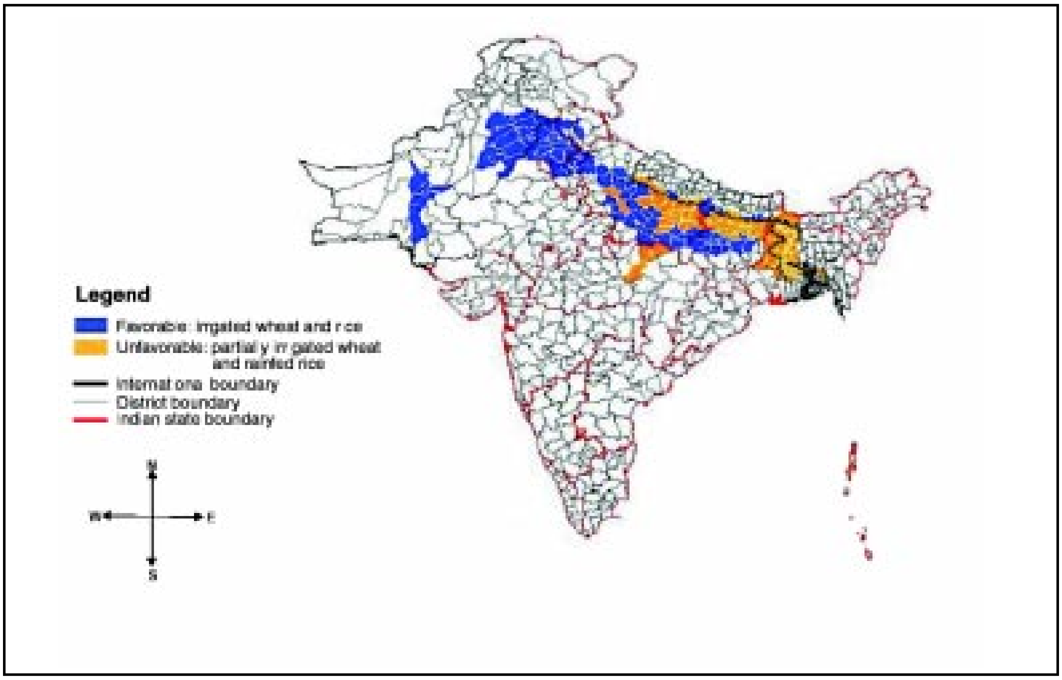
Research and Extension Issues for Farm-Level Impact on the Productivity of the Rice-Wheat Systems in the Indo-Gangetic Plains of India and Pakistan

Background

The Indo-Gangetic Plains (IGP) are endowed with plentiful natural resources. These include deep productive soils, good quality surface- and ground-water, climatic features that permit multiple-cropping and, above all, very forward-looking farmers. The region can be best described as "the cradle of the Green Revolution" of the 1970s and 1980s. For decades the continuous rotation of rice and wheat – two crops or more per year – on more than 12 million ha in the four RWC countries has provided food and livelihoods for hundreds of millions of rural and urban poor in South Asia. The Indo-Gangetic Plains, which occupy about one-fifth of the area of the Indian sub-continent in Punjab, Haryana, Uttar Pradesh, Bihar and West Bengal, produce nearly half its food grains and support more than half the population. They also receive more than half the total canal irrigation and are well endowed with groundwater potential. Expansion of irrigation, adoption of high-yielding varieties (HYV) and improvement of infrastructure have increased cropping intensities to more than 160% in the NW and 135% in eastern regions of the Plains. In addition, groundwater development has improved the quality of irrigation.

The national agricultural research systems (NARS) of South Asia, together with the RWC (an eco-regional initiative), have been addressing the critically important challenges of food security, natural resource conservation and poverty alleviation in the IGP. The last two years have witnessed swift and accelerating adoption of productivity-enhancing, resource-conserving practices that reduce carbon emissions and input-use and improve resource quality, while raising system productivity and farm-level profits. The RWC organized a traveling seminar for regional scientists, farmers and manufacturers. The seminar, which took place from 1 to 19 April 2000, had the following objectives:

- Visit farmers' fields and experiment stations in north-western India (Haryana and Punjab States) and Pakistan (Punjab) to assess the performance of various new tillage techniques being adopted by farmers.
- Facilitate interactions within and among multi-disciplinary teams of scientists, machine manufacturers, progressive farmers and practitioners of conservation tillage (CT), in evaluating performance of reduced tillage approaches.
- Study agronomic practices associated with CT, as tested and fine-tuned by farmers to suit local requirements and socioeconomic conditions.
- Use 'feed-forward and feed-back' mechanisms to assess direct and potential benefits of CT and bed-planting systems, with and without crop residues.
- Exchange views to improve machinery for efficient placement of seed and fertilizer, thus enhancing germination, seedling emergence, plant vigor and growth, with and without crop residues.
- Obtain input from farmers, scientists and extension workers to develop efficient nutrient- water- and weed-management options for various situations, as well as facilitating exchange of experiences between them and seminar participants.



An agroecological analysis of rice-wheat area and production in the Indo-Gangetic Plains of South Asia.

- Discuss with local manufacturers and farmers strengths and weaknesses of new tillage machinery and agronomic practices used by farmers. Document all such practices and make suitable improvements.
- Identify and discuss other productivity/ sustainability constraints in rice-wheat cropping systems (e.g., salinity, reclamation, nutrient management, weed control, etc).
- Create a congenial atmosphere for free exchange of ideas and experiences among RWC members.

The itinerary comprised visits to farms, research institutes, agricultural universities, a NGO-institute and manufacturers.[1] In addition, there were semi-structured evening discussions.

Composition of the Seminar Team

Multi-disciplinary teams were selected from the four RWC member countries, with emphasis on India and Pakistan. There were 28 participants comprising engineers, agronomists, soil scientists, social scientists, plant breeders and pathologists, progressive farmers and machine manufacturers (Table 1). Three Indian participants dropped out after the Indian leg of the seminar for lack of visas or 'leave of absence' from their jobs.

In addition to the selected participants, many scientists from host institutions, extension specialists from line departments, farm-machinery experts from industry, local small-scale farm-equipment manufacturers and several hundred farmers were available for discussions along the seminar route. The participants also met many senior executives of the apex research organizations, civil administration and rural development organizations. They shared experiences, reported on the actual benefits of zero-till and bed-planting systems, assessed benefits on farm-gate incomes, obtained a rough idea of adoption levels and offered expert

1. GPS readings of some locations visited are provided in Annexure III.

Table 1: Composition of the participants in the traveling seminar.

Country	Scientists	Extension	Farmers/Manufacturers	Total
India	5	3	1	9
Pakistan	10	0	2	12
Nepal	2	0	0	2
Bangladesh	1	0	0	1
China	2	0	0	2
International	2	0	0	2
Total	22	3	3	28

comments. During discussions, participants sought answers to key organizational, implementational, and management issues of research and extension. Participants greatly appreciated the farmer-participatory, strategic research and extension model practiced in Haryana for large-scale adoption of the zero-till technologies.

Due to delays in obtaining visas, the seminar started on April 1, 2000 in India without the participants from Pakistan. The Pakistan contingent traveled to India with the whole group on April 13 and returned on 19 April. All the participants were together during the traveling seminar in Pakistan.

Outcomes

Each participant prepared a short write-up on subjects of interest. The following report summarizes group reports, travelogs, discussion notes; and farmers' reports, as well as statements and documents presented by researchers to the participants.

Zero-tillage with Inverted-T Seed Drill

This was the highlight of the tour; the group evaluated hundreds of fields where farmers had used the seed-cum-fertilizer drill. It is estimated that more than 8,000 ha in Haryana, India, alone and 5,000 ha in Pakistan Punjab were planted to this practice this year. In the course of the seminar no bad field was observed and no farmer was unhappy using this technology. All had benefited from production-cost savings ranging from INR 1500 to 2000 per ha, higher yields in many cases (1–2 quintals per ha), fewer weed problems,[2] less water applied (10–12 cm per hectare water), and a whole host of other benefits that became apparent through farmers feedback. In one farmer-participatory trial in Teek village, Karnal district (India), several leading wheat varieties were being tested for their suitability under zero-till conditions. It was observed that WH 157 and HD 2386 were more effective in suppressing *Phalaris minor* than other cultivars, pointing out the need for further breeding research to develop weed-suppressing wheats.

One farmer who had experimented with wheat establishment under zero-till vs broadcasting in the last week of November reported a yield advantage from the former due to the longer growing period (a full week). Other benefits of sowing wheat with zero-till included less lodging, no crop yellowing after the first irrigation, less tractor use/wear of parts, better germination in salt-affected soils, less need for herbicide, improved residue management (it can be left on the soil instead of being burned) and savings in time, labor, and fuel – all of which contribute to

2. Populations of *Phalaris minor* were reduced to nearly one-third in first year. This was mainly due to buried seed not being able to germinate. In addition, timely seeded wheat suppressed the weed growth since the optimum temperature (<10°C) for germination of *P. minor* occurs after the wheat canopy covers the surface.

A scientist-farmer seminar on resource conservation technologies was organized in Mona, Pakistan. Major General Sarfraz Iqbal in conversation with Dr R.K. Gupta, Regional Facilitator, RWC. Dr M. Akram Kahlown, Project Director, Mona Project, Pakistan is in the center

An innovative and progressive farmer from Karnal, Haryana, with his puddler-cum-planker which saves energy and facilitates good puddling and leveling.

enhanced profits. Farmers indicated that stem borers were not a problem under zero-till. There were cases where more broadleaf weeds were present, but these are easier to control.

A suitable seed drill is available in both countries (India and Pakistan) and is being manufactured by local artisans. The Indian version is based on the old *rabi* drill with a stronger frame and the openers changed to inverted T's. The Pakistan model is based on the original Aitchison drill from New Zealand and is heavier and stronger and also uses inverted-T openers. Both are good and perform well. However, because seed tubes remain several centimeters above the furrow, some seed falls outside the open slit. This seed germinates after the first irrigation. Discussions were held on ways to improve this drill. The findings arising out of the discussions will be presented in a detailed report.

Irrigation-induced crop yellowing and zero-tillage

In situations when seed had fallen outside the slit opened by the T's or the soil moisture was sub-optimal for germination, Indian farmers advanced irrigation by 7–10 days or more with satisfactory results. One farmer who seeded his wheat crop with lower soil moisture irrigated the field four days later and obtained an excellent crop stand. Normally, irrigation is applied to wheat at the crown root stage after 25 days. In Pakistan, farmers apply the first irrigation at 30–35 days. In conventionally sown wheat, yellowing of plants is common after the first irrigation due to temporary waterlogging and oxygen starvation. Yellowing due to irrigation at the crown root stage has been reported to result in yield losses of 5–10%. Spraying urea at 10 kg ha^{-1}, immediately after the first irrigation, helps the crop to recover quickly, but farmers also reported complete absence of yellowing in zero-till fields.

In India, delaying first irrigation by 5–7 days is often recommended for wheat on partially reclaimed alkaline soils, to avoid yellowing from waterlogging. Much wheat in Pakistan is grown on partially reclaimed alkaline soils.

Rice Residues and Planting Wheat

The basmati rice crop is often harvested by cutting plants manually near ground level, with residues being used to feed cattle. Planting wheat with the zero-till drill is no problem under these circumstances. Where medium-fine and fine high-yielding rice varieties are harvested with reapers or combines (a common practice), farmers also reported no difficulty establishing wheat in the anchored crop residues, which vary in height from 5 to 50 cm. The rice stubble remains green until the December cold and then decomposes rapidly during wheat season. Rice residues, left on the surface or incorporated, return potash and other nutrients to the soil and help build soil organic carbon, improve biophysical properties, and slightly enhance yields of the following crop.

Combine-harvesting of wheat leaves behind both anchored and loose residues, which can clog seed tubes due to raking of straw during planting of a subsequent wheat crop. Some farmers had pillion riders on the drill to detach raked residues from furrow openers using long sticks. Others lifted the drill to drop the raked residue, a practice that increases tractor time and spills. Most farmers reported that dropping seed in the residues delayed only seedling emergence from the straw, rather than germination. Other options to facilitate wheat sowing included partial burning of residues and removal of residue piles or spreading them evenly.

The major issue is adapting drills to sow into loose residues. Strategies discussed included chopping and spreading residue during or after combining (a combine modification), partially removing or raking loose straw, and use of disc-type trash drills. All, including farmers, agreed that retaining surface residue would greatly benefit soil health and organic matter dynamics. Dr Malik reported that residue retention increased earthworm populations and represents a potentially attractive alternative to burning, which pollutes local air and possibly worsens global warming. All agreed that these issues require priority attention, with close interaction among engineers, manufacturers, extension workers and farmers. Where farmers must manage large amounts of residue from rice-wheat or maize–wheat rotations, a microbial decomposition strategy could be used to complement engineering solutions and contribute to biological control of crop pathogens.

Regarding stem borers, the need for scientific monitoring was recognized and work is under way this year in many farmers' fields. Though further study is required, certain data suggest that surface residue retention promotes the survival of beneficial insects (wasps, spiders and beetles), as opposed to burning or incorporation of stubble.

This seminar exploded the myth that zero-till is best for sowing wheat late in the season; farmers confirmed that advantages of zero-till are greater with early planting (i.e., late October) and diminish as planting is delayed. Among other things, early establishment of wheat allows the crop to shade out the *Phalaris minor*.

Researchable issues

- Developing a tractor-drawn rake to collect loose straws.
- Exploring the use of a coulter or chopping device in front of the zero-till drill.
- Chopping/spreading straw behind the straw walker of a combine harvester.
- Developing a suitable drill for planting into residue. (This could include the use of disk-type trash coulters or trash rakers.)
- Complementing engineering approaches by promoting surface decomposition of crop residues using decomposer microbes, as well as fostering a population of bio-control agents by manipulation of energy sources.

Time-lag in Technology Adoption within the Same IGP Transect

Almost all the farmers of Mutzapur, Fathehabad, Tohana, Teak and Govindgarh villages have opted for zero-till. Only a few farmers in the villages of Murtzapur, Teak and Jadaula of Kaithal district continue to burn rice crop residues before planting wheat. The farmers of these villages enthusiastically showed the performance of the zero-tilled wheat crop in their fields, explained the benefits accruing from zero-till and shared their experiences and innovations with the participants. Most farmers in these villages also have relations in Punjab. Mr Joginder Singh, a sikh farmer from Tohana village, was very unhappy and complained that his relations in Punjab were losing lots of grains because the extension agencies were not doing enough to promote and educate his relatives there about zero-till technology. He has to go there with his zero-till machine for planting wheat. His concerns about the time lag in adoption of the technology were very genuine. Such searching questions forced the participants to look around and search for plausible answers. Will Punjab be deprived of the benefits of the conservation tillage that is creating a revolution in Haryana?

The participants discussed the key issues coming to the fore on this topic.

Technology-adoption issues

- Why has not adoption of zero-till technology picked up in Tarai and western parts of Uttar Pradesh in India, where the prototype of the machine was first developed?
- Why has not the technology received support of the extension agencies in Punjab state (India), where zero-till machines are being manufactured (Ludhiana and Jandiala, Amritsar) and supplied to other parts of the country?
- Why do farmers in West Punjab (Pakistan) accept the technology, where nearly 20,000 acres of wheat have been planted with zero-till in 1999–2000? The acreage of zero-till planted wheat was only 1000 acres in 1998–99 and 100 acres in 1997–98.
- Why did the technology become a success in Haryana, where farmers had neither the benefit nor the availability of a machine prototype a few years back, nor the availability of quality machines in good number? The area coverage under zero-tillage was more than 20,000 acres in 1999–2000.

- Why is this technology-spread so fast in Haryana and the Pakistan Punjab, and is being still evaluated in other places?

There were several rounds of discussions among participants and they in turn raised this issue with Dr AS Aulakh, Pro- Vice Chancellor, Dr MS Bajwa, Director of Research, Dr Kollar, Director Extension and Mr BS Sidhu, Jt. Director (Farm Machinery), Department of Agriculture, Government of Punjab. Dr Aulakh pointed out that the Punjab Agricultural University (PAU) had recommended zero-till planting of wheat in 1980s and would now launch a special campaign for bridging the information gap and popularizing conservation-tillage technologies next year. The senior research management of the PAU hopes that next year Punjab will have more than 50,000 ha of zero-till wheat.

Probably Dr R.K. Malik, from the CCS Haryana Agricultural University (HAU), Haryana, gave the best explanation. He explained that this technology was first considered to combat the serious problem of *Phalaris minor* in his state (this weed had developed resistance to the popular *Isoproturon* herbicide). Farmers were willing to accept anything to solve the problem. Zero-till was introduced to cut costs and thus allow farmers to pay more for new and more costly herbicides. Dr Malik's team decided to demonstrate zero-till on farmers' fields where *P. minor* was a problem. In the first year they convinced farmers to allow them to plant one-acre demonstrations. Results were excellent and yields obtained were as high as 6.3 t ha^{-1}. Next year, farmers were given the drill to plant their own land in the village. They did so and were very pleased with the results and so they bought their own drill in the third year. After planting their entire farm in the third year, they had other farmers lining up to rent the drill.

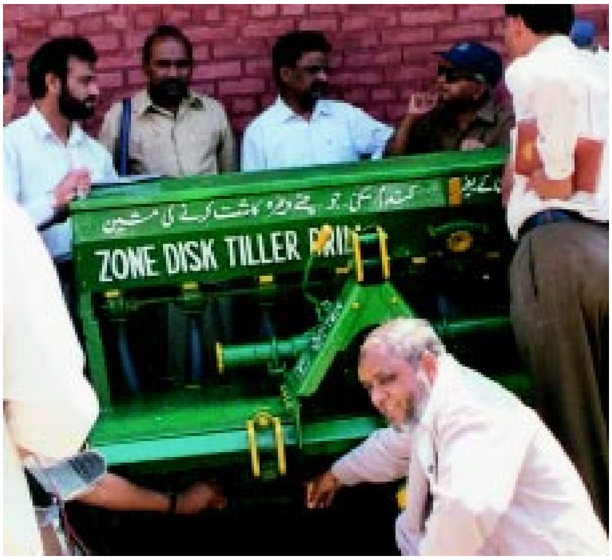
Custom Services for Zero-till Drills

Farmers reported to the traveling seminar (TS) participants that custom charges for the machine varied from INR 200 to 300 per acre. The rental charges for the machine and the tractor range between INR 400 and 500 per acre. The participants encountered many farmers who rented their machines and tractors to their neighbors for planting wheat, meaning that all farmers can utilize this technology. More enterprising farmers even traveled long distances in Punjab, Delhi and to Paonta Sahib in Himachal Pradesh to offer custom hiring services for wheat planting. Such farmers earned more than INR 35,000 within a short span of 35 days.

Machine Quality and Subsidy

During the TS, it was noted that the Directorate of Wheat Research had provided nearly 100 zero-till drills in 1997–98 for experimentation and demonstrations to several research stations. Most of these machines have been parked and are not being used due to their poor quality (they have a chain slippage problem). This brought out the fact that quality machine prototypes will be a key factor in the speedy adoption and spread of the technology in the region. Seeing the acceptance and satisfaction level of farmers, the participants believed that many more farmers would buy their own drill and the area would expand dramatically in Haryana and Punjab. It will not be a surprise if the zero-tilled wheat occupies more than 0.1 million ha next year in Haryana and Punjab alone. Concerted efforts can take this number even higher. The only factor constraining the acreage this year (1999–2000) was the availability of suitable good-quality drills. The same happened in Pakistan under the leadership of Dr Mushtaq Gill, Director-General of On-Farm Water Management Scheme.

Farmers often asked for a subsidy on zero-till machines. Participating scientists and extension specialists from line departments were against this, arguing that it would reduce machine quality, the key component of the technology. It was observed that farmers by and large agreed with this



Sitting in front of the machine, Dr M. Sharif Zia, Director, Land Resources Research Institute Islamabad, discussing the functioning of disk tiller drill with Indian participants.

contention and would settle for a provision of easy bank loans for purchase of machines, rather than a subsidy. The technology also saves the farmer so much (INR 1,000 per acre) that he can easily recoup his costs in the first year and even make a profit if he rents the machine to other farmers.

Reasons for Slow Adoption

Dr T.C. Thakur, Professor, Farm Machinery, GB Pant University of Agriculture and Technology, Pantnagar, who had been associated with the development of the first prototype machine with Dr Bachhan Singh, felt that "the mind-set of the researchers and lack of confidence" were the main reasons for slow adoption of the technology. This explained the query "how many acres of wheat crop have been planted by the University with zero-till drill on its 10,000-acre farms at Pantnagar (UP)?"

Talking to the many small-, medium- and large-scale farmers and seeing crop performance and the innovations farmers made in zero-till techniques to meet site-specific situations, the participants were largely convinced of the potential of conservation tillage. Listening to farmers' initial reactions in the testing phase was as interesting, as was their strong support for the technology after seeing on-farm crop performance. In the villages of Murtzapur, Teek and Tohana, the total arable land of the village was planted with zero-tillage machines. Mr Ranjit Singh, a farmer who migrated from East Punjab to the Govindgarh village, Karnal, Haryana, and who has a very rich experience with zero-till, remarked: "The menace of *Phalaris minor* has led to the development of the technology and it is ultimately proving a boon in disguise for the farmers. It cuts down the cost of cultivation, saves water and reduces the weed problems." Farmers reported yields of 5.8–6.0 t ha^{-1} in zero-till fields — nearly 2–3 q ha^{-1} more than those with conventional tillage practices. Participants agreed that it is likely that the advantages will be greater in late-planted basmati rice areas of the Pakistan Punjab.

We now feel that a more farmers-participatory approach, where farmers test, adapt and feedback information, will allow the technology to be adopted much faster and more efficiently. In other states, the emphasis was placed on researcher-managed trials in farmers' fields. The impact was less and the drills were not left in the village for farmers to experiment.

Bed-Planting Technology

Scientists of the RW region who had visited CIMMYT in Mexico several years back and worked with agronomist Ken Sayre in Sonora State, Mexico, brought this technology back for testing in the region. More than 90% of Sonoran farmers now use bed-planting on 1.0 million acres of irrigated lands. The furrow irrigated raised bed (FIRB) technology was shown at a number of places in Haryana and Punjab. In this technology the seedbed is prepared conventionally and raised

A bed-planter of the Punjab Agricultural University in operation in one of its fields.

beds and furrows are prepared using a raised bed-planting machine. The machine makes two beds of about 70 cm width and can plant 2 to 3 rows on each bed. Discussions with farmers and national scientists revealed several advantages:

- Saves about 50% seed.
- Saves 30–40% water.
- Yields are higher than those with conventional systems.
- Lodging is reduced.
- Facilitates mechanical weeding and hoeing of wheat by tractor.
- Offers opportunity for a last irrigation at grain filling.
- Avoids temporary waterlogging problems.
- Allows subsurface basal and topdress fertilizer placement, thus reducing N losses in rice/ wheat.
- Promotes rainwater conservation.

In India and Pakistan, the technology is still in the experimental stage. Many fields were visited in India and Pakistan where wheat was planted in 2 or 3 rows on top of raised beds using a bed-maker-cum-planter developed at ASS Foundry near Amritsar, Punjab, India. A prototype of the drill was exported to Pakistan and has been copied and manufactured by Greenland Engineering in Daska.

The participants are looking at the performance of bed-planted wheat.

Results of this technology were excellent wherever proper management of inputs (especially fertilizer and water) was practiced. Farmers were impressed and agreed they would experiment more next year. Farmers generally reported that the bed-planting system saves water, eases irrigation, has less lodging and better growth. Scientists discussed this technology and also agreed that it held many benefits, including the ability to weed mechanically (reducing herbicide used), ability to place basal and top-dress fertilizer and increase their efficiency (if the center wheat row is eliminated), the ability to apply the last irrigation without lodging, less compaction (traffic pans would be restricted to the furrow where the tractor tyres go), and the potential to raise yields. The following suggestions resulted from discussions on this topic:

(a) The technology is better adapted at the moment to non-rice-wheat systems since the technology is not available yet for growing rice on beds. It is costly to make the beds each wheat season after rice harvest. Permanent beds where each succeeding crop is planted into the previous crop residues would be the best option. However, this system would be for crop diversification in rice-wheat areas where the introduction of soybeans, maize, cotton, canola and sunflower on beds would be possible.

(b) There is a need to improve the bed-planter so that it can plant more efficiently into residue. This would be similar to the needs of the above zero-till drill. It should also be a multi-crop planter, may be using a sponge feed to allow farmers flexibility in crops they can plant.

(c) Rice on beds needs to be assessed. This would require suitable weed control strategies, but these will be needed for other non-rice crops as well.

(d) The long-term benefits of this technology need to be monitored in farmers' fields to provide quantitative data for assessment.

(e) This technology is particularly favorable for seed multiplication and crop production using hybrid seed since seed rates can be lowered significantly. Bed-planting system can reduce cultivation costs and has much potential for expanding the hybrid area through reduced seeding rates.

(f) Irrigation schedules × nutrient interaction (N physical forms, placement depth and timing) may have to be worked out for this crop establishment system.

Rice Establishment Issues

The group discussed this in detail and many suggestions were made. The present system of puddling soils and transplanting rice seedlings is very laborious and creates untold drudgery to workers, many of whom are women. There are also suggestions that labor for this arduous seasonal task is not easy to find, costs ever more and often results in wide spacing and poor yield. The issue of puddling soils is also moot, since data suggests that where puddling is not practiced in rice, the next wheat crop planted by zero-till is much better. This negative interaction in the rice-wheat soils needs further investigation. The following are a list of topics discussed:

(a) Both Chinese and Japanese mechanical rice transplanters have been evaluated in Pakistan and India. The Chinese version costs less (INR 130 thousand compared to 700 thousand which is the cost of the Japanese version). The Chinese tractor was found to be the more cost-effective model, although it had some problems, especially with raising the mat-type seedlings, planting them into unleveled fields and sinking problems in many soils. The Heavy Machinery Complex (HMC) in Pakistan was visited where they are copying the Chinese transplanter (10) for testing this year. This mechanical rice-transplanting system is more suitable for commercial farms and in fact may provide employment for agricultural labor where rice transplanting would be contracted to commercial companies using this labor. More attention is needed on seedling raising, leveled fields and proper water management to make this more effective and popular. Some data from Pakistan last year showed poor yields in some farmers' field. This needs to be monitored and assessed in more detail this year.

(b) Discussion on rice broadcasting, a popular technique in China, identified the technique as a potentially significant breakthrough for the subcontinent. The Chinese have been asked to send some of the PVC sheets used to raise the seedlings, so that studies can be undertaken this year. They are also producing a video for viewing in the region. Selected RWC scientists visited China in May, 2000 for first-hand observation and their report has been published.

(c) The IRRI drum seeder is another method for rice establishment that does away with the drudgery of transplanting and raising seedlings. This places sprouted seed in rows on puddled soils.

(d) The participants agreed that there are areas where puddling is not needed for rice. In fact, in Sind, Pakistan farmers do not puddle. In some situations (lower terraces with finer-textured soils and poor drainage, alkaline soils or partially reclaimed soils, and *tarai* soils with high water-tables) experiments are needed on establishing rice without puddling. Weed control will be a big issue, but several strategies are available for minimizing this problem (stale seedbeds, use of pre-plant non-selective herbicides, use of post-emergent selective herbicides, mechanical weeding, competitive varieties etc.). *Laeving* is another technique that is time tested for dry seeded rice conditions in eastern Uttar Pradesh. In laeving, fields are irrigated and shallow plowed to exhaust the seed bank of weeds. Rice seed is then broadcast and mixed at very shallow depths followed by planking. The seedlings are allowed to grow to 10 cm along with the weeds, if any escape the earlier plowing. Fields are then ponded with rain or irrigation water and planked to bury weeds. Under ponded water conditions rice seedlings again stay erect, whereas weeds die. If necessary, another laeving can be done. The practice can be reintroduced. It may be pointed out that laeving differs from bushening, which is practiced in Chattishgarh in the plateau region of Central India.

(e) Planting rice on beds would be similar to dry seeded rice on non-puddled soils. Rice planted on permanent beds can be zero-tilled and fertilizer can be placed at 10 cm depth to reduce ammoniacal losses of nitrogen.

(f) It was agreed that some research on these rice establishment issues, would start this year on selected sites. The work should also look at this in a systems perspective, so that any benefits to the next wheat or winter crop can also be properly evaluated.

Participants also discussed very key questions regarding provisions of custom services for hiring of the rice transplanter and raising community mat-type rice nurseries. They also discussed whether the rice transplanter is really needed, given the fact that RWC will be moving in the direction of conservation-tillage technologies in rice (unpuddled rice, surface seeding, rice on beds, stale beds, laeving and DSR) for increasing the system productivity. There was no clear consensus and, hence, a need to examine the issues at some sites.

Weed Management

Weed-management issues for the rice crop have been discussed in previous sections. In wheat, *Phalaris minor* is the most damaging weed in rice-wheat areas. In farmer-participatory trials, zero-tillage reduced the *P. minor* population by two-thirds in the first year. Growing competitive varieties like WH 157 can further reduce weed infestations. Result of trials by Dr R.K. Malik and his team clearly suggest a strategy of rotating herbicides yearly to control *P. minor*. Continuous use of a single herbicide may lead to resistance and emergence of new weed biotypes.

Laser Leveling and Water Management

Water management is becoming very important, as lack of quality water increasingly limits productivity. Rainfall in the last monsoon in Pakistan was very poor; water levels in major dams are low. One technology that was seen and admired by all was the laser leveling and watercourse development by the Pakistan Punjab On-Farm Water Management (OFWM) group. In one FAO-sponsored village, a group of farmers had agreed to consolidate land and have it laser leveled and laid out with improved watercourses and field layout. This resulted in major land savings (4%)and better water-distribution systems leading to better water efficiency and production. Farmers elsewhere are requesting help in leveling their land.

A couple of manufacturers were available during the trip to discuss follow-up in India. A lack of laser units is the main constraint. In Pakistan, the bucket and tractor attachments were made locally with the laser coming from the USA. The OFWM team is also thinking of making the laser unit in Pakistan.

***Phalaris minor* is the most damaging weed in rice-wheat areas.**

Adoption of laser-leveling technology by farmers in Pakistan is becoming popular.

Laser leveling is a major ingredient for increasing water-use efficiency. It is also a key in some of the new technologies listed above. Zero-tillage and the use of the mechanical rice transplanter would be better on leveled fields. The same applies to rice broadcasting and drum seeding on puddled soils. Zero-tillage would also minimize field level disturbance during land preparation and, therefore, increase the time between leveling. Bed-planting in laser-leveled fields would allow precise water application without overflows at the distal tail end of furrows.

Water-use efficiency can be substantially improved by cleaning and lining of unlined water courses, use of pre-fabricated water outlet gates, adoption of reduced tillage, zero-tillage, bed-planting systems, use of combine-harvested residues as mulches, and to facilitate the even spread of irrigation water following land shaping and smoothing by the laser leveler. The OFWM Project in Punjab Province of Pakistan has taken a lead in the region in this regard and has achieved remarkable success. The NATP in India should encourage scientists to develop a guided land plane system, and immediately move in this direction. Keeping in view the all-round shortage of irrigation water, receding water-tables, uncertain rains, and drought, greater emphasis on water management is needed in India. Existing

Participants discussing laser-leveling technology with the scientists of the On-Farm Water Management Group in Lahore, Pakistan.

laser land-leveling systems, imported at huge costs and available at several institutions, should be used in farmers' fields to demonstrate the benefits of leveling and efficient water management.

Nutrient Management

Organic and inorganic fertilizers are key components for increasing yield. Being expensive, they must be used as efficiently as possible. Several discussions held on this topic are summarized as follows:

(a) In Pakistan, there is a recommendation for a 1:1 N:P ratio. This seems high and wasteful of costly P fertilizer. In India the ratio is 2:1 or higher. What is really needed is an assessment of the N, P, and K supplying capacities of soils, followed by a recommendation on what additional nutrients are needed to achieve a specified yield level. Farmers can thus be given proper fertilizer recommendations. Dr Zia and his team are conducting site-specific, nutrient management field trials at 20 sites in Pakistan with RWC competitive grant money. Participants also had the chance to see the trials near Kala Shah Kaku. The field results clearly showed that P-levels do not need to be as high as presently recommended in Pakistan.

(b) Nitrogen-use efficiency can be improved by banding nitrogen in bed-planting systems or in direct-seeded, zero-tilled rice.

(c) In zero-tillage planting, DAP fertilizer can be placed along with the seed. An alternative would be to develop a new coulter that does a better job of separating fertilizer, especially urea, from the seed. Zero-tillage does have an advantage over conventional broadcasting methods because of fertilizer placement, but if nitrogen is placed in close proximity to the seed, germination could be impaired. Farmers, however, have not observed any problem so far.

(d) Rock phosphate may be mixed with surface residues in zero-tillage areas, as a cheap way to add this nutrient.

Reclamation and Management of Alkaline Soils

Salt-affected soils occupy a large area in Pakistan. In Pakistan, these soils are broadly classified into three categories namely (1) saline soils, (2) sodic/alkaline soils, and (3) saline-alkaline soils. There is some confusion about whether saline-alkaline soils should be reclaimed and managed like alkaline or saline soils.

To facilitate discussions on the genesis and management of salt-affected soils, Indian scientists categorize them into two broad classes: (i) saline soils, and (ii) alkaline soils. Using the definitions and the technology developed in India, more than one million ha of alkaline soils have been reclaimed in Haryana and Punjab in the last three decades. Pakistan has many acres of saline-sodic soils and several discussions took place to capitalize on the Indian expertise. It was suggested that the Indian definitions be used for saline and alkaline soils in Pakistan. The following reasoning was advanced for consideration in Pakistan for adopting the criteria used in India for diagnosing and differentiating saline and alkaline soils.

(a) Not all "saline-alkaline" soils need application of gypsum. Leaching and provision of drainage alone could reclaim many of them. Gypsum should be recommended only for the alkaline soils.

(b) Many farmers use gypsum for reclaiming alkaline soils in Pakistan and it is recommended that gypsum-amended soils be deep tilled. Instead, in India it is recommended that gypsum should be incorporated only in the top 10 cm of the soil and planted with rice, to initiate the reclamation process. Subsequently, the reclaimed surface layer should not be plowed deep for establishment of a second crop of wheat. We observed that farmers prefer deep plowing in the wheat season. Deep plowing brings the partially reclaimed sub-surface layers to the surface, adversely affecting wheat yields. Reclamation programs will be more effective by not bringing soil from lower depths to the surface.

(c) Rice should be grown as the first crop to initiate a reclamation program on alkaline soils. Pakistan farmers reported that they plow the alkaline soils deep, amend with gypsum, and puddle them after ponding water for transplanting rice. Instead, India recommends rice should be transplanted in unpuddled soils. Puddling should be avoided in alkaline soils for several years after initiating a reclamation program. Alkaline soils already have poor drainage; puddling would further restrict infiltration of water down through the soil profile. Reduced infiltration slows down the reclamation process on alkaline soils and hence both deep ploughing and puddling are counter-productive in reclamation and unhelpful in obtaining higher yields in wheat.

(d) Bed-planting seems to be a useful technology for crop production on alkaline soils, since it doubles the depth of the reclaimed rooting profile. This recommendation was confirmed in the FAO-assisted village. An excellent wheat crop was seen on beds in a 5.0 ha field of partially reclaimed alkaline soil.

(e) OFWM has dug out a tank in the FAO-assisted village to store canal water for a fishery. The on-farm water storage tanks should be used for irrigation and fishery. Many areas in the Punjab province of Pakistan have low quality 'alkaline waters' having residual sodium carbonates (RSC) of more than 5 meq/L. On-farm canal water storage tanks can be very safely used to blend the alkaline waters to augment the canal water supplies and bring the RSC of tubewell waters to within safe limits. A variety of fish that feed from different layers can be grown in such tanks. Tanks can be used to store excess surface flows during the rainy season when water is available and then used for irrigation in the dry season. Mixing RSC water (alkaline) with canal water in the winter season has other advantages. The strategy of blending ground- and surface-waters in OFWM tanks would promote conjunctive use of water and provide the additional head required for faster flow of water in the field. On-farm storage tanks would facilitate daytime irrigation and reduce irrigation time and save water on laser-leveled fields.

Germplasm Issues

Discussions about including plant breeders in rice-wheat activities produced the following suggestions:

- Breeders should start evaluating their germplasm under the new tillage options to harness significant nutrient × water interactions.
- Seed multiplication and use of hybrids should be encouraged on bed-planting systems. Flat sowing methods would require more seed. Higher seed rates lower the rates at which high-yielding varieties are replaced by new ones and slows area expansion of hybrids.
- Competitive rice and wheat varieties are needed to reduce weeds under zero-till and

dry-seeded rice. They should also have good foliar disease resistance (blast and sheath blight in rice, foliar blights in wheat).

Farm Machinery

In the earlier sections, we described farmers' reactions to zero-tillage. To sum-up, farmers feel very happy with its advantages over the conventional system. The participants had several rounds of discussions on issues related to the use of available farm machinery in rice-wheat systems and topics for additional research (e.g., upgrading prototypes to address system ecology problems). The agricultural engineering expert sub-group in India made several recommendations:

Improving machine designs for rice crop

- Tractor cage wheels and peg and helical blade puddlers can reduce puddling time and costs by 50%.
- For mechanical transplanting of rice, shallow puddling is beneficial. It should be demonstrated to the farmers.
- For uniform spraying of chemicals in rice/wheat crops, a twin-leaver operated knapsack (LOK) sprayers with long booms or a stationary/rotating power sprayer with a long boom should be used. For herbicides, a multi-nozzle boom with flat fan nozzles should be used.
- Besides combines, self-propelled, riding-type and tractor-drawn vertical conveyor reapers are available for harvesting rice and wheat and should be demonstrated to farmers.
- Loose straw, especially thrown as combine litter (litter piles), hampers proper operation of the seed drill. For chopping standing rice stubbles, shrub master/stubble shaver/reapers are commercially available. Before or after

Participants in the ASS Foundary Works, Jandialaguru, Amritsar, a well-known Indian manufacturer of good quality zero-till machines.

Participants visiting agricultural machinery manufacturer in Daska, Lahore, Pakistan.

seeding wheat with zero-till, tractor-drawn stubble shavers can be used to create mulch. The controlled traffic wheel can be used for all subsequent operations. One farmer in Sonepat district tried this with excellent results. He reported reduced germination in the wheel tracks. But wheel tracks can be used for controlled traffic and subsequent operations during the cropping season. This concept of controlled traffic should be introduced in zero-till wheat. It will save seed and facilitate operations without any adverse effect on crop production.

- High capacity, axial flow paddy threshers should be demonstrated for threshing paddy.

Improving machine designs for wheat crop

For sowing wheat after rice, the Pantnagar no-till drill is recommended as simple and farmer friendly. Several manufacturers (ASS Foundary Amritsar; NFEC, Ludhaina; and Greenland Corp., Pakistan, to name three) are making quality machines that should be promoted. All agree that there is no need to tamper with the current design at this stage of technology take-off. Specialists in farm machinery, however, felt that some of the following suggestions could be immediately incorporated to boost efficiency without increasing costs. In fact, one manufacturer (NFEC, Ludhiana) has already effected some of the changes, after discussions at his factory.

- The furrow opener tip should be made of high carbon/tungsten steel to reduce wear.
- The drive-wheel bracket should be stronger to avoid twisting and frequent loosening of the drive chain.
- The holes on the rectangular tool bar of the drill for fixing furrow openers should be discarded in favor of a bracket-type clamping mechanism. This will strengthen the tool bar.

- At the bottom of the furrow opener, an inverted angle iron piece may be welded to enable separate placement of seed and fertilizer in two bands.
- The bolt fixing the furrow opener blade with the tine should be countersunk.

In addition to the above, the experts suggested that the following machines already available within NARS might be popularized:

- Besides combines, self-propelled, riding-type and tractor-drawn vertical conveyor reapers are available for harvesting rice and wheat and should be demonstrated to farmers.
- High-capacity threshers should be used for threshing.
- Straw combines should be used for making *bhusa* of the combine harvested straw.

Improving bed-planter

- There is a commercially available planter that needs improvement to facilitate sowing at 3–5 cm and to tamp the soil lightly after sowing, to make moisture available near the seed. This may call for restructuring the bed- and furrow-making components, as well as adding a press wheel/tamping roller.

Researchable issues : The possibility of using narrow tyres on standard 35 hp tractors, facilitating tractor operations needs to be explored.

Conclusions

Zero-tillage establishment of wheat after rice has the following advantages over conventional seedbed preparation:

- Savings in seedbed preparation of about INR 1000 per acre.
- Savings in water of 30–50% in the first irrigation.
- Allowing 2–4 weeks earlier sowing.
- 30–50% less incidence of *Phalaris minor*.
- Increaseing wheat yield by 1–3 quintals per acre.

All felt that the traveling seminar was an extremely useful exercise for promoting exchange of ideas and a first-hand acquaintance with new technologies under farmer circumstances. Interactions among participants were open, collegial, and supportive. Several participants shed their initial skepticism concerning the value of new tillage technologies, after seeing their performance in farmers' fields. Informal and group discussions were extremely productive and should help improve the efficiency of research and, if new practices are widely adopted, sustainable food production in the region. Hopefully, similar seminars will be held throughout the region, if the RWC obtains continued funding.

Annexure I

Participants: Traveling Seminar

[Indian Leg 1–6 April, 2000; Pakistan Leg 7–12 April, 2000; and Second Indian Leg 13–18 April, 2000]

Bangladesh

I S Mollah
Agronomist
Bangladesh Rice Research Institute
Gazipur, Joydebpur
Tel 880 2 9350122
Fax 880 2 8823416
E-mail brrihq@bdonline.com

China

He Zhonghu [1]
Liaison Officer
CIMMYT-China, Beijing Office
C/o Chinese Academy of Agricultural Sciences
No. 30 Baishiqiao Road
Beijing 100081
Tel 86 10 621 70333
Fax 86 10 689 18547
E-mail z.he@cgiar.org

Tang Yonglu
Crop Research Institute
Sichuan Academy of Agricultural Sciences
Chengdu
Sichuan 610066
Fax 86 28 479 0147
E-mail zhjguo@mail.sc.cninfo.net

India

S S Dhillion
Professor
Punjab Agricultural University
Ludhiana, Punjab
Tel 91 161 401960/Extn. 250
Fax 91 161 400945

K S Gangwar [2]
Scientist (SS)
Project Directorate of
Cropping Systems Research
Modipuram, Meerut, Uttar Pradesh
Tel 91 121 570708
Fax 91 121 571548
E-mail pdcsr@nda.vsnl.net.in

R K Gupta
Regional Facilitator
Rice-Wheat Consortium for the Indo-Gangetic Plains
C/o CIMMYT–India, NBPGR (Old) Building,
Pusa Campus, New Delhi
Tel 91 11 5822940
Fax 91 11 5820800
E-mail r.gupta@cgiar.org

R K Malik
Professor (Weed Science)
Department of Agronomy
CCS Haryana Agricultural University,
Hisar, Haryana
Tel 91 1662 31175
Fax 91 1662 34952
E-mail rkm13@haci.hry.nic.in

J S Mann (Farmer) [3]
Kothi # 25
New Kunjpura House
The Mall, Karnal, Haryana
Tel 91 184 254682

R S Mehla
Joint Director (Agriculture)
Department of Agriculture
Government of Haryana
SCO #4, Sector 17–E
Chandigarh
Tel 91 172 571554
Fax 91 172 570662

N S Pasricha
Director
Potash Research Institute of India
Sector 19, Gurgaon, Haryana
Tel 91 124* 6340185 (*91 from Delhi)
Fax 91 124* 6341792 (*91 from Delhi)

B S Sidhu
Joint Director (Agricultural Engineering)
Department of Agriculture
Government of Punjab
SCO #85–88, Sector 34A
Chandigarh
Tel 91 172 604409
Fax 91 172 600275

Baldev Singh
M/s Amar Agricultural Implements Works
Amar Street, Janta Nagar, Gill Road
Ludhiana, Punjab
Tel 91 161 491780
Fax 91 161 491780

N S L Srivastava [4]
Assistant Director General (Engg.)
Indian Council of Agricultural Research
Krishi Bhawan, New Delhi
Tel 91 11 3382716
Fax 91 11 3387293
E-mail nsl@icar.delhi.nic.in

T C Thakur
Professor and Joint Director (Engineering)
GB Pant University of Agriculture and Technology
Pantnagar, Uttar Pradesh
Tel 91 5944 33363, 33380
Fax 91 5944 33473

M R Varma
Professor (Agricultural Engineering)
ND University of Agriculture and Technology
Narendra Nagar, Kumarganj
Faizabad, Uttar Pradesh
Tel 91 5270 62071
Fax 91 5270 62023

J K Verma
Additional Director (Agriculture)
Department of Agriculture, Govt. of Haryana
SCO # 4, Sector 17–E, Chandigarh
Tel 91 172 702089
Fax 91 172 570662
E-mail Lehari_chd@yahoo.com

Nepal

P R Hobbs
Co-Facilitator, Rice-Wheat Consortium for the Indo-Gangetic Plains and Regional Representative
CIMMYT–South Asia Regional Office
P.O. Box 5186, Lazimpat, Katmandu
Tel 977 1 422773
Fax 977 1 419352
E-mail p.hobbs@cgiar.org

T P Pokharel
National Wheat Coordinator
Nepal Agricultural Research Council
Khumaltar Lalitpur, Katmandu
Tel 977 1 52 5703
Fax 977 1 52 1197
E-mail narced@mail.mos.com.np

J Tripathi
Senior Scientist (Agronomy)
Nepal Agricultural Research Council
Khumaltar, Lalitpur, Katmandu
Tel 977 1 52 5703
Fax 977 1 52 1197
E-mail narced@mail.mos.com.np

Pakistan

M A Akhtar
Senior Scientific Officer
Central Disease Research Institute
National Agricultural Research Centre
Park Road, Islamabad 45500
Tel 92 51 240269
Fax 92 51 240909

M Ashraf
Chief Scientist
Crop Sciences Institute
National Agricultural Research Centre
Park Road, Islamabad 45500

B M Khan
Senior Scientific Officer (Wheat)
National Agricultural Research Centre
Park Road, Islamabad 45500
Tel 92 51 240269
Fax 92 51 240909

Abdul Shakoor Khan
Director
Farm Machinery Institute
National Agricultural Research Centre
Park Road, Islamabad 45500
Tel 92 51 240370
Fax 92 51 240909

G A Khuhro
Director
Rice Research Institute
Dokri, Sindh

S S Malik (Farmer)
11–Asad Jan Road, Lahore Cantt, Lahore

R A Paracha (Farmer)
1022–C Canal View
Housing Society, Lahore
Tel 92 42 5412451
Fax 92 42 5420840
E-mail nasreenayub@hotmail.com

M Rafiq
Wheat Botanist
Department of Agriculture
Government of Punjab, Lahore

M G Khan Rao
Director
Rice Research Institute
Kalu Shah Kaku, Lahore

M Salim
National Coordinator (Rice-Wheat)
National Agricultural Research Centre
Park Road, Islamabad 45500
Tel 92 51 9255062
Fax 92 51 9255034
E-mail munri@rwcs.sdnpk.undp.org

M Sharif Zia
Director
Land Resources Research Institute
National Agricultural Research Centre
Park Road, Islamabad 45500
Tel 92 51 240105
Fax 92 51 240909
E-mail : niazi@plantnut%.sdnpk.undp.org

Allah Dita Sheikh
Social Sciences Institute
National Agricultural Research Centre
Park Road, Islamabad 45500
Tel 92 51 240269
Fax 92 51 240909

All Indian participants attended 1–12 April, 2000 and all Pakistani participants attended 7–18 April, 2000

1. Attended only 1–10 April, 2000
2. Attended only 1–3 April, 2000
3. Attended only 1–6 and 13–18 April, 2000
4. Attended only 1–5 April, 2000

Annexure II

Itinerary: Traveling Seminar

Indian Leg

Date	Day	Activity
31 March, 2000	Friday	Chinese/Bangladeshi/Nepali/Indians arrive in Pusa and stay overnight
1 April, 2000	Saturday	Delegates assemble in CIMMYT Office/Ganga International House Attend Farmer *Mela* in Kalram village Visit Uchani Station and farmer fields Night stay at CSSRI
2 April, 2000	Sunday	Visit farmer fields Kurukshetra Visit Dhaund; farmer fields
3 April, 2000	Monday	Leave for Kaithal; visit farmer fields Reach Tohana and visit fields Reach Ludhiana
4 April, 2000	Tuesday	Visit PAU Farms Meeting with Vice-Chancellor, PAU Visit PAU Departments Visit farmer fields Night stay at Ludhiana
5 April, 2000	Wednesday	Visit machinery manufacturer in Ludhiana Visit farmer fields around Ludhiana Visit farmer fields outside Ludhiana
6 April, 2000	Thursday	Leave for Amritsar Visit ASS Foundry at Jandialaguru Board train for Lahore from Attari Railway Station

Pakistan Leg

7 April, 2000	Friday	Meeting with Provincial Secretary Agri. Govt of Punjab/DG (OFWM) Lahore Visit Millat Tractors Ltd., Lahore Travel to Sheikhupura area for field visits Travel to Lahore and night stay
8 April, 2000	Saturday	Travel to Faisalabad Visit Agriculture University, Faisalabad Ayub Agricultural Research Institute, Faisalabad Travel to Lahore and night stay

9 April, 2000	Sunday	Visit Rice Research Institute (RRI), Kala Shah Kaku Visit DFID village, Maridkey; Travel to Daska Visit agricultural machinery manufacturers Visit farmers fields, site-specific nutrient management experiments Travel to Lahore and night stay
10 April, 2000	Monday	Participate in Irrigation and Drainage Project Seminar, Mona Travel to Sargodha Chak 44-SB, FAO Project Bahwal field area Travel to Islamabad and night stay
11 April, 2000	Tuesday	Meeting with PARC/NARC Senior Management Visit NARC Experimental Station Interact with senior citizens and farmer representatives Night stay at Islamabad
12 Aril, 2000	Wednesday	Discussions among seminar participants Sight-seeing in Lahore Travel to Lahore and night stay
13 April, 2000	Thursday	Travel to Delhi by Train

Indian Leg (Second trip with the Pakistani Group)

13 April, 2000	Thursday	Indian and Pakistani Group reach Attari by train Travel to Ludhiana and night stay
14 April, 2000	Friday	Visit PAU farms Visit ASS Foundry, Jandialaguru, Amritsar Visit late-sown fields, bed-planted fields Travel to Ludhiana and night stay
15 April, 2000	Saturday	Visit manufacturers in Ludhiana Demo of 2-wheel tractor Visit farmer fields *en-route* Demo of reaper (wheat), *bhusa* maker Travel to Hisar and night stay
16 April, 2000	Sunday	Visit farmer fields in Fathebad/Tohana Visit farmer fields Visit farmer fields in Dhaund Travel to Karnal and night stay
17 April, 2000	Monday	Visit DWR and fields Visit HAU Regional Station, Uchani Visit fields in Uchana village, Govindgarh (zero-till) Visit farmer fields Kurukshetra Night stay at Karnal

18 April, 2000	Tuesday	Leave for Delhi (morning) Visit IARI Departments (Nematology, Soil and Agricultural Chemistry, and CAAS) Night stay at IARI, Delhi
19 April, 2000	Wednesday	Sight-seeing in Delhi Leave by bus to Lahore

Annexure III

GPS Readings of some locations visited

Longitude	Latitude	Location	Activity
N29 31.292	E77 00.878	Kalram, Haryana	Zero-till and bed-planting
N29 43.754	E76 58.858	HAU Uchani, Haryana	Zero-till and bed-planting
N29 45.973	E76 54.789	Kurak, Haryana	Bed-planting
N29 45.272	E76 55.065	Sultanpur, Haryana	Zero-till
N29 43.471	E76 55.904	Budanpur, Haryana	Zero-till
N29 43.471	E76 57.283	CSSRI, Haryana	
N29 43.973	E76 57.659	Uchana, Karnal	Zero-till and bed-planting
N29 44.241	E76 57.407	Uchani, Karnal	Zero-till and bed-planting
N29 42.591	E77 02.342	Kulvehri, Haryana	Zero-till and bed-planting
N29 55.055	E76 52.164	Amin, Haryana	Zero-till
N29 57.802	E76 49.542	Kurukshetra tank	
N29 59.020	E76 39.878	Murtazapur, Haryana	1000 acre zero-till
N29 53.523	E76 35.946	Dhaund, Haryana	Zero-till
N29 51.137	E76 31.756	Teek village	3 years zero-till
N29 54.055	E76 23.521	Ferozepur, Punjab	Zero-till and bed-planting
N30 54.130	E75 51.919	AMAR Agricultural Implements	Machinery manufacturing
N29 58.348	E76 39 934	Murtzapur	Zero-till
N29 53.330	E76 35.911	Jadaula	Zero-till
N30 54.083	E75 48.972	PAU, Ludhiana	Bed-planting
N30 46.334	E75 38.408	Sudhar, Ludhiana	Bed-planting
N30 46.914	E75 38.014	Jagtarpur, Amritsar	Bed-planting
N31 36.963	E75 38.014	Millat Tractor Factory, Lahore	Tractor manufactur
N31 42.228	E73 48.166	Farukhabad, Lahore	Laser leveling, zero-till
N31 23.638	E73 02.837	AARI, Faisalabad, Pakistan	Breeding trials
N31 36.887	E73 16.965	Faisalabad, Pakistan	Microbial factory

Rice-Wheat Consortium Traveling Seminar Report Series 1

Research and Extension Issues for Farm-Level Impact on the Productivity of the Rice-Wheat Systems in the Indo-Gangetic Plains of India and Pakistan

Edited by
R K Gupta, P R Hobbs, M Salim,
R K Malik, M R Varma, T P Pokharel,
T C Thakur, and J Tripathi

Facilitation Unit
Rice-Wheat Consortium for the Indo-Gangetic Plains
IARI Campus, Pusa, New Delhi 110 012, India
2000

Editors

R K Gupta is Regional Facilitator, Rice-Wheat Consortium for the Indo-Gangetic Plains, CIMMYT–India Office, NBPGR (Old) Building, IARI, Pusa Campus, New Delhi 110 012, India.

P R Hobbs is Co-facilitator, Rice-Wheat Consortium for the Indo-Gangetic Plains, New Delhi and Regional Representative, CIMMYT, South Asia Regional Office, P.O. Box 5186, Lazimpat, Katmandu, Nepal.

M Salim is National Coordinator (Rice-Wheat), National Agricultural Research Centre, Park Road, Islamabad 45500, Pakistan.

R K Malik is Professor (Weed Science), Department of Agronomy, CCS Haryana Agricultural University, Hisar, Haryana, India.

M R Varma is Professor (Agricultural Engineering), Department of Agricultural Engineering, ND University of Agriculture and Technology, Kumarganj, Faizabad, Uttar Pradesh, India.

T P Pokharel is National Wheat Coordinator, Nepal Agricultural Research Council, Khumaltar, Lalitpur, Katmandu, Nepal.

T C Thakur is Professor and Joint Director (Engineering), G B Pant University of Agriculture and Technology, Pantnagar, Uttar Pradesh.

J Tripathi is Senior Scientist (Agronomy), Nepal Agricultural Research Council, Khumaltar, Lalitpur, Katmandu, Nepal.

Citation : Gupta, R.K., Hobbs, P.R., Salim, M., Malik, R.K., Varma, M.R., Pokharel, T.P., Thakur, T.C. and Tripathi, J. (eds.) 2000. Research and extension issues for farm-level impact on the productivity of the rice-wheat systems in the Indo-Gangetic plains of India and Pakistan: Rice-Wheat Consortium Traveling Seminar Report Series 1. New Delhi, India: Rice-Wheat Consortium for the Indo-Gangetic Plains. pp 26.

The initial support from the Asian Development Bank and the International Fund for Agricultural Development provided the groundwork for establishment of the RWC in 1994 and formalizing the collaborations between the NARS, IARCs and ARIs. The NARS-driven strategic ecoregional research initiatives with financial support from the Governments of the Netherlands, Sweden, Switzerland, Australia and the US Agency for International Development and the World Bank have grown over the years into a dynamic agenda of resource conservation technologies appropriate to different transects of the Indo-Gangetic Plains. The on-going successes in scaling-up resource conservation technologies for enhancing productivity and sustainability of the rice-wheat systems are beginning to create a revolution and favorably benefit large areas and more numbers of farm families.