	India	Human Nutrition	Ph.D.	Coursework; Research to be in Bangladesh
Sarah Johnson	United States	Soil Chemistry	Ph.D.	Coursework; research to be in Nepal
Anne Marie Mayer	England	Human Nutrition	Ph.D.	Data analysis; research in Bangladesh
Andy McDonald	United States	Soil Physics	Ph.D.	Coursework; research in Nepal
Jon Padgham	United States	Soil Fertility/Pathology	Ph.D.	Research in Bangladesh
IAAS, Rampur, Nepal				
Deepak Bhandari	Nepal	Plant Pathology	M.S.	Research/thesis preparation
Deepak Sharma	Nepal	Plant Pathology	M.S.	Research/thesis preparation
Bishnu Adhikari	Nepal	Agronomy	M.S.	Research/thesis preparation
Narayan Khanal	Nepal	Plant Pathology	M.S.	Coursework/research
Dinesh Adhikari	Nepal	Soil Science	M.S.	Coursework/research
Krishna P. Devkota	Nepal	Agronomy	M.S.	Coursework/research
Dil Raj Yadav	Nepal	Agronomy	M.S.	Coursework/research

VII. Acronym Definitions

BRRI	Bangladesh Rice Research Institute
BARI	Bangladesh Agricultural Research Institute
CIMMYT	International Center for Maize and Wheat
IAAS	Institute for Agriculture and Animal Science
ICAR	Indian Council of Agrictual Research
ICDDRB	Int. Center for Diarrheal Disease Research, Bangladesh
IGP	Indo-Gangetic Plains
IRRI	International Rice Research Institute
LIBIRD	Local Initiatives for Biodiversity, Research & Development
NARC	Nepal Agricultural Research Council
NARS	National Agricultural Research Scientists
PAU	Punjab Agricultural University, Ludhiana, India
RWC	Rice Wheat Consortium

VIII. Cost Sharing

A. Collaborating Institutions

USAID GRANT NO: LAG G00 97 00002 00		
SM-CRSP AT CORNELL UNIVERSITY REPORTING PERIOD: 2/11/2000-2/10/2001 COLLABORATING INSTITUTIONS COST SHARING		
		Contribution
Bangladesh		
CIMMYT @ 0.40 FTE	1 Staff Scientist	10,000
BARI & BRRI @ 0.50 FTE	17 Principal Investigators	17,473
Nepal		
CIMMYT @ 0.10 FTE	2 Staff Scientists	10,000
NARC @ 0.50 FTE	12 Principal Investigators	7,086
IAAS @ 0.50 FTE	6 Principal Investigators	4653
TOTAL COLLABORATOR COST SHARE		**$49,212**

B. Cornell University

CORNELL UNIVERSITY COST SHARING REPORTING PERIOD: 2/1/1997-12/31/2000	
	Total Matching
PERSONNEL:	
Cornell Faculty Salaries	236,552
Fringe Benefits	90,094
TOTAL PERSONNEL	**326,646**
CIIFAD:	
Travel	45,402
Equipment	19,500
Supplies	10,870
Misc. Other	36,302
TOTAL CIIFAD	**112,074**
TOTAL DIRECT	**438,720**
TOTAL INDIRECT	**237,362**
TOTAL COST SHARE	**$676,082**

IX. Financial Statement

USAID GRANT NO: LAG G00 97 00002 00
SM-CRSP
REPORTING PERIOD: 2/10/2000-1/31/2000
EXPENDITURE REPORT - RICE/WHEAT

CATEGORY:	**BUDGET PERIOD:** 02/10/00 -1/31/01*
PERSONNEL:	
Salaries/Wages	$128,445
Employee Benefits, Fees	$36,763
TOTAL PERSONNEL:	**$165,208**
NON-PERSONNEL:	
Travel- International only	$76,478
Nonexpendable Equipment	$2,206
Supplies, Materials	$47,184
Services	$80,657
Subcontracts >25,000	$69,808
Other Direct	$55,612
TOTAL NON-PERSONNEL:	**$331,945**
TOTAL DIRECT:	**$497,153**
TOTAL INDIRECT:	**$132,111**
TOTAL EXPENSES THIS PERIOD:	**$629,264**

Fringe Benefits rates:	**Indirect Cost rates:**
2/00-6/00: 31.3%	On campus: 55.13%
7/00-2/01: 32.91%	Off campus: 23.60%

*Data taken from Cornell University Monthly Transaction Statements, summarizing expenses from 2/10/00 thru 1/31/2001. To be updated to include data from February1-10, 2001 when available.